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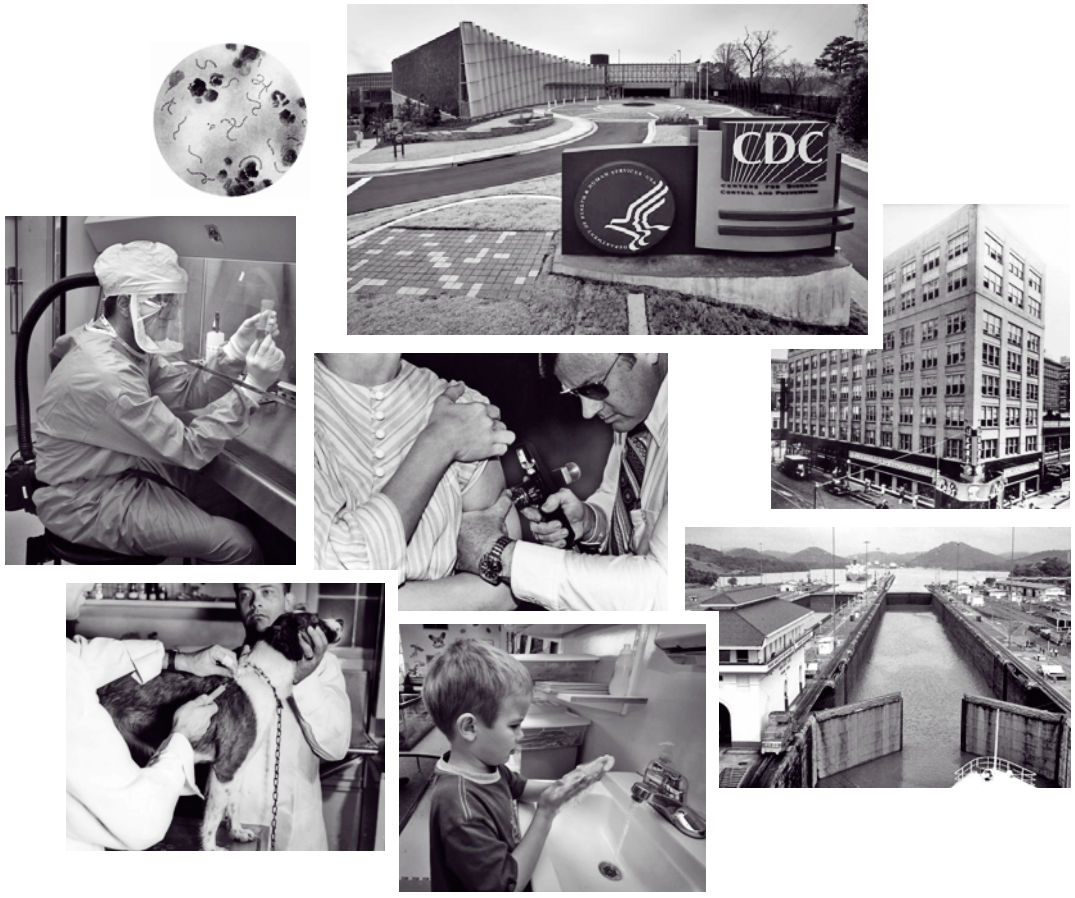
60 Years of Public Health Science at CDC



DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION

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On the cover: *Clockwise*: Tom Harkin Global Communications Center at CDC (built in 2006). In 1946, the Communicable Disease Center, or CDC, opened in the old Office of Malaria Control in war areas in downtown Atlanta, Georgia. Locks at the Pacific Ocean end of the Panama Canal where public health officials instituted sanitation measures that eliminated the yellow fever and malaria carrying mosquitoes, which made building the canal possible. A child washing his hands after handling a pet turtle. An adult receiving a vaccination with a jet injector during the swine flu nationwide vaccination campaign. Two CDC veterinarians administering a rabies vaccination to a dog. A CDC microbiologist examining reconstructed 1918 Pandemic Influenza Virus inside a specimen vial containing a supernatant culture medium. Photomicrograph of *Streptococcus pyogenes* bacteria.

Preface: 60 Years of Public Health Science at CDC

In 2006, CDC celebrates its 60th anniversary. From the agency's relatively humble beginnings in 1946 as a malaria-control agency through its rapid growth in mission and expansion of staff and public health partnerships by 2006, science has been the foundation for everything CDC does. Public health science comprises numerous disciplines that, combined, are more than simply the addition of their parts. This synergy is public health's unique scientific strength.

Public health's "patient" is the community. CDC's mandate to protect the community has broadened as scientists have learned about what constitutes health and how they can positively affect health outcomes in the "patient." CDC's health protection goals, formally adopted in 2005, capture the essence and spirit of the agency's charge: healthy people in every stage of life, healthy people in healthy places, people prepared for emerging health threats, and healthy people in a healthy world.

Accomplishment of these goals requires close collaboration across scientific disciplines, a multidisciplinary approach to public health problems, and highly coordinated efforts to implement solutions. The increasing complexity of factors that contribute to health requires use of the full spectrum of scientific disciplines, and expansion of scientific disciplines at CDC has been impressive. From the entomologists and engineers dominating CDC's scientific ranks in the 1940s to the addition of epidemiologists, veterinarians, microbiologists, and medical officers through the 1970s to the latest addition of economists, behavioral and social scientists, molecular biologists, statisticians, urban planners, informaticians, and other scientists, current CDC staff represent approximately 25 scientific disciplines.

This supplemental issue of *MMWR* celebrates CDC's scientific strength and diversity by describing the public health contributions of 11 disciplines. It begins with the fundamental, cross-cutting disciplines of laboratory sciences and epidemiology, then focuses on disciplines new to public health, yet essential to CDC's success. Although this supplement only partially illustrates the variety of disciplines contributing to public health, the 11 articles provide a flavor of public health's scientific diversity and strength. They highlight contributions of many disciplines to each of CDC's health protection goals and emphasize how synthesizing scientific information is essential to impact health and maximize scientific investments.

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Epidemiology and Public Health at CDC

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Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations and the application of this study to control health problems (*1*). However, in public health, the terms "field epidemiology" (*2*) and "applied epidemiology" (*3*)—which emphasize use of results in public health settings—define the practice of epidemiology at CDC. Epidemiology has been characterized as the basic science of public health (*2*), and its practice at CDC has shaped the agency's development and will contribute to its future success.

Epidemiology at CDC

Epidemiology at CDC began with Dr. Alexander Langmuir and his extraordinary contributions to CDC and to public health. Hired in 1949, Langmuir served as first Chief Epidemiologist at CDC and remained in that position until 1970 (*4*). In 1952, he convened the first Conference of State and Territorial Epidemiologists, which became the organization representing the approximately 2,500 epidemiologists working today in states. Langmuir defined disease surveillance at CDC (*5*), and this model since has become an established global public health practice. In 1961, Langmuir helped bring the *MMWR* to CDC to disseminate timely public health surveillance data and to communicate the results of public health investigations. He was an international consultant in epidemiology at the Winnipeg flood disaster of 1950; the radiation studies that followed the bombings at Hiroshima and Nagasaki, Japan; the global smallpox-eradication program; and other international issues of public health importance.

During the 1960s, CDC epidemiologists continued to work in infectious diseases domestically, especially drug-resistance in hospitals and *Salmonella* in commercial chicken products. A 1961 study of leukemia in Niles, Illinois (*6*), marked the first of several investigations of cancer clusters and the introduction of chronic disease epidemiology to CDC. Langmuir extended the scope of CDC epidemiology by initiating a family planning activity in 1963, and 4 years later, he established the Metropolitan Atlanta Congenital Defects Program.

Possibly Langmuir's most recognized contribution was the Epidemic Intelligence Service (EIS), a combined training and service program formed initially in response to the threat of bioterrorism (*7*). Since 1951, approximately 2,700 EIS officers have provided CDC and the states with a rapid-response capacity for any public health need in an estimated 10,000 investigations domestically and internationally (*8*). EIS-trained epidemiologists remain at CDC in leadership positions; others occupy prominent positions in other government agencies, academia, and international organizations.

One investigation put CDC and applied epidemiology in the public eye for the first time. On April 12, 1955 (the anniversary of the death of Franklin Roosevelt), the favorable results of the field trial of inactivated poliovirus vaccine were announced; 5 days later, a massive national vaccination campaign was initiated. However, within a week, paralytic polio was diagnosed in a child who had received the vaccine, and as new cases emerged, Langmuir was called on to investigate. A surveillance unit was set up and began issuing daily reports. On May 8, the U.S. Surgeon General declared a moratorium on the program. Using all the EIS officers and working with the states, CDC established the association with two lots of vaccine from one manufacturer, cleared the other four manufacturers, and persuaded public authorities by June 1 to restart the program (*9*).

The 1970s saw an expanding role for epidemiology at CDC. CDC epidemiologists identified contaminated bottles of intravenous fluid, leading to a national recall; linked liver cancer in certain workers with exposure to vinyl chloride; played a pivotal role in the global eradication of smallpox; identified Ebola virus in Zaire and the Sudan; identified toxic-shock syndrome; and uncovered the association between aspirin use and Reye syndrome. The Cancer and Steroid Hormone Study, conducted in collaboration with the National Cancer Institute, and the Study of the Efficacy of Nosocomial Infection Control were important not only for their findings but also for the introduction of large numbers of analytic epidemiologists and statisticians to CDC. The 1976 investigation of Legionnaires disease in Pennsylvania highlighted collaboration between laboratory scientists and epidemiologists in the discovery of new and important pathogens (*10*). Field epidemiology training programs established in Canada and Thailand were the first of now 34 EIS-like programs around the world (*11*).

Acquired immunodeficiency syndrome dominated the 1980s and, together with expansion of agency programs in noninfectious diseases, added behavioral and social scientists

to CDC's team of epidemiologists, statisticians, and laboratory scientists. Infectious diseases—notably *Escherichia coli* O157:H7 associated with hemorrhagic diarrhea and hemolytic-uremic syndrome—remained important. However, studies of chronic diseases, violence, disasters, refugees, and toxic exposures to both environmental and commercial products such as cooking oil, medications, diet supplements, and paint engaged increasing numbers of epidemiologists.

Since 1990, CDC epidemiologists have collaborated with an expanding array of partners around the world to tackle noninfectious diseases and injuries, as well as emerging infections, such as hantavirus, cryptosporidiosis, West Nile virus, severe acute respiratory syndrome, and the threat of pandemic influenza. Global eradication programs in polio and dracunculiasis (guinea worm disease) engage a global network of epidemiologists with the World Health Organization, international governments, and the private sector. Prevention effectiveness and informatics have been added to the epidemiologist's toolkit. Hundreds of epidemiologists were deployed to address disasters at the World Trade Center and the anthrax poisonings in 2001 and hurricanes Katrina and Rita in 2005.

The Role of the Epidemiologist in the Future

CDC epidemiologists will continue to respond to emergent events, be they newly emerging infections, natural disasters, or terrorism, and will continue to study public health problems, such as unintentional injuries, environmental exposures, cardiovascular disease, obesity, tobacco use, and violence domestically and internationally (*12*). Public and private partners on the public health team will expand to include new disciplines. The analytic tools and technologies available will increase, and CDC epidemiologists will maintain a critical role in capacity building. Finally, CDC epidemiologists must maintain the scientific integrity the agency has established by remaining rigorous yet adaptable to the challenges new global realities bring to public health.

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Laboratory Science and Public Health at CDC

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Laboratory technology is as essential to public health practitioners for monitoring threats to public health as it is to clinical practitioners who depend on laboratory technology to diagnose and monitor disease in individuals. Laboratory technology provides essential information for effective public health interventions, whether monitoring emerging infectious diseases, such as avian influenza globally; identifying pathogens, such as *Escherichia coli* in the U.S. food supply and pinpointing its source; screening newborns for devastating disorders, such as phenylketonuria, that can be prevented by early intervention; or developing the capacity to quickly screen for exposure to chemical and biologic agents.

Role of the Laboratory in Infectious Diseases

CDC was founded to address infectious diseases important in the post-World War II era. Today, combating infectious diseases remains a vital part of the CDC mission, including investigating new outbreaks caused by infectious agents and detecting, characterizing, and devising methods for prevention. The laboratory also has been instrumental in identifying newly recognized or reemerging microbes that caused outbreaks, including *Legionella*, hantavirus, West Nile virus, and severe acute respiratory syndrome-associated coronavirus (SARS-CoV). CDC's ability to identify new pathogens has improved over time as laboratory technologies have advanced, as illustrated by *Legionella* in 1977 (*1*) and SARS-CoV in 2003 (*2*). *Legionella*, a bacterium, was discovered after many months of extensive laboratory testing when a scientist inoculated guinea pigs with lung tissue from a patient and caused a febrile illness. Spleen suspensions from the guinea pigs were inoculated into embryonated eggs, and a bacterium grew. Serum from 101 of 111 patients whose illness met the clinical criteria for Legionnaires disease showed diagnostic increases in antibody titers. The laboratory tools used to describe this new bacterium were state-of-the-art in the 1970s, although by today's standards they are rudimentary.

Contrast laboratory techniques used to identify *Legionella* with those used 3 decades later to identify another new organism, the SARS-CoV. The SARS outbreak began in 2003 in China and within weeks affected people in approximately 30 countries. Scientists from about a dozen countries around the world held daily teleconferences to compare findings from specimens they had received. CDC obtained blood from a World Health Organization physician caring for patients whom we now know had SARS; tested it by standard techniques, including tissue culture; and discovered a cytopathogenic effect in one of the tissue culture cell lines. The supernatants from the cells were examined by electron microscopy, and a coronavirus was identified. Patient specimens then were examined for antibody reactions to the isolated virus. Virus-infected cells and cell extracts were used to develop an antibody assay. Then, taking clues from partial RNA sequences of the coronavirus, a molecular assay also was developed, and in record time, CDC had assays to deploy to the state public health laboratories to detect both antibody and antigen. Three weeks after initial identification of SARS-CoV, the complete sequence was determined and compared with other coronaviruses (*3*).

Role of the Laboratory in Chronic Diseases and Environmental Health

CDC's experience in environmental health and chronic disease is more recent than its work in infectious disease. Still, CDC laboratories dedicated to these important public health disciplines provide vital expertise for accomplishing the CDC mission to protect public health.

Smoking and exposure to secondhand smoke (SHS) are responsible for a substantial proportion of death and disease in the United States and worldwide. The Surgeon General's recent report, *The Health Consequences of Involuntary Exposure to Tobacco Smoke*, showed that exposure to SHS increases the risk for developing heart disease by 25%–30% and lung cancer by 20%–30% (*4*). The CDC Environmental Health Laboratory contributed to understanding the risks from SHS. This work included the first national estimate of nonsmokers' exposure to SHS in the U.S. population (*5*) and documentation of a substantial decrease in SHS exposure using cotinine (a marker in the blood for exposure to nicotine) measures

from the Third National Health and Nutrition Examination Survey (NHANES III [1998–1991]) (*6*). Earlier studies used less reliable estimates based on self-report or questions related to lifestyle rather than to laboratory measurements of SHS exposure.

The decline in exposure to lead in the United States has been called one of the most important recent accomplishments of public health (*7*). Most of the decline in blood lead levels occurred during the 1970s and 1980s, paralleling removal of lead from gasoline (*8*). Understanding of this relation can be attributed to the accurate and precise blood lead measurements of the CDC Environmental Health Laboratory, which used atomic absorption spectrometric methods to measure lead levels for NHANES III. Analytical results indicated a dramatic decrease in blood lead levels for the population. In addition, the percentage of children with blood lead levels ≥10 μg/dL also decreased sharply, from 89% in NHANES II (1976–1980) to 8.9% in NHANES III.

Conclusion

From CDC's beginnings, its expertise in laboratory science has played a vital role in accomplishing its public health mission both domestically and internationally. That role continues to grow as advances in laboratory technology are developed and used in the service of promoting the nation's health and quality of life.

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Veterinary Medicine and Public Health at CDC

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Introduction

People readily associate the role of veterinarians with private veterinary practice focused on pets and farm animals, but the true dimensions and contributions of veterinary medicine are much broader and reflect expanding societal needs and contemporary challenges to animal and human health and to the environment (*1*). Veterinary medicine has responsibilities in biomedical research; ecosystem management; public health; food and agricultural systems; and care of companion animals, wildlife, exotic animals, and food animals. The expanding role of veterinarians at CDC reflects an appreciation for this variety of contributions.

Veterinarians' educational background in basic biomedical and clinical sciences compare with that of physicians. However, unlike their counterparts in human medicine, veterinarians must be familiar with multiple species, and their training emphasizes comparative medicine. Veterinarians are competent in preventive medicine, population health, parasitology, zoonoses, and epidemiology, which serve them well for careers in public health. The history and tradition of the profession always have focused on protecting and improving both animal health and human health (*2*).

Veterinary Contributions to Public Health

The veterinary profession contributes to improvement of human and public health by improving agriculture and food systems, advancing biomedical and comparative medical research, preventing and addressing zoonotic diseases, enhancing environmental and ecosystem health, and helping manage 21st century public health challenges (*3,4*).

Bridging Agriculture and Medicine

Since 1892, a total of 14 diseases have been eliminated from equine, poultry, and livestock populations in the United States (*5*). The elimination of these livestock diseases, along with outstanding research in animal health, is key to the remarkable gains in the efficiency of U.S. animal production. Partly as a consequence, U.S. residents spend only approximately 10% of their disposable income on food, whereas residents in other countries pay three or four times more (*7*). Although this achievement is recognized to have added billions of dollars to other parts of the U.S. economy, its success in allowing the U.S. public access to a nutritious, affordable, and sustainable food supply—also important for the public's health and well-being—is far less appreciated. The success of the national brucellosis and tuberculosis elimination campaigns has benefited not only the U.S. livestock industries but also human health by substantially reducing these zoonotic threats in animals. Additional public health contributions can be attributed to the Food Safety and Inspection Service of the U.S. Department of Agriculture (USDA), which has substantially reduced the burden of foodborne illnesses, improved food safety, and eliminated other zoonotic threats. Over the years, CDC has worked closely with USDA and the Food and Drug Administration to improve the safety of U.S. foods and reduce antimicrobial resistance in pathogens that infect both humans and animals.

Research

Research in veterinary science is critical to understanding and improving human health (*8*). In 1858, Rudolph Virchow, the father of comparative medicine, stated, "Between animal and human medicine there are no dividing lines—nor should there be. The object is different but the experience obtained constitutes the basis of all medicine" (*9*). Today comparative and interdisciplinary research is critical to translating scientific advances from one discipline or species to another and providing new insights into human health problems. Scientific fields such as laboratory animal medicine, pathology, and toxicology, when combined with veterinary medicine, have proven especially relevant to success in biomedical research (*10*).

Zoonoses in Companion Animals

Veterinarians also have contributed to public health through the care of companion animals. Fifty-seven percent of all U.S. households own a dog, cat, or both. In addition, millions of exotic animals, birds, and reptiles are kept as pets (*11*). Although pets enrich the lives of humans, they also potentially can threaten public health. Veterinarians help educate the public about prevention of zoonoses; vaccinate large num-

bers of pets for zoonotic diseases, such as rabies and leptospirosis; and reduce the level of ecoparasites that can transmit human diseases and intestinal worms, such as roundworms and hookworms, which can cause serious health problems in humans. The 60,000 private-practice veterinarians in the United States form a valuable front line for detecting adverse health events, reducing zoonotic diseases, and delivering public health education (*7*).

Environmental Health

Because veterinarians work at the interface of human, animal, and environmental health, they are uniquely positioned to view this dynamic through the lens of public health impact. Significant changes in land use, expansion of large and intensified animal-production units, and microbial and chemical pollution of land and water sources have created new threats to the health of both animals and humans (*12*). Because animals share human environment, food, and water, they are effective sentinels for environmental, human, and public health problems, including bioterrorism.

Concerns are increasing about antimicrobial resistance of pathogens, waste and nutrient management, and potential runoffs into streams, rivers, and oceans. Food animal and wildlife populations are inextricably linked to some environmental problems. Together these have led to creation of a new scientific discipline called ecosystem health, and veterinarians are assuming a leadership role in the field (*13*).

Contemporary Challenges: Convergence of Animal and Human Health in a New Era

Several decades ago, special factors came together to create a new epidemiologic era characterized by increases in emerging and reemerging zoonoses (*14*). Humans, animals, and animal products now move rapidly around the world, and pathogens are adapting, finding new niches, and jumping across species into new hosts. In 2005, approximately 21 billion food animals were produced to help feed a world population of 6.5 billion persons; the United Nations' Food and Agriculture Organization estimates that demand for animal protein will increase by 50% by 2020, especially in developing countries (*15*).

The lessons learned from severe acute respiratory syndrome, West Nile virus, monkeypox, and avian influenza are reminders of the need to view diseases globally; integrate animal and public health surveillance, epidemiology, and laboratory systems; and create new strategic partnerships among animal, human, and public health professions (*16,17*). Veterinarians are essential to the detection and diagnosis of and response to these threats and are integral to first-line defense and surveillance for bioterrorism agents.

Veterinary Contributions and the Changing Emphasis at CDC

Just as CDC has expanded its role, scope, and influence in public health since its inception in 1946, so has the veterinary profession (D. Satcher, CDC, personal communication, October 21, 1996). Early in the history of CDC, veterinarians in the U.S. Public Health Service and the CDC Veterinary Public Health Division helped reduce zoonotic diseases, especially rabies and foodborne illnesses (*18*). Today, 89 veterinarians serve throughout CDC in positions that address not only infectious diseases but also the entire spectrum of public health challenges: environmental health, chronic diseases, human immunodeficiency virus infection and acquired immunodeficiency syndrome, injuries, immunizations, laboratory animal medicine, global health, migration and quarantine, health education, and bioterrorism. Veterinarians contribute as epidemiologists, laboratory scientists, policymakers, researchers, and surveillance experts and in environmental and disease prevention and control programs both domestically and globally.

At CDC, 228 veterinarians have participated in the Epidemic Intelligence Service since 1951 (*19*). Forty-one states now have State Veterinary Public Health officials. In 2005, almost 300 students and faculty attended the first veterinary student day at CDC; in April 2007, CDC will co-host an inaugural conference with the Association of Schools of Public Health and Association of American Veterinary Medical Colleges. In addition, CDC has been recognized as a World Association for Animal Health Collaborating Center for Emerging and Re-Emerging Zoonoses. The CDC publication, *Emerging Infectious Diseases*, has highlighted zoonotic diseases in nearly every issue to zoonotic diseases and has devoted an annual issue in each of the previous 2 years. Thus, CDC has provided an important scientific forum for zoonotic disease research and programs both domestically and globally.

The convergence of human and animal health drove creation of the newly proposed National Center for Zoonotic, Vector-Borne, and Enteric Diseases. Plans are being completed to establish several multidisciplinary state-level zoonosis research and development centers. The veterinary profession at CDC has evolved in prominence as a member of the health professions and has established its importance and usefulness to human and public health. Because their education is based on the concept of multiple determinants of health in popula-

tions, veterinarians are well suited to help define and achieve the new CDC health protection goals and to continue to contribute to the CDC mission in ways more important, diverse, and profound than ever before.

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Engineering and Public Health at CDC

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Introduction

Engineering is the application of scientific and technical knowledge to solve human problems. Using imagination, judgment, and reasoning to apply science, technology, mathematics, and practical experience, engineers develop the design, production, and operation of useful objects or processes. During the 1940s, engineers dominated the ranks of CDC scientists. In fact, the first CDC director, Assistant Surgeon General Mark Hollis, was an engineer. CDC engineers were involved in malaria control through the elimination of standing water. Eventually the CDC mission expanded to include prevention and control of dengue, typhus, and other communicable diseases. The development of chlorination, water filtration, and sewage treatment were crucial to preventing waterborne illness. Beginning in the 1950s, CDC engineers began their work to improve public health while developing the fields of environmental health, industrial hygiene, and control of air pollution (*1*). Engineering disciplines represented at CDC today include biomedical, civil, chemical, electrical, industrial, mechanical, mining, and safety engineering. Most CDC engineers are located in the National Institute for Occupational Safety and Health (NIOSH) and the Agency for Toxic Substances and Disease Registry (ATSDR).

Engineering research at CDC has a broad stakeholder base. With the cooperation of industry, labor, trade associations, and other stakeholders and partners, current work includes studies of air contaminants, mining, safety, physical agents, ergonomics, and environmental hazards. Engineering solutions remain a cornerstone of the traditional "hierarchy of controls" approach to reducing public health hazards (*2*).

Key Engineering Contributions to Public Health

Air Contaminants

CDC engineers at NIOSH Hamilton Laboratories have worked in industrial ventilation, isolation and containment, contaminant control, indoor environmental quality, and computational fluid dynamic modeling. Successful engineering-control studies have led to advancements for 1) controlling air contaminants, such as asphalt fumes, silica, and lead; 2) developing strategies under national emergency preparedness to protect buildings from attacks by chemical, biologic, or radiologic agents (*3*); 3) preventing transmission of infectious diseases in occupational settings (*4,5*); and 4) controlling carbon monoxide on recreational boats (*6*).

CDC engineering work has focused on innovative solutions for controlling air contaminants. During the mid-1990s, NIOSH engineers, working with paving equipment manufacturers, designed a control that reduced worker exposure to asphalt fumes by 80% (Figure 1) (*7*). NIOSH engineers have studied control of respirable silica dust in nearly a dozen industries—in one example, employee exposure to respirable silica dust was reduced approximately 87% after a china manufacturing plant implemented its dust-control recommendations. CDC engineers at NIOSH also have designed studied, and had installed ventilated booths for radiator repair shops, reducing blood lead levels of workers in those shops by 70%.

Lung-Function Testing

CDC engineers have contributed substantially to the practice of lung-function testing. Accomplishments include development of the standard approaches to testing lung-function equipment; international leadership in developing

FIGURE 1. Asphalt paver before (left) and after installation of an engineering control to reduce exposures to asphalt fumes

Before After

Photo/CDC

and disseminating lung-function testing standards; and collaborations with epidemiologists in studies of occupational and general populations. A notable collaboration between NIOSH and the CDC National Center for Health Statistics led to development of a commonly used set of reference values for evaluating spirometry in the United States (*8*).

Mining

Mining presents a challenging work environment; concerns include excessive noise levels, dust exposures, explosive and toxic gases, and massive equipment in near-constant motion. The NIOSH mining research program developed engineering controls for surface and underground mining to improve miners' health and safety. Successful controls adopted within the mining industry include water-jet sprays for dust control, noise reductions on conveyors and drill units, roof and structural support systems, designs for improved ventilation, mine-escape operations, and improved materials-handling systems.

The mining community has successfully implemented products resulting from engineering research. These products include several programs that helped improve roof, floor, and sidewall stability and prevent the likelihood of roof collapse and major causes of death and injuries (*9*). Coal pillar recovery guidelines and mobile roof supports have made pillar recovery safer (*10*). Guidelines for designing deep-cover mines to prevent coal bumps (violent failures of highly stressed coal) contributed to 7 consecutive years without fatalities. A research and education campaign on rock-fall injuries and use of surface controls in coal mines has reduced rock-fall injury rates by approximately 25%.

Safety

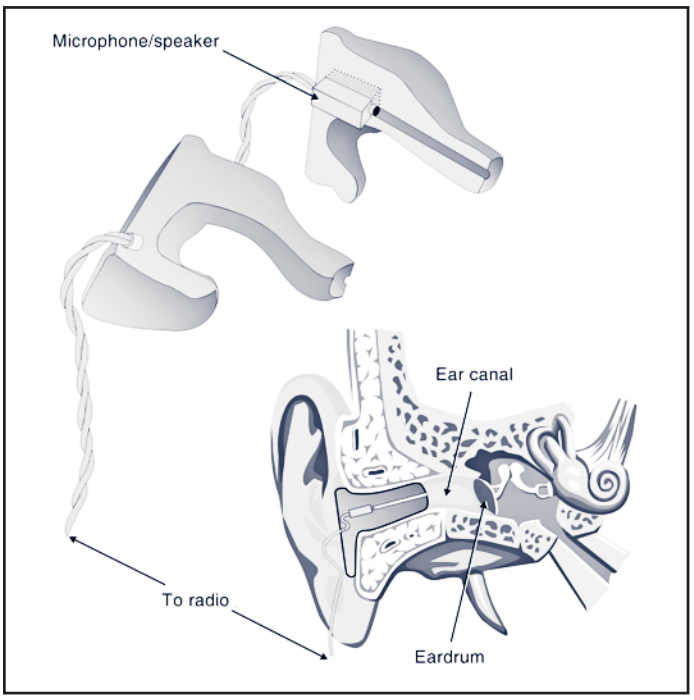
CDC engineers at NIOSH conduct safety engineering research to prevent occupational injuries by developing practical products and interventions in areas such as fall prevention, machine safety, and equipment safety research. Examples of engineering-control research include improved lock-out devices for paper balers and rollover protective structures for tractors, equipment responsible for numerous deaths and injuries. More rigorous standards have been examined for machine safeguarding, to better match international standards (*11*). Other projects include improving the safety of roof-bracket assemblies to protect roofers and construction workers from disabling or deadly falls (*12*) and developing improved work practices and computer modeling on scissor-lift tip-over controls to prevent fatalities. NIOSH safety engineers also study personal protective equipment for workers exposed to fall-from-elevation hazards (*13*). Research on the interface between the human body, machinery, and protective equipment represents an advancing area of safety engineering. These practices have provided the basis in developing injury-control innovations and moved many safety engineering technologies to product-design practices, standardization, and commercialization.

NIOSH engineers and epidemiologists worked together in Alaska after deck machinery on commercial fishing vessels was identified as the cause of 40% of injuries requiring hospitalization in one of the country's most dangerous industries. Engineering researchers developed a solution to prevent entanglements from a capstan-style deck winch. Fishermen praised the device as a safety and productivity improvement that reduces injuries and work stoppages (*14*).

Physical Agents: Noise, Heat, and Radiation

Hearing loss prevention engineers at CDC study the effects of noise-induced hearing loss that affects an estimated 30 million U.S. workers. Engineers design and develop instruments and methods to assess and characterize hazardous noise exposures. NIOSH engineers have an international reputation for their work on hearing protection devices, controlling exposure to impulsive noise, and novel engineering noise-control research. They developed and patented EarTalk™, a hearing-protection and communication system that enables workers to communicate in noisy environments (Figure 2). They also developed a novel system for characterizing exposure to impulsive noise and applied for U.S. and international patents (*15,16*).

FIGURE 2. NIOSH-developed and -patented EarTalk™ hearing protection and communication system, which uses miniature microphones built into custom-molded earplugs to capture speech signals from the ear canal and transmit it using portable radios



Engineering assessments have shown that workers are exposed to ionizing radiation from technologies recently developed to improve homeland security. These technologies (many of which were introduced to market after the terrorist attacks of September 11, 2001) use X-rays to screen checked baggage at every major airport throughout the world for explosive materials or use gamma radiation to screen cargo containers for illegal contraband. NIOSH engineers characterized unnecessary exposures from these technologies and recommended measures to prevent or reduce these exposures (*17*).

Ergonomics

Engineers support the NIOSH program to reduce work-related musculoskeletal disorders and contribute to the design of new or improved exposure-assessment techniques, tools, and equipment. According to the Bureau of Labor Statistics, approximately 32% of lost workdays result from overexertion or repetitive motion. CDC engineers developed an exposure-assessment technique to quantify risk factors associated with workplace postures and job tasks. Workers using nonpowered hand tools have been studied using force sensor technology to identify the portion of the work cycle resulting in the greatest forces to the hand. Effective interventions and solutions that reduced repetitive motion injuries have been applied to the agriculture, shipyard, mining, and construction industries (Figure 3). NIOSH also conducted an intervention trial that demonstrated a strategically designed patient-lifting program can markedly reduce musculoskeletal injuries to nursing staff in health-care facilities. CDC engineers at NIOSH worked to produce patentable devices to address specific concerns when commercially available interventions were not available (*18–20*).

Environment

Engineers at ATSDR are involved in determining, through engineering interpretation of environmental investigations and sampling results, how the public could be exposed to hazardous materials in the environment. In addition, situation-specific sampling methodologies have been developed to determine how exposures have occurred to hazardous materials. Cutting-edge environmental modeling techniques are used to reconstruct past exposures from contaminated drinking water supplies. These remodeling techniques permit more accurate determination of adverse health impacts and reduce the exposure misclassification bias in ATSDR epidemiologic studies. During emergency response situations, ATSDR engineers analyzed community infrastructures to help determine when the public could safely return home (*21,22*).

Water quality is a public health concern worldwide. CDC engineers at the National Center for Infectious Diseases, working with epidemiologists, have conducted water quality testing, developed standardized chlorine-dosing regimens, and

FIGURE 3. Construction worker being evaluated by engineers for musculoskeletal disorder risk factors

Photo/CDC

collaborated to develop regional safe-water systems that are inexpensive and easy to transport and have the appropriate chlorine dosing. Engineering design has increased the impact of this program by making the chlorine solution available at lower cost to more persons in developing countries. Last year, 8 billion liters of water were treated in 15 countries throughout Africa and Asia.

Conclusions

For decades, CDC engineers have played a key role in enhancing U.S. and international public health by focusing on CDC goals concerning healthy communities, workplaces, homes, and schools. CDC engineers are meeting public health challenges by conducting laboratory and field studies, overseeing research and development that result in solutions-based products, conducting disaster relief and emergency response, and engaging in public health program management. Engineers are an integral part of the public health team that helps define what is possible, identify existing limitations, and shape workable solutions. Their efforts have contributed immensely to reducing disease and preventing injury in the United States and around the world.

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Behavioral and Social Sciences and Public Health at CDC

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Introduction

Although the history of CDC spans 60 years, only during the last 2 decades of the 20th entury did the agency come to recognize and better understand the importance of the behavioral and social sciences to its overall mission. This recognition was a consequence of several events, notably the growing public awareness of the many conditions and diseases linked to unhealthy behavior and the creation of three new organizational units at CDC—the National Center for Chronic Disease Prevention and Health Promotion in 1988, the National Center for Injury Prevention and Control in 1992, and the National Center for HIV, STD, and TB Prevention in 1993—that focused on conditions, diseases, and injuries with clear behavioral risks. Accordingly, the relatively small number of CDC behavioral and social scientists were initially concentrated in these three centers. In 1995, to raise awareness of behavioral and social sciences at CDC and to integrate these fields into CDC-conducted and -supported research and practice activities, the agency's behavioral and social scientists established the Behavioral and Social Sciences Working Group (BSSWG). The application of the behavioral and social science disciplines to public health attests to the success of the working group. Today, BSSWG continues as a formal organization sponsored by the Office of the Chief Science Officer within the CDC Office of the Director.

Contributions of Behavioral and Social Science to CDC

The behavioral and social sciences incorporate a number of disciplines, and each brings a variety of theoretical perspectives and methodologic approaches to its particular areas of study. At CDC, these sciences are represented primarily by psychology, sociology, anthropology, and economics. Armed with their unique frameworks, scientists from these fields can use qualitative, quantitative, or multiple methods to explore the effects of behavioral, social, and cultural factors on public health problems. As with all research at CDC, behavioral and social science research ranges from basic to applied; however, these disciplines contribute most to applied public health through intervention research, program evaluation, and policy analysis.

Development and testing of new interventions that are behaviorally and socially based or that include behavioral and social components have been active areas of study at CDC, especially with regard to the acquired immunodeficiency syndrome (AIDS) epidemic. During the 1980s and 1990s, numerous interventions were developed and tested to reduce the risk for human immunodeficiency virus (HIV) infection (*1*). For example, using experimental or quasi-experimental designs, many studies examined the impact of psychosocial factors on sex- or drug-related outcomes among clinic or drug-treatment populations. In addition, social and behavioral scientists have evaluated many of these interventions—those developed not only for reduction of HIV infection (*2*) but also for other areas of public health significance, such as violence prevention (*3*) and occupational safety and health (*4*).

Another contribution to CDC and public health is the monitoring of key behavioral outcomes through surveillance systems to assess policy impact. For example, in one study, using data from the U.S. Behavioral Risk Factor Surveillance System and a quasi-experimental approach, the prevalence of drinking and driving behavior was examined before and after enactment of a new state policy. The authors found a statistically significant decrease in drinking and driving after laws were passed and enforced to both lower the blood alcohol level considered to be *prima facie* evidence of intoxication and to suspend the drivers' licenses of persons found guilty of driving while intoxicated (*5*).

The contributions of behavioral and social scientists to the CDC mission span the breadth and depth of public health research and study. Within CDC, behavioral and social scientists have conducted research in the areas of AIDS/HIV infection (*1,6*), chronic diseases (*7,8*), intentional and unintentional injury (*3,9*), occupational safety and health (*4,10*), health education and promotion (*11*), reproductive health (*12*), birth defects and developmental disabilities (*13*), and environmental health (*14,15*). For example, behavioral and social scientists applied social cognitive theory to data from the Family

Adolescent Risk Behavior and Communications Study to examine the influence of multiple social factors on sexual behavior among adolescents (*12*). They used a similar theoretical framework to explore the impact of parental communication on adolescent risk behavior for HIV infection (*16*). Others at CDC have emphasized the need for behavioral and social scientists to systematically examine economic, social, political, and organizational factors to learn about behaviors important to disease prevention (*17*). Recently, behavioral and social scientists have directed their attention toward environmental health. They are uniquely suited to uncover the social forces affecting the environment that could create a health disadvantage to persons who inhabit that environment (*14*).

Furthermore, behavioral and social scientists are well trained to study the effects of not only attitudes and behaviors on the public's health but also social factors—such as class, family structure, and community integration—that affect it. The influence of race and ethnicity on health and illness has been important to investigations by behavioral and social scientists (*18*) and critical to the CDC goals of identifying, understanding, and reducing health disparities.

The application of innovative approaches, such as meta-analyses and translational research, to public health problems also has been an important contribution by behavioral and social scientists (*2,3*). These contributions are especially apparent in the *CDC Guide to Community Preventive Services* (*19*), where systematic reviews of evidence for the effectiveness of prevention programs and interventions have been conducted for key programmatic areas throughout the agency.

The Behavioral and Social Sciences Working Group

The successful integration of behavioral and social science into CDC's work can be attributed in large part to BSSWG and the commitment of its members. The group has achieved its goals through major initiatives that include an annual speaker series and support for BSSWG member attendance at relevant professional conferences, which helps identify new scientists who may be interested in public health and employment at CDC. New in 2006 was an annual award for outstanding behavioral or social science research. These achievements have resulted in substantial increases in the number of such scientists and expansion of their roles at CDC.

From only a handful of behavioral and social scientists in a few parts of the agency just 15 years ago, CDC today employs approximately 300 behavioral and social scientists who work with epidemiologists and biomedical researchers throughout the agency and collaborate with other federal agencies and with nongovernment partners on a myriad of public health concerns. Moreover, behavioral and social scientists have increasingly competed successfully for positions in traditional public health training programs, such as the Epidemic Intelligence Service, and participated actively in outbreak investigations and emergency responses. The behavioral and social sciences are expected to continue to contribute to public health at CDC in areas not already reached by these disciplines and through greater participation in areas of traditional public health, such as infectious diseases (*20*).

As CDC has grown over the past 60 years, its workforce has become increasingly multidisciplinary. The influence of these workforce changes reaches far into CDC's extensive network of public health partners. Behavioral and social science perspectives and approaches to public health extend to collaborative activities with state and local partners, other federal partners, and other public and private organizations, both domestically and globally. Public health research and practice have been strengthened by the disciplines represented among the behavioral and social sciences, disciplines that have come to play a vital role at CDC as it carries out its mission to make people safer and healthier.

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Economics and Public Health at CDC

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What is Economics, Really?

Economics is the study of decisions—the incentives that lead to them and the consequences that result from them—as they relate to present and future production, distribution, and consumption of goods and services when resources are limited and have alternative uses (*1*). At CDC, economics is used to systematically identify, measure, value, and compare the costs and consequences of alternative prevention strategies. Costs and consequences in public health can be measured in various ways, including incidence or prevalence of disease; numbers of adverse events; utility measures, such as quality-adjusted life years; and monetary values. Because it deals with behavior, economics is not really about money at all. Money is just a convenient way to measure incentives and consequences.

Contributions of Economics to CDC and Public Health Research

Health economics has developed as a subdiscipline of economics and led to consideration of public health economics as its own field (*2*). Its developmental history is evident in milestone disciplinary publications (*3*–*11*). A few applied contributions illustrate the breadth to which economics has been used at CDC and in public health; a more expansive review of applied economic evaluation in public health (including methods) and the ways economic studies have affected decisions is available elsewhere (*12*).

Policy Analysis

Useful at various levels of decision-making responsibility, applied economic studies have been conducted to evaluate in-place policies and public health programs and practices. At the policy level, examples include the effects of tobacco excise taxes on cigarette consumption (*13*) and the effects of liquor taxes on rates of sexually transmitted diseases (*14*). Both studies found that increases in taxes result in decreases in undesirable health outcomes. Cost-benefit and cost-effectiveness analyses of vaccines are explicitly considered by the Advisory Committee on Immunization Practices (ACIP) when it makes recommendations (*15*), although ACIP has never rejected a vaccine on the basis of the results of an economic evaluation. ACIP makes recommendations on vaccines and immunization practices, but it influences both government and private policy decisions. When ACIP votes to include vaccines in the Vaccines for Children (VFC) program, the decision is codified as a VFC resolution. A VFC resolution usually takes effect after a CDC contract is established for purchase of that vaccine. Hence, ACIP decisions on VFC have budgetary consequences. Recommendations also are often followed by private health-care providers and affect third-party payers.

Program Priority Setting and Analysis

In 2002, the National Center for Injury Prevention and Control (NCIPC) developed its *Injury Research Agenda* with input from its academic research centers, national nonprofit organizations, and other federal agencies with a stake in injury prevention (*16*). The agenda was intended to guide research in key areas of injury prevention and control. Among the criteria for including a topic area among the NCIPC research priorities were economic and social cost measures of public health burden. As a result, cost-of-illness studies were conducted in injury topic areas. Such studies are important, necessary starting points for subsequent economic evaluations used to finalize intervention implementation priorities.

Recent work at the National Center for Immunization and Respiratory Diseases (proposed) (formerly the National Immunization Program) illustrates program economic analysis that goes beyond cost analysis and economic evaluation. Economists there are studying the economics of vaccine supply to understand the costs of vaccine development, production, and pricing. Although manufacturers consider this information proprietary, it can be estimated and used by federal government negotiators to evaluate their negotiation strategies for vaccines purchased for the VFC program.

Practical Impact

Economic evaluation has proven influential at the public health practice level when alternative means exist of achieving a specific health goal. Different therapies, different populations, and different timing of interventions have been exam-

ined to determine the best use of resources. An analysis of drug therapy options for treating *Chlamydia trachomatis* infections in women indicated that a more costly, more effective drug than was in current use could be cost-saving when considered from a broad perspective (*17*). Use of the drug resulted in a net cost, however, when the more limited perspective of the budget of a publicly funded clinic was considered. Results of the analysis were used to negotiate a lower price for the more effective drug so clinics could consider adopting it for treatment.

Compilations of recommendations of clinical and community preventive services have used economic evaluations to varying degrees. The U.S. Preventive Services Task Force (*18*) and the Task Force on Community Preventive Services (*19*) make evidence-based recommendations on the use of preventive services. Both include economic information in their recommendations, but neither incorporates it as a criterion on which to base recommendations. Conversely, the National Commission on Prevention Priorities published a ranking of U.S. Preventive Services Task Force-recommended clinical preventive services based in part on cost effectiveness evidence (*20*).

Economics and Public Health Growing Together

Although the application of economics to health and public health issues did not begin at CDC, its use at the agency no doubt has accelerated its development and maturity in the field. Economics was introduced to public health research because of a desire to make transparent and fair decisions on the basis of the best tools and data possible. Beginning in the late 1970s, the Office of Program Planning and Evaluation was the agency's focus of economic evaluation and decision analysis. Economic expertise was brought to CDC under short-term interagency personnel agreements, and economic studies were conducted through contracts.

Interest increased throughout the 1980s, and in the early 1990s, economics began to be formally incorporated at CDC, beginning as an allied discipline with decision sciences under the rubric of prevention effectiveness. It continues in that role to this day, although one is more likely now to encounter the term "economics" than "prevention effectiveness" as more economists are embedded throughout CDC. A training course in prevention effectiveness methods was developed for the Epidemic Intelligence Service starting in 1992 and then for CDC staff. Thus far, these courses have attracted well over 2,000 attendees. The Prevention Effectiveness Fellowship Program (subsequently renamed in honor of Steven M. Teutsch for his contributions) welcomed its first class of five post-doctoral fellows in 1995 (http:www.cdc.gov/epo/fellow.htm). Since then, approximately 80 fellows have participated in the program, and nearly 50 have been employed throughout CDC. Fellows and alumni have published nearly 300 peer-reviewed articles. Initially the analytic tools employed proved satisfactory; however, as more of the early basic questions have been answered, research problems and topics have grown more complicated. Economists at CDC participate in the development and adaptation of methods and measures to meet new challenges.

The need for better tools for decision making recognized early on has not disappeared and may even have intensified. CDC's economists face no shortage of research opportunities. Public health policymakers and managers know they need to demonstrate the value of interventions when budgets are highly scrutinized and must be justified in detail. They also need to make decisions about resource use and understand that economics can help make more efficient use of resources. Recognizing the concept of opportunity cost, policymakers and managers also have come to understand that resources employed in one activity cannot be used in another.

The integration of economics into public health research has provided decision makers with a valuable tool. Economics cannot provide the answer to all decisions because all aspects of a decision cannot be quantified. However, a systematic, transparent analysis can demonstrate value and help make decisions that improve efficiency in providing public health services.

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Genomics and Public Health at CDC

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Genomics is the study of the entire genome, including all genes and their interactions with each other and with the environment (*1*). The scope of public health genomics is even broader, encompassing genetic variation in populations, both human and microbial. Molecular typing of pathogens—a mainstay of infectious disease surveillance, prevention, and control—already is used to trace epidemics (*2*), provide information for vaccine development (*3*), and monitor drug resistance (*4*). Now genomic research is producing powerful new tools for public health; for example, a newly described, microchip-based method promises to diagnose influenza infection, distinguish among viruses of human or animal origin, and detect mutations that suggest increasing virulence—all in a matter of hours (*5,6*).

Until recently, public health applications of human genetics were limited largely to state-mandated programs that screened newborn infants and ensured access to genetic services for affected children and families. Now genomic research and technology have generated new molecular targets and new tests for newborn screening, kindling renewed debate on their relative benefits, risks, and costs (*7*). Public health investigations of diseases with infectious and environmental causes also are beginning to evaluate the contribution of human genetic variation to susceptibility and natural history (*8*).

Most population-based research in genetic epidemiology has focused on common, chronic diseases, as reflected in approximately 22,000 scientific publications during the last 5 years (*9*). The results point to complex interactions among multiple genes and environmental factors, which remain poorly understood. However, small successes in translation illustrate the potential for public health genomics in three areas: stratifying risk to guide multilevel interventions, understanding environmental causes of disease, and identifying new opportunities for prevention.

Family health history, which captures information about shared inherited and environmental factors, is a simple and inexpensive genomic tool for identifying persons and families at high risk (*10*). For example, a Utah study indicated that the 14% of families with positive family histories for coronary heart disease (CHD) accounted for 48% of all persons with CHD and for 72% of CHD events occurring before age 55 years (*11*). Population-based data and careful cost-effectiveness analysis are needed to determine whether combining traditional, population-level prevention strategies with more intensive interventions for families at increased risk will improve the return on investment in prevention (*12*).

Public health interventions are based on understanding and modifying environmental risk factors. For example, recognition of inadequate folate status as a cause of neural tube defects led to an effective public health intervention to increase folic acid intake among reproductive-aged women (*13*). A systematic review of epidemiologic data on birth defects in relation to folic acid intake and variation in the *methylenetetrahydrofolate reductase* (*MTHFR*) gene illustrates "Mendelian randomization" (*14*), in which the effects of specific environmental exposures, such as dietary elements, drugs or toxins, are either accentuated or mitigated in persons with different variants of genes involved in physiologic response. Because genotype is "randomized" at birth, biologic information thus can strengthen evidence obtained from traditional environmental risk factor studies and provide a less biased framework for interpreting data on gene-environment interactions (*15*).

Public health genomics can provide information about population-level interventions that do not depend on knowledge of individual genotypes. For example, a study in Mexico of children with asthma found that supplementation with the antioxidant vitamins C and E improved lung function in children with a common polymorphism of *glutathione S-transferase M1* (*GSTM1*) who are exposed to ozone (*16*). If confirmed by other studies, this finding might suggest a simple intervention—antioxidant vitamin supplementation—for children with asthma who are exposed to ozone. Without genotype-specific analysis, a potentially important population-level intervention could have been overlooked.

Just as genomics will enhance the knowledge base for public health research and practice, public health principles and methods can provide information for genomics research and translation. Rigorous application of population-based methods for collecting, evaluating, and interpreting the evidence on genetic variation in relation to health and disease will improve research quality, promote knowledge synthesis, and help identify research gaps. By keeping the focus on population-level implications, the public health perspective helps

ensure the entire population benefits from public investment in genomics research.

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Statistics and Public Health at CDC

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Have you ever wondered how an association between exposure and disease is evaluated? For example, how does the severity of salmonellosis depend on ingested dose of egg products (*1*)? Or how is the relation between blood lead levels and gasoline lead levels determined (*2*)? Each of these studies involves statistical analysis.

Since CDC's inception, an important function of the agency has been the compilation, analysis, and interpretation of statistical information to guide actions and policies to improve health. Sources of data include vital statistics records, medical records, personal interviews, telephone and mail surveys, physical examinations, and laboratory testing. Public health surveillance data have been used to characterize the magnitude and distribution of illness and injury; to track health trends; and to develop standard curves, such as growth charts. Beyond the development of appropriate program study designs and analytic methodologies, statisticians have played roles in the development of public health data-collection systems and software to analyze collected data. CDC/ATSDR employs approximately 330 mathematical and health statisticians. They work in each of the four coordinating centers, two coordinating offices, and the National Institute for Occupational Safety and Health.

FIGURE 1. Statistician in the field, collecting data for a study on asphalt milling in Rapid City, South Dakota

Photo/CDC

Statistics and Research

The integration of statistics and analytic techniques into public health research is a critical asset to the agency (Figure 1) and has resulted in important applications in various disciplines, such as epidemiology, economics, and the behavioral and social sciences. Examples include economic determinations contributing to folic acid supplementation of foods to decrease birth defects (*3*); behavioral science methods leading to the development of strategies for preventing human immunodeficiency virus infection and acquired immunodeficiency syndrome (*4*); quantitative epidemiologic analyses leading to understanding the relation between radon and lung cancer in coal miners (*5*); and evaluations of the effectiveness of using back belts to reduce back injury claims and back pain (*6*). Other areas of continuing statistical contribution include survey planning and analytic methodology, data-collection systems, detection algorithms and scan statistics to document health trends and identify emerging health issues, and model development to project disease incidence and injury or numbers of cases prevented through treatment and public health measures during an outbreak. For example, new methods have been developed to enable comparisons of population characteristics across data-collection programs and over time when data-collection methods change (*7*) and to quantify disparities in health and health care (*8*). Methodologic work also has addressed high levels of nonresponse on central variables such as income (*9*). Reliance on data for policy and programmatic use and the growing number and diversity of users have required ongoing research and innovative approaches to protect the confidentiality and security of data while offering the widest possible access to data (*10*).

The CDC National Center for Health Statistics (NCHS) is the nation's principal health statistics agency and has broad responsibilities to monitor the health of the United States. In addition to conducting a data-collection program that encompasses vital statistics, interview surveys, examination surveys, and provider surveys, NCHS prepares the annual report, *Health, United States* (*11*), which the Secretary of Health and Human

Services submits to the President and Congress. *Health, United States*, presents a comprehensive profile of health in the United States and tracks key health indicators and trends. NCHS also is responsible for advancing the field of health statistics through research into statistical and analytic methods. The National Laboratory for Collaborative Research in Cognition and Survey Measurement, an NCHS program, applies cognitive methods to questionnaire design research and testing of data-collection instruments to improve data quality (*12*).

Recent CDC activities presenting new analytic and statistical challenges include emergency preparedness and emerging infectious diseases. CDC statistical programs have contributed to development of syndromic surveillance methods; evaluation of different civilian smallpox vaccination proposals; characterization of emerging infectious diseases, such as severe acute respiratory syndrome; and development of national health report cards.

The anthrax investigations of September–December 2001 spurred development of multiple analytic techniques. These included maps linking analytic sampling activity with analytic results developed to better understand the spread and deposition of spore-containing particles and analyses of environmental sampling information (CDC, unpublished data, 2002). Stochastic simulation has been used to optimize patient flow-through in clinics dispensing oral antibiotics after a bioterrorism attack (*13*).

Aberration detection in public health data represents another area of statistical contribution. For example, CDC's Smallpox Preparedness and Response Activity receives vaccination and adverse event data from several sources. These sources employ both active and passive data collection and provide registry, contraindication, and adverse events information.

The CDC/ATSDR Statistical Advisory Group

The CDC/ATSDR Statistical Advisory Group (SAG), a scientific workgroup sponsored by the Office of the Chief Science Officer (*14*), coordinates statistical activities throughout the agency. SAG was established in 1989 to act in an advisory capacity to the Office of the Director to facilitate and address statistical issues, problems, and opportunities that influence the quality and integrity of science at CDC and to coordinate agencywide statistical activities and increase communication across organizational components.

SAG activities illustrate the breadth of statistical activity throughout CDC/ATSDR. Since 1989, biennial symposia have been held on topics of interest to the public health community, such as surveillance (*15*) and study design and decision making (*16*). Each year, SAG recognizes outstanding statistical papers published during the previous year with the CDC/ATSDR Statistical Science Awards. The most recent winners included manuscripts on capture-recapture analysis (*17*) and genetic studies (*18*). SAG is responsible for advanced statistical/epidemiologic training at CDC/ATSDR and maintains a listserv and intranet site.

Other SAG statistical activities include participation in statistical/protocol review and institutional review boards and leadership in the development, procurement, and installation of statistical software available for use by researchers in the CDC/ATSDR community. SAG has provided review and advice on complex statistical and broad scientific issues, such as validation of the statistical design of the Vietnam Experience Study of the health of Vietnam veterans, and codeveloped an evaluation of recruitment and retention policies at CDC/ATSDR. Other special requests, such as for development of training materials or requests for interagency collaboration and sentation, also frequently are handled through SAG. Since 1990, SAG has sponsored an exhibit booth highlighting statistical activities at CDC/ATSDR that has been displayed at the Joint Statistical Meetings and other conferences for informational and recruiting purposes.

Future Directions for Statistics at CDC/ATSDR

The critical role of statistics in accomplishing the mission of CDC/ATSDR will become even more apparent as the agency begins to align its activities around its overarching health protection goals. The assessment of burden, effectiveness of interventions, cost considerations, and evaluation frameworks all will require rigorous attention to methods of data-ollection, study design, and analytic technique. The ability of statisticians to ensure the most effective use of quantitative science in research and analysis and in meeting new challenges in the evolving public health mission of CDC/ATSDR will require reexamination of statistical skills and contributions. A multidisciplinary approach to investigation of public health problems, such as emergency preparedness and obesity, already is being realized. Continued valuable statistical input will be key to efficient use of new technologies, such as in informatics, Web-based query systems, geographic information systems, and survey data collection methodologies. Advances in the field of relational databases, for example, and its coupling with Web-based technology have facilitated improvements in the efficiency of data collection and increases in size and completeness of data available for analysis. The developing BioSense

program (*19*), initiated at CDC and operational throughout the United States, uses existing health-care information from hospitals, ambulatory-care clinics, and commercial laboratories for early event detection and health situational awareness. Use of multisource data and further development of record linkage techniques to extract maximal information from existing data sources also will require addressing privacy and confidentiality concerns, as well as appropriate methods of communication of important public health findings to the nation.

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Informatics and Public Health at CDC

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Since CDC acquired its first mainframe computer in 1964, the use of information technology in public health practice has grown steadily and, during the past 2 decades, dramatically (Table 1). Public health informatics (PHI) arrived on the scene during the 1990s after medical informatics (intersecting information technology, medicine, and health care) and bioinformatics (intersecting mathematics, statistics, computer science, and molecular biology). Similarly, PHI merged the disciplines of information science and computer science to public health practice, research, and learning (*2–5*). Using strategies and standards, practitioners employ PHI tools and training to maximize health impacts at local, state, and national levels. They develop and deploy information technology solutions that provide accurate, timely, and secure information to guide public health action.

Early PHI Applications

Advances in PHI resulted in public health innovations and added value to interventions by providing the capability for more timely detection of health threats and more complete and efficient health communications. Early PHI initiatives at CDC assisted the collection and analysis of data. Epi Info™ showed that combining questionnaire development with data base creation and specialized analytic tools gave greater facility during surveillance and outbreak investigations (*6,7*). When Internet use became common, the CDC PHI initiatives linked users and incorporated integrative and open-networked architecture. In this new, integrated environment, CDC PHI initiatives shifted to serve the broader public health community through development of enterprise architecture, standards, systems, and interoperability.

Evolving from the Enhanced Surveillance Project in four states, the National Electronic Telecommunications System for Surveillance (NETSS) began in 1990 (*8*). NETSS (which supports the National Notifiable Diseases Surveillance System) provided a standard record and variables for reporting all individual cases of disease, without requiring a specific software solution. Early on, NETSS data were communicated by dial-up modem each week from state health departments to CDC. This improved the timeliness of public health surveillance.

In 1990, CDC released the Wide-ranging OnLine Data for Epidemiologic Research (WONDER) (*9,10*). This tool provided access to data on the CDC mainframe for analyses by CDC epidemiologists. WONDER/PC—released to the broader public health community in 1992—included access to e-mail for practitioners from local and state health departments, private bulletin boards, and searchable CDC document libraries plus the capability to download data in CDC surveillance programs while maintaining data security and patient confidentiality.

PHI Crossroads

By the early 1990s, CDC and its partners recognized both the costliness of systems specific to categorical diseases and health conditions and the capability of the Internet to permit more efficient approaches to data collection and analyses. In 1993, CDC launched a plan with partners to conceive and develop integrated surveillance (*11*). Furthermore, in 1993, the Information Network for Public Health Officials (INPHO) initiative began to enhance broader access to CDC information technology, networking, and software systems by users (*12,13*). These initiatives marked a PHI milestone for CDC: movement from stand-alone solutions for individual problems to networked, integrated solutions and standards-based data exchange. Six current CDC PHI initiatives reflect this vision and highlight the critical role of PHI in transforming public health practice: PulseNet USA (*14*); the National Electronic Disease Surveillance System (NEDSS) (*15*); the Epidemic Information Exchange (*Epi-X*); the Health Alert Network (HAN) (*16,17*); BioSense (*18*); and the Public Health Information Network (PHIN) (*19*).

In 1993, a large outbreak of foodborne illness occurred in the western United States (*20*). Laboratory scientists performed DNA "fingerprinting" and determined the strain of *Escherichia coli* O157:H7 found in patients had the same pattern as that found in hamburger patties served at a large chain of regional fast-food restaurants. Prompt recognition of this outbreak and its cause might have prevented as many as 800 illnesses. As a result, CDC created PulseNet USA, the molecular surveillance network for foodborne infections in the United

TABLE 1. Evolutionary milestones in public health informatics at CDC, 1976–2006

Milestone	Year	Stakeholder	References	URL
"Gale Report" released calling for coordinated surveillance	1976		*1*	
Enhanced Surveillance Project (later to become the National Electronic Telecommunication System for Surveillance [NETSS]) released	1984	Four state epidemiologists		
Epi Info™ developed	1985	Epidemiologists	*6,7*	http://www.cdc.gov/epiinfo
NETSS initiated	1990	State epidemiologists	*8*	http://www.cdc.gov/epo/dphsi/netss.htm
Wide-ranging OnLine Data for Epidemiologic Research (WONDER) released	1990	Public health practitioners	*9,10*	http://wonder.cdc.gov/WelcomeA.html
WONDER/PC released	1992	Public health practitioners		
Report on Public Health Information and Surveillance System Development released	1993		*11*	
Information Network for Public Health Officials (INPHO) begun	1993	Public health practitioners	*12,13*	
PulseNet USA created	1996	Public health laboratorians	*14*	http://www.cdc.gov/pulsenet
Public Health Informatics fellowship program begun	1996	Public health informaticians		http://www.cdc.gov/phtrain/informatics.html
National Electronic Disease Surveillance System (NEDSS) launched	1999	State epidemiologists	*15*	http://www.cdc.gov/nedss
Secure Data Network goes into production	1999	CDC electronic data providers and external users of CDC-hosted systems		
Epidemic Information Exchange (*Epi-X*) launched	2000	Public health officials designated by health agencies		http://www.cdc.gov/epix
Health Alert Network (HAN) launched	2000	Public health practitioners	*16,17*	http://www2a.cdc.gov/han/Index.asp
National Environmental Public Health Tracking Program	2002	Researchers, policymakers, and public health practitioners		http://www.cdc.gov/nceh/tracking
BioSense launched	2003	Public health officials designated by health agencies	*18*	http://www.cdc.gov/phin/component-initiatives/biosense/index.html
Public Health Information Network (PHIN) initiated	2004	Public health practitioners	*19*	http://www.cdc.gov/phtrain/informatics.html
Public Health Laboratory Interoperability Project begun	2005	Public health laboratorians		
National Center for Public Health Informatics formed	2005			http://www.cdc.gov/ncphi

States and an indispensable tool for early detection of foodborne disease outbreaks (*14*).

In 1999, CDC launched NEDSS. With the goal of integrating public health surveillance through case reporting of approximately 100 diseases using a standards-based data interchange, NEDSS enabled new electronic data feeds from clinical laboratories and substantially reduced the latency of data transmission, improved completeness of reporting, and decreased data-reporting burdens (*15*).

Created in 2000, *Epi-X* is the CDC secure communications solution for practitioners to access and share information. Recently, an epidemiologist in Colorado noted an unusual bacterial infection, *Burkholderia cepacia*, in patients who had sinus surgery. This information was posted on *Epi-X*. After further investigation, a common epidemiologic link was found: the use of a particular nasal spray of the same lot, made by the same company. *Epi-X*'s notice informed officials that this lot most likely was contaminated, and through this alert, the Food

and Drug Administration and the company intervened to recall that lot of nasal spray.

Also launched in 2000, HAN was developed to improve public health interconnectivity through a statewide and a national alert system. In response to the increased threat of bioterrorism, in 2003, CDC launched BioSense to improve the nation's capabilities for real-time biosurveillance and situational awareness. BioSense maintains patient confidentiality and uses secure methods to receive health data from sources such as hospitals and health-care systems in major metropolitan areas. BioSense connects existing health information to public health and will enable simultaneous access to data analytic and visualization tools by authorized users at all jurisdictional levels.

Balanced with secure protection from misuse, CDC's vision for interoperable and integrated networking is embodied in PHIN. Initiated in 2004, PHIN promotes standards and, in some cases, software solutions to enable real-time data flow, computer-assisted analyses, decision support, professional collaboration, and rapid dissemination of information (Box).

These PHI initiatives and others reflect CDC's ongoing commitment to make evidence-based decisions and maximize health impacts. They support PHI tools that will effectively monitor the health of communities, identify causes of disease, and provide the tracking and management capabilities necessary to respond to and contain outbreaks. They also help evaluate the performance and measure the costs of health information systems (*21*). Furthermore, they connect public health systems to clinical-care systems (e.g., electronic medical records).

PHI Training at CDC

Although a workforce trained in PHI is essential, the supply of informaticians is not sufficient to meet national needs (*17*). To address this, CDC initiated a 2-year PHI fellowship program in 1996, which has graduated 51 fellows. These fellows have contributed to standards development, enabled agencywide knowledge management, and performed research. During the responses to hurricanes Katrina and Rita in 2005, three PHI fellows deployed to Texas and Louisiana to support integration of surveillance and develop electronic-based surveillance tools, and two were assigned to the CDC Director's Emergency Operations Center to manage surveillance data. CDC recently initiated a plan to define competencies for public health informaticians.

The Future of PHI

Recognizing the growing importance of PHI across the agency, CDC created the National Center for Public Health Informatics (NCPHI) in 2005 to provide leadership and coordination of shared systems and services. NCPHI's mission is to protect and improve the public's health through PHI discovery, innovation, and service. NCPHI is developing a national PHI research agenda and advancing the state-of-the-science through a grant program with academic institutions and state and local health departments. NCPHI has funded five Centers of Excellence in PHI and has awarded additional research grants to support the BioSense program to further the science of early detection and analyses. Collectively, these projects reflect CDC's ongoing efforts to build

BOX. Public Health Information Network (PHIN) preparedness functional areas and corresponding software solutions

Functional area	Software solutions
Early event detection and situational awareness	BioSense/Call triage services
Surveillance	National Electronic Disease Surveillance System (NEDSS)
Outbreak management	Outbreak Management System (OMS)
Connecting laboratory systems	Laboratory Response Network Results Messenger systems (LRN Results Messenger)
Countermeasure/Response	Countermeasure and Response Administration system
Partner communications and alerting	Public Health Information Network (PHIN) directory Health Alert Network (HAN) Epidemic Information Exchange (*Epi-X*) Partner Alerting Services
Cross-functional area	PHIN Vocabulary Access and Distribution System (PHIN-VADS) PHIN Messaging System (PHIN-MS)

and support a national network of integrated, standards-based, and interoperable public health information systems that will enhance its partners' capabilities to detect, register, confirm, report, analyze, provide feedback and alerts, and communicate to drive evidence-based decisions that make health impacts.

One challenge now facing PHI is to facilitate the development of electronic medical and personal health records that both protect patient privacy and confidentiality and serve legitimate clinical and public health needs. With U.S. healthcare costs steadily rising—now representing approximately 16% of the gross domestic product—and the increase of acute and chronic health threats, PHI must help meet these challenges through more efficient and effective disease prevention (e.g., better detection, communication, public health action, and health protection). These benefits, combined with the increasing expectation of (and requirements for) instantaneous access to public health data, make the potential contribution of PHI to public health practice even more promising and urgent. PHI is now positioned to accelerate, building from the substantial increase in information technology invested in health care and capitalizing on major trends toward electronic medical and personal health records. Future PHI systems will include innovative solutions extending the reach of public health practice to more efficiently and effectively impact health.

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Law and Public Health at CDC

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Health officers must be familiar not only with the extent of their powers and duties, but also with the limitations imposed upon them by law. With such knowledge available and widely applied by health authorities, public health will not remain static, but will progress.

—James A. Tobey, 1947 (*1*)

Introduction

Public health law is an emerging field in U.S. public health practice. The 20th century proved the indispensability of law to public health, as demonstrated by the contribution of law to each of the century's 10 great public health achievements (Table 1) (*2,3*). Former CDC Director Dr. William Foege has suggested that law, along with epidemiology, is an essential tool in public health practice (*4*).

Public health laws are any laws that have important consequences for the health of defined populations. They derive from federal and state constitutions; statutes, and other legislative enactments; agency rules and regulations; judicial rulings and case law; and policies of public bodies. Government agencies that apply public health laws include agencies officially designated as "public health agencies," as well as healthcare, environmental protection, education, and law enforcement agencies, among others.

Scope of Public Health Law

Law is foundational to U.S. public health practice. Laws establish and delineate the missions of public health agencies, authorize and delimit public health functions, and appropriate essential funds. The concept of public health law gained momentum early in the 20th century in James Tobey's seminal volumes (*1*). Frank Grad's practical guide, *The Public Health Law Manual* (*5*), and Lawrence Gostin's treatment of public health law under the U.S. constitutional design followed (*6*). A CDC-related contribution to this literature emphasized the interdisciplinary relation between law and public health practice (*7*).

The concept of public health law has evolved into overlapping paradigms. One paradigm frames public health practice in relation to multiple sources of law (e.g., statutes and regulations) and to fields of law (e.g., constitutional and environmental law). The other, a more scholarly view, focuses on the legal powers and duties of government to ensure public health and limitations on government powers to constrain the protected liberties of individuals.

Integration of Public Health Law Within CDC and State Public Health Practice

Public health law at CDC and at many of its partner organizations has earned explicit recognition only recently. During CDC-sponsored workshops on public health law in 1999–2000, major public health stakeholders, including health officers, epidemiologists, public health lawyers, educators, and legislators, called for strengthening the legal foundation for public health practice. These stakeholders concluded that public health would benefit by adding legal skills and scientific knowledge about the impact of law on public health to the toolkits of public health practitioners. CDC consequently established its Public Health Law Program (PHLP) in 2000 with a mission for improving the public's health through law (*8*).

Primary goals of PHLP are to enhance the public health system's legal preparedness to address emerging threats, chronic diseases, and other national public health priorities and to improve use of law to support program activities. PHLP focuses on these goals by 1) strengthening the competencies of public health professionals, attorneys, and other practitioners to apply law to public health; 2) stimulating applied research about the effectiveness of laws in public health; 3) fostering partnerships among organizations and professionals working in public health and law; and 4) developing and disseminating authoritative information about public health law to public health practice, policy, and other communities (*8*). PHLP does not provide legal advice to CDC programs; that remains the separate responsibility of the Office of the General Counsel of the U.S. Department of Health and Human Services.

TABLE 1. Ten great public health achievements and selected supportive laws and legal tools — United States, 1900–1999*

Public health achievement	Selected supportive laws and legal tools		
	Local	State	Federal
Control of infectious diseases	Sanitary codes and drinking water standards; quarantine and isolation authority; zoning ordinances and building codes; mosquito- and rodent-control programs; inspection of food establishments	Authority to conduct disease surveillance, require disease reports, and investigate outbreaks; regulation of drinking water and waste disposal; regulation of food supplies; licensure of health professionals	Public Health Service Act of 1944; Safe Drinking Water Act of 1974; National Environmental Protection Act of 1976
Motor vehicle safety	Speed limits; limitation on liquor-store hours; penalties for serving inebriated bar patrons	Seat-belt, child-safety-seat, and motorcycle-helmet laws; vehicle inspections; driver licensing and graduated drivers license systems; authorization to conduct sobriety checkpoints; zero tolerance for alcohol among drivers under age 21 years; prohibition on alcohol sales to minors; 0.08% blood alcohol content per se laws; speed limits	Performance and crash standards for motor vehicles; standards for road and highway construction; safety-belt use in some commercial vehicles; financial assistance to states to promote and enforce highway safety initiatives; airbag warning labels; creation of state offices of highway safety; federal court ruling upholding motorcycle-helmet use
Fluoridation of drinking water	Ordinances authorizing fluoridation; referenda and initiatives authorizing fluoridation	Legislation authorizing fluoridation; court rulings upholding fluoridation	Federal court rulings upholding fluoridation of public drinking water supplies; Environmental Protection Agency caps on fluoride levels
Recognition of tobacco use as a health hazard	Excise taxes; restrictions on retail sale to minors; clean indoor air laws	Excise taxes; restrictions on retail sale practices; clean indoor air laws; funding for public antismoking education; lawsuits leading to the Master Settlement Agreement of 1998	Excise tax; mandated warning labels; prohibition of advertising on radio and television; penalties on states not outlawing sale to persons under aged <18 years; financial assistance to state and local tobacco-control programs; Department of Justice lawsuit to recover health-care costs
Vaccination	School board enforcement of school entry vaccination requirements	Court rulings supporting mandatory vaccination; school entry admission laws	Court rulings supporting mandatory vaccination; licensure of vaccines; financial aid to state vaccination programs
Decline in deaths from coronary heart disease and stroke	Education for and information programs	Tobacco-control laws; education and information programs	Food-labeling laws; Department of Transportation funding for bikeways and walking paths; National High Blood Pressure Education Program
Safer and healthier foods	Standards for and inspection of retail food establishments	Mandated niacin enrichment of bread and flour; standards for and inspection of foods at the producer level; limits on chemical contamination of crops	Pure Food and Drug Act of 1906 and later enactments to regulate foods and prescription drugs; mandated folic acid fortification of cereal grain products; limits on chemical contamination of crops; food stamps; the Women, Infants, and Children program; school meals
Healthier mothers and babies	Sewage and refuse ordinances; drinking water codes; milk pasteurization	Establishment of maternal and child health clinics; licensure of obstetrics health-care professionals; mandated milk pasteurization; funding for Medicaid services	Drinking water quality standards; creation of the Children's Bureau (1912) with education and service programs; licensure of sulfa drugs and antibiotics; creation of the Medicaid program; the Infant Formula Act of 1980
Family planning	Funding for family planning clinics	Authorization to provide birth control services; authority to provide prenatal and postnatal care to indigent mothers	Family Planning Services and Population Research Act; Supreme Court rulings on contraceptive use
Safer workplaces	Authority to inspect for unsafe conditions; building and fire safety codes	Laws to inspect and regulate workplace safety practices, including toxic exposures; criminal penalties for grossly negligent worker injury or death	Minimum safety standards for federal contractors; inspection and regulation of mine safety; mandates on states to adopt minimum workplace safety standards; Occupational Safety and Health Act of 1970

*Adapted from CDC. Ten great public health achievements—United States, 1900–1999. MMWR 1999;48:241–3 and from Moulton AD, Goodman RA, Parmet WE. Perspective: law and great public health achievements. In: Goodman RA, Hoffman RE, Lopez W, Rothstein MA, Foster KL, eds. Law in public health practice. 2nd ed. New York, NY: Oxford University Press; 2007:3–21.

State and local partners also are strengthening public health legal preparedness. CDC has stimulated this in part through initiatives such as "Public Health Emergency Law," a course delivered nationally in state and local health departments (*8*). In some states, grassroots activities are increasing competencies of practitioners to use law and strengthening legal preparedness capacities of public health systems. For example, in California, the Public Health Law Work Group (comprising representatives of county counsel and city attorney offices) drafted a legally annotated health officer practice guide for communicable disease control (*9*). Related activities in California include a 2006 conference on legal preparedness for pandemic influenza, and a series of forensic epidemiology joint training programs for public health and law enforcement agencies.

Role of Public Health Law in Addressing High Priorities in Public Health

The indispensable role of law is evident across the entire history of U.S. public health—from early colonialists' needs to defend against infectious threats to today's innovative law-based approaches to preventing chronic diseases, injuries, and other problems (Table 2). The U.S. experience with smallpox illustrates how, at some points in history, law-based interventions were implemented even before science elucidated the nature of the public health threat and the basis of the intervention. The legal-epidemiologic strategy of quarantine to prevent the spread of smallpox was employed on Long Island as early as 1662 (*10*). Smallpox prevention also was at the root of the 1905 landmark decision in *Jacobson v. Massachusetts* in which the U.S. Supreme Court upheld the Massachusetts statutory requirement for smallpox vaccination (*11*).

Public health is examining law-based countermeasures to the use of smallpox virus and other infectious pathogens as biologic weapons. In its program of grants supporting states' development of capacity to address public health emergencies, CDC expects states to attain legal preparedness for such emergencies in the wake of the 2001 anthrax attacks, the severe acute respiratory syndrome epidemic in 2003, the 2005 hurricane disasters, and the specter of an A(H5N1) influenza pandemic. Response to these threats has spawned new and innovative resources, such as the draft Model State Emergency Health Powers Act, the CDC forensic epidemiology course for joint training of public health and law enforcement officials, community public health legal preparedness workshops for hospital and public health attorneys, public health law "bench books" for the judiciary, and the CDC Public Health Emergency Legal Preparedness Clearinghouse (*8*).

Public health law also helps address high priorities other than infectious diseases and emergencies, as illustrated by the roles of law and legal strategies in tobacco control (*12*). CDC and others are exploring the role of law in preventing chronic diseases (*13*), including development of legal frameworks for addressing cardiovascular disease (*14*) and obesity (*15*), and for fostering healthy built environments (*16*). Injury prevention has benefited from litigation, laws requiring preventive measures, and other legal interventions (*17,18*).

In 2002, a rich multidisciplinary public health law community began taking shape at the first national public health law conference, which CDC convened. This community com-

TABLE 2. Selected laws for the prevention of chronic diseases and injuries*

Law	Public health issue addressed	Effectiveness	How it works
Smoking bans or restrictions	Exposure to environmental tobacco smoke	Strong evidence	Requires behavioral change to change the environment
Tobacco excise taxes	Tobacco initiation and use	Strong evidence	Applies a financial disincentive to evoke behavior change
Required coverage of cessation services costs	Tobacco use	Sufficient evidence	Requires organizational change that promotes behavioral change
Zoning and land-use policies	Physical inactivity	Sufficient evidence	Requires environmental change to facilitate behavioral change
Child safety-seat–use laws	Unintentional injuries of children	Strong evidence	Directly requires behavioral change
Safety-belt–use laws	Unintentional injuries of older children, adolescents, and adults	Strong evidence	Directly requires behavioral change
Blood alcohol concentration limit of 0.08% for operators of motor vehicles	Unintentional injuries of older children, adolescents, and adults	Strong evidence	Primarily provides powerful psychological deterrent to evoke behavioral change; also provides disincentive to evoke behavioral change through fines and other penalties
Sobriety checkpoints for motor vehicle operators	Unintentional injuries of older children, adolescents, and adults	Strong evidence	Provides psychological deterrent to evoke behavioral change
Fluoridation of community water supplies	Dental caries	Strong evidence	Directly changes the physical environment requiring no action on the part of the target population
Food fortification	Nutritional deficiencies	Strong evidence	Directly changes the physical environment requiring no action on the part of the target population

* Adapted from Mensa GA, Goodman RA, Zaza S, et al. Law as a tool for preventing chronic diseases: expanding the range of effective public health strategies. Prev Chronic Dis 2004;1:A13.

prises practitioners trained in the classical disciplines of public health, attorneys in the public and private sectors, increasing numbers of professionals trained and experienced in both public health and law, elected officials, emergency management and law enforcement professionals, judges, educators, researchers, and others. The more than 7,000 current subscribers to the weekly *CDC Public Health Law News* (*8*) attest to the size of the community.

Requirements for Achieving Full Public Health Legal Preparedness to Support the Mission of Public Health

Effective responses to emerging threats and attainment of public health goals require CDC, partner organizations, and communities to achieve full public health legal preparedness (*13,19*). Public health legal preparedness, a subset of public health preparedness, is the attainment by a public health system of specified legal benchmarks or standards essential to preparedness of the public health system (*19*). The elements of public health legal preparedness (Table 3) include requirements to

- **Ensure the presence of effective legal authorities to carry out essential public health services.** U.S. communities, states, and the nation as a whole should have public health legal authorities consistent with modern jurisprudence.
- **Establish and sustain the competencies of public health professionals to apply those laws.** Public health officials, their staff and legal counsel, judges, and others should have access to training to achieve competencies in public health law and be skilled in applying essential legal authorities.
- **Provide for coordination of law-based efforts across jurisdictions and sectors.** Law-based measures to protect communities and promote health must be coordinated effectively across the local-state-federal-international dimension and among multiple public and private sector entities (i.e., disciplines, officials, and organizations having diverse missions and enabling legal authorities).
- **Develop and make accessible information about public health law best practices.** Public health agencies, policymakers and lawmakers, and others must have access to science-based knowledge about effective public health laws.

CDC increasingly envisions public health law as an integral element in the armamentarium of each of its programs and in the competencies of its professionals. CDC and its partners are working vigorously toward full legal preparedness throughout the public health system, developing and deploying new legal tools that policymakers and front-line practitioners will apply to the entire spectrum of 21st-century public health challenges and opportunities.

TABLE 3. Core elements of public health legal preparedness and illustrative functions, tools, and activities

Core element	Illustrative functions, tools, and activities	
	Functions	**Tools and activities**
Essential legal authorities	• Public health surveillance and epidemiologic investigations • Interventions to contain disease spread (e.g., quarantine and isolation) • Restrictions on indoor smoking • Zoning standards to promote physical activity	• Draft Model State Emergency Health Powers Act • Turning Point Model State Public Health Act (*20*)
Competencies to apply laws	• Assessment of existing public health laws and ordinances • Recommendations to elected officials about needed improvements in existing laws • Application of laws that are effective and consistent with protections for personal liberty and private property	• CDC "Public Health Emergency Law" curriculum • CDC "Community Public Health Legal Preparedness" curriculum • "Indiana Public Health Law Bench Book" for state judges
Coordination across jurisdictions and sectors	• Response to public health emergencies by multiple states and diverse disciplines • Collaboration by multiple sectors (e.g., public health, land use, transportation, and housing) to design healthy communities	• The Emergency Management Assistance Compact • The "Healthy Communities" initiatives of CDC, the American Planning Association, and the National Conference of State Legislatures • Planning and operational exercises such as TOPOFF
Information about public health law best practices	• Scientific findings about effective public health laws • Current or recent changes in public health law • Best practices and innovations in application of legal authorities to public health priorities	• Recommendations of the Task Force for Community Preventive Services (see also Table 2) • The weekly "CDC Public Health Law News" • The "CDC Public Health and the Law in the 21st Century" national conference series

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Urban Planning and Public Health at CDC

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Introduction

Urban planning, also called city and regional planning, is a multidisciplinary field in which professionals work to improve the welfare of persons and communities by creating more convenient, equitable, healthful, efficient, and attractive places now and for the future. The centerpiece of urban planning activities is a "master plan," which can take many forms, including comprehensive plans, neighborhood plans, community action plans, regulatory and incentive strategies, economic development plans, and disaster preparedness plans (*1*). Traditionally, these plans include assessing and planning for community needs in some or all of the following areas: transportation, housing, commercial/office buildings, natural resource utilization, environmental protection, and healthcare infrastructure.

Urban planning and public health share common missions and perspectives. Both aim to improve human well-being, emphasize needs assessment and service delivery, manage complex social systems, focus at the population level, and rely on community-based participatory methods. Both fields focus on the needs of vulnerable populations. Throughout their development, both fields have broadened their perspectives. Initially, public health most often used a biomedical model (examining normal/abnormal functioning of the human organism), and urban planning often relied on a geographic model (analysis of human needs or interactions in a spatial context). However, both fields have expanded their tools and perspectives, in part because of the influence of the other.

Urban planning and public health have been intertwined for most of their histories. In 1854, British physician John Snow used geographic mapping of an outbreak of cholera in London to identify a public water pump as the outbreak's source. Geographic analysis is a key planning tool shared by urban planning and public health. In the mid-1800s, planners such as Frederick Law Olmsted bridged the gap between the fields by advancing the concept that community design contributes to physical and mental health; serving as President Lincoln's U.S. Sanitary Commission Secretary (*2*); and designing hundreds of places, including New York's Central Park. By 1872, the disciplines were so aligned that two of the seven founders of the American Public Health Association were urban designers (an architect and a housing specialist) (*3*). In 1926, the U.S. Supreme Court, in validating zoning and land-use law as a legal government authority in *Village of Euclid v. Ambler Realty,* cited the protection of public health as part of its justification (*4,5*). Other connections have included 1) pioneering urbanist Jane Jacobs, who during the 1960s, called for community design that offered safe and convenient options for walking, biking, and impromptu social interaction; and 2) the Healthy Cities movement, which began in Europe and the United States during the 1980s and now includes projects in approximately 1,000 cities that in various ways highlight the role of health as much more than the presence of medical care (*6*).

Contributions of Urban Planning to Public Health

During the 19th and early 20th centuries, the synergies between urban planning and public health were evident in at least three areas: creation of green space to promote physical activity, social integration, and better mental health; prevention of infectious diseases through community infrastructure, such as drinking water and sewage systems; and protection of persons from hazardous industrial exposures and injury risks through land-use and zoning ordinances. During the middle of the 20th century, the disciplines drifted apart, to a certain extent because of their success in limiting health and safety risks caused by inappropriate mixing of land uses.

The disciplines recently have begun to reintegrate. During the last 20 years, shared concerns have included transportation planning to improve air quality, encourage physical activity, prevent injuries, and promote wellness. In addition, some original crossover ideas, such as the potential for parks and recreational facilities to contribute to physical activity and mental health, have reemerged. Relatively recently, urban planning has focused on the effects of community design on energy use and greenhouse gas emissions to affect the growing

public health concern of climate change. Finally, emergency preparedness (e.g., community infrastructure assurance, evacuation planning) and access to health care (e.g., assurance of accessibility and adequacy of facilities) are topics important to both disciplines.

Recent contributions to the public health knowledge-base by urban planners and other community designers, such as architects and engineers, are important. A recent tabulation of the 50 most-read/most-cited articles within the *American Journal of Public Health* (*AJPH*) (as of October 1, 2006) included topics of interest to both urban planning and public health professionals, such as social capital, neighborhood-level effects on health, housing and health, and clustering of fast-food establishments around schools (*7*). Examples of cross-discipline collaborations (Table 1) from publications such as *JAMA* and *AJPH* address such diverse CDC program areas as aging studies, air pollution and respiratory diseases, disability and health, unintentional injury, and nutrition and physical activity.

As individual collaborations have increased, calls for broad profession-level integrations also have increased (Table 2). Thus far, CDC has employed only a few urban planners, either temporarily or permanently. Urban planners, for instance, have worked within the ATSDR Policy Office, Division of Health Assessment and Consultation, and Office of Tribal Affairs; within the National Center for Environmental Health Policy Office and Division of Emergency and Environmental Health Services; within the National Center on Birth Defects and Developmental Disabilities Division of Human Development and Disability; and within the National Center for Chronic Disease Prevention and Health Promotion Division of Nutrition and Physical Activity. Although these urban planners have conducted some research, their primary role has been to bridge the broader urban planning, academic, and practitioner worlds.

Specific Findings, Activities, and Contributions

The interdependence of urban planning and public health in both research and intervention activities is evident in many areas. For example, to increase physical activity, persons need safe and accessible areas; development of these areas can be aided by determining the environmental barriers and facilitators that affect activity levels; designing, constructing, and maintaining community environments to help ensure safety and accessibility; and developing programs to encourage people to use improved community environments to increase their activity levels. Without the contributions of both disciplines, the odds of substantial increases in community physical activity decrease considerably.

Pedestrian and bicycle safety programs also illustrate the interdependence of public health and urban planning. Transportation planners are charged with creating streets and intersections on which all modes of transportation can safely coexist. However, considerable morbidity and mortality occur annually because of injuries related to interactions between motorists, bicyclists, and pedestrians, indicating that many communities have failed to truly balance choices of transportation modes.

Examples of recent successful cross-discipline activities include chronic disease prevention, injury prevention, health promotion for older adults and persons with disabilities, and air- and water-quality assurance. Reviews of research studies conducted by cross-disciplinary teams on behalf of the *Guide to Community Preventive Services* have documented that street-scale urban design and land-use policies affect levels of physical activity and result in recommendations for wider implementation of such policies (*8*). Similarly, research has documented the potential for design choices to reduce both unintentional (*9,10*) and intentional (*11,12*) injuries.

Research has described some of the impacts of physical environments on the health and quality of life of persons with disabilities (*13*), residents of low-income housing projects (*14*), and older adults (*15*). In environmental health, data analysis of waterborne-disease outbreaks and extreme weather events indicates potential interaction between land-use patterns and risk for waterborne diseases (*16*). In an equally important area of environmental health—air quality and respiratory health—CDC staff used the unique "natural experiment" of the Atlanta Olympics to document a 42% decrease in acute asthma events among children that were attributable to reductions in automobile traffic and associated air pollution (*17*). Other impacts of the interdependence of urban planning and public health also have been demonstrated (Table 3).

Urban planning in particular and the array of community design professions in general historically have played major roles in public health, and public health disciplines have played major roles in urban planning. In recent years, as reintegration between the two professions has accelerated, academia has responded by offering cross-cutting courses and, in at least five schools, joint graduate degrees in urban planning and public health. At the federal level, CDC leadership selected seven "place-related" goals reflecting this reintegration (*18*), many of which are impacted by urban planning. CDC scientifically and programatically addresses all factors associated with the interaction between people and their natural and human-made environments and promotes design and construction of places that improve both physical and social environments

TABLE 1. Selected examples of cross-disciplinary publications that link urban planning and public health

Category	Citation example
Publications in the urban planning literature (often by public health professionals)	
Overview of links between public health and urban planning	• Greenberg M, Popper F, West B, Krueckeberg D. Linking city planning and public health in the United States. Journal of Planning Literature 1994;8:235–9. • Spielman SE, Golembeski CA, Northridge ME, et al. Interdisciplinary planning for healthier communities: findings from the Harlem Children's Zone Asthma Initiative. J Am Plann Assoc 2006;72:100–8.
Research review	• Lee C, Moudon AV. Physical activity and environment research in the health field: implications for urban and transportation planning practice and research. Journal of Planning Literature 2004;19:147–81.
Empirical research	• Frank LD, Engelke PO. The built environment and human activity patterns: exploring the impacts of urban form on public health. Journal of Planning Literature 2001;16;202–18.
Program evaluation	• Boarnet MG, Day K, Anderson C, McMillan T, Alfonso M. California's safe routes to school program: impacts on walking, bicycling, and pedestrian safety. J Am Plann Assoc 2005;71:301–17. • Wernstedt K. Devolving Superfund to Main Street: avenues local community involvement. J Am Plann Assoc 2001;67:293–313. • Takahashi LM, Smutny G. Community planning for HIV/AIDS prevention in Orange County, California. J Am Plann Assoc 1998;64:441–56.
Policy analysis	• Rodriguez DA, Khattak AJ, Evenson KR. Can new urbanism encourage physical activity? Comparing a new urbanist neighborhood with conventional suburbs. J Am Plann Assoc 2006;72:43–54.
Practice guidelines	• Kochtitzky CS, Duncan RC. Universal design: community design, public health, and people with a disability In: Morris M, ed. Planning and universal design in integrating planning and public health: tools and strategies to create healthy places. Chicago, IL: American Planning Association; 2006:51–64 (APA Planning Advisory Service Report 539/540).
Publications in the public health literature (often by urban planners or allied professionals)	
Overview of links between public health and urban planning	• Corburn J. Confronting the challenges in reconnecting urban planning and public health. Am J Public Health 2004;94:541–6.
Research review	• Zimring C, Joseph A, Nicoll GL, Tsepas S. Influences of building design and site design on physical activity: research and intervention opportunities. Am J Prev Med 2005;28(Suppl 2):185–93.
Methods development	• Boarnet MG, Day K, Alfonzo M, Forsyth A, Oakes M. The Irvine–Minnesota Inventory to measure built environments: reliability tests. Am J Prev Med 2006;30:153–9.
Empirical research	• Koepsell T, McCloskey L, Wolf M, et al. Crosswalk markings and the risk of pedestrian motor vehicle collisions in older pedestrians. JAMA 2002;288:2136–43. • Tester JM, Rutherford GW, Wald Z, Rutherford MW. A matched case–control study evaluating the effectiveness of speed humps in reducing child pedestrian injuries. Am J Public Health 2004;94:646–50. • Lopez R. Urban sprawl and risk for being overweight or obese. Am J Public Health 2004;94:1574–9.
Policy analysis	• Boarnet MG, Anderson CL, Day K, McMillan T, Alfonzo M. Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. Am J Prev Med 2005;28 (2 Suppl 2):134–40.
Research framework	• Dannenberg AL, Jackson RJ, Frumkin H, et al. The impact of community design and land-use choices on public health: a scientific research agenda. Am J Public Health 2003;93:1500–8.
Cross-disciplinary overviews	• Frumkin H, Frank L, Jackson RJ. Urban sprawl and public health: designing, planning, and building for healthy communities. Washington, DC: Island Press; 2004. • Frank LD, Engelke PO, Schmid TL. Health and community design: the impact of the built environment on physical activity. Washington, DC: Island Press; 2003.

(http://www.cdc.gov/healthyplaces). Providing safe and healthy places in which to live, work, and play is more likely to succeed if urban planning and public health work together. Future integration of and collaborations between the disciplines can serve as a cornerstone for the immediate and long-term success of the Healthy Places goals (*19*). A long-term blending of the responsibilities, tools, and eventually perspectives of public health and urban planning can result in many positive outcomes, including the following:

- Public health explicitly recognizing the importance of place-based approaches and the leverage these provide for addressing public health opportunities and threats.
- Public health and urban planning professionals increasingly drawing on tools and processes developed by the other field. Key examples are geographic information systems (*20*); health impact assessment (*21*); and community assessment tools, such as the Protocol for Assessing Community Excellence in Environmental Health (*22*).

TABLE 2. Examples of professional association policies and recommendations on issues involving urban planning and public health

Topics of organizational policy or recommendations	American Planning Association	U.S. Green Building Council	American Public Health Association	National Association of County and City Health Officials
Housing	X	X	X	X
Smart growth	X			
Land use	X		X	X
Surface transportation	X		X	
Energy	X		X	
Air quality			X	X
Water resources management	X		X	
Healthy community design	X	X	X	X
Health impact assessment				X
Sustainability	X			
Solid and hazardous waste	X		X	
Environmental justice	X			X
Disability issues	X		X	

TABLE 3. Sample of public health projects with significant contributions from urban planning

Project lead/Title	Project description
CDC, National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP), Division of Nutrition and Physical Activity: Active Community Environments Initiative	Promotes walking and bicycling and development of accessible recreation facilities. Developed in response to public health, urban design, and transportation planning data suggesting community characteristics, such as proximity of facilities, street design, density of housing, availability of public transit and of pedestrian and bicycle facilities play an important role on physical activity. Available at http://www.cdc.gov/nccdphp/dnpa/physical/health_professionals/active_environments.
Washington State Department of Health/ Jefferson County, Wash. (CDC-supported): Disability Awareness Starts Here (DASH) Program	Creates a community environment in which persons with disabilities have opportunities to participate in every aspect of community life equal to those of persons without disabilities. This project works closely with the Public Works Department to plan improvements to streets, sidewalks, mechanisms of traffic control, and other aspects of the urban plan. Available at http://www.o3a.org/DASH.htm.
Prevention Research Center Healthy Aging Research Network (CDC-supported): Healthy Aging Network Built Environment and Physical Activity in Older Adults Audit Tool Development	Pilot study to develop and pilot test a research audit instrument to collect data on the street-scale factors associated with physical activity in several older adult populations (i.e., persons aged ≥65 years, with an emphasis on those with special needs, such as wheelchairs or oxygen tanks) across multiple settings (e.g., urban/rural areas, colder/warmer climates, presence/absence of diverse racial and economic groups, residential/commercial, and flat/hilly areas). Available at http://depts.washington.edu/harn/publications/engaging_older.pps.
CDC, NCCDPHP, Division of Nutrition and Physical Activity: KidsWalk-to-School Initiative	Encourages children to walk or bike to and from school by, for example, advocating for communities to create an environment that supports walking or bicycling safely to school. Benefits include 1) increased levels of daily physical activity for children; 2) increased likelihood that children and adults will choose to walk or bike for other trips; 3) improved neighborhood safety; 4) fewer cars traveling through the neighborhood; and 5) friendlier neighborhoods as people get out and interact with each other. Available at http://www.cdc.gov/nccdphp/dnpa/kidswalk.
CDC, National Center for Injury Prevention and Control, Division of Unintentional Injury Prevention: National Strategies for Advancing Child Pedestrian Safety	Recommendations for encouraging children to explore their environments by walking while reducing their risk for pedestrian injury. Key strategies include encouraging 1) revised laws and practices to promote construction of sidewalks and traffic-calming measures, 2) consideration of pedestrian safety—particularly for children and persons with disabilities—when designing new communities or modifying existing ones, and 3) enhancement of pedestrian accessibility and safety when building/ remodeling schools, parks, and businesses. Available at http://www.cdc.gov/ncipc/pedestrian.
CDC, NCCDPHP: Steps to a Healthier U.S. Program	Encourages persons to make small behavior changes to reduce the burden of some of the leading causes of death. Communities are taking steps to implement community, environmental, and policy interventions in school, community, health-care, and workplace settings to 1) engage community members in assessing, planning, delivering, and evaluating intervention activities; 2) create supportive environments to sustain individual efforts; 3) provide social support for healthy choices; and 4) improve access to and use of quality health-care services. Available at http://www.cdc.gov/steps.
Georgia Institute of Technology/ University of British Columbia (CDC-supported): Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality (SMARTRAQ)	Assesses how land use relates to travel choice, vehicle emissions, and physical activity. Its goal is to develop a framework for assessing land use and transportation policies that have the greatest potential for reducing the level of automobile dependence and vehicle emissions in the Atlanta metropolitan area while sustaining the economic vitality and environmental health of the region. Available at http://www.act-trans.ubc.ca/smartraq/pages/home2.htm.

TABLE 3. (*Continued*) Sample of public health projects with significant contributions from urban planning

Project lead/Title	Project description
ATSDR, Division of Health Studies: Geospatial Research, Analysis, & Services Program (GRASP)	Uses geographic information systems (GIS) for public health applications. GIS techniques and applications developed in urban planning have direct implications for public health. The tracking and management of city infrastructure, such as water and sewage, have implications for environmental health. GIS is used to look at green space and sidewalks in the city and the impact on physical activity and health. Population data can overlay land-use/facility data to examine the context in which public health events occur. Available at http://www.atsdr.cdc.gov/gis.
American Planning Association: Model Zoning Codes Project (supported by the Environmental Protection Agency [EPA] and CDC, National Center for Environmental Health [NCEH], Division of Emergency and Environmental Health Services)	Developed model zoning codes designed to promote healthy, walkable communities. Available at http://www.planning.org/smartgrowthcodes/pdf/section48.pdf.
US Green Building Council: LEED-ND Public Health Report (supported by EPA and CDC, NCEH, Division of Emergency and Environmental Health Services)	Produced the LEED-ND Public Health Report that comprehensively summarized the relation between community design—land use, design character, transportation system, and density—and public health outcomes such as physical activity, traffic crashes, respiratory health, and mental health. This report is used as part of the foundation for the LEED-ND Rating System, currently in draft, which integrates the principles of smart growth, urbanism, and green building into the first national standard for neighborhood design. Available at https://www.usgbc.org/DisplayPage.aspx?CMSPageID=148# report.

- Public health professionals increasingly engaging in the urban planning arena, participating in zoning decisions and serving on urban planning boards, and incorporating health into urban planning decision-making.
- Urban planning professionals increasingly engaging in the public health arena, participating in campaigns promoting physical activity and pedestrian injury prevention and serving on boards of health, and incorporating design into public health decision-making.

This renewed integration is essential in restoring and enhancing the health and vitality of the nation's places and people.

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