Report of the

Surgeon General's Workshop on Healthy Indoor Environmment

January 12-13, 2005

Department of Health and Human Services

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List of Acronyms

Acronyms

ETS	environmental tobacco smoke
HVAC	heating, ventilation, and air conditioning
IAP	indoor air pollution
IAQ	indoor air quality
MCS	multiple chemical sensitivity
RADS	reactive airways dysfunction syndrome
VE	Value Engineering

Organizations

AAAAI	American Academy of Allergy Asthma and Immunology
AAEE	American Academy of Environmental Engineers
AARST	American Association of Radon Scientists and Technologists
AFE	Association of Facility Engineers
AIA	American Institute of Architects
AIACOTE	American Institute of Architects Committee on the Environment
ALA	American Lung Association
APHA	American Public Health Association
APRHB	Air Pollution and Respiratory Health Branch
ARTI	Advanced Research and Technology Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
ATS	American Thoracic Society
ATSDR	Agency for Toxic Substances and Disease Registry
BASE	Building Assessment Survey and Evaluation Study
BEIR IV	Committee on the Biological Effects of Ionizing Radiation
BIDS™	Building Investment Decisions Support
BOMA	Building Owners and Managers Association
Cal/OSHA	California Division of Occupational Safety and Health
CDC	Centers for Disease Control and Prevention
CIAQ	Committee on Indoor Air Quality
CMU	Carnegie Mellon University
CPSC	Consumer Products Safety Commission
DARPA	Defense Advanced Research Projects Agency
DHHS	Department of Health and Human Services
DOC	Department of Commerce
DoE	Department of Education

DOE	Department of Energy
DRDS	Division of Respiratory Disease Studies
EPA	U.S. Environmental Protection Agency
EPAC	Engineer Professional Advisory Committee
FEMA	Federal Emergency Management Agency
FEMAC	Federal Energy Management Advisory Council
FFC	Federal Facilities Council
GAO	General Accountability Office
GSA	General Services Administration
HHE	Health Hazard Evaluation
HIE	Healthy Indoor Environment
HUD	Department of Housing and Urban Development
IBI	Integrated Business Institute
IDCE	International Design Center for the Environment
IIDA	International Interior Design Association's
IOM	Institute of Medicine
ISEA	International Society of Exposure Assessment
ISIAQ	International Society of Indoor Air Quality and Climate
ISWG	Interagency Sustainability Working Group
JCAHO	Joint Commission on Accreditation of Healthcare Organizations
LEED	Leadership in Energy and Environmental Design
NAEPP	National Asthma Education and Prevention Program
NAHB	National Association of Home Builders
NAS	National Academy of Sciences
NCEH	National Center for Environmental Health
NCHS	National Center for Health Statistics
NCICAS	National Cooperative Inner City Asthma Study
NFPA	National Fire Protection Association
NHANES	National Health and Nutrition Examination Survey
NHLBI	National Heart, Lung, and Blood Institute
NIAID	National Institute of Allergy and Infectious Diseases
NIBS	National Institute of Building Sciences
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NORA	National Occupational Research Agenda
NRC	National Research Council
NSF	National Science Foundation
NSLAH	National Survey of Lead and Allergens in Housing
ORIA	Office of Radiation and Indoor Air

ORISE	Oak Ridge Institute for Science and Education
OSG	Office of the Surgeon General
OSHA	Occupational Safety and Health Administration
OSTP	Office of Science Technology and Policy
OSW	Office of Solid Waste
PBS	Public Buildings Service
PHS	Public Health Service
PNIER	Program Needs for Indoor Environment Research
SAME	Society of American Military Engineers
SSPC	Standing Standard Project Committee
TISP	The Infrastructure Security Partnership
TSAC	Technical and Scientific Advisory Committee
USDA	U.S. Department of Agriculture
USGBC	U.S. Green Building Council
WHO	World Health Organization

Introduction

The 2005 Surgeon General's Workshop on Healthy Indoor Environment was conducted to:

- Enhance understanding of the public health consequences of the non-industrial indoor environment (e.g., homes, schools, office buildings);
- Provide information to the U.S. Surgeon General, the public, the medical community, and the public health community; and
- Provide the building design, construction, and ownership community with a better understanding of public health issues as they relate to the indoor environment.

The workshop included presentations from experts in healthy indoor environment, federal officials, and advocacy organizations.

The stated goals and objectives of the workshop were to:

1. Seek collaboration throughout the public health community in reducing indoor environmentally related communicable respiratory infections, asthma, hypersensitivity pneumonitis, and allergic diseases; and
2. Gain a better understanding of public health issues and research needs on this topic.

The Surgeon General's Workshop on Healthy Indoor Environment was the first activity to take place under the 2005 Year of The Healthy Child (YOTHC) agenda set by the Surgeon General. The YOTHC agenda provides for a year of examining issues surrounding the health and well being of children throughout the Nation and the world. Under this extremely comprehensive and aggressive single year agenda, the Office of the Surgeon General has taken a holistic approach, focusing efforts on the body, mind and spirit of the growing children. As a child grows, so do their health needs. The Office of the Surgeon General will address such issues as immunizations, childhood obesity, physical activity, illness and injury prevention, and the *healthy indoor environment.*

Workshop Proceedings

This document summarizes the views and issues addressed by invited speakers and discussants at the Surgeon General's Workshop on Healthy Indoor Environment. The views expressed in these *Proceedings* reflect the opinions of the individual participants at the Workshop and do not necessarily reflect the official position of the Office of the Surgeon General, the Department of Health and Human Services, or other federal entities.

Welcome

RADM Robert C. Williams, P.E., DEE
U.S. Public Health Service Chief Engineer

The Surgeon General's Workshop on Healthy Indoor Environment (HIE) was called to order on January 12, 2005 by Rear Admiral (RADM) Robert C. Williams. RADM Williams welcomed participants and outlined the first day's sessions, which would review scientific evidence showing a need for HIE, present information about HIE factors and their impact on health, and identify gaps in information that need to be assigned priorities so that action can be taken to promote pubic health and well-being. He then introduced the Surgeon General, Vice Admiral (VADM) Richard H. Carmona, who set the charge and goals for the workshop.

Charge and Goals

VADM Richard H. Carmona, M.D., M.P.H., F.A.C.S.
U.S. Surgeon General

VADM Richard Carmona emphasized the role of health literacy for success in addressing priority health areas. The Surgeon General and public health professionals must disseminate their wealth of knowledge to both the public and practitioners in as timely a fashion as possible to effect behavioral change and improve the health of the populations they serve. The Surgeon General defined indoor environments as built, non-industrial structures. This includes workplaces, schools, offices, houses, and apartment buildings.

He also stated that the data clearly indicate the need for this workshop. According to a recent study, we Americans spend 85%–95% of our time indoors (Rauh VA, Chew GR and Garfinkel RS. Deteriorated Housing Contributes to High Cockroach Allergen Levels in Inner-City Households. *Environmental Health Perspectives* 2002,110(Supplemental 2):323–7). So while we need to be cognizant of and concerned about our outdoor environment, including pollution and smog, we must put at least equal emphasis on the long-overlooked issue of indoor environment.

In just the past 25 years, the percentage of Health Hazard Evaluations (HHE) that the National Institute for Occupational Safety and Health (NIOSH) at the Centers for Disease Control and Prevention (CDC) has conducted related to indoor air quality has increased from 0.5% of all evaluations in 1978 to 52% of all evaluations since 1990. This means that in those years, the evaluations related to air quality concerns have increased from one of every 200 evaluations to one of every two.

The problem is adversely affecting our children's health: the General Accountability Office (GAO) has indicated that one in five schools in America has indoor air quality (IAQ) problems (GAO 1995, 1996, and 1999). This can trigger various allergies and asthma. Asthma alone accounts for 14 million missed school days each year. The rate of asthma in young children has risen by 160% in the past 15 years, and today one of every 13 school-age children has asthma. Asthma alone costs the United States economy at least $11 billion annually.

VADM Carmona presented three major goals for the workshop:

1. Identify relevant scientific data that establish a basis for assessing and interpreting indoor environment hazards.
2. Identify research needs and areas where scientific information is lacking or inconclusive.
3. Establish common goals for implementing measures that are known to be effective for improving indoor environmental quality.

Beyond these specific goals, he stated that it is important to illuminate HIE issues in the context of larger public health concerns and related issues such as lead paint toxicity, and to move the public health agenda forward using sound scientific evidence.

Day 1: First Morning Session

What is the scientific evidence for health problems associated with the indoor environment?

The morning presentations described the scientific evidence for health problems associated with the indoor environment. In the course of the presentations and the audience's response to them, many issues relevant to the Surgeon General's goals were made evident.

Overview

John D. Spengler, Ph.D.
Harvard University School of Public Health

The first speaker, Dr. John Spengler, provided an overview of research on toxic agents in the indoor environment and how modern building practices affect the health of building occupants. As Winston Churchill said, "we shape our buildings and, in time, our buildings shape us." It is often difficult to anticipate indoor environmental quality problems since prevailing building materials and construction practices change faster than scientists are able to evaluate their potential health impacts. For example, we are finding that fiberglass ductwork cannot be cleaned as effectively as sheet metal ducts. In addition, new synthetics and glues release novel types of organic compounds into the air that may cause allergic symptoms; and emulsifiers used for the new generation of high-resolution inkjet printers introduce complex new compounds into the indoor environment of offices. Added to this are relatively well understood toxic agents (such as radon, nitrogen dioxide, and carbon monoxide) that are often concentrated in the indoor air environment as an unintended consequence of energy conservation practices or inadequate ventilation.

In a study conducted in public housing during the heating season, the increased frequency of respiratory symptoms among infants at risk for asthma was correlated with increased indoor levels of nitrogen dioxide, which reached levels that exceeded U.S. Environmental Protection Agency (EPA) outdoor standards. Another study measured personal exposures to volatile organics with known carcinogenic risk potential in New York City and Los Angeles. It showed that contributions from the indoor air environment greatly exceeded those from outdoor exposure. Problems due to high levels of mold in indoor environments, currently a "hot" issue because of media attention, are often exacerbated by modern building practices. Use of building materials such as vinyl siding, aluminum studs, gypsum, and synthetic wood products reduce the water-holding capacity of homes. Inadequate ventilation and drainage practices can trap moisture behind siding, encouraging mold growth. Increased manufacture and use of synthetic organic compounds have increased the presence of these compounds in the environment worldwide, and have also increased their concentration in indoor air and dust samples (88 different compounds were found in samples from 120 homes in one study).

The indoor environment also presents some unique problems. For example, DDT levels were still found to be high in indoor dust samples taken recently in Cape Cod, even though DDT has declined in the outdoor environment since the ban on its use in the 1970s. This is because DDT

does not break down rapidly indoors in the absence of ultraviolet (UV) light exposure. Significant concentrations of many potentially toxic chemicals are found in the indoor environment. These include pesticides, phthalates (used as plasticizers and emulsifiers), O-phenylphenols (disinfectant), 4-nonylphenol (detergent metabolite), 4-t-butylphenol (adhesive), and polybrominated diphenyl ethers (a class of chemicals with flame retardant properties that may act as endocrine disruptors via thyroid hormone, and bioaccumulate and concentrate in breast milk). A study conducted in Sweden highlighted the significance of phthalates that may be found in the indoor environment (Bornehag C-G, Sundell J, Weschler CJ, Sigsgaard T, Lundgren B, Hasselgren M, and Hägerhed-Engman L. The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case-control study. *Environmental Health Perspectives*, 2004:112: 1393–1397.).

Asthma and Allergic Effects

Thomas A. E. Platts-Mills, M.D., Ph.D.
University of Virginia Asthma and Allergic Disease Center

Dr. Thomas Platts-Mills discussed indoor environment quality factors responsible for increased asthma incidence, particularly among urban African-American children, a trend reflected in the 20-fold increase in hospital admissions for acute asthma attacks between 1958 and 1997. Asthma is an allergic reaction causing constriction of smooth muscle, reducing patency of the bronchioles. Determining the most important allergens to prioritize from a public health standpoint can be difficult because of the complexity of allergic responses, individual differences in susceptibility, and complicated dose-response patterns for specific indoor air allergens due to sensitization and desensitization effects. Dr. Platts-Mills pointed out the difficulties in addressing asthma incidence and severity as a public health issue. For example, children in New Zealand have very high mite exposure whereas children in Sweden have very little or none; the prevalence of wheezing in New Zealand (21%) is more than twice that in Sweden (8%). Recent evidence suggests that asthma is in large part attributable to the allergic response to dust mites. Dust mite, cockroach, and *Alternaria* (fungal) allergens have strong positive associations with asthma. Higher exposure to such allergens generally leads to both higher sensitization and higher prevalence of asthmatic symptoms. Dog and cat allergens, on the other hand, can induce asthmatic reactions, but when present at higher levels for longer periods of time, also seem to induce tolerance. The presence of multiple cats and dogs in a house, particularly when children are exposed during the first year of life, can significantly reduce asthma risk.

U.S. asthma mortality rates by quintile of median income show the highest mortality for asthma in the poorest segment of the population in 1987–1989 National Center for Health Statistics (NCHS) data, but not in 1969–1972 data, indicating that something has changed over that time interval (it is not clear what). Cockroach allergen may be more important in certain parts of the country. In Northern low-humidity cities (e.g., Boston, Chicago, New York), dust samples from public housing have cockroach allergens but virtually no dust mite allergens or pet dander (since pets are not allowed). In the South (e.g., Atlanta), however, dust mite and mold allergens are just as important as cockroaches. In rural areas, asthma incidence is substantially reduced by the presence of cows kept in a barn near the house. While there is good evidence that the effect of cows is attributable to endotoxin, this does not explain the tolerance induced by cats or dogs. Indeed, measurements of airborne endotoxin show lower levels in homes with a cat. The pres-

ence of IgE antibody to cats is lower in countries where a large proportion of homes have cats, suggesting that development of tolerance to cat allergens may be a primary protective factor. Similarly, the "hygiene hypothesis" has also been advanced to explain the historical asthma increase. It suggest that factors such as decreased exposure to soil mycobacterium and changes in bacteria colonizing the gut have contributed to a population with increased sensitization to other common allergens. However, changes in hygiene do not adequately explain the scale, time course, or consistency of the historical asthma increase over the period 1960–1995.

Dr. Platts-Mills emphasized the observation that increased body weight and decreased physical activity have been associated with increased inflammation and wheezing among allergic children. In this case, the time course of increasing inactivity and obesity is more closely coincident with the increase in asthma. This is an interesting association from a public health point of view because interventions to reduce obesity and increase physical activity may also reduce asthma morbidity and mortality.

Non-Asthma and Non-Allergic Building-Related Health Effects

Clifford S. Mitchell, M.S., M.D., M.P.H.
Johns Hopkins University Bloomberg School of Public Health
Michael Hodgson, M.D., M.P.H.
Department of Veterans Affairs

Dr. Clifford Mitchell gave a presentation developed by Dr. Michael Hodgson and himself. He discussed non-asthma and non-allergic adverse health effects associated with the indoor environment. This presentation, covering a broad range of agents, interactive factors, and health endpoints, concentrated on defining the complexity of interacting factors that impact on taking a public health approach to indoor environment issues.

Dr. Mitchell presented a model of building-related health effects that is based on understanding the complex relationships between the building, building systems and contents, and building occupants. Hazards within the built environment may be related to:

- Building structure and/or design (e.g., the permeability of the envelope to moisture);
- Mechanical systems within the building (e.g., ventilation and heating systems);
- Furnishings within the building (fabrics, adhesives, paints, etc.);
- Human occupants of the building; and
- Other sources both inside and outside the building.

All of these can give rise to potential health hazards and modify the risk associated with hazards. These potential hazards include:

- Chemicals such as formaldehyde offgassing from carpets or building envelope materials;
- Biological agents such as bacteria and fungi in condensed water in air conditioning systems;
- Particulates generated from building materials or occupant activity within the building;
- Physical agents including noise and ergonomic hazards; and
- Psychological stressors.

Some of the hazards, such as carbon monoxide (which accounts for more than 100 fatalities per year), or *Legionella* bacteria, may be intrinsically associated with building systems. Others may be associated with building design (for example, hazards that may contribute to the risk of falls

from heights). Health and comfort can also be affected by physical factors, such as lighting and heat, and by the physical organization of the space. The ultimate health consequences of these hazards depend not only on building-related factors, but also on characteristics of the population and various effect modifiers. For example, transmission of infectious viral agents within a building may be influenced by airflow, temperature, and humidity. However, the spread of infectious agents also depends on demographic features of the building occupants, including their genetic susceptibility and health history, and could also potentially be modified by other exposures inside and outside the building.

The health effects that have been associated with buildings are quite diverse. Building-associated infections include *Legionella* and fungal infections. Other infectious agents, although not necessarily unique to building systems, may nonetheless be either contained or disseminated by conditions within the building. For example, in at least one case, a tuberculosis species has been shown to be released during building demolition. Also of current concern is the deliberate release of toxic or infective agents in buildings as an act of terrorism. Non-infectious pulmonary effects include hypersensitivity pneumonitis and inhalation fevers. There is also great interest in understanding more about the potential non-infectious pulmonary effects of mold exposures. In addition, there is increasing awareness of various irritation phenomena related to chemical, physical, and biological exposures, and the extent to which these irritation phenomena may play an important role in conditions such as reactive airways dysfunction syndrome (RADS). Building air-handling systems play a critical role in the distribution of and exposure to physical, chemical, and biological agents. The air-handling systems can affect the amount of moisture in a building and thereby prevalence of upper respiratory tract symptoms. Evidence suggests that irradiating the coils of heating, ventilation, and air conditioning (HVAC) units with ultraviolet light (UV), even without cleaning them, can significantly reduce microbial load and resulting irritation symptoms. This has been verified in blinded studies where building occupants were not aware whether the UV was on or off.

Dr. Mitchell described a few additional risk factors about which research is just getting underway. Two such areas are the relationship between obesity and building design and cancer in relation to lighting and hormone levels. Lighting is known to affect circadian rhythms and hormone levels, but little is known about the health implications of changes in lighting spectrum and levels. Building design, operation, and maintenance can all have critical impacts on worker health and well-being, and some interventions have been found to improve health. However, there is little understanding of why or how these mechanisms reduce exposure. Still, it is clear that many problems that are recognized are associated with well-characterized building system failures and could have been prevented had basic engineering and obvious health considerations been taken into account. It is important to understand the role of susceptible populations in evaluating the impact of building changes and to address the need of more sensitive populations, such as children and the immunocompromised.

Building-Related Health Effects and Potential Economic Impact

Eileen Storey, M.D., M.P.H.
University of Connecticut Health Center

Dr. Eileen Storey discussed the potential economic impacts of health problems related to indoor environment quality problems, important both as a socioeconomic issue in itself and as a potential source of "leverage" for encouraging employers and building owners to implement changes to benefit the health of building occupants. Even in the absence of serious health effects and morbidity, discomfort of building occupants because of temperature or can translate into lower productivity, reduced job satisfaction, increased employee turnover, and greater work loss due to illness. On the other hand, remediation efforts can be hampered by short-term disruption costs, relocation costs, and labor relations issues. Although productivity issues related to building comfort can be difficult to quantify, one blinded study of typing speed showed a 4%–6% loss of measurable work output when old carpeting was present in the environment. Office building managers respond to a loss of tenants and property value as a primary motivator in taking on the costs of assessment and remediation. Employers may be less aware of more subtle effects on productivity. As people are made more sensitive to these issues, the economic implications should increase. School buildings serve as a primary focus for indoor environmental issues because of strong teacher and parent awareness and involvement. However, remediation programs can cause substantial diversion of attention and resources that will not always be productive unless the efforts are well directed. Asthma is a leading chronic disease causing lost school days, but the relationship of indoor environment quality problems to other symptoms, such as headaches and fatigue (reported by staff and students in association with particular halls and classrooms), has rarely received the type of follow-up attention that might be useful in identifying and correcting subtle building problems before they result in major health problems.

Questions and Comments

This first series of presentations stimulated a large number of questions and comments, many focused on the school environment. One "healthy schools" advocate maintained that schools should be given priority over office environments because they have a higher concentration of more vulnerable people in closer physical proximity. Several participants pointed to particular problems associated with investigating and mitigating indoor environment issues in schools, including:

- Overcoming fears of unwelcome publicity and getting approval from school boards and administrators;
- Building problems within a school district can vary greatly among individual schools because of great variation in building age and, consequently, construction characteristics;
- Curriculum trends that have reduced or eliminated recess and physical education during the school day, leading to the type of increase in inactivity cited by Dr. Platts-Mills as a possible asthma risk factor;
- The location of school facilities on land with poor drainage or a high water table (the least desirable land in a development, donated by the developer for public use); and
- Budget constraints, which may result in deferred maintenance that can create and exacerbate moisture problems.

While dampness is recognized as a problem, several people commented on the lack of standards for what can be considered a "dry" or "wet" building environment. There are no clear quantitative data on how humidity affects mucosal symptoms (in the case of dryness) on one hand, and mold and other dampness-related problems on the other.

An audience member raised the issue of multiple chemical sensitivity (MCS), considering the role of highly allergic or chemically sensitive individuals as a sentinel population. Other countries have given more attention to this issue. Canadian and Swedish demonstration projects have shown that it is possible to build for hypersensitive people, but also that it is very hard to remediate problems for them after construction. A Japanese conference on indoor air quality emphasized MCS, and an extensive bibliography on the subject is available. Dr. Mitchell pointed out that prevention of MCS symptoms ties into many of the same concerns and approaches used to address asthma and allergy issues, so the problem can be dealt with in a practical way regardless of how valid one finds claims of MCS. He stressed that a quality remediation approach (rather than just covering up problems) can improve many health problems, including MCS.

Highlights of the Scientific Evidence for Health Problems Associated with the Indoor Environment Session

There is good scientific evidence that allergies, asthma, and the spread of respiratory infections are influenced by the indoor environment.

There is a need for better understanding of the influence of agents such as mold species and chemicals on respiratory diseases, immunological and cognitive disorders, and other health endpoints.

The relationship between the indoor environment and health is complex. It encompasses a broad range of chemical, physical, and biological agents; interactive factors; individual susceptibilities; and health endpoints.

Some of the indoor environmental control and remediation techniques used to deal with asthma and allergy issues will likely address some of the other indoor environment health issues.

New building materials and construction practices are being introduced with little understanding of their impact on the indoor environment and the health of the occupants. Data are also lacking on dose-effect relationships for many of the known toxic indoor agents and the interplay of genetic and other health risk factors, making it difficult to predict the effectiveness of control and remediation techniques with precision.

Day 1: Second Morning Session

What are the challenges to bringing about health-promoting changes in indoor environments?

William J. Fisk, B.S., M.S.
Lawrence Berkeley National Laboratory

Mr. William Fisk introduced the topic of how to release market forces to influence building professionals and decision makers to make their buildings more health-protective. Most building designers and managers focus on immediate functional requirements (space requirements, temperature ranges, and attractive design), meeting building-code requirements at minimum cost, and providing a facility that is marketable and will attract a good rental return. The impact of design considerations on indoor environment quality, occupant health, and productivity is generally not emphasized. This places primary importance on first costs, perhaps tempered by measures that will reduce long-term maintenance costs; indoor environmental quality is a secondary consideration. Building professionals are often isolated from the consequences of decisions that result in suboptimal indoor environment quality. Overcoming this type of barrier to change requires providing incentives (benefits) or demonstrating the economic penalties of ignoring indoor environment quality issues.

Mr. Fisk's key points included the following:

- In office work, salaries are by far the greatest employer cost, so even a small increase in productivity (due to an improved work environment) can provide a favorable return on investment;
- A speculative developer has little responsibility for indoor environment quality unless it is bad enough to result in litigation (i.e., there is a disconnect between a developer who assumes the development costs and an employer who obtains the benefits of long-term improvements in indoor environment quality);
- Health insurance costs are not directly tied to indoor environment quality even if illness can be linked to a poor indoor environment; and
- In residential settings, poor maintenance practices that often account for poor indoor environment quality are often found in low-income housing, where resources and motivation of the tenant or owner to correct problems are often lacking.

There is a need to convey the economic implications of improved practices and provide scientific evidence that intervention is effective. As an example, Mr. Fisk discussed economizer control module system technology, an energy-efficient approach that increases ventilation rates during mild weather to reduce the need for mechanical cooling. Economizer systems are rarely used in small office buildings and almost never in residential settings. It has been estimated that use of an economizer control module system could result in energy savings of approximately $26/person/year in the climate of Washington, DC. These estimates are usually used as a basis for determining whether the energy savings (benefit) exceed technology cost. Frequently building professionals believe that the economic returns are insufficient. However, because economizers increase average ventilation rates, they can be shown to reduce levels of infectious

airborne particles in the building and therefore could decrease respiratory illnesses. Mr. Fisk recommended that these systems be used more broadly. Calculations predict that sick-leave reductions worth approximately $200/person/year occur in addition to the energy savings. Mr. Fisk emphasized that developing and testing economic incentives for engineering health-protective buildings can provide a sound economic basis for investing much more in practices that assure good indoor environmental quality. He concluded with the following specific recommendations:

- Establishing lease and contract terms that reward indoor environment quality efforts;
- Rewarding facility managers of office and public housing properties for better indoor environment quality;
- Establishing a program of building labeling (analogous to EPA's Energy Star program) that allows consumers to recognize structures that have realized superior indoor environment quality in their design and construction;
- Tying HMO rates to indoor environmental quality protective practices of employers; and
- Linking professional liability insurance rates to indoor environmental quality training and practices.

Eileen Storey, M.D., M.P.H.
University of Connecticut Health Center

Dr. Eileen Storey expanded on general points made in her earlier presentation, using two ultimately successful case studies to illustrate how difficulties in initiating effective indoor environment air quality improvements in schools can be overcome. If administrators do not understand the health effects and risks involved, they may tend to stigmatize those reporting adverse health symptoms as disgruntled employees or overly "sensitive" individuals and dismiss the need for remediation. Alternatively, if those reporting problems are treated as "index cases," they can provide an opportunity to effectively address problems before they become too expensive to correct. Among the challenges to assessing the true risk is that carbon dioxide levels are often taken as a surrogate for effective air exchange, and no qualitative assessment is made of biological agents, which may have a great impact on health issues even when air exchange appears to be "adequate." The EPA's *Indoor Air Quality Tools for Schools* program has proved to be a very effective mechanism for identifying and correcting building problems in schools by establishing a building team directed toward applying relatively inexpensive solutions to IAQ problems. The same model could be applied to office buildings.

Some remediation efforts prove to be more successful than others. In her case studies, Dr. Storey indicated the complexity of issues that can arise. She first described a middle school in the Northeast, built in the 1950s with later additions. Staff and children were reporting a range of symptoms, including headaches. One teacher developed respiratory illness. Remediation of her classroom served as a starting point for more extensive evaluation of building problems. Since time was needed to plan and fund systematic remediation, sensitive individuals were removed from the area. An engineer was hired to evaluate the building and to make recommendations. Survey results indicated that irritant and discomfort symptoms extended over a larger area of the school than the area where people were reporting acute respiratory symptoms. For financial reasons, remediation efforts began with the classroom in which the teacher developed respiratory illness. Carpeting was removed from the classroom, which introduced an additional

problem because the underlying asbestos floor tile also had to be removed. A roof leak causing moldy partition and wet insulation problems above the deck was addressed initially by patching the leak and increasing ventilation under the roof, but these measures only enabled moldy air to spread through the school. The eventual solution, motivated in part by extensive public attention and involvement, required isolating and closing parts of the building while applying effective remediation measures sequentially. The multi-year remediation program included repeated staff and student health surveys and monitoring of air quality, with suitable measures to protect occupants during construction.

The second case was a late 19th-century Hartford, Connecticut, elementary school with a 15% asthma prevalence as compared the national prevalence of 5%. The building was heated by a centrally located boiler and the only ventilation was provided by windows. Water leakage linked to health problems for students and staff could be traced to primary structural problems, which were scheduled for needed repairs. In this school, the principal took a primary role in pushing the health improvement initiative using the *Tools for Schools* approach. Problem areas ("hot spots") identified on the basis of student and staff symptoms were the focus of systematic interventions. The effectiveness of the repairs was evaluated by closely monitoring the health of students before and after repairs were made. The principal stressed the role of the faculty in the prevention of asthma in their students. Dr. Storey indicated that this high level of involvement by the key school administrator was the major factor in the success of the program in this school.

Peyton A. Eggleston, M.D.
Johns Hopkins University

Dr. Peyton Eggleston discussed challenges facing those trying to reduce airborne allergens and toxins in inner-city areas, particularly as they affect the health of children. Respiratory morbidity can be seen as a consequence of a complex series of interacting factors. The primary causal sequence for asthma can be attributed to environmental allergens causing immunologic sensitization, resulting in asthmatic airway constriction. Secondary factors include toxic air pollutants that can affect general health status; susceptibility factors (inflammation, bronchial hyperresponsiveness); and underlying social factors (low income, stress, poor access to medical care, lack of education, etc.) that may impede both effective environmental solutions and medical treatment.

Results of the National Cooperative Inner City Asthma Study (NCICAS), conducted in eight urban centers in two stages (a cross-sectional study in 1992–1993 and a randomized intervention trial in 1994–1996) provided the primary basis for discussing environmental problems and impediments to their solution. Some of the problems in indoor environmental quality can be related to the problems of low-income housing conditions, such as the following:

- Using a gas stove for heating in the winter (source of nitrogen oxides [NO_x]);
- Homes with windows painted shut, preventing their use for ventilation;
- Roofing that is poorly maintained by landlords, resulting in leakage;
- Occupied rental homes located next to abandoned row homes with severe water leakage and pest problems;
- Inadequate cash flow to permit proper maintenance and capital improvements; and

- Accumulation of trash in the home or nearby, encouraging pests and inhibiting effective pest extermination.

Many indoor air quality problems can be related to lifestyle characteristics that residents do not necessarily see as harmful, but which are contributing factors for asthma problems. For example, Dr. Eggleston indicated that the NCICAS study found that a cigarette smoker was a caregiver in 69% of the homes and that some significant contributions to indoor air particulates were a consequence of cultural preferences, such as burning incense. Other problems are a secondary effect of other social problems (e.g., neighborhood violence and drug dealing may keep children confined to the home for their safety, increasing their indoor environment exposure and reducing opportunities for outdoor exercise).

Hal Levin, B.Arch., ASHRAE Fellow
Building Ecology Research Group

Mr. Hal Levin discussed architectural and engineering performance standards that impact the design of healthier indoor environments. For the most part, there are few standards or agent limit values that can be applied to indoor environment pollutants. Only light levels, noise and acoustics, and temperature range are addressed in clearly established standards, although the California Division of Occupational Safety and Health (Cal/OSHA) has adopted moisture control regulations. Mr. Levin suggested that there is strong industry opposition to setting mandatory standards. In the current anti-regulatory political climate, adequate indoor environment regulations are unlikely in the near term. Building permitting is only partially effective for addressing indoor environment issues because it regulates only initial building design and construction, and has limited impact over the total life of the building.

To "fill the gaps" in indoor environment regulation (or guidance, in the absence of enforceable standards), it is necessary to establish concentration limits for indoor pollutants of concern and devise cost-effective methods for realizing them. Mr. Levin reported that indoor air experts agree that source control is more effective than dilution by increased ventilation rates. Although the quality of outdoor air used for ventilation can also be a factor, air filtering is typically limited to protection of mechanical and electronic equipment or to reduce housekeeping costs, not to improve health. In general, most buildings are "run blind" with respect to monitoring ventilation, indoor environment quality, and the effectiveness of air treatment technology. There is an absence of data that can be used to evaluate products and services claiming to improve indoor air quality, such as portable air cleaners or duct cleaning services. A lack of clear standards also complicates evaluation of the effectiveness of any measures taken.

A comparison of symptom prevalence as a function of ventilation rate in building studies shows up to 10-fold variations in individual sensitivity at a given ventilation rate, as well as some general trends such as a gender difference (women generally showing higher sensitivity). There is no single "correct" ventilation rate for all buildings or for all individuals, and "applying conclusions from aggregated data obtained in multi-building studies can be hazardous to someone's health." Furthermore, in an era of increasing global energy use and cost and diminishing supplies, increasing ventilation will not be the preferred solution to indoor air pollution problems. Mr. Levin stressed the importance of diverse individual responses by designating the

potency of an environmental agent as a function of "exposure" (defined as the product of concentration, time, and dose) and susceptibility factors (genetics, exposure history, health status, and age), which generally vary significantly in a population, often in unpredictable ways. There is inherent resistance in the building community to changing established building practices and techniques, or to making changes that might increase building costs. As a solution, Mr. Levin advocated taking an integrated or "ecological" approach, considering the full range of interdependent factors that produce the indoor "ecosystem," with an emphasis on formulating cooperative efforts to solving indoor environment problems.

James E. Woods, Ph.D., P.E, ASHRAE Fellow.
The Building Diagnostics Research Institute, Inc.

Dr. James Woods addressed the engineering challenges in ensuring healthy levels of performance from environmental control systems. Buildings are designed to provide safe, secure, and healthy conditions under both normal and extraordinary conditions. Standards and guidelines generally focus on safety or system performance issues, not on health protection or well-being of the occupants. Most codes and standards are enforced during design and construction stages, not during operations. Different categories of buildings have different requirements and issues. While most engineering interest centers on large public buildings (educational, health care facilities, office and mercantile, public assembly and worship – industrial buildings being excluded from this discussion), most buildings are small and most of our time is spent in residential and other small buildings.

Dr. Woods defined six barriers to improving building performance from a health standpoint:

1. The disaggregated history of building practice and reliance on established practices work against a consensus approach to introducing health-protective features and practices.
2. There is a lack of accountability for the health consequences of design and construction decisions; occupant health is often specifically excluded from contracts and is avoided in project documentation.
3. While there are little credible scientific data that relate exposures to health consequences, there are many speculative and anecdotal reports, making it difficult to get clear cost/benefit information. Most available health data concern residential structures, and there is little information regarding commercial buildings. It is not easy to get cooperation to do such studies because of liability/litigation issues.
4. Misapplication of Value Engineering (VE) management practices to reduce first costs only (rather than achieve the long-term values realized by improved performance and beneficial health consequences) may increase occupant health and safety risks.
5. Deferred maintenance and other cost reduction policies (such as premature occupancy or occupancy during interventions) may increase health risks.
6. Liability and threat of litigation present major impediments to professionally attacking health issues; obtaining insurance to cover health issues or engineering to address health issues is extraordinarily costly, and many insurance policies have exclusion clauses for indoor environmental health issues.

Dr. Woods identified accountability as a key issue in making buildings healthier. He described the "healthy building cycle" (an approach similar to the life-cycle analysis approach), which is

used by organizations such as the Healthy Building Network to evaluate environmental and health impacts of a material, building practice, or a service throughout its life cycle. In the cycle of addressing building problems (diagnosis, intervention, evaluation of the effectiveness in reaching a healthy building status), an accountable person must be identified who is empowered to ensure building performance and trained to know how to provide adequate performance and occupant protection in each phase in the building's life. In Dr. Woods' experience, 90% of problem buildings can be attributed to poor functioning of their control systems.

Questions and Comments

Many questions and comments followed these presentations. While most comments were in general agreement with the points outlined by the speakers, many reflected individual differences among participants as to how to weight priorities, assess the impact of different environmental agents, and promote research to provide a more solid scientific basis for action. Many advocated taking more precautionary actions based on limited indications of potential risk.

One environmental consultant commented on issues of route of exposure, suggesting that while indoor air quality issues are important, 60–80% of exposures are through non-inhalation routes of exposure such as hand contact. Mr. Levin stated that CDC has done work indicating the importance of skin absorption and hand-to-mouth transmission of pentachlorophenol in children, but that more still needs to be done. Mr. Fisk commented on building cleaning practices and how they can reduce exposures. For example, integrated pest management generally results in lower pesticide levels and reduced opportunity for contact exposure. Dr. Woods commented that health care facilities research suggests that half of nosocomial (hospital acquired) infections occur by contact and that cleaning practices are critical in reducing the rates.

Dr. Spengler raised the issue of conflicting practices, such as having fire code and security objectives that run counter to healthy indoor environment objectives. All implications of solutions for performance problems, such as energy conservation, must always be considered. Dr. Woods suggested that a bigger problem is legacy construction, meaning that any innovations, no matter how good, will take some time to affect the health of a majority of the population. He estimated that 80% of existing buildings will still be in use 20 years from now.

Mr. Levin commented that the EPA's *Indoor Air Quality Tools for Schools* material is a model for what can be done to inform individuals on how to improve their home environment. Mr. Fisk mentioned Finland's outreach program discussed at the Healthy Building 2000 Conference. Several participants emphasized the need to educate the public on practices that can improve indoor environment quality rather than waiting for more definitive research information to establish stronger cost-benefit arguments. Dr. Eggleston pointed out that low-income-housing residents have limited ability to resolve issues such as roof leaks and that the landlord population can be a particularly tough group to motivate and educate. A federal legislative aide in the audience discussed a pending toxic mold bill (there have been several in previous legislative sessions and a number of state bills have passed) and stressed the public health needs conveyed to him by individuals describing their personal health problems. He suggested that the scientific community work with legislators to address the issue. A participant indicated that the National Academy of Sciences' (NAS) Institute of Medicine (IOM) report, *Damp Indoor Spaces and*

Health (2004), conveyed the impression that mold problems are not so serious. Others stated that the report had identified the problem clearly, and suggested that the alternative view is perhaps a misunderstanding based on the type of cautious language scientists use when dealing with possibly causal associations that are not firmly established (see the following section for more discussion on this report).

Several participants discussed the economic impact of health problems attributable to poor indoor environment quality and how to motivate health payers to take a more active role in effecting changes. Some HMOs and employee health providers are ready to invest in an environmental approach, but some still need a business plan to persuade them it is in their best long-term interests to do so. Some participants mentioned that the economic impact of health problems attributable to poor indoor environment could support this kind of intervention for Medicare patients.

Some participants suggested that proof for the effectiveness of environmental measures seems to be held to a higher standard than that used for medical interventions. This resulted in considerable back-and-forth discussion on the limited ability of intervention research to provide convincing data supporting the cost-effectiveness of environmental intervention in solving health issues. It was also mentioned that there is a high cost to conducting good field studies that are sufficiently large enough to generalize the results for policy decisions and that there are few sources of funding available for these types of interventional studies.

Highlights from Challenges to Bringing about Health-Promoting Changes in Indoor Environments Session

Non-inhalation routes of exposure to indoor contaminants can be just as important as inhalation.

Some health problems associated with the indoor environment can be related to the problems of low-income housing conditions.

The lack of comprehensive standards for indoor environmental criteria, especially for indoor air pollutant concentrations, is a barrier to establishing standards for healthy building materials, ventilation, and other critical factors.

Building professionals are generally isolated from the consequences of decisions that result in suboptimal indoor environment quality.

Applying market forces by demonstrating favorable cost-benefit ratios requires better data on health and productivity benefits that result from specific measures to improve indoor environment quality.

Current market forces are heavily weighted toward initial costs, whereas making buildings more health-protective requires good practices through the entire building life cycle.

A significant portion of existing buildings will still be in use 20 years or more from now. Healthy indoor environment activities will need to address both existing and new building issues.

There is a need to convey the economic implications of improving the indoor environment and of ignoring indoor environment problems, and to provide scientific evidence that intervention is effective.

Day 1: Afternoon Session

What are the research needs related to public health and the indoor environment?

Research Needs from the National Academy of Sciences' Institute of Medicine Report, *Damp Indoor Spaces and Health*

Noreen Clark, Ph.D.
University of Michigan School of Public Health

Dr. Noreen Clark, who chaired of the NAS IOM committee that wrote the *Damp Indoor Spaces and* Health report, discussed findings of the final report, published in 2004 by the National Academies Press (*http://www.iom.edu/CMS/3793/4703/20223.aspx*). The NAS committee found that there was sufficient evidence to conclude that there is an association between the presence of mold and the following health effects:

- Upper respiratory tract symptoms,
- Wheeze,
- Cough,
- Asthma symptoms in sensitized persons, and
- Hypersensitivity pneumonitis in susceptible persons.

Building dampness was associated with the same health outcomes, except hypersensitivity pneumonitis (which has been studied in relation to various indoor exposures but not dampness in general). The committee also found suggestive evidence that excessive indoor dampness might be associated with development of asthma, but alternative explanations for the association could not be ruled out with confidence. Similarly, limited evidence was found for an association between excessive indoor dampness and two other conditions: shortness of breath and lower respiratory illness in children. Although the committee found no association of dampness to a wide range of other symptoms or conditions, given existing evidence, the committee found ample scientific justification to conclude that dampness is a public health problem. It therefore makes sense to adopt a widespread approach to correcting the condition rather than to take a clinical approach to treating the symptoms. Although dampness can occur in many communities, low-income and substandard housing encourage poor building design, construction, and maintenance practices, making dampness a particular problem for these residences.

There are still unresolved research issues that have practical implications in addressing respiratory health problems. It is not clear what constitutes "safe" levels of dampness or appropriate levels of dampness reduction; the magnitude of the risk produced by dampness and where it ranks among other health risk factors is not clear; and, with few exceptions, the relationship between particular causal agents (such as specific species of mold) and specific adverse health effects has not been established. When Saegert et al. reviewed 72 intervention studies, they found that technological interventions were most effective in reducing dampness-related health problems when they were inexpensive, simple, durable, and required little effort to maintain or use (Saegert SC, Klitzman S, Freudenberg N, Cooperman-Mroczek J, Nassar S. Healthy hous-

ing: a structured review of published evaluations of United States interventions to improve health by modifying housing in the United States, 1990–2001. American Journal of Public Health 2003;93[9]:1471–7). In addition, a set of studies by Krieger et al. showed that high-intensity education and support for low-income families, including dampness control measures, resulted in significantly decreased asthma symptoms.

Dr. Clark outlined several specific research needs identified by the committee:

- Define metrics of exposure and dose;
- Determine health benefits and associated medical cost savings of interventions;
- Conduct longitudinal studies to assess the long-term benefits of interventions;
- Evaluate various alternative and complementary approaches such as building code changes, economic incentives, and education programs;
- Assess economic gains from remediation and prevention efforts that result from extending the useful life of buildings; and
- Conduct studies to assess the effectiveness of communication instruments designed for various audiences, including specific segments of the public and health professionals.

The committee also noted a need to develop dampness control guidelines with multidisciplinary input from a range of stakeholders so that they are applicable to a variety of situations and are soundly based on scientific evidence and professional judgment.

Peyton A. Eggleston, M.D.
Johns Hopkins University

Dr. Peyton Eggleston discussed research needs identified in the *Damp Indoor Spaces and Health* report associated with exposure to mold. Comparing results of two major epidemiologic studies of the association between asthma symptoms and exposure to a damp indoor environment, Dr. Eggleston noted that one study found a higher association with self-reported dampness in a subject's previous home than in the subject's present home, and discussed mechanistic implications of such findings. Mold produces health problems through three mechanisms:

1. Acute infection,
2. Toxic disease, and/or
3. Immune-mediated disease.

As illustrations of infection, he discussed fungal diseases such as athlete's foot and ringworm, and respiratory fungal infections such as histoplasmosis. In the case of histoplasmosis, endemic areas associated with large river valleys can be mapped by positive skin tests. Opportunistic fungal infections can occur in sensitive populations, for example, *Aspergillus* or *Candida* infections in immunodeficient AIDS patients. In these cases, the infecting organism can usually be identified. Toxic diseases are produced by an agent of the fungal organism, tend to be self-limited, and do not result in antibodies to the fungi causing the problem. An example is organic dust toxic syndrome occurring in farm workers 4–8 hours after exposure to moldy hay. Immune-mediated diseases follow a typical pattern of initial sensitization at some time prior to presenting with symptoms, often followed by increasing symptoms with repeated exposure, with indicators of immune system reactivity. Examples include hypersensitivity pneumonitis, allergic bronchopulmonary aspergillosis, and allergies.

Dr. Eggleston outlined immune-system responses and their diagnostic indicators (IgE, IgG, and T-cell levels). He emphasized the prevalence of immunological sensitivities in the United States population: 38% is affected by allergic rhinitis and 8%–10% are affected by asthma. Some major unanswered research questions have implications for effectively controlling asthma:

- The role of microorganisms in the development and exacerbation of diseases for occupants of damp indoor environments;
- How indoor spores are aerosolized, transported, resuspended, and tracked for measuring exposure;
- What specific mold organisms are most important for disease effects;
- What physical factors increase the effects (e.g., relative importance of aerosol versus dermal or oral contact);
- Which toxins produced by mold are important; and
- Whether spores have to be viable to induce disease.

Similarly, there are research needs in some technical areas:

- Specific and sensitive detection methods for exposure assessment of molds, particularly improved non-culture techniques;
- Methods for rapid and accurate detection of allergens, endotoxins, extracellular polysaccharides, and spores;
- Techniques for detecting toxins in tissues and specific tissue effects of toxins (both for understanding the mechanisms of action and for routine diagnostic purposes); and
- Dose-response information to establish safe levels of exposure.

Priority Research Needs for Improving the Health of Workers in Indoor Environments

Jean Cox-Ganser, Ph.D.
National Institute for Occupational Safety and Health, CDC

Dr. Jean Cox-Ganser discussed research needs in the context of occupational indoor environmental issues. About 70% of today's 89 million workers are employed in non-industrial indoor environments, including schools. Average Health Hazard Evaluation (HHE) requests per year related to indoor air quality issues increased between 1978 and 2002, peaking in 1993–1997 as a consequence of heightened "sick building syndrome" press coverage. HHE requests in schools increased steadily during the same period, as did requests related to asthma health complaints.

Dr. Cox-Ganser discussed results of work from a NIOSH project on building-related asthma in indoor environments. She described an HHE of building-related asthma in a community college conducted in 2000. The college consisted of 40 buildings built in the 1920s, 1970s, and 1990s with 1,200 full-time faculty and staff. A number of the buildings had a history of water incursions, high humidity and mold contamination. The primary aims of the HHE were to obtain semi-quantitative measures of dampness and to determine exposure-response relationships between them and work-related symptoms. The study evaluated 721 rooms for indications of present dampness (moist materials or standing water) and signs of past damage (water stains, visible mold, and mold odor). Staff time spent in various rooms was documented and used

together with the semi-quantitative scores to create indices of exposure against which self-reported health symptoms were modeled. There were exposure-response associations between exposure indices and work-related symptoms such as wheezing, chest tightness, shortness of breath, throat irritation, and nasal and sinus symptoms.

Another study, performed in a health care facility, compared two hospitals. One of the hospitals had six new-onset asthma cases on a top floor where there was a history of water incursions and evidence of fungal contamination in the walls and ceiling. Symptoms correlated with semi-quantitative indices of water damage and mold, as well as with air particle count, air fungal spore count, and *Penicillium/Aspergillus* (cultured fungi and extracellular polysaccharide levels) in chair and floor dust. A third study surveyed work-related symptoms and health concerns (asthma, hypersensitivity pneumonitis, and sarcoidosis) for 1,300 people occupying a 20-floor building with a history of water incursions. There were 900 participants in the cross-sectional survey. Results indicated increased prevalence ratios (2.7 to 4.7) for respiratory symptoms compared to an EPA study of United States office workers, and a 7.5-fold increase in asthma incidence density since building occupancy (66 of 103 adult onset asthma cases arose after building occupancy). These increases were reflected in increases for various objective measures of symptoms (such as higher rates of abnormal lung function tests and asthma medication use in symptomatic employees as compared to asymptomatic employees, and increased use of sick leave). Symptom clusters are sometimes ascribed to "disgruntled employees," but an assessment of job stress and job satisfaction indicated similar levels of satisfaction in the respiratory case group and in asymptomatic comparison workers (87% were very or somewhat satisfied with their job in the respiratory group, 93% in the comparison group) and only a small increase in the percentage of workers who thought they were required to work hard frequently or very often (51% of respiratory cases, 45% of the comparison group).

Dr. Cox-Ganser described an HHE carried out in a school, and indicated that NIOSH had plans to continue indoor environmental quality studies in schools by applying a strategy to prioritize environmental interventions in relation to dampness and mold. The strategy is to use a standard-ized semi-quantitative environmental assessment linked to information on the prevalence and distribution of symptoms within buildings.

Dr. Cox-Ganser also discussed the NORA (National Occupational Research Agenda) Indoor Environment Team white paper which recommends priority research needs (Mendell MJ, Fisk WJ, Kreiss K, Levin H, Alexander D, Cain WS, et al. Improving the health of workers indoor environments: priority research needs for a national occupational research agenda. *American Journal of Public Health* 2002;92:1430–1440). These include establishing priorities to:

- Identify critical indoor exposures and their relationship to adverse health effects typical of "sick building syndrome" (mucus membrane irritation, headaches, and fatigue), com-municable respiratory illnesses (influenza, common cold), and building-related allergies and asthma;
- Develop prevention strategies for these adverse health effects;
- Understand how the design, operation, and maintenance of buildings and the activities of occupants affect concentrations of indoor air pollutants; and
- Identify strategies to reduce barriers and increase incentives for undertaking health-protective building practices.

Energy-Related Indoor Environmental Quality Research: A Priority Agenda

Vivian Loftness, B.S., M.Arch., F.A.I.A.
Carnegie Mellon University

Ms. Vivian Loftness discussed health- and energy-related aspects of the built environment from an architectural perspective. She focused on which physical aspects of a building tend to result in indoor environmental quality problems, and how to get people to invest in buildings that better promote the health and well-being of occupants. As previous speakers had pointed out, costs associated with salary far outweigh expenses related to rent, energy usage, or technology. The financial impact of health insurance and lost productivity related to diseases and symptoms associated with indoor air quality (eye problems, upper respiratory symptoms, allergies, asthma) constitute a substantial proportion of the total cost, although there are other single factors, such as musculoskeletal problems, that are also significant. She related that the annual relocation rate of 40% has associated costs of dissatisfaction with environmental conditions, including poor indoor air quality. While increased ventilation rates can contribute to improved health and productivity, energy costs must be managed through innovations such as task air (delivering air quality control to the worker's desk) or air-to-air heat exchangers. Since such measures require more engineering expertise and a break with the status quo (an economic penalty), there is a need to document the cost/benefits accurately.

Professor Loftness suggested that the most important building attributes for both energy efficiency and health are air, thermal control, lighting quality, access to nature, ergonomics, and material quality (considered both in relation to toxins released in the workplace and material longevity or reuse, as well as land use and mobility). While improvements in these factors have associated costs, they can be offset by economic gains in increased health and individual productivity, as documented in numerous studies. Design approaches that maximize the use of natural daylight without introducing glare can increase productivity, worker health, and energy savings. UV and sunlight, coupled with good air flow, may be among the best strategies for reducing mold growth. Seated views of the outdoor environment for every worker, and windows that open, have health and motivational benefits, and can also impact indoor environment quality. New concerns about security and blast-resistant building as anti-terrorist measures, however, may negatively impact the design and engineering for improved indoor environmental quality in new and retrofit projects.

Ms. Loftness concluded by noting that there is a need to focus research on links between the built environment, human health, and productivity. She identified the e-BIDS (energy and building investment decision support) tool from Carnegie Mellon University (CMU) as a reference (http://cbpd.arc.cmu.edu/ebids) for information on what CMU is doing to promote building practices that optimize productivity, health, energy use, and organizational objectives.

CDC's Agenda for Research, Training, and Outreach to Minimize Adverse Exposures in Indoor Environments

Clive Brown, M.B.B.S., M.Sc., M.P.H.
National Center for Environmental Health, CDC

Dr. Clive Brown discussed CDC's agenda for research, training and outreach to minimize adverse exposures in indoor environments. CDC's Healthy Homes program and other CDC activities address many indoor environment issues such as lead, carbon monoxide, and environmental tobacco smoke (ETS), but dampness and allergic fungal disease constitute a major portion of their public response activity. Approximately 60%–80% of the 100 calls per month received by the Air Pollution and Respiratory Health Branch (APRHB) involve dampness-related issues. A large proportion of the population is affected by mold allergies and about 10% have a positive skin test for fungal extracts; upwards of 80% of people with respiratory allergy symptoms are sensitized to fungi.

Reviewing some of the major points of the *Damp Indoor Spaces and Health* report (which was commissioned by CDC), Dr. Brown noted there is no agreed upon definition of dampness, and the report's findings of "sufficient evidence of an association" for many symptoms and diseases mean that causal relationships are implicated but not proven. Defining exposure to mold is difficult because multiple species of molds are found everywhere. Results will vary depending on sampling and analysis methods. As there are no recognized standards for sampling mold or for analyzing and interpreting sampling data, it is difficult to know what level of mold presence is acceptable. There is a need for better quantitative biomarkers to clearly define the link between indoor microbial and mold growth and adverse health effects, and between specific chemical markers (such as mycotoxins and glucans for mold, or endotoxins for bacteria) and levels of microbial agents. There is also a need to evaluate potential interactions between environmental exposures to other toxic agents and the role of genetic susceptibilities in health effects.

Hill's Criteria of Causation (the minimal conditions needed to establish a causal relationship between two items) suggest certain characteristics that should be present if an association is to be considered causal (temporality of exposure preceding symptoms, high strength of association indicated by a large risk ratio, clear dose-response relationship, consistency of association in repeated studies, specificity of association, biologic plausibility). However, many environmental studies are unable to satisfy these criteria and to clearly relate exposure to disease outcome. One indirect approach used by epidemiologists is to do intervention studies to demonstrate reversibility, i.e., does an intervention that corrects the suspected risk factor result in an improvement in the health condition? However, the chain of causal events can be complicated: a study performed in Atlanta in 1998–2000 showed a significant decline in cockroach and house dust mite antigen levels after appropriate interventions but no corresponding improvement in asthma severity. If we extrapolate to mold, similar results in other studies led the 2000 IOM report on asthma, *Clearing the Air*, to conclude that although there is evidence that fungal removal measures reduce levels of fungi, there was insufficient evidence that fungal control measures improve lung function. There are social and institutional barriers to effective interventions, notably: poverty, compromised dampness control measures in construction to save costs, and lack of

awareness of long-term benefits and health advantages of addressing dampness issues promptly. This suggests the need for training about dampness, its prevention, and its consequences, among those who design, build and maintain buildings, and also among individual homeowners.

Current and planned APRHB activities related to damp indoor environments include:

- Scientific reviews and original studies of health effects associated with damp/moldy indoor environments, including school-based studies;
- Developing appropriate science-based material for responding to the public about damp indoor problems; and
- Capacity building, i.e., determining how state and local agencies (health departments) respond to mold-related health concerns and developing their capacity to deal with these issues effectively.

If it is determined that it is appropriate for CDC to develop a program for Healthy Indoor Environments, APRHB's plan would include activities which:

- Promote intramural and extramural research and develop standard investigative and laboratory practices;
- Provide a public health response that includes investigating outbreaks/clusters, strengthening state and local capacity, conducting surveillance and intervention activities, and public health promotion and education; and
- Establish partnerships with building community stakeholders, federal and local government agencies, researchers, and industry to better address knowledge gaps and recommend better design and construction practices.

The *Damp Indoor Spaces and Health* report contained some specific research recommendations, such as a study of environmental factors associated with pulmonary hemorrhage in infants; studies of the cost-effectiveness of prevention and mold remediation strategies; economic evaluations of the benefits of economic incentive programs and implementation of mold-related legislation; and interaction with other important indoor environment issues (such as carbon monoxide, allergens, and combustion products including environmental tobacco smoke and nitrogen oxides).

Despite the gaps in the science to appropriately address this issue, the report also concluded that "the high prevalence of dampness suggest that what is known about its causes and prevention is not consistently applied in building design, construction, maintenance, and use." Dr. Brown stressed that even as we plan etiologic studies to define exposures and health outcomes related to mold and as we design effective remediation strategies, we need to focus on prevention, making use of current knowledge to implement measures that reduce indoor dampness and mold growth.

Questions and Comments

The questions and comments following these presentations focused on addressing the interrelated issues raised by the speakers. Several people commented on the particular needs of low-income housing and the need to communicate risk effectively so that people are motivated to take effective measures and are not just alarmed because they have neither the money nor the

ability to mitigate. A free radon mitigation program run through Home Depot could serve as a model for a similar program to address mold issues. Many building problems are traced to poor initial construction practices (such as badly applied stucco), so quality assurance programs may help to prevent a lot of future problems. Some problems can be traced to poor design; for example, buildings often have indoor air quality problems that can be traced to a design that places parking spaces near air intakes for the buildings.

A journalist commented on press coverage of the *Damp Indoor Spaces and Health* report and how it may have misled many people by over- or under-emphasizing (depending on the publication) committee conclusions regarding the seriousness of the health concern. Dr. Clark indicated that they made every effort to help the media cover the report effectively, but acknowledged that accurate media messages may not have reached the public. A health activist suggested that some responses to the report may have resulted partly from things that were not evaluated, contending that the report was primarily a respiratory study and that non-infectious health effects such as headaches and fatigue were not really examined. Mold hypersensitivity and autoimmune-like symptoms have been reported by some people, but have not been adequately recognized by scientists or by physicians. One participant suggested a need for an anecdotal reporting center for such cases, indicating that there is too much emphasis on determining causation and not enough on finding effective treatment or training physicians to be sensitive to the needs of these patients. In reply, Dr. Clark indicated that the report did not consider only respiratory symptoms, but that these were the symptoms for which associations were strongest. She noted that "absence of evidence is not evidence of absence," and said that the report did not intend to dismiss the possibility of effects for which the existing evidence of association was not strong or for which evidence was not available.

A building technology representative commented on damage produced during the recent Florida hurricane season, where there were cases of extensive water leakage without structural damage, providing an opportunity for large-scale studies of dampness-related health problems under these changing conditions. Dr. Brown responded that during post-disaster situations people generally have more pressing needs than to participate in such studies. Another person involved in building design questioned the reliability of self-reported symptoms when used as health effects endpoints. Dr. Cox-Ganser indicated that, in their community college study, they did some quality assurance as a test for reporting bias, surveying non-participants and finding that the prevalence of asthma and some lower respiratory symptoms was similar in those who agreed to participate. Dr. Eggleston commented that there are no good objective measures of respiratory disease endpoints (even lung volume is not very accurate), and most studies around the world use questionnaires with similar questions. Ms. Loftness indicated that this may be the only practical way to collect large amounts of health information from many sites inexpensively.

Several speakers commented on indoor environment issues in schools. One participant suggested that the U.S. Department of Education (DoE) should be more involved in this type of research and thought more effort should be devoted to programs to monitor health and the success of interventions rather than waiting for funding for good scientific studies. One speaker commented at length on his experience with school remediation efforts in southern Maine, where, in spite of financial constraints, there was a well-run program to inform the public and respond to parental concerns about health issues, as well as to address practical repair and

remediation issues. EPA's Indoor Air Quality *Tools for Schools* material points out some small-scale improvements that can be made at relatively low cost even in school systems where funds are very limited. Several speakers returned to the problem of defining "dampness" and providing guidelines for people to determine how pressing the need for action is. One speaker suggested developing guidelines for categorizing a school building situation as low/medium/high-risk for health concerns.

Highlights from Research Needs Related to Public Health and the Indoor Environment Session

There is ample scientific justification to conclude that damp conditions found indoors are a public health problem.

There is strong scientific evidence for an association between buildings with mold growth and upper respiratory tract symptoms, asthma symptoms in sensitized persons, hypersensitivity pneumonitis in susceptible persons, wheeze, and cough in occupants. There is limited scientific evidence that links moisture problems indoors with asthma development, shortness of breath, and lower respiratory illness in children.

There are inexpensive, simple, and durable intervention measures that are effective in reducing dampness-related health problems.

There are achievable energy-efficient building design solutions that provide a healthy indoor environment with good lighting, access to nature, good ergonomic working conditions, and improved indoor air quality.

The financing of building and health care is not managed or conducted in a manner that would permit direct cost-benefit analysis.

Healthy indoor environment risk communication should be conducted so as to empower, motivate, and inform people about how to improve indoor environmental conditions.

There are social and institutional barriers to effective interventions.

There is a need for continued research to better define the public health implications of the indoor environment. Some organizations have outlined their suggestions for high-priority research (e.g., IOM, CDC-NIOSH/NCEH, and EPA).

The Importance of Collaborative Efforts between the Building, Medical and Public Health Communities to Achieve Health-Promoting Changes in Indoor Environments

Jonathan Samet, M.D., M.S.
Johns Hopkins University Bloomberg School of Public Health

Dr. Jonathan Samet initiated a discussion of the collaborative efforts needed to reduce the public health burden related to inadequate indoor environment quality and pollution. He noted that reducing the public health burden related to inadequate indoor air quality and indoor air pollution (IAP) inherently involves multiple professional disciplines. The occurrence of exposures to IAP reflects many decisions made in the design of a building, choice of materials, uses of the building, and the operation of the building. Health care professionals and researchers are involved in establishing linkages between exposures in the indoor environment and adverse health effects, but problem mitigation is likely to involve indoor environment specialists as well as other building professionals. Thus, some of the professionals involved in preventing and solving health problems arising from IAP include architects, engineers, industrial hygienists, physicians and other health professionals, and indoor environment specialists. Unfortunately, professional disciplines tend to follow their disciplinary interests and establish "silos" of focus on the specific concerns of their constituents. Interactions among groups have been limited, both among the relevant professional organizations and among individual practitioners around specific buildings or health problems. A physician dealing with health outcomes may be interested in understanding etiology to affect a long-term solution, but his or her primary focus is on treatment of the patient's specific symptoms.

The need for cooperative effort was recognized at a 1995 American Thoracic Society (ATS) Workshop (Achieving Healthy Indoor Air. Report of the ATS Workshop: Santa Fe, New Mexico, November 16–19, 1995. *American Journal of Respiratory and Critical Care Medicine,* 1997;156:33S–64S.). Among other recommendations, participants at that meeting suggested that some organization should:

- Take the lead in addressing indoor air quality-related health effects;
- Encourage interdisciplinary participation in developing solutions; and
- Assemble a body of successful and non-successful case studies to help determine viable approaches to correcting indoor air quality problems.

Studies of second-hand smoke provide an example of one such case study, demonstrating the lack of health benefits from separating smokers and non-smokers in the same air space.

John Girman, M.S.
Office of Radiation and Indoor Air, EPA

Mr. John Girman followed with a discussion of a successful case study describing collaborative efforts to address the problem of indoor radon as an etiologic factor in lung cancer from the 1970s to the present. Radon is estimated as the second leading cause of lung cancer after smoking, accounting for approximately 20,000 lung cancer deaths per year. The problem was recog-

nized in the late 1970s as winter weatherization programs tightened up homes and reduced natural air exchange. The initial focus was on building materials as a radon source, but the Department of Energy (DOE) quickly realized that soil gas (such as in the Reading Prong Physiographic Province in Pennsylvania and other regions) was a major source. Understanding the problem and how to address it involved building scientists, geologists, physicists, and state agencies. The EPA, DOE, and Canadian agencies were instrumental in developing mitigation methods. By the mid-1980s, public guidance was provided by EPA, the Department of Health and Human Services (DHHS), and CDC with publication of *A Citizen's Guide to Radon* (now on the web in the May 2004 revision, http://www.epa.gov/radon/pubs/citguide.html).

Through the 1980s, a number of collaborative activities refined approaches to dealing with radon issues and made the public aware of the need for action. A federal interagency Committee on Indoor Air Quality (CIAQ) was established with the participation of EPA, DOE, NIOSH, Occupational Safety and Health Administration (OSHA), and the Consumer Products Safety Commission (CPSC). The Voluntary Radon Measurement Proficiency Program (involving DOE, EPA, and the radon industry) was established to guide residential measurement and mitigation. Additional collaborative efforts for informing the public through public service announcements (involving the Ad Council) and promoting remediation practices included public health officials at federal, state, and local levels, physical scientists, engineers, and the American Association of Radon Scientists and Technologists (AARST; http://www.aarst.org/), a radon industry association. The National Research Council's (NRC) Committee on the Biological Effects of Ionizing Radiation (BEIR IV) established a firm scientific basis for assessing health effects associated with radon. Continuing action through the late 1980s and 1990s included the U.S. Surgeon General's radon warning to the public, Radon Training Centers and State Indoor Radon Grants Program (established by EPA), publication of radon potential maps of the United States, and new construction standards developed for reduced radon exposure. The real estate industry and home inspection have become the primary point of action for radon testing and remediation at the time of home sales.

As a result of these collaborative efforts, an estimated 1.2 million homes have been built with radon-resistant construction since 1990; about 0.5 million homes have installed active radon mitigation systems (as of 2003); and radon standards have been adopted into building codes (National Fire Protection Association [NFPA] 5000, International Residential Code). The main conclusions that can be drawn from this case history are that:

- Many disciplines need to interact to define the problem and develop effective solutions;
- Many stakeholders need to be involved in implementation of solutions (epidemiologists, realtors, the radon industry, residential construction industry, building scientists, communications specialists, and code officials, for example); and
- Government agencies need to provide the stimulus to develop information and serve as an "honest broker" of that information.

Mr. Girman listed several other areas where similar collaborative efforts could be applied: environmental tobacco smoke (ETS), mold/moisture, indoor air toxics, asthmagens and triggers, human performance/productivity, and green buildings and green building management. He suggested that the *Damp Indoor Spaces and Health* report provides enough information for taking action, noting that an EPA study of office buildings indicated that 45% have leaks and

34% have leaks in occupied spaces. In addition, the EPA study found that a high percentage of workers may be frequently exposed to indoor air toxins (resulting from pesticides, paint fumes, new carpets, etc.). In another report by the IOM entitled *Clearing the Air*, the section on asthma triggers indicated that fewer than 50% of asthma patients state that their doctors have suggested environmental management. The EPA Office of Air and Radiation has proposed collaborative efforts in its *Healthy Buildings, Healthy People* report (http://www.epa.gov/iaq/hbhp/). The public is willing to pay for better air quality, as indicated by the approximately $1 billion spent per year on stand-alone air cleaners and more spent on cleaning heating and air conditioning ductwork. This occurs in spite of a lack of evidence that these are effective approaches to improving the indoor environment.

Questions and Comments

The discussion following these presentations continued with several topics raised earlier. One audience member discussed the importance of people with MCS. The heightened allergic responses of people with MCS due to other exposures may make them sentinel indicators of more subtle indoor environment problems. Dr. Samet commented that researchers do tend to oversimplify problems by focusing on one or two elements, and a broader, more ecologic approach may be needed to address issues such as MCS.

The issue of defining levels of dampness was raised again. Dr. Cox-Ganser said that NIOSH has used ranking based on semi-quantitative environmental assessments to compare locations within a study area. Dr. Eggleston and Mr. Fisk suggested that while 40%–50% relative humidity is generally considered optimal, there is no humidity standard used to define "damp." It is also not clear whether damp spots (i.e., local damp areas that can produce mold in an indoor environment where the overall indoor humidity is within normal limits) are as harmful to health as more generalized dampness. One function of a workshop such as this might be to propose a standard that could be tested. A consultant questioned Mr. Girman's statement that the government was perceived as an "honest broker," indicating that industry does not see dampness as a major health problem and does not want to fund research that could be used to generate restrictive standards. There needs to be more effort to involve industry, since at present they will only reluctantly fund research to resist regulation or block litigation. Mr. Girman replied that he thinks the public sees government as an honest broker, but perhaps industry less so. Industry is involved in the guidance process and Mr. Girman believes that EPA is responsive to industry concerns, but perhaps the agency could do better. One commenter suggested that industry gets involved too late in the process, after regulations or guidelines are already proposed, and it ends up taking a defensive position. Local governments sometimes pass restrictive regulations that have a poor scientific basis, placing government and industry in an adversarial position.

Commenting on how government can lead the way, one audience member described a major study conducted in Hong Kong to monitor 50 buildings for 12 indoor air quality parameters. The study resulted in a voluntary program that allowed building owners to certify their buildings and advertise them as meeting indoor air quality standards. The participant suggested that a similar standard could be prepared based on current World Health Organization (WHO), Nordic, and Canadian recommendations to establish a certification program that would "pull people into the program rather than pushing them." Mr. Girman responded that there might be problems in

agreeing exactly on target levels for various agents; moreover, EPA lacks a legislatively mandated authority to establish such a program. A federal Congressional aide in the audience encouraged people attending the workshop to work with his office and with some of the Representatives who have strong interests in improving the indoor environment. Ms. Loftness commented on her experience in trying to inform Congressional decision-making about funding for health and productivity research in relation to building quality. She suggested that there is opportunity through National Science Foundation (NSF) and National Institutes of Health (NIH) to provide collaborative teams with the resources they need to investigate these issues. Dr. Samet pointed out that radon is an example of a health concern that caught the interest of Congress and resulted in targeted funding, which led to a coordinated inter-agency effort of research and development that had a very favorable outcome.

A consultant suggested there are missed opportunities in not involving the building cleaning industry, a group that has already developed expertise in improving conditions in buildings and is highly motivated to maintain a healthy indoor environment. Dr. Samet commented that he did not mean to exclude cleaning professionals from his list of stakeholders. He also noted, however, that there is a lack of research on the effectiveness of cleaning practices in terms of health effects. The same applies to the air cleaning industry. Ms. Loftness mentioned observations made in several government office buildings that when cleaning was moved to daytime hours as an economy measure, there was an increased pest problem in the building as a consequence of late afternoon food remnants being left in trash containers overnight. Therefore, unintended consequences of cost-cutting in cleaning practices need to be monitored and evaluated. Another participant commented on generally lax practices in the residential building industry, where most homes are not individually designed by architects and most contractors are not educated about the best available practices. This individual suggested a need to work with the trades (roofers, plumbers, and remodelers, as well as builders) to encourage practices that would reduce water penetration problems in buildings.

Dr. Woods expressed concern that the afternoon panel consisted of only researchers and no members of the general public or industry representatives. Returning to a theme of his earlier presentation, he suggested that dampness is a source problem for which there are already good solutions that can be applied once accountability is established. Dr. Eggleston disagreed, indicating that there is still important research issues involved in linking dampness to health effects. Reports of health effects are inconsistent in part because there are no standard ways of describing degrees of water incursion into a building. While there are clear recommendations on how to avoid sources of water or how to correct water problems, there are no standards that can be used to evaluate successful remediation from a health effects standpoint.

Highlights from Importance of Collaborative Efforts between the Building, Medical, and Public Health Communities to Achieve Health-Promoting Changes in Indoor Environments Session

Building design and operation involves a large number of diverse professions with different interests and priorities. Collaboration is the key to improving the indoor environment. Bringing affected stakeholders (e.g., the public and industry associations) into the process early is advantageous.

There is a lack of research on the effectiveness of many building and cleaning practices and technologies that claim to improve the indoor environment.

The successful program of radon testing and remediation serves as a model that can be applied to other indoor environmental problems. The evolving programs and efforts to reduce exposure to ETS could also serve as models.

Day 2: First Morning Session

Review of Federal Research and Development and Outreach Activities: A Federal Agency Panel

RADM Robert Williams began with a summation of the first day's activities and introduced the Federal Agency Panel assembled to review and discuss federal research and development and outreach activities, summarizing goals, scope, and efforts.

Mr. William Fisk introduced the session, acknowledging that it was not possible to include representatives from every federal agency with stakeholder interest in the indoor environment at this workshop (such as the U.S. Department of Education, for example), but that the involvement and coordination of all agencies is still valued and encouraged. The session was structured in two parts: (1) presentations by each panel member on indoor environment issues addressed by his or her agency; and (2) individual responses to a series of questions presented on slides that Mr. Fisk wanted panel members to address from the perspective of the agency they represented.

Henry Falk, M.D., M.P.H.
Centers for Disease Control and Prevention

Dr. Henry Falk suggested that indoor environment problems are likely be solved by many small steps, rather than with a single sweeping action like removing lead from gasoline. Indoor environment issues tend to occur in all areas of the neighborhood/community environment, from the home to related problems in schools, workplaces, health care facilities (such as hospitals and nursing homes), and recreational and travel facilities. Indoor environment issues encompass factors that impact on asthma (such as mold, dust, pollen, animal and insect allergens, cigarette smoke, and volatile organic chemicals), pesticides and toxicants, lead and mercury (in paint, dust, and vapor), radon, vapor intrusion (from landfills or Superfund sites), carbon monoxide injuries and poisonings, and infectious diseases. There are more than 6 million substandard housing units nationwide and a critical need to address the public health problems that stem from these units; the Healthy People 2010 program goals call for a 52% improvement in reducing the number of occupied substandard housing units. CDC's Healthy Homes Initiative includes development of guidance documents for housing inspection and risk evaluation, integrated pest management and field surveys for rodent control, and the National Healthy Homes Training Center and Network. Asthma prevalence shows minority group disparities related to housing conditions.

CDC takes a traditional public health approach, linked to NIH medical information and EPA environmental surveillance activities. Science-based CDC-funded intervention programs, such as the Inner City Asthma Intervention (based on research funded by the National Institute of Allergy and Infectious Diseases [NIAID]), are complemented by additional activities based on cooperative agreements with many state agencies. Dr. Falk discussed the evaluations reported in the *Damp Indoor Spaces and Health* report and the *Second National Report on Human Exposure to Environmental Chemicals* (released January 2003). CDC has been monitoring exposure of the United States population to ETS and has documented the effects of decreased exposure to

second-hand smoke by a decrease in 50th percentile serum cotinine levels from 0.20 ng/ml to 0.05 ng/ml, comparing population samples taken in 1999–2000 to a comparable group evaluated in 1988–1991. The next *National Report* will look at an expanded list of chemicals, including volatiles from water use and groundwater. NIOSH HHEs assess potential health concerns in the workplace; about 30% of the 12,378 requests received through fiscal 2003 were related to indoor air quality issues. Common problems related to heating and air conditioning system maintenance and operation occur often.

Dr. Falk concluded by discussing CDC's international outreach program, which includes indoor environment issues in developing countries. There is an "energy ladder," moving from the least expensive fuels (animal dung, crop by-products, wood) to more expensive and complex fuel sources (natural gas and electricity) that provide increasing cleanliness and convenience in parallel with increasing cost. Low-quality fuels introduce more particulates into the air; but even without fuel changes, dramatic reductions in indoor air particulates can be achieved by introducing simple and inexpensive technology, such as replacing a traditional open fireplace with a wood stove and chimney.

Samuel H. Wilson, M.D.
National Institutes of Health

Dr. Samuel Wilson said his agency's focus since around 1998 has been on health effects of the built environment. In the view of NIH, the built environment essentially defines "indoor" exposures that not only contribute directly to human disease but also interact indirectly with social and lifestyle factors that can result in health problems. For example, in looking at the increased incidence of asthma, the built environment may increase human exposure to indoor allergens and other agents through poor air quality, and may also increase time spent indoors and decrease physical activity, possibly contributing to the health risk. A poorly designed built environment also contributes to resource waste and environmental degradation. The National Institute of Environmental Health Sciences (NIEHS) has a strong interest in the possible contribution of biological factors to health problems.

Asthma is not only a serious health concern but also represents a $13 billion annual cost for the United States health care system. NIH supports research on asthma in three focus areas: genetic predisposition (susceptibility), environmental factors (e.g., indoor allergens, endotoxin, ETS, viral infections, outdoor pollution), and allergy and asthma responses. The agency supports both observational and interventional studies. Dr. Wilson described the complex sequence of epithelial and immune system cellular and biochemical responses involved in asthma. Various steps in these reactive pathways suggest potential molecular targets for medical intervention. Studies of environmental factors offer other opportunities for intervention. However, because most previous indoor allergen and endotoxin exposure studies have been small and geographically localized, they have limited application to other regions or different socioeconomic groups. In collaboration with the Department of Housing and Urban Development (HUD), NIH has added allergen exposure levels to a nationwide study of lead exposure in housing (National Survey of Lead and Allergens in Housing [NSLAH]) to identify prevalence, to establish correlates for identifying problem homes, and to begin to examine the relationship between indoor allergen exposure and disease (allergy and asthma).

Another collaborative effort is the allergy and asthma component of the National Health and Nutrition Examination Survey (NHANES). In this study, funded by NIEHS and conducted in collaboration with investigators from NIAID and CDC, data from 5,000–6,000 subjects per year will be collected from 2005 to 2008. The allergy assessment will involve analysis of blood samples for serum total IgE, and for specific IgE (antibodies) to 19 indoor, outdoor, and food allergens. In parallel environmental sampling, vacuumed dust samples from two home locations will be collected and tested for markers of specific allergens (endotoxin and markers of cat and dog, cockroach, dust mite, two genera of fungi, and rodents). Information will be collected by questionnaire on housing characteristics, pet ownership, diagnosed allergy and related diseases, exposure to tobacco smoke, diet and nutrition, and occupational exposures. In conclusion, Dr. Wilson indicated that a series of conferences on the built environment played a key role in stimulating interest in indoor environment issues and developing objectives for each institution involved in these studies. The resulting cooperative studies indicated what can be done by taking a broad holistic approach.

Elizabeth Cotsworth, B.A., M.A.
U.S. Environmental Protection Agency

Ms. Elizabeth Cotsworth described her agency's indoor environment activities, emphasizing that EPA's current program is the cumulative response to limited statutory authority. EPA co-chairs and is a major participant in the CIAQ, along with the CPSC, DOE, OSHA, and NIOSH.

EPA works with other agencies to identify unique, high-impact niches that it can fill related to overall agency mission and strategic priority decisions. In addition to well-established regulatory programs on lead and asbestos, Ms. Cotsworth indicated that EPA's indoor environment program largely provides sound science and technology-based information related to any and all indoor issues, including carbon monoxide poisoning in homes, mold in schools, product use in commercial office buildings, and reducing indoor cooking smoke in developing countries. EPA has sponsored reviews assessing the effects of low-level ionizing radiation, such as the NAS Biological Effects of Ionizing Radiation BEIR VI Committee review (1999).

EPA currently focuses its major investments on a high-priority set of issues in which behavioral changes to reduce public health risks in indoor environments are promoted. These priority investment areas are: indoor radon, environmental management of indoor asthma triggers, childhood exposure to ETS, and indoor air quality in schools. EPA has established quantitative national goals in these four areas and tracks progress against these goals. For example, EPA set an objective of reducing ETS exposure levels by 12% for children lees than 6 years of age, and has now achieved a level of 11%. EPA's model for addressing each of these areas involves defining a sound scientific rationale, raising public and stakeholder awareness of the issue, recommending (in some cases developing) mitigation measures, leveraging resources with the use of cooperative partners and "train the trainer" approaches, and seeking institutionalization of the issues through non-federal means (local building codes, mortgage company requirements, etc.). For example, EPA played a key role in the development of standards for radon-resistant new homes and practices in the radon mitigation industry. For environmental management of indoor asthma triggers, EPA's primary objective is to motivate people to take essential actions to reduce their exposures by providing culturally appropriate information. An example of this type of audience-focused information is the *Tools for Schools* material such as *Managing Asthma in*

the School Environment (http://www.epa.gov/iaq/schools/asthma/). Approximately 30% of schools have adopted an EPA indoor air plan. EPA also supported a University of Michigan School of Public Health study of best intervention practices. EPA has classified secondhand smoke as a Group A carcinogen, and has established voluntary programs to encourage smoke-free homes and day care centers (e.g., http://www.epa.gov/smokefree/index.html).

Ms. Cotsworth also described EPA's development of a strategic vision (EPA's *Healthy Buildings, Healthy People: A Vision for the 21st Century,* published in 2001) for the future of healthy indoor environments in consultation with a broad set of stakeholders. This document serves as the basis for an informed discussion on public policy, health, building sciences, product manufacturing, and environmental research. The *Healthy Buildings, Healthy People* initiative is based on six strategies for producing improvements:

1. Partnership,
2. Technologies,
3. Market incentives,
4. Research and development,
5. Legislation/standards, and
6. Public information.

EPA is involved in identifying knowledge gaps related to indoor air quality, particularly in the areas of pollution sources, building design, and homeland security needs. To help achieve its vision, EPA recently completed a more than year-long effort to codify its indoor environmental research and development needs. The draft *Program Needs for Indoor Environment Research* (PNIER) document will be released soon and posted on the EPA Web site. Ms. Cotsworth indicated that EPA has already started to market those needs inside and outside the agency through various channels.

Jerome Dion, M.S.
Department of Energy

Mr. Jerome Dion, substituting for Richard Moorer, summarized the impact of his agency's activities on indoor environment issues. DOE has a $1.3 billion research and development budget with components that include energy-efficiency programs and low-income home weatherization. Research targeted toward the achievement of Zero Net Energy buildings (buildings that produce on average as much energy as they use) has a goal of reducing energy use by 50% by 2015. Three strategies have been developed for addressing indoor air quality issues in this energy conservation program:

1. Reducing the need for dilution air in buildings;
2. Source control (reducing pollutants from building materials); and
3. Cleaning recirculated air.

These strategies recognize the need to address health and safety concerns while promoting reduced and more economic energy use. Activities are closely coordinated with HUD's Healthy Homes and EPA's Energy Star programs. There are research and development programs (budgeted at about $3.5 million per year) involving Lawrence Berkeley National Laboratory, the National Institute of Standards and Technology (NIST), and the National Center for Energy Management and Building Technology.

Some of the technical pathways being investigated include:

- Developing new methods for determining the amount of outdoor air needed in buildings;
- Improving controls and equipment to supply outdoor air;
- Improving techniques for measuring and monitoring the quality of air supplied to buildings;
- Finding ways to reduce pollutant emissions from building materials; and
- Finding ways to clean recirculated building air.

The technological challenge in maintaining environmental quality in tight buildings is to ensure that energy-efficient buildings are healthy buildings by good design and operation. To this end, DOE is developing a "best practices" guide for energy efficiency in hot/humid climates, to be followed by similar material for conditions applicable to other regions of the country. DOE's current unmet research and development needs include getting better information on building performance and its impact on health, and defining better minimum ventilation requirements. The agency is currently using American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards as guidance. Mr. Dion explained that DOE depends on other agencies to identify potential health problems and counts on other agencies concerned primarily with health issues to promote solutions that are as energy-efficient as possible.

Kevin Kampschroer
General Services Administration

Mr. Kevin Kampschroer described General Services Administration (GSA) workplace initiatives designed to provide the "best value" for customer agencies and taxpayers. His perspective on indoor environment issues was primarily economic, particularly with respect to justifying improvements and motivating changes. Responsible asset management at GSA ("the nation's landlord") requires research to know how the built environment can affect work, and to define and deliver what is really best while taking into account all factors, including the health and productivity of employees.

Workplace quality is a major factor in attracting and retaining good employees; this will be a particular problem for the federal government as up to 70% of the federal workforce becomes eligible for retirement by 2005. Factors such as providing an opportunity for contact with nature or aesthetic and sensory variability should be considered from an economic as well as a humanistic perspective in the effort to attract new workers. GSA places 60,000 government workers per year into new office space (mainly due to lease turnover). A healthy indoor environment is usually assumed to be a feature of rented office space, but is often not addressed beyond making sure that the work environment is comfortable. Factors that promote psychological well-being and cognitive functioning are important for a workforce composed primarily of "knowledge workers," and need to be included in a workplace evaluation. Mr. Kampschroer indicated that he would like GSA to develop a way to rate the environmental quality of a building, such as the Hong Kong building certification system discussed the previous day. The acoustic environment is often most troubling to people, but air flow and temperature are most often the subject of worker complaints, perhaps because most people do not think noise problems can be solved. GSA developed the Workplace 20•20 program to address issues of economic pressures, demo-

graphic shifts, and technological opportunities, and to evaluate their consequences on workers' performance, resource constraints, and human capital challenges. The program uses a scorecard to evaluate four domains important to knowledge workers. They have limited experimental work underway (11 projects for 2005) to measure changes in performance factors after changes are made in the workplace.

Mr. Kampschroer discussed potential improvements to the office environment as analogous to improvements in modern zoo design. He showed a four-panel slide that depicted the old system of small barred cages compared to the newer design of large naturalistic environmental enclosures, and a typical windowless office with cubicle work stations compared to a blank space with a question mark. The point made was that just as zoos are trying to look beyond simple survival to an animal's well-being by giving the animal more control over its behaviors and environment, we should try to give offices more aesthetic and sensory variety, provide places to be alone or work together as appropriate, and allow more control over our environment.

There are many emerging challenges for GSA in accommodating changing technology and work patterns, but the economic leverage of GSA real estate management activities provides an opportunity to advocate for and promote workplaces with good environmental quality. Economic concerns and productivity outcomes (evaluated with behavioral research methods) form a substantial portion of GSA's concerns, but workplace environment (including issues like levels of carbon dioxide, particulates, volatiles, formaldehyde, and mold and mildew) is part of that evaluation.

David Jacobs, Ph.D., CIH
Department of Housing and Urban Development

Dr. David Jacobs described HUD's efforts to address indoor environment issues in the context of providing quality affordable housing in the United States. He discussed the history of public health interest in housing, starting from the late 19th century, when substantial improvements in tuberculosis and typhoid morbidity were achieved by successful efforts to reduce crowding, improve sanitation, and bring more light and fresh air to urban housing. Physical characteristics of housing have an impact on the social and psychological characteristics of the home's occupants, and, at a broader level, the neighborhoods. In the United States, half of the lowest-income households spend 50% or more of their incomes on housing, nearly 2 million live in severely inadequate housing, and 2.5–3.5 million people are homeless at some time during any given year. These factors result in a segment of the population that is at much higher risk for asthma and infectious diseases.

Lead toxicity has been recognized for over a century, as illustrated by a paint advertisement from 1897, which claims it is "not made with lead and is non-poisonous." Lead abatement programs have reduced the percentage of 1- to 5-year old children with blood lead levels at or above 10 µg/dL from 88.2% in 1976–1980 to 2.2% in 1999–2000. However, as of 2000, there were still an estimated 38 million houses containing lead paint and 434,000 children with elevated blood lead levels. Lessons learned from dealing with lead paint might be applied to other housing-related diseases and injuries, specifically diseases caused by mold and allergens in indoor air, exposure to neurotoxicants, carbon monoxide fatalities, and fall and trip hazards. Progress on residential

lead hazard control was made by (1) assessing the magnitude of the problem in existing housing, with studies like the NHANES dust lead survey and the National Survey of Lead and Allergens in Housing; and (2) establishing mandated standards and guidelines for hazard assessment and abatement. Exposure assessment is feasible, but hazard levels are not currently well established for mold and allergens.

HUD's primary focus is on low-income homes and community development. In this context, improvements made for one purpose can produce other unrecognized health benefits. For example, moving people to more stable, mixed-income neighborhoods results in significant improvements in the physical condition of housing, as well as in mental health and reduced obesity, according to HUD's *Moving to Opportunity for Fair Housing* experiment. Window replacement programs remove a major source of lead paint and lead-contaminated dust in low-income housing and also address energy conservation and moisture infiltration. New windows can impact indoor air quality by improving ventilation because they can be opened and closed more easily. While it is recognized that energy conservation offsets the cost of windows over a 5- to 10-year period, the health benefits are generally not recognized in the market value of housing, although they may be even more substantial in terms of reduced medical and other health care costs.

Dr. Jacobs pointed to the need to make the economic benefits of improved indoor environment more evident so as to use market pressures to favor interventions. At present, many home improvements that would address health issues are not carried out because they would be economically irrational from a homeowner's point of view. When we improve our homes with a new furnace or roof, we anticipate at least a partial return on investment in the form of increased market value when that home is sold, but measures taken to produce health benefits like radon or lead abatement generally are not reflected in the market value of the home. In dollar terms, health benefits may greatly outweigh the value of improvements in other areas, but most improvements that affect health generally do not affect the market value of homes. Dr. Jacobs suggested that we need to find a way to articulate the cost of not making health-based housing improvements and to document the cost-shifting to the medical sector that results from allowing substandard housing, and the illnesses associated with it, to persist.

Dr. Jacobs concluded by mentioning the HUD publication *Basic Healthy Housing Reference Manual*, which is being reissued in collaboration with CDC. He discussed a list of specific research needs and national and international policy objectives with respect to healthy housing and other indoor environments that have been formulated at recent international conferences. He recommended that the Surgeon General and others work with WHO to advance these objectives. Several of these recommendations are focused on developing a specific way of assessing policy effectiveness (e.g., research to develop better housing-hazard measurement technologies, to determine the interactions of specific housing conditions and physical and mental health, and to measure interactions with confounding variables). He stressed the importance of not focusing on hazards individually, but rather taking an integrated approach to establishing healthy conditions by looking at housing systems and integrated housing and community intervention. It is important to assess how variables interact, and how social conditions impact on health issues (e.g., obesity). There is a need to partner with the private sector in marketing healthy home improvements. Window and door manufacturers market primarily on aesthetics and energy conservation

and typically do not consider advertising the health aspects of their products. He suggested a program, analogous to EPA's Energy Star program, for labeling new and existing homes and products that contribute to improved indoor environment design. Looking at marketing techniques would be a key research need. There is a need to formulate policy and develop technology for developing healthy housing on contaminated sites that often provide low-cost real estate in urban areas. Finally, he noted that unique ethical issues arise in intervention research on substandard housing, which must be taken into account when planning studies. We should not be using our children as detectors of substandard housing; we have technologies and techniques we can use to provide America's families with decent, safe, and affordable housing.

James E. Hill, Ph.D.
National Institute of Standards and Technology

Dr. James Hill discussed NIST's engineering and technology perspective on indoor environment issues. The agency's primary mandate is to strengthen the technological innovation infrastructure in the United States for the occupational sector, but to do so with attention to public safety and security while maintaining quality of life and jobs. NIST conducts and supports extramural air quality and ventilation research to improve indoor environmental conditions in a cost-effective manner, which is done through development of measurement and design procedures and simulation programs for air and contaminant transport in buildings. Ventilation research is a $2 million-per-year program carried out with 10 permanent staff members plus students and guest researchers and supported by the Air Conditioning and Refrigeration Technology Institute, California Energy Commission, DOE, EPA, HUD, and the U.S. Navy. As with DOE's program, NIST is looking for technology that improves indoor air quality without substantially increasing energy costs. Addressing indoor environment issues should be a routine aspect of engineering and should be included in computerized design tools. There is a need to understand health-effects studies at a level where useful information is provided that can be used by engineers ("what to do and what not to do"). Also, standards cannot be too complicated if firms are expected to implement them.

NIST works on many issues that impact on the indoor environment, such as developing test methods and standards for contaminant emissions (e.g., sulfur in fossil fuels), gaseous air cleaner performance, alternative refrigerants, volatile organic compound emission rates into indoor air, and residential and office building ventilation technology. NIST activities have expanded recently to include security issues, and the CONTAM modeling program is being used in research supported by the Defense Advanced Research Projects Agency (DARPA) on enhancing the software to analyze the impact of protective measures and analyze chemical/biological agent transport in buildings. Dr. Hill stressed the need to develop practices that can be implemented quickly and easily, because otherwise there is a tendency to "keep building new buildings like the last building."

Questions and Comments

In audience comments following these presentations, one participant indicated disappointment at the lack of progress made in determining adequate ventilation rates for homes to ensure indoor air quality, noting that the ASHRAE standard used in the United States is about one third or one

half the rate used in the rest of the industrialized world. Fundamental research to understand the health implications of this has not been carried out. Day care centers and schools may require even higher ventilation rates than common workplace settings to reduce infection rates. There is also a lack of research information on the basic spread of infectivity and ventilation. Several people from the audience commented on points made in the presentations from the perspective of their particular public health interests. One participant commented that HUD housing should be able to accommodate those with MCS; another suggested a need for better environmental health education for health professionals, particularly with regard to mental health problems. Several audience members reinforced points made by the speakers regarding health care costs associated with inadequate indoor environment practices. Ms. Cotsworth responded that EPA works with the health insurance industry and providers to try to understand management of environmental triggers, and Dr. Falk indicated that CDC is also promoting these programs.

Highlights from Federal Research and Development and Outreach Activities Session

Many federal agencies conduct research and operate health intervention programs that involve agents in the indoor environment.

Federal agencies work collaboratively to identify and address common problems in the indoor environment. These collaborative efforts include sharing expertise for research design and evaluation, co-funding basic research and needs assessment studies, and cooperative programs to inform the public and promote behavioral changes that reduce public health risks associated with poor indoor environment conditions. HUD's Healthy Homes and EPA's Energy Star programs are examples of programs that have promoted public behavioral changes.

There is lack of research on certain basic scientific questions, such as understanding how infective agents are spread in the indoor environment.

Federal agencies work together to develop building technology solutions that meet multiple objectives, such as producing a healthier indoor environment without compromising energy efficiency or substantially increasing costs of managing government facilities.

There is a need to understand health effects research at a level that can be applied by engineers.

Day 2: Second Morning Session

Review of Federal Research and Development and Outreach Activities: Questions for the Federal Agency Panel

In the second session, each panel member was asked in turn to respond to and discuss some specific questions:

Question 1: Is federal indoor environment research and outreach commensurate with need?

Most panel members indicated additional areas where more studies should be conducted. Ms. Cotsworth noted the resource limitations for her agency and suggested that it is important to encourage non-federal entities to contribute and leverage available resources. Dr. Falk noted that concerns evolve, and that it is important to coordinate and prioritize efforts to obtain the best results given these changing interests. Dr. Wilson noted substantial information gaps in understanding disease-exposure relationships and the magnitude and prevalence of exposures. More coordinated research is needed in these areas. Mr. Dion indicated that DOE is mostly on the receiving end of indoor environment health effects research and needs help in making the best use of it to design and implement technical changes in building practices (they need it "translated from the health domain into the engineering domain"). Mr. Kampschroer noted that the building industry is very fragmented, with many small companies involved in architecture and construction, and it is difficult to move big research forward. He estimated that the industry spends less than 0.5% of gross receipts on research. He suggested that the Surgeon General could take the lead in motivating and coordinating more high-quality industry-funded research. Dr. Jacobs suggested that we have not fully articulated the needs. We do not know what fraction of disease is caused by indoor environment factors or the costs of addressing these issues. He pointed to lead, and the efforts made to address it as a health issue, as a model of what needs to be done with indoor environment issues in order to define environmental hazards and the cost-benefit of cleanup. Dr. Hill and Mr. Fisk indicated that there is not enough funding to address the real-world problems that have already been identified.

Question 2: What can we do to improve responses to indoor environment problems?

Ms. Cotsworth emphasized coordination and communication, suggesting that educational activities and science must be shared across agencies. She advocated leverage and partnerships between agencies while still fulfilling individual agency missions, and stressed the role of the CIAQ in facilitating this kind of collaboration. Dr. Falk stressed two main points: (1) much more collaboration is needed, including working with agencies at the state and local level, and (2) public health agencies should be more visible in this coordinated action. Using lead abatement as an example, he noted that regulation can eliminate major sources (e.g., in gasoline and paint), but remediation still has to be addressed on a house-by-house basis. Dr. Wilson suggested that visibility of health aspects of the built environment is too low. He suggested establishing some way of indicating health status, such as a "scorecard" for homes and communities that would be analogous to rating homes for energy efficiency and could be a driver to achieving

more visibility. Mr. Dion pointed out the need for a single federal entity to take the lead in a collaborative effort, and that this function could be filled by the Surgeon General. It is hard to address these issues one pollutant at a time, and an integrated approach is more likely to be successful.

Mr. Kampschroer thought that combining health research with engineering research is the key to more effective responses. Dr. Jacobs noted the central role of housing in dealing with any public health issues, and suggested revitalizing the President's Task Force on Environmental Health Risks and Safety Risks to Children (1997), building on asthma and lead safety reports already produced. He felt that a Cabinet-level initiative is needed to drive an effective program. Dr. Hill again stressed a need for collaboration to make the best use of scarce resources. Mr. Fisk, noting how often collaboration has come up in the discussion, asked for specifics. Dr. Hill stressed the role of interagency committees to plan budget initiatives and research. Mr. Dion stressed the need for more communication at lower levels, with technical people from the agencies working with each other and with state and local experts. Dr. Falk also supported including more local-level collaborations. Ms. Cotsworth thought a President's commission focused on asthma might be a good model. It is more defined in scope and objectives, she said, and therefore more likely to result in a productive collaboration than other indoor environment areas where hazards and consequences are not as well understood or objectives are too far-reaching.

Question 3: What is the role for regulations, standards, and guidelines?

Dr. Hill suggested that there are pros and cons for efforts such as these. Industry standards are generally developed by a consensus process that may not satisfy those at either end of the spectrum. However, the consensus process produces a set of standards that everyone has "bought into" and is able to meet (the ASHRAE standards, for example). Federal regulations may not have to deal with a consensus process, but are often difficult to implement (EPA's attempts to tighten air standards, for example). Dr. Jacobs pointed out that there must be authority to enforce standards for them to be effective. Mr. Kampschroer considered the long time needed to establish industry standards by consensus to be a significant problem because building materials and practices change too quickly for consensus to catch up with current practices. Market forces provide an alternative to regulatory action that can often move faster to establish best practices. Mr. Dion suggested that standards are called for when the market fails to respond, which is not all that uncommon. He indicated that it may be necessary to do research first to establish best practices, and then get them out into the marketplace. Dr. Falk indicated that regulations can be helpful for certain issues, but indoor environment problems such as dust mites and cockroach allergens are not easily regulated. In these cases, education and guidelines to produce behavioral changes may be more productive. Ms. Cotsworth indicated the need for a wide ranging "toolbox" of approaches to cover various health issues, suggesting that more can be achieved by education and marketing than through regulation alone.

Questions and Comments

Mr. Fisk then asked for audience comments on the issue of coordination among federal agencies. One consultant responded that when the objective is change, information alone may not be enough. Since the federal government is the single biggest building owner in the United States,

actions taken by the government regarding its own built space could have a strong market impact. Collaboration with agencies that manage and use property (but have no direct mission that includes indoor environment health effects) could be useful in this regard. An audience member with connections to GSA pointed to senior-level collaborative efforts for energy accounting, and suggested that a similar approach could be applied to health or green building issues by developing a green building measurement tool. Responding to this point, Mr. Kampschroer indicated that there is a structural impediment to life-cycle costing (favoring green building) in that the costs and benefits go to different parties. It can be difficult to move from theory to practice, but energy-efficiency labels that may produce marketing pressure are one idea of how to accomplish this. The financial community must be brought into the process, for example by providing lower mortgage rates for healthy homes. Dr Jacobs underscored this accounting problem, using window replacement as an illustration of the disconnect that can occur between who pays and who benefits. On the other hand, market forces can work. The lead paint disclosure rule helped to solve the lead problem in many homes without mandating any specific corrective measures: there was improvement to over 150,000 housing units just from disclosure. An audience member who had real estate experience in California agreed that the disclosure rule has been very helpful in that state, but in order to act on the disclosed information, people still need to know why it is a health problem and what they can do to correct it. Tenants should also be required to disclose water infiltration problems to their landlord so they can be corrected promptly. This audience member stressed two needs: to raise public awareness of hazards and the need for disclosure.

An audience member with a background in community health and nursing indicated that she is now in the private sector, evaluating homes for potential health problems. She observed that as lead paint abatement programs were more successful, problems with mold increased because lead is toxic to mold. She described home building as "manufacturing in the field," suggesting it is inherently more complex and difficult to regulate than other manufacturing activities. In her work, she looks to government to set some standards and criteria for what constitutes an acceptable healthy home, focusing on the total environment rather than on individual agents and issues.

Several participants commented on the government's role in leading corrective efforts. One participant suggested that information on good practices should be distributed through as many different routes as possible to reach the audience of all those who can effect change. Builders will look to the government to provide credible guidelines and practices that they can use to produce healthy homes. Acceptable standards will cut across the differing concerns of individual agencies. A Congressional legislative aide in the audience suggested a joint multi-agency (NIH, CDC, EPA, and HUD) study on the health and economic impact of mold, funded under a Congressional mandate, to result in a set of model standards or regulations. Citizens affected by mold problems find it difficult to get help from the government because of gaps between agencies. However, he indicated that no matter how collaborative the process, there should ultimately be a single government resource to answer questions from the public in order to avoid confusion. Dr. Falk responded that the need for more study and agency collaboration is clear, but there may be too many objectives to address in a single study. He suggested that a task group from this workshop could explore the specifics of what to address first and make recommendations. Dr. Wilson commented that this was an excellent suggestion, and that he would be interested in following up to see if it could be implemented.

In a similar context, a representative of the building technology industry spoke as a consultant to the National Institute of Building Sciences (NIBS) to represent their interests at this workshop. He indicated that the financial and insurance industries are very interested in having a mold standard, which they could use to address risk and protect their commercial interests. A group of key stakeholders in the home ownership industry (including mortgage companies like Fannie Mae and Freddy Mac) met at a 2002 NIBS workshop on mold and are vitally interested in addressing health and liability issues associated with mold. They have started to form a building-and-mold alliance with the objective of developing guidelines for new and old construction based on the existing knowledge base. Some federal agencies, such as GSA, DOE, the U.S. Army Corps of Engineers, and the Veterans Administration, are starting to work with them. This group has had two meetings as a council of NIBS, and would be happy to serve as a vehicle for establishing this kind of program.

Highlights from Federal Panel Discussion Session

The Surgeon General could take the lead in motivating and coordinating healthy indoor environment initiatives.

More effective collaboration between federal, state, and local government and non-government agencies can help to improve the indoor environment, and public health agencies should take a more visible role in this coordinated effort.

Collaboration of all stakeholders will likely result in sound guidelines and be more effective than regulations.

There are many unmet research and program needs; specifically in understanding disease-exposure relationships, determining the magnitude and prevalence of exposures, documenting cost-benefits of intervention strategies, and developing cost-effective technologies for improving indoor environmental quality in new and existing buildings.

Best practices to improve the indoor environment should be specifically developed and distributed to many different audiences so that change can be effected.

A definition of a “healthy home” is needed.

A task force should be formed to identify and prioritize indoor environment issues.

A mixed approach combining public information, applied market forces, and standards setting and regulatory actions is likely to be more effective than any single approach (e.g., public-private partnership in Hong Kong).

Day 2: Afternoon Session

Vision for the Future

Kathleen Kreiss, M.D., National Institute for Occupational Safety and Health, CDC
CAPT Stephen Redd, M.D., National Center for Environmental Health, CDC

Dr. Kathleen Kreiss and CAPT Stephen Redd facilitated a discussion session entitled "Vision for the Future," intended to provide workshop coordinators, speakers, and audience members with an opportunity to discuss possible conclusions and recommendations to appear in the Workshop Summary Report.

CAPT Redd began by restating the importance of the problems and difficulties that can arise in addressing indoor environment problems. He made four primary points related to the importance of this issue:

1. Health issues can be hard to define and the impact of indoor environment risk factors hard to measure. From the perspective of promoting well being rather than just the absence of disease, a perspective of the CDC Futures Initiative, measuring health impact can be even more difficult.
2. As work goes on, we are likely to identify more hazards associated with the indoor environment and we need to have a comprehensive strategy in place to deal with them effectively.
3. There is already a gap between knowledge of hazards and remediation practice and action; i.e., there are things we know how to do that are just not getting done.
4. There is a sense of urgency in responding to these problems and providing knowledge that members of the community need to improve their health.

Dr. Kreiss stressed the value of building on the multi-disciplinary approach of this workshop. Workshop organizers may want to refine some of the suggestions made by presenters and members to produce a Workshop Report, she said. To this end, Dr. Kreiss presented a set of questions and asked the group to respond to them (also calling on certain audience members whom she knew have expressed ideas on these topics).

Question 1: What can be done to ensure that the momentum of the multidisciplinary and multi-agency approach of this workshop is sustained?

There are two good models of large successful programs that address health effects from agents in the indoor environment (as described in Mr. Girman's presentation): radon and ETS. Members of the audience suggested several other programs to serve as models of collaborative multi-agency efforts. A representative of a regional EPA office in New York mentioned a collaborative effort between her office and a CDC Asthma Partnership in New Jersey. EPA funds them to reduce environmental triggers to asthma, but she noted that if they got full state implementation funding, this program could do a lot more in medical management (and allow CDC money to go to organizations outside the state's implementation plan). An audience member spoke about the National Children's Study, a longitudinal study of 10,000 children in the United States from before birth to age 21, including examination of schools, homes and day care centers to evaluate

many outcomes and environmental factors, including those related to the indoor environment. This study will be an important vehicle for gaining insight into child health in relation to the indoor environment. The program is at the stage of developing protocols and issuing RFPs for participating organizations. The Web site for this project is www.nationalchildrensstudy.gov and the contact is ncs@mail.nih.gov.

Audience members suggested some additional organizations with multidisciplinary programs in and outside the government that could serve as partners or provide models for collaborative indoor environment programs:

- Building industry organizations, such as the National Association of Home Builders (NAHB), which has a research program.
- State cooperative extension services, an arm of the U.S. Department of Agriculture (USDA), located at state land grant colleges. They conduct community-level education and outreach and have had indoor air quality programs since 1993. This structure also serves as a good model of how to provide information and advice to the public.
- Interagency committees on green building issues and indoor environment quality such as the Interagency Sustainability Working Group (ISWG), the Committee on Indoor Air Quality (CIAQ), the Federal Facilities Council (FFC), the Federal Green Building Council, and the White House Task Force on Waste Prevention and Recycling.
- Professional societies, such as the Association of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) and the American Institute of Architects.
- Building maintenance organizations and industry representatives, such as the Association of Facility Engineers (AFE) and the Building Owners and Managers Association (BOMA).

A physician suggested that the solution to indoor air quality issues lies in the materials used for building and renovating. He noted that outgassing from materials used in building construction, which can be a major problem for asthmatics, determines how much ventilation is needed. He recommended the book *Less-Toxic Alternatives,* by Carolyn Gorman, as a good resource on this topic. Most asthmatics already know what products they can and cannot tolerate, and this serves as a starting point to determine what components are dangerous to health. There needs to be more cooperation with groups like the American Institute of Architects (AIA) and building material manufacturers to make use of this body of experience from a community of people who have greater sensitivity to environmental pollutants than does the general population.

Mr. Fisk strongly advocated for more federal agency collaboration. Individual agencies are themselves fairly multi-disciplinary, but they can still benefit from combining their resources and expertise. He supported the specific suggestion made by Dr. Hill, and sustained by Dr. Wilson, to establish a committee in the Office of Science Technology and Policy (OSTP) to serve as the key agency for organizing and promoting a coordinated effort on the indoor environment, noting this office's role in joint planning for research and budget needs. OSTP is in the Office of the President and functions by setting up committees, subcommittees and task groups in various areas of science and technology, populated by representatives of all agencies involved in that particular area, and charged with developing joint planning for research. OSTP also defines research funding levels (or has in prior administrations), and was responsible for setting the research priority for fuel cells. This would be a good venue in which to bring together the

agencies involved in the workshop, as well as to draw in other agencies not represented at this workshop. The mechanism for this would be asking the Surgeon General to contact John H. Marburger, OSTP Director. Mr. Fisk suggested that this is the critical place in the government to "put a lever."

The moderator asked how the existing CIAQ would fit with an OSTP committee. An audience member noted another executive branch interagency group: The White House Task Force on Waste Prevention and Recycling, in the Office of the Federal Environmental Executive, formed a Federal Green Building Council about a year ago. This is another interagency group concerned with indoor environmental quality. An audience member from the CPSC who served on CIAQ spoke about its history and the present activities of the group. Initially, CIAQ served as a way to coordinate research funding, but as funds to the member agencies have dried up in recent years, it has not been as active. They are still a group that is well informed on what research is going on in each agency, and they review each other's protocols and provide technical support among agencies.

A participant from HUD's Office of Healthy Homes and Lead Hazard Control suggested issuing joint RFPs to address specific indoor environment problems that multiple agencies agree are important topics. HUD could apply their funds to the research infrastructure that exists in other agencies to examine, for example, the cost/benefit of integrated pest management, under the HUD Healthy Homes initiatives. There are many small issues that have not been well researched. For example, asthmatics are advised to remove carpeting from their homes, but there is no scientific evidence on how effective that is. A participant suggested the need for a multidisciplinary approach to school issues, including research on green schools and sustainable technology, and health effects for teachers and students.

Question 2: What are the best strategies for implementing the things that we already know need to be done?

The moderator pointed out that strategies must be developed; for example, we know enough about the harmful effects of damp buildings to begin to take action, so what would be the best way to proceed? One participant indicated that, in spite of comments that there has been failure to effectively apply OSHA standards and ASHRAE 62 standards to indoor air quality issues in industry; there is one example of a "success story." Under the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), there are architects' guidelines on dealing with aerosols. Since JCAHO determines whether hospitals can bill for their services, they have great leverage in effecting change. They inspect hospitals and require plans and protocols to protect patient safety. It is currently not possible to facilitate construction in hospitals without a plan for control of particulates and bioaerosols. Similarly, there are requirements for plans to address normal maintenance and water damage issues. Having a quasi-regulatory agency forcing health care facilities to maintain indoor environment standards has been very effective, and may be the only "success story" for a regulatory approach in the last 10 years.

Another participant underscored the need to address the chemically sensitive in any interagency effort, pointing out overlapping concerns for issues like pesticide use. A participant from the NRC stressed collaborative efforts, mentioning the Green Schools program being set up in

collaboration with the Commonwealth of Massachusetts. The program will be looking at sustainable technology and its effects on student health and productivity. This individual also stressed the need to move ahead with available technology without waiting for more basic research.

An audience member suggested that a fundamental problem with current building practices is the standard of care used in construction and the use of a "punch list" approach of correcting problems after the fact: "We find that you can't fix everything effectively, and, consequently, the majority of new buildings have poor indoor air quality." This individual pointed out a need to document and approve construction at each stage (foundation, backfill, etc.) when it is still possible to take effective corrective measures for good indoor environment as the building is constructed. This has been done for school buildings and hotels, resulting in better indoor environments in the final product. A panel member suggested possibly including indoor environment standards in building codes, but the audience member indicated that most correct procedures are already in the code: the problem is lack of oversight. The same individual also indicated a simple solution for indoor air quality issues during renovations: set a requirement to use negative air pressure to restrict movement of dust into occupied areas. A panel member commented on construction issues, noting that they illustrate the complexity of dealing with indoor environment issues because they impact on so many different interests and professional concerns (architects, construction trades, building owners, insurance industry, medical care providers, etc.) even when focusing only on a single issue, such as water intrusion. As the number-one strategy, he suggested using the Office of the Surgeon General to issue a document that frames the debate on indoor environment, as was done for second-hand smoke. Just choosing one issue to begin with (e.g., dampness) would start to move public policy actions, beginning with changes such as keeping insurance companies from writing policy exclusions for mold.

Dr. Mitchell suggested "changing the metric" for success to focus more on the health of building occupants rather than on the building itself, using the *Tools for Schools* approach as a model. By assessing occupant health and comfort, it is possible to move away from debating issues such as the relative importance of maintenance or initial construction and direct attention to the outcome of good practices in both. The Surgeon General can suggest in his report that focusing on the health of the occupants is an indicator of whether the building is working well.

Another participant discussing implementation strategy pointed out that schools represent a large business with considerable market leverage: it should be possible to motivate businesses to market green materials to schools. In turn, schools have a strong influence on the community of parents and the public at large. Guidelines are needed to allow businesses to know what to market. An industrial hygienist in the audience mentioned the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) Green Building Rating System®, which has improved building performance; indoor air quality is part of the rating. Their certified and registered products and assessment strategies provide an example of using marketplace forces and increasing consumer awareness of good building practices.

Question 3: Is it appropriate to organize stakeholder input and plans for action by type of building (i.e., differentiating between schools, offices, and residences)? What stakeholders may be brought into the mix by considering buildings other than residences and schools?

Ms. Loftness, who serves on the board of LEED, thought this would be a good strategy. She suggested that it may be better not to address schools as a separate category since their construction varies considerably by age and location (climate). She pointed out that hospitals, nursing homes, and laboratories are other building types that are hard to include in categories because their construction and operation is often very different from other buildings. There would be some issues involving particular stakeholders, that would be limited to their particular type of building, but other issues, such as diagnostic techniques might cut across all types of buildings. Labeling spaces for certain levels of moisture and damage might be a way to cut across various building types.

Dr. Woods thought that a more important issue, from the perspective of accountability, would be building ownership: for example, schools may be privately or publicly owned. Offices may be private, owned by the state, or owned at the federal level, etc. He suggested using the public sector to lead the way in taking health initiatives. In terms of strategy, there are already federal regulations in place (e.g., Code of Federal Regulations, Title 10, Parts 434 and 435) that require energy budgets be set for a building; an analogous mandate for health-quality levels would be relatively easy to put in place. He felt that government agencies could do more to lead by example in the buildings directly under their control.

Drawing from experience with a Maryland task force on indoor air quality, one panel member suggested that a government agency that leases space and writes contract requirements has the most opportunity to specify operational requirements. Mr. Kampschroer agreed that GSA could do more to use their building management activities to set an example, but also pointed out the need to couple good practices with research to demonstrate the effectiveness of any methods that are advocated. There should be continued effort to proving economic and health advantages with demonstration projects. He also pointed out that GSA holds only 40% of the buildings used by federal government agencies, so the other owner agencies could have a substantial impact with their properties as well. Dr. Kreiss agreed, noting that there are also logistical advantages to involving the military and other government groups in outcomes research: cooperation may be greater than in studies conducted in the private sector, and clearances required for federal studies with regard to public burden do not apply. She mentioned a military indoor air quality study performed in the early 1980s that showed that basic trainees housed in new, tight, energy-efficient barracks had a much higher rate of infectious respiratory disease than those housed in older, leaky barracks, and consequently greater time lost to illness, which required them to begin basic training again. (Brundage JF, Scott RM, Lednar WM, Smith DW, Miller RN. Building-associated risk of febrile acute respiratory diseases in Army trainees. *Journal of the American Medical Association.* 1988:259(14):2108–2112.)

Question 4: How do we unleash market forces to improve indoor environments?

An audience member enumerated some of the organizations that can be approached to apply market forces: ASHRAE, CDC, DHHS, DOE, DoE, EPA, GSA, HUD, and NIH. It is also important to include building operators and maintainers among stakeholders who bring a life-cycle perspective. This commenter advocated a Call to Action from the Surgeon General, as it should be clear that there is a problem, both with regard to public health criteria of scope and to

number of people affected. Another audience member who had worked with GSA indicated that, in his experience, government branches that lease and rent space have much more latitude to specify operations and maintenance provisions in their contracts than branches that build them outright. Leasing and renting is one area that could be used to unleash market forces. Another audience member, who had experience working on federal buildings using UV radiation and cleaning air coils for improving indoor air quality and energy use, suggested worker productivity as a primary economic "lever." The government is able to run their program under orders to improve energy efficiency, and they can show that the same measures that make the building more energy-efficient can make it healthier at the same time. Executive Order 13123 requires energy savings in federal buildings. There has been a lot of research recently on the economic impact of improving the health of building occupants. He suggested the term "presenteeism," meaning that the worker is physically there, but is unable to work effectively or productively due to health issues. Labor savings from decreased presenteeism and increased worker productivity can be a substantial market force. The moderator pointed out that this is partly a knowledge issue, making companies aware of the potential impact of indoor environment on presenteeism, but it is also an accounting issue, since, as pointed out in the morning presentations, employers must see the cost/benefit effects of their actions.

A consultant commented on the role of GSA in buying huge amounts of goods and services, which acts as a huge "economic motor," but suggested there is some confusion due to conflicting or uncertain claims and standards for healthy building products. He suggested that a certification program is needed to guide purchasing decisions to products that truly enhance the indoor environment. Another audience member suggested making sure that insurance adjustors, especially those paying for reconstruction after flood damage, ensure that good practices are being followed when buildings are rebuilt. What insurance adjustors say, goes, unless someone wants to take them to court to force better practices. With large private-sector owners (real estate investment funds, pension funds, partnerships, etc.), there can be a disconnect between risk managers (who deal with fear) and facilities managers (who desire to keep operations costs to a minimum), so there is a need to work at the ownership level to be sure that the communication takes place and "market forces," such as fear of litigation, are applied.

Question 5: How can we assure that interventions are rigorously evaluated?

One participant commented that if you want rigorous evaluation, you need to be sure that people at the building site have the right tools and the right information. There is a need to reach out to building remodelers and their associations as well as to new home builders to encourage best practices. There should be input to the media and trade press to ensure accurate reporting and follow-up of positive and negative results of research into innovative building practices and hazards. CAPT Redd pointed out that people responsible for building do not necessarily have the research expertise to determine best practices. In radon control, for example, collaborative efforts with physicists were needed to move the program forward. An audience member from HUD noted the importance of good investigative practices, such as adequate sample size and good measures of change with multiple endpoints. Some small asthma intervention studies never had the statistical power to demonstrate anything.

Dr. Mitchell pointed out two barriers he has experienced to conducting good quality, well-evaluated research: (1) the need to identify agencies with specific mandates to fund studies concerning indoor environment (to put in place adequate funding for large-scale, high-quality studies), and (2) fear of liability on the part of building owners, operators, and contractors. Each time he has tried to conduct research in this area; it has been stopped by legal concerns within either the private or public sector (e.g., local government or school boards). Any time ideas are raised about linking health to a building, liability issues are also raised. The legal department puts up obstacles that can severely limit access to the building and its occupants. The moderator asked how that has been overcome. Dr. Mitchell responded that it has not been overcome. Lack of access to the indoor environment and its occupants is a huge impediment. He suggested that if this workshop can address that issue, that would be the single most valuable contribution it could make to further research on indoor environment issues.

An occupational health consultant pointed to the success of NORA and the interest and expertise that NIOSH has in evaluating intervention effectiveness. This process could serve as a model for making some progress in setting priorities in indoor environment concerns. Intervention effectiveness is a research priority for NIOSH, and for the international company senior health and safety managers with whom this consultant works. NIOSH must evaluate interventions in very complex, multi-variable occupational environments. The commenter also indicated the value of case studies and other designs based on social sciences models, suggesting that you do not need double-blind case-control studies to answer every research question.

A safety engineer consultant discussed his experience with a Blue Ribbon Panel in Washington State charged with monitoring school health and safety. The panel used funds allocated to schools by DoE to triage the needs for correcting structural and operational problems presented by individual schools in the state and to give advice on the most effective intervention. While he agreed with Dr. Mitchell that there are legal barriers (because the schools are afraid of confessing or disclosing problems), with $100,000 awards per school district, they were able to get 100% participation in the program. The panel came up with the top 96 projects and evaluated them with architects, engineers, school nurses, and environmental health professionals. That evaluation, which is available from the Washington State Superintendent of Public Instruction Office, could be used as a model for a national program. Another audience member suggested a specific project: a request for proposals (RFP) should be issued to evaluate changes in GSA-controlled buildings. NIEHS has already suggested that they might be interested in doing this, but it should be a limited and very specific RFP.

Question 6: How can the barriers for implementing widely accepted interventions, such as remediation of water intrusion, be overcome?

The barriers to implementing interventions include issues such as cost, and, in some situations, opposing market forces. Several audience members pointed to the issue of lack of public awareness of the ill-health consequences and the greater long-term costs of not addressing problems promptly. Required disclosure at time of sale in the real estate industry provides one good model of how to overcome this barrier by using market forces. The seller becomes aware of the problem and has to deal with it. Another audience member commented that the elderly on fixed incomes and low-income renters often face financial barriers in meeting the costs of remediation,

and lenders are often not responsive to the needs of these people. Weatherization programs that use vouchers and low-interest loans provide one model of how to overcome this barrier. Tax breaks also work for those with enough income to pay taxes. This person also suggested working backwards from the homeowner, dealing with agencies that work with homeowners such as realtors, housing inspectors, code officials, HUD, etc. She also recommended the informational pamphlets produced in English and Spanish by HUD to raise the public's level of awareness.

Mr. Levin suggested that the Surgeon General should use his position to frequently raise consciousness on indoor environment issues at all levels of society. The interests touched by indoor environment concerns are broad and affect every level of society and income level. Having worked in the field since 1978, he believes that no single action will correct the problems, but that each effort motivates the next action by increasing public awareness and by building public and government support for taking indoor environment problems seriously. An audience member referred to an employee relocation program that moves 30,000–40,000 people a year and often deals with mold cases, in Texas and elsewhere. They could not sell old properties affected by mold, and that situation added to the cost of the program. As a reaction to this problem in Texas, J.C. Penney Company, Inc. mounted a proactive videoconference program on operational maintenance, showing that it is financially more advantageous to make repairs on your house to prevent problems than to pay $5,000 later for mold abatement. Twenty thousand people responded to the program and the company saw a 25% reduction in their costs in 6 months.

Another audience member stressed financial limitations as an overriding concern: school collecting water in buckets from a leaking roof certainly understands that there is a problem and how to correct it. Funding issues in the public sector might best be addressed with some sort of escrow strategy, establishing a funding source based on holding back a small percentage of new construction funding so that in 20–30 years, funds will be available to allow repairs to be made quickly. The moderator commented that California (through Cal/OSHA) has declared mold in a building as a sanitation issue in the occupational setting, indicated that it is not acceptable, and issues fines to employers who do not repair water damage. This is a simple and effective solution, but only operative in California at present.

Question 7: What are the areas of research for which we have an inadequate knowledge base?

The moderators suggested some candidate areas for research:

- The role of indoor environment in transmission of respiratory infections;
- Ventilation standards and their impact on health;
- Exposure assessment methods for health studies;
- How to get researchers to do multidisciplinary work in linking health risks with environmental measures; and
- The nature of residential exposures.

Dr. Spengler used the SARS outbreak as an illustration. There were articles in the *New England Journal of Medicine* describing how one incident case on a flight to Hong Kong led to 20 subsequent cases and an apparent example of residential transmission of disease from an incident case on the eighth floor of a tower apartment building to an adjacent apartment building, based on

ambient airflow patterns. However, basic information is lacking about the spread of viral vectors through ventilation systems and the survival of disease organisms on various surfaces, so the apartment infection pattern cannot be analyzed with precision. There is a fundamental lack of knowledge about how we are infected in our buildings, especially in schools and day care centers, which can be a major factor in spreading disease. This is a major multidisciplinary research problem that needs to involve medicine, engineering, and public health expertise. The infectious disease community, the building science community, and the epidemiology community would have to join forces, and there is no agency that does this at present.

Dr. Woods pointed out that exposures and ventilation are often considered separately, but ventilation is a flow rate, and is just an engineering tool to achieve indoor air quality. Research is needed to understand loads and emission rates of contaminants so that ventilation rates can be calculated. We can get by with about one cubic foot per minute (cfm) per person (or 2–3 cfm/person in submarines) because the respiratory rate is about a 10th of a cfm/person, but we need to know a lot more about optimal rates. He mentioned Finnish and Danish Institute studies as examples of the kind of research that is needed to calculate ventilation rates. Mr. Fisk mentioned the need for research on how indoor chemical exposures affect allergy and asthma outcomes, for which there is only European research. Other research needs include determining how people are exposed to bioaerosols, and how classroom ventilation rates affect health. Finally, better exposure assessment for bioaerosols in relation to the health effects associated with damp and mold growth is a research need.

Another audience member mentioned neurotoxicology as an endpoint, specifically for toxins such as organophosphates. More basic information is needed on neurotransmitter physiology and immune system function in relation to indoor environment factors, specifically to understand their interaction in health status. Another participant suggested that a better understanding of guideline effectiveness is needed to determine whether guidelines are adequately protective with a high probability. Many research studies are carried out to answer scientific questions, but the answers are hard to apply to operational use. For example, it is necessary to reduce SARS studies to a practical level regarding issues such as how diseases are actually transmitted in the office environment. Another audience member pointed to open questions about the relationship between building material properties and their impact on the indoor environment. For example, research is currently lacking to guide the choice of building products in terms of their ability to support mold growth. Basic information on material properties, such as the capacity of wallboard to hold water, is often not available even from the manufacturer.

Dr. Storey commented on the need to assess the burden of disease attributed to the indoor environment, which would provide some measure of the impact of changes in building conditions over time. While green building innovations are very exciting, the point was already made that 80% of our building stock will still be with us in 20 years, so change in our communities will have to be incremental. She suggested a need to give good advice about dealing with current buildings, and suggested that agencies should give grants only to programs that are seriously multidisciplinary and address components of exposure, mechanisms of disease causation, disease burden, and intervention.

One audience member addressed the element of exposure, pointing out that many indoor pollutants undergo chemical transformations in the indoor environment, and the resulting reaction products may be more toxic than their precursors. NIOSH sponsored a workshop on this topic, Indoor Chemistry and Health (held at the University of California, Santa Cruz, July 12–15, 2004). Information from the workshop will be available on the NORA Indoor Environment Team Web page, and a workshop summary will be published in *Environmental Health Perspectives*.

Damp buildings may be a particular concern because dampness causes hydrolysis reactions, or favors microbial growth that changes the pH of building materials, favoring certain chemical transformations. The moderator commented that we often do not know exactly what these toxic agents are, and therefore what to measure, although it still may be possible to solve a lot of problems by mitigating dampness. In this context, Ms. Loftness suggested classifying specific human health effects that are impacted by the physical environment by human organs or systems – vision, skin, respiratory, digestive, etc. This exploration would support building material and systems research and their impact on short- and long-term health problems. She also suggested that the importance of access to nature should be in the equation because of its interaction with mental and physical well-being. One participant noted that there are four Japanese environmental medicine units, and they often focus on susceptible populations. She suggested that we should be using this approach as a model for what we do in the United States. The moderator noted the large number of agency programs related to indoor environment discussed or mentioned during the comments, and underscored the evident need for coordinated, integrated federal research effort with more stakeholder input.

Question 8: What are the key economic issues? What provides the cost-benefit rationale for health care payers?

These economic issues are important areas with potential for driving change. One participant suggested that there is great interest among corporate health and safety managers and human resource managers in enhanced productivity as a key economic benefit of improved employee health. An audience member affiliated with a state health department indicated that health care coverage costs were very "disaggregated" from building management costs, making it hard to unite costs and benefits in the analysis (referred to as "the disaggregation problem") and suggested that there must be a way of reversing this. He used the example of the automobile industry as a model: without market and regulatory pressure, most of the improvements in safety and fuel efficiency would not have come about. Similar pressures now need to be applied to the building industry. Disaggregated stakeholders are a major barrier to progress. If GSA really understood and acted on health care and productivity loss costs attributed to indoor environment issues, it would serve as a good example to motivate change. The moderator returned to the suggestion of commissioning a NAS report on the economic consequences of indoor environment issues as a way of moving people to action.

An audience member from a regional EPA office suggested the need to better inform Medicare, as well as private health care payers, about the economic impact of indoor environment issues. Since private insurers only cover what the contracts say they should cover, the federal government should lead the way in determining what federal health benefits programs cover. Another

audience member indicated that Social Security (as insurers of last resort) and state disability programs should take on these costs, and should be included in discussions. State Social Security agencies can consider environmental illness on a case-by-case basis and may dismiss "sick building syndrome" cases as psychosomatic somatoform disorders rather than bill back the costs as work-related disabilities. Changing this practice would bring about a strong economic incentive to make indoor environment improvements.

Another audience member disagreed, suggesting that the slide from Ms. Loftness' presentation was very convincing from the perspective of a large employer in indicating that the economic impact of health-related productivity improvements resulting from indoor air quality were minor compared to ergonomic and other factors. He predicted that productivity increases associated with indoor environment quality would be too small to be a prime motivator in industry. In addition, the "charge-back" process and use of market controls are inefficient and ineffective in practice, even for changes with a clearly highly beneficial cost/benefit. The clearest example is the automobile industry, where market forces were insufficient without government regulatory pressure to improve automobile safety. An analogous situation occurs during building construction where basic quality flaws (like poor flashing) result in only minor market pressures on the builder because they are hard to monitor and enforce, but have major long-term negative effects down the line. Quality improvement procedures rather than market forces are needed to effect better building practices.

Another audience member commented on application of life-cycle cost theory: she agreed that market pressures are not very effective in dealing with such issues without regulations and standards enforcement that provide more immediate penalties. It is the federal government's responsibility to apply tools such as life-cycle management to the problem.

Mr. Fisk suggested that economics may be a stronger incentive than these views indicate, and he advocated using both economic incentive and regulatory action. He suggested that any business that can save money in health care costs will be well motivated because such costs will surely increase. Another participant also disagreed that cost savings associated with improved indoor air quality were too small to be effective, citing statistics from the Washington Business Group on Health and the Integrated Business Institute (IBI) that calculated costs based on employee loss of productivity. The cost of allergy was estimated at $250 per affected employee per year, $100 for each employee with asthma, and $125 for each employee with respiratory infections. As health care costs are escalating each year, there is good potential here for return on investment.

Question 9: What are the best ways to reach the public and those responsible for the performance of buildings?

The moderator mentioned Mr. Levin's recommendation for a "homeowner's instruction manual" and indications by others that such materials have already been produced by some agencies. Audience members cited various educational publications, such as *Inspecting a House* from Cornell University Cooperative Extension Service. The USDA Cooperative Extension Service was suggested as a means for outreach to the public. EPA, HUD, and CDC have all produced good materials. There may be more need for training materials on the building practices side. Another commenter recommended the U.S. Green Building Council's publications on sustain-

ability as a good model of public education. Audience members suggested that there is a need to inventory and evaluate existing manuals and similar material to see what is already available before producing new educational tools.

Several audience members supported the idea of using a Surgeon General's Report to elevate the public's awareness of indoor environment as a health concern, while others spoke to the need for instructional materials targeted to the interests of specific groups. Based on his 30-year history of interest in these issues, Dr. Woods spoke to the need to educate the professions (such as architects and architectural engineers on one hand, and health professionals on the other) to take indoor environment issues seriously. He noted that only 2% of engineering/architecture schools have any component of the curriculum dealing with health issues. On the other hand, he asked, how many health professionals study building materials and performance issues? One audience member mentioned the American Lung Association's Health House: Builder Guidelines and described her own experience with an environmental illness and the problems she had in finding a contractor willing to build to those guidelines. She suggested that while some people are in "desperate need" of housing constructed to high indoor environment standards, they may have difficulty finding informed and willing contractors. This indicates a need for material aimed at builders and remodelers. The Surgeon General's Report from this workshop could provide support to contractors with an interest – pioneers are needed!

Several audience members discussed reaching segments of the public in support of economic incentives. One suggested that different classes of commercial buildings are not uniform; they have different standards and fiduciary requirements, so it may be necessary to explain health benefits in different ways to different business interests. In addition, one architect/engineer suggested the model of the U.S. Green Buildings Council, implying the potential value of a similar "Healthy Buildings Council." An audience member who works at a local health department mentioned that he finds checklists and basic information on issues like water intrusion are effective. Renters and landlords of small properties need to be approached differently from large housing agencies; well thought-out guidelines are helpful.

Dr. Spengler wrapped up discussion of the questions by stressing the need for supporting research and education, suggesting that if well documented toxic effects are found for a particular building product, manufacturers will eliminate it from the market (an example being p-dicholorobenzene, which was recognized as a carcinogen and is no longer used in building materials and now rarely turns up in assessments). Programs such as the EPA's Toxic Release Inventory help to remove such materials from the outdoor environment, but such a labeling requirement does not extend too many products that go into our homes.

Finally, Mr. Levin urged the Surgeon General to take the lead in encouraging and facilitating collaborations among federal government agencies as well as encouraging private sector research and public information programs. Mr. Levin said that the Surgeon General was ideally positioned to raise public awareness and provide the basis for broader application of current knowledge as well as development of the necessary new understanding of the importance of the indoor environment for public health and welfare.

Highlights from Vision for the Future Session

A committee established under the Office of Science Technology and Policy could serve as the key to coordination and collaboration on improving the indoor environment.

Multidisciplinary programs to improve indoor environmental quality exist in and outside government, providing models and partners for new collaborative efforts.

One focus of any indoor environment activities should be improving the health of the occupants.

Good applied research is needed to demonstrate the effectiveness of various building management activities and technologies. Federal government buildings could be used as demonstration projects to model both innovative technology and the use of market forces and contract requirements to motivate better practices.

The Surgeon General should continue to advocate action to improve the indoor environment as a public health policy priority.

To advance healthy indoor environment research, both funding and liability issues need to be addressed. Liability concerns often severely limit a researcher's access to a building and its occupants.

The public is generally not aware that delays in improving their indoor environment conditions, can result in potential long-term costs that can have an impact on their health.

Health care coverage costs are "disaggregated" from building management costs: Medicare and private health care payers need to be made aware that failure to improve the indoor environment can increase long-term health care costs.

How the indoor environment influences the transmission of respiratory infections is poorly understood. Intervention studies may play an important role in clarifying these influences.

If improvements to the indoor environment can reduce the occurrence of asthma, allergic responses, and respiratory infections, the cost savings will be significant.

Programs yielding new approaches must be balanced with programs to apply or enforce known best practices. This approach will produce the greatest incremental health improvement for residential and office building occupants.

As the nation's doctor, the Surgeon General is uniquely situated to advocate for and help to coordinate collaboration to promote healthy indoor environments.

Broad outreach is needed to educate homeowners, builders, maintenance personnel, architects, and planners about healthy indoor environment issues.

A coordinated, integrated federal research effort with more input from stakeholders is needed.

Closing and Action Steps

VADM Richard H. Carmona, M.D., M.P.H., F.A.C.S.
U.S. Surgeon General

The Surgeon General, VADM Richard Carmona, closed the workshop with his impression of what was said over the past 2 days. He indicated that the workshop presentations have made the case that the time has come to take action in this area. Some workshop participants have spent 25–30 years doing anonymous indoor environment research and advocacy. The Surgeon General complimented those who have worked so hard for their passion and dedication to making the world a better place in which to live. The indoor environment, where we spend 85%–95% of our time, is a complex, multifactorial issue that requires a multidisciplinary approach. He indicated that the time has come for moving forward on this issue.

He noted that presentations at this workshop are like "preaching to the choir." For the public at large, however, indoor environment issues are not widely recognized or understood. In dealing with other environmental and health issues, he has come to feel that our society is mostly "health illiterate." He stated that what we really need to do for the public is to provide clear information that will effect behavioral changes. More research is indeed needed, but there is already enough good information that can be used to make practical improvements in the indoor environment. What we are lacking is the "translational element" needed to overcome health illiteracy. The outcome we are seeking is to effect behavioral changes that improve morbidity and mortality and reduce health care costs. This task is made more complex because, for indoor environmental issues, the public this group is trying to reach is not only the home owner but also the builder, the maintenance staff, the architect, and the city planner; therefore, a very broad outreach is needed.

The next action step will be determined by a continuum of processes that starts with the issuance of the Summary Report for this workshop. Based upon the discussions that occurred during these 2 days, the Summary Report, and guidance from various federal, state, and local public health stakeholders, a Surgeon General's Call to Action may be the appropriate next step. A Surgeon General's Call to Action helps to focus the nation's attention on issues that impact health. As we move forward with trying to achieve a healthy indoor environment, there may be the development of a Surgeon General's Report, which takes greater effort and commitment of resources than what it took to develop this workshop.

VADM Carmona closed the workshop by thanking the workshop participants. He indicated his commitment and his feeling that this is the right issue at the right time.

Appendix A

Speaker Biographies

Surgeon General's Workshop on Healthy Indoor Environment

Clive Brown, M.B.B.S., M.Sc., M.P.H.

Clive Brown, M.B.B.S, M.Sc., M.P.H., is a Medical Epidemiologist with the Field Section of the Air Pollution and Respiratory Health Branch (APRHB), National Center for Environmental Health at the Centers for Disease Control and Prevention (CDC). He completed his medical training in Jamaica in 1987 where he served as the Medical Officer of Health for the Parish of St. James. He joined the CDC's Epidemic Intelligence Service program in 1993 and completed his preventive medicine residency at CDC in 1996, where he worked on getting asthma onto the CDC agenda. He has an M.P.H. degree in Epidemiology from Columbia University and a M.Sc. degree in Health Systems Management from the London School of Hygiene and Tropical Medicine.

Dr. Brown is CDC's main contact for issues related to non-occupational indoor air quality and for the investigation of pulmonary hemorrhage in infants. He also does research on asthma. He has served as a consultant to the Pan American Health Organization where he was assigned to the Caribbean Epidemiology Center. Dr. Brown is also an Associate Professor for Epidemiology at the University of Technology in Jamaica and Clark Atlanta University in Atlanta, Georgia.

VADM Richard H. Carmona, M.D., M.P.H., F.A.C.S.

Vice Admiral (VADM) Richard H. Carmona, M.D., M.P.H. F.A.C.S., was sworn in as the 17th Surgeon General of the United States Public Health Service on August 5, 2002. Prior to being named Surgeon General, he was the chairman of the State of Arizona Southern Regional Emergency Medical System, a professor of surgery, public health and family and community medicine at the University of Arizona, and the Pima County Sheriff's Department surgeon and deputy sheriff.

VADM Carmona has worked in various positions in the medical field including paramedic, registered nurse and physician. VADM Carmona completed a surgical residency at the University of California, San Francisco, and a National Institutes of Health-sponsored fellowship in trauma, burns and critical care. He is a Fellow of the American College of Surgeons, and is also certified in correctional health care and in quality assurance.

VADM Carmona has held progressive positions of responsibility as chief medical officer, hospital chief executive officer, public health officer, and finally chief executive officer of the Pima county health care system. He has also served as a medical director of police and fire

departments and is a fully-qualified peace officer with expertise in special operations and emergency preparedness, including weapons of mass destruction.

VADM Carmona has published extensively and received numerous awards, decorations, and local and national recognition for his achievements. A strong supporter of community service, he has served on community and national boards and provided leadership too many diverse organizations.

Born and raised in New York City, VADM Carmona dropped out of high school and enlisted in the U.S. Army in 1967. While enlisted, he received his Army General Equivalency Diploma, joined the Army's Special Forces, ultimately becoming a combat-decorated Vietnam veteran, and began his career in medicine. After leaving active duty, VADM Carmona attended Bronx Community College of the City University of New York, where he earned his Associate of Arts degree. He later attended and graduated from the University of California, San Francisco, with a Bachelor of Science degree (1977) and medical degree (1979). At the University of California Medical School, VADM Carmona was awarded the prestigious gold-headed cane as the top graduate. He also earned a Masters of Public Health from the University of Arizona in 1998.

Noreen M. Clark, Ph.D.

Noreen M. Clark, Ph.D., is Dean of the University of Michigan School of Public Health, Marshall H. Becker Professor of Public Health, and Professor of Pediatrics, University of Michigan Medical School. She is interested in systems, policies and programs that promote health, prevent illness, and enable individuals to manage disease.

Dr. Clark has served in numerous leadership positions. She serves as National Program Director for the Robert Wood Johnson Foundation *Allies Against Asthma* Program. From 1999–2002, she was a member of the Advisory Council of the National Institute of Environmental Health Sciences. She has been president of the Society for Public Health Education and chair of the Public Health Education Section of the American Public Health Association (APHA). She has served as chair of the Behavioral Science Section of the American Thoracic Society, as a member of the Pulmonary Diseases Advisory Committee for the National Heart, Lung, and Blood Institute, and as a member of the Institute's Advisory Committee on Prevention, Education, and Control. Dr. Clark is a member of the Coordinating Council of the National Asthma Education and Prevention Program and of its Science Base Committee, and has chaired the American Lung Association (ALA) Technical Advisory Group on Asthma, and the Lung Diseases Care and Education Committee. She has served on both the Board and Council of the ALA. She chaired the Institute of Medicine Committee on Damp Indoor Spaces and Health. She is the former editor of *Health Education and Behavior* and is currently Associate Editor of *Annual Reviews of Public Health*. Among other honors, she is the recipient of the Distinguished Fellow Award, the highest honor bestowed by the Society for Public Health Education; the Derryberry Award for outstanding contribution to health education in behavioral science given by the APHA; the Health Education Research Award conferred by the National Asthma Education Program for leadership and research contributions; the Distinguished Career Award in Health Education and Promotion given by the APHA; the Behavioral Science Lifetime Achievement Award of the American

Thoracic Society; and the Healthtrac Education Prize. She is a member of the Institute of Medicine of the National Academy of Sciences.

Dr. Clark's primary research specialty is management of disease, and she has conducted many large-scale program evaluations. She is attempting to identify the elements of self-regulation, and uses management of asthma and heart disease as models for examining constructs. Her studies of self-management have contributed to the research literature and the field of practice by demonstrating that educational interventions can decrease asthma hospitalizations and medical emergencies. Her work has resulted in an archetype educational program for health care facilities distributed by the National Institutes of Health and used in hundreds of clinics nationally and internationally. A program developed in subsequent research to adapt the model for use in public schools is being disseminated by the ALA and has to date reached almost 500,000 American school children. Other model programs for management of asthma and heart disease by patients, clinicians, and communities are currently being evaluated by Dr. Clark and her research team.

Dr. Clark has extensive international experience. Her research has focused on development and testing of interventions designed to improve health status, quality of life, and collaborative activity among rural people in Kenya and in the Philippines. In addition, she has been a consultant for a wide range of organizations working around the world, including the Ethiopian Women's Welfare Association, the Ministry of Education in Nepal, the Asia Foundation in Pakistan, the Directorate of Health in Portugal, the World Bank, the United Nations Development Program, the Synergos Institute, the Community Health Authority of Madrid, and the Beijing Heart, Lung and Vessel Institute, among others. She serves on the board of directors of World Education Inc. and of Family Care International. Dr. Clark is a member of the Council on Foreign Relations, has served on the Overseas Development Council, and is on the board of the Aaron Diamond Foundation.

Elizabeth A. Cotsworth, B.A., M.A.

Elizabeth A. Cotsworth, B.A., M.A., is currently the Office Director of the U. S. Environmental Protection Agency's Office of Radiation and Indoor Air (ORIA). Ms. Cotsworth provides national direction for protecting people and the environment from harmful and avoidable exposure to radiation, as well as protective measures and guidance for indoor air environments. Prior to joining ORIA, Ms. Cotsworth was the Office Director of the Office of Solid Waste (OSW) from 1997 to 2002, after holding a series of positions managing national hazardous and solid waste programs. She entered the Agency as a Management Intern in 1973. She holds a B.A. degree from Chatham College in History and an M.A. degree from the University of Virginia in Government and Foreign Affairs.

Jean M. Cox-Ganser, Ph.D.

Jean Cox-Ganser, Ph.D., is Research Team Leader for the Field Studies Branch of the Division of Respiratory Disease Studies (DRDS) of the National Institute for Occupational Safety and Health (NIOSH). She is a primary investigator in a 5-year NIOSH research program on Work-

Related Asthma in Office Buildings and Schools, and is currently involved in planning for continued work on Indoor Environmental Quality work in schools. Dr. Cox-Ganser is also team leader for the NIOSH National Occupational Research Agenda (NORA) Indoor Environment (IE) team. The goal of the NORA IE team is to focus and facilitate research that will improve the health of workers in indoor environments.

Dr. Cox-Ganser has served as Acting Deputy Director of DRDS and Acting Team Leader of the Epidemiology Team at DRDS. She was a member of the editorial committee for the World Health Organization (WHO) proposed document *Guidance for Biological Agents in the Indoor Environment* and was program leader for the NIOSH NORA project "Work-related Asthma in Offices and Schools." At West Virginia University, she has served as Post-Doctoral Research Fellow in the Department of Animal Science, as Bio-Statistician in the Department of Community Medicine, and as Adjunct Assistant Professor, Department of Community Medicine.

Dr. Cox-Ganser received a B.Sc. degree in Animal Behavior and Immunology and B.Sc. and M.Sc. degrees in Biological Sciences from the University of Natal, South Africa. She earned her Ph.D. degree in Animal Science and an M.S. degree in Statistics from West Virginia University.

Jerome P. Dion, M.S.

Jerome P. Dion is the Supervisor of Research and Development for the Building Technologies Program in the Office of Energy Efficiency and Renewable Energy of the Department of Energy (DOE). Mr. Dion has served in a variety of capacities in Efficiency and Renewables over the past 13 years, including Corporate Planning Lead, and Senior Advisor in the Federal Energy Management Program and Office of Building Technologies, State and Community Programs (predecessor organization to the Building Technology Program). Prior to joining DOE, he served the Arizona Energy Office for 10 years, leaving as Planning and Policy Program Manager. Mr. Dion holds a Master of Urban Planning degree from the State University of New York at Buffalo.

Peyton A. Eggleston, M.D.

Peyton A. Eggleston, M.D., is the Director of the Center for Children's Environmental Health at the Johns Hopkins University, one of a network of Centers of Excellence sponsored by the National Institute of Environmental Health Sciences and the U.S. Environmental Protection Agency. He is currently directing several clinical trials of the effect of allergen abatement on chronic asthma.

After graduation from the University of Virginia medical school, Dr. Eggleston received training in Pediatrics and in Allergy-Immunology at the University of Washington. He returned to the University of Virginia faculty in 1972, and then joined the Johns Hopkins University in 1981, where he is now a Professor of Pediatrics in the School of Medicine and of Environmental Health Sciences in the School of Public Health. His research interest has been in the area of the contribution of IgE-mediated inflammation to chronic asthma. He participated in immunotherapy trials in pediatric asthma and in the use of Fel d 1 peptides. Most of his work has addressed the

characterization of home environmental allergens and their relation to acute and chronic airway disease, especially the acute effects of airborne animal allergens and the chronic effects of cockroach and dust mite allergens. He participated in the National Cooperative Inner City Asthma Study that described the effect of cockroach and rodent allergen exposure on chronic asthma morbidity in inner city populations.

Dr. Eggleston's *Curriculum Vitae* lists over 190 publications. He serves on the editorial board of the *Journal of Allergy and Clinical Immunology*. He was a member of the American Board of Allergy and Immunology and has been an active member of the Academy of Asthma, Allergy and Immunology for most of his career.

Henry Falk, M.D., M.P.H.

Henry Falk, M.D, M.P.H., currently heads two organizations spearheading the Department of Health and Human Services' work in environmental health. He serves as Director of both the National Center for Environmental Health (NCEH) and the Agency for Toxic Substances and Disease Registry (ATSDR). In 2003, these two entities consolidated to form NCEH/ATSDR. At NCEH, Dr. Falk heads the federal government's efforts in preventing and controlling environment-related diseases, illness, and deaths. He previously served at NCEH for 14 years as director of the Division of Environmental Hazards and Health Effects. At ATSDR, which was created by the 1980 Superfund legislation, Dr. Falk leads the federal agency whose mission is to protect public health against toxic substances in the environment.

Dr. Falk earned his medical degree from the Albert Einstein College of Medicine in 1968. He received a master's degree from the Harvard School of Public Health in 1976. He is board certified in Pediatrics as well as Public Health and General Preventive Medicine. Dr. Falk arrived at the Centers for Disease Control and Prevention (CDC) in 1972. He is also a 30-year veteran of the U.S. Public Health Service Commissioned Corps. This service culminated with his being named rear admiral and an appointment as Assistant U.S. Surgeon General.

Throughout his career at CDC, Dr. Falk has brought learning and leadership to myriad public health projects around the country and the world. His work includes contributions to the federal responses to Three Mile Island, Mount St. Helens, Hurricanes Hugo and Andrew, and the terrorist attacks of September 11, 2001.

Dr. Falk has written or co-written more than 100 publications in a variety of subjects, including vinyl chloride-induced liver cancer, prevention of lead poisoning, and health effects of environmental hazards. Widely recognized for his distinguished work and service, his honors include the Vernon Houk Award for Leadership in Preventing Childhood Lead Poisoning and the Homer C. Calver Award from the American Public Health Association. He has also received CDC's William C. Watson Jr. Medal of Excellence, as well as the Distinguished Service Award from the U.S. Public Health Service.

William J. Fisk, B.S., M.S.

William J. Fisk, B.S., M.S., is a Senior Staff Scientist and the Department Head of the Indoor Environment Department at the Lawrence Berkeley National Laboratory, managed by the University of California. The Department staff of 60 conducts research on building ventilation, indoor environmental quality, energy use, exposure and risk assessment, and the relationship of indoor environmental quality to health and work performance. In addition to department leadership since 2000, Mr. Fisk has conducted research for 25 years at Lawrence Berkeley National Laboratory on indoor environmental quality. His current research focuses on technologies for ventilating and controlling indoor air quality, on the relationships of indoor air quality and related building characteristics with health, and on the economic consequences of indoor environmental quality.

Mr. Fisk serves on the Editorial Board for the journal *Indoor Air*, was elected to the international Academy of Indoor Air Sciences in 1999, and has served on National Academy of Sciences – Institute of Medicine committees on Asthma and Indoor Air Quality and on Damp Buildings, Mold and Health. He also served for several years on the National Occupational Research Agenda – Indoor Environment Team and has been active in the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE).

Mr. Fisk received his M.S. and B.S. degrees in mechanical engineering from the University of California, Berkeley and the University of New Mexico, respectively.

John R. Girman, M.S.

John R. Girman is the Center Director for the U. S. Environmental Protection Agency (EPA) Indoor Environments Division Center for Analysis and Studies. His Center is responsible for the technical analysis and content of reports and guidance documents on indoor air quality, as well as for providing technical input into policy decisions and developing research agendas for indoor air quality. The Center is currently developing priorities for research on indoor air quality, developing criteria for good indoor air quality in homes, examining economic considerations for indoor air quality, analyzing data from a major national survey of baseline indoor air quality and occupant perceptions in office buildings (the BASE Study) and developing a strategy for Indoor Air Toxics.

Previously, Mr. Girman was the Deputy Manager of California's Indoor Air Quality Program and a Group Leader in Lawrence Berkeley Laboratory's Indoor Environment Program. He has worked on indoor air quality for more than 25 years, including research on combustion appliance emissions, volatile organic emissions from building materials and consumer products, instrument development and protocols, study design and risk assessment. Mr. Girman has authored or co-authored more than 60 publications and reports on indoor air quality. He is a founding member of the International Society of Indoor Air Quality and Climate (ISIAQ) and has served as its Vice President (Policy) and as a Trustee. He also served as an Editorial Advisor for the journal *Indoor Air*, as a Councilor for the International Society of Exposure Assessment (ISEA) and a member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE)

Environmental Health Committee. He has been elected to the International Academy of Indoor Air Quality Sciences.

Some of his accomplishments include initiating and conducting EPA's Building Assessment Survey and Evaluation Study (BASE) and supervising development of the EPA guidance for improving indoor air in schools, *IAQ Tools for Schools*. He also supervised the laboratory development and a comparative field validation of a commercially successful formaldehyde passive sampler and directed research to determine and model the organic emissions from consumer products, including comparisons of average concentrations and breathing-zone concentrations and a field validation of a model. He also conducted an epidemiologic study of carbon monoxide poisonings in California and a major field study of residential radon concentrations. He was co-chair of the committee that developed California's Minimum Ventilation Standard, the first state-operational ventilation standard, and he conducted a chamber emissions and modeling study for the California Attorney General in support of Proposition 65 that led to a national consumer product recall and reformulation and a substantial financial settlement for the State of California.

James E. Hill, Ph.D.

James E. Hill, Ph.D., joined the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards [NBS]) as a Mechanical Engineer in the Thermal Engineering Section, Center for Building Technology, in September 1972. He served as Leader of the Thermal Solar Group from 1978 to 1980 and Chief of the Building Equipment Division from June 1980 until October 1986 when the Division was expanded and reorganized as the Building Environment Division. During 1983, Dr. Hill served as a Program Analyst in the NBS Office of the Director. Dr. Hill resumed his duties as Division Chief in January 1984. From 1994 to 1997, Dr. Hill was on a part-time assignment in the NIST Advanced Technology Program administering a three-year program on Refrigeration Technology. Dr. Hill served as Deputy Director of the Building and Fire Research Laboratory from February 1999 to October 2003. His responsibilities included strategic planning, program and professional development for the Laboratory. In October 2003, he was appointed Director of the Building and Fire Research Laboratory. Dr. Hill was Assistant Professor of Mechanical Engineering at the University of Maryland for 3 years before joining NBS in 1972.

Dr. Hill is a member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), has held numerous positions on committees and councils of the Society since 1972, and was the Society's President in 1996–1997. He was named a Fellow of ASHRAE in 1992 and received their Distinguished Service Award in 1995. He held student memberships in Tau Beta Pi, Pi Tau Sigma, Omicron Delta Kappa, and Phi Kappa Phi. He is listed in the 11th edition of American Men of Science. He received the Crosby Field Award from ASHRAE for the best overall Technical Paper in 1975 and received an additional ASHRAE award in 1976 for the Best Technical Paper presented at the 1976 Seattle Annual Meeting. He received the 1976 Department of Commerce (DOC) Silver Medal for "significant national and international contributions to the development of efficient solar energy systems." He has authored over 60 technical papers in the building research/solar energy area.

In 1988 and 1998, the President of the United States conferred the rank of Meritorious Executive in the Senior Executive Service on Dr. Hill. From 1985–1991, Dr. Hill served on the advisory committee for the Architectural and Engineering Department at the Pennsylvania State University and is currently on the advisory committee for the Mechanical Engineering Department of Georgia Institute of Technology and the Environmental Energy Technologies Division of the Lawrence Berkeley Laboratory. In 1994, Dr. Hill was named DOC-NIST Engineer of the Year and received the DOC Gold Medal for "significant technical leadership in mechanical engineering research to improve environmental systems of buildings."

Dr. Hill received a B.S. degree in Mechanical Engineering (1963) from Virginia Polytechnic Institute and M.S. and Ph.D. degrees in Mechanical Engineering (1971, 1973) from Georgia Institute of Technology.

Michael Hodgson, M.D., M.P.H.

Michael Hodgson, M.D., M.P.H., is Director, Occupational Health Program, Office of Public Health and Environmental Hazards, Veterans Health Administration. Dr. Hodgson began work on health and the built environment in 1981 as an Epidemic Intelligence Service Officer for the Centers for Disease Control (CDC), investigating outbreaks of disease in wet and "moldy" buildings, leading the National Institute for Occupational Safety and Health (NIOSH)/CDC's 1984 guidance on moisture control in the workplace. He has studied objective health outcomes, symptoms, and exposures in a wide variety of settings (schools, office buildings, homes, and health care) focused on moisture and bioaerosols and on volatile emissions. He has worked on novel strategies to document health effects, on questionnaire use, and on causal relationships between symptoms and a wide variety of exposures (humidity, volatile organic compounds, bioaerosols, work organization/stress, and thermal comfort).

Dr. Hodgson has been active in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) since 1985 and was a member of several ASHRAE committees: he was chair of the Environmental Health Committee for 3 years, a voting and non-voting member of the Standing Standards Project Committee 62 (Ventilation for Acceptable Air Quality), and a corresponding member for Thermal Comfort. He was also on the steering committee for several of the International Conferences on Indoor Air Quality and Climate. Additional formal research interests have included metabolic bone disease in uremia and calcium homeostasis, the effects of organic solvents on the liver and brain, low-level environmental exposures on chronic diseases of adults, and healthcare worker hazards.

Dr. Hodgson attended medical school at the Universities of Wuerzburg, Heidelberg, and Frankfurt, where he obtained his M.D. degree in 1975. He obtained an M.P.H. in epidemiology from the University of Pittsburgh School of Public Health in 1985. Dr. Hodgson is board-certified in internal medicine (residency at DC General Hospital and the Washington, DC Veterans Administration Medical Center and in occupational medicine (CDC/NIOSH). He served as a commissioned officer in the Epidemic Intelligence Service, Public Health Service, CDC (1981–1983); was director of the Occupational and Environmental Medicine Program in the Department of Medicine at the University of Pittsburgh School of Medicine (1986–1991); and established and directed a residency program in occupational medicine at the University of Connecticut (1991–

1998). In 1998 and 1999, he served as a Senior Scientist in the Office of the Director, NIOSH, before moving to the Veterans Health Administration.

David E. Jacobs, Ph.D., CIH

David Jacobs, Ph.D., is with the Office of Community Planning and Development at the U.S. Department of Housing and Urban Development (HUD). He has worked on lead-based paint and healthy homes issues, and related research, public education, regulatory, enforcement and training activities. He has testified before Congress on several occasions and has published numerous scientific papers and other articles. He holds degrees in Environmental Engineering, Science and Technology Policy, Environmental Health, and Political Science and is a board-certified industrial hygienist. He is a principal author of the President's Task Force report on childhood lead poisoning prevention, the HUD Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing, and several reports to Congress.

Kevin Kampschroer

Kevin Kampschroer is the Director of Research Expert Services for the General Services Administration's (GSA) Public Buildings Service (PBS). Focusing on the relationships among the physical environment, individual and group behavior and organizational performance, Mr. Kampschroer has developed a framework—of building + behavior + business—tested in real office conditions, that is unique. His research team's goal is a fundamental re-thinking of the practice of workplace making. To support this ground-breaking effort, he has forged alliances with key forward-thinking companies, and developed collaborations with leading universities, including Carnegie Mellon, University of California at Berkeley, Georgia Institute of Technology, University of Michigan, and MIT.

Before establishing PBS' research and workplace innovations initiatives, Mr. Kampschroer served in a variety of GSA regional and headquarters positions. He contributed to the creation of real estate portfolio management, establishment of performance measures linked to pay and budget, and he developed an overall information technology strategy for a re-engineered real estate business in GSA. He was the project manager for the Ronald Reagan Federal Building and Trade Center, then the second largest office building in the United States. He has been employed by GSA since 1975. Mr. Kampschroer is a graduate of Yale University.

Mr. Kampschroer has lectured at Harvard, MIT, Johns Hopkins and Georgia Institute of Technology and frequently presents for various industry groups such as CoreNet Global. He is the Research Chair for the Advanced Building Systems Integration Consortium (at Carnegie Mellon University) and the Industry Partner Chair for the Center for the Built Environment (at the University of California at Berkeley), and the recipient of the International Interior Design Association's (IIDA) Star Award for 2004.

In creating the WorkPlace 20•20 program, Mr. Kampschroer and his team have applied all the research completed to date, together with best practices in the field to create a new process that emphasizes organizational performance before design. In its pilot stage, Workplace 20•20 will

develop and deliver between 25 and 40 projects for federal customers over the next 3–4 years. Each project couples the new workplace-making process with research in the ultimate effectiveness of spatial objectives to influence productivity and organizational performance.

Kathleen Kreiss, M.D.

Kathleen Kreiss, M.D., is Branch Chief for the Field Studies Branch of the Division of Respiratory Disease Studies (DRDS) of the National Institute for Occupational Safety and Health (NIOSH). She is also Adjunct Professor, Department of Community Health, West Virginia University School of Medicine. From 1992 to 1996, she served as Residency Director, Occupational and Environmental Medicine Residency/Fellowship at the University of Colorado School of Medicine.

Dr. Kreiss was Director, Occupational and Environmental Medicine Division, Department of Medicine, National Jewish Center for Immunology and Respiratory Medicine in Denver, CO, as well as Assistant Associate (1989) and Full (1995) Professor, Department of Preventive Medicine and Biometrics Department of Medicine, University of Colorado School of Medicine.

She received her M.D. degree from Harvard University and completed her internship at San Francisco General Hospital and residencies at Beth Israel Hospital, Boston, and the Centers for Disease Control and Prevention (CDC). She received a B.A. degree in Biology from Radcliffe College. At CDC, she served as Epidemic Intelligence Service Officer, Center for Environmental Health, and Acting Chief, Special Studies Branch, Chronic Diseases Division.

Dr. Kreiss is co-author of "Improving the health of workers in indoor environments: priority research needs for a national occupational research agenda," published in the *American Journal of Public Health* (2002), and author of "Building-related asthma," published in *Clearing the Air, Asthma and Indoor Air Exposures*; Institute of Medicine: Committee on the Assessment of Asthma and Indoor Air (2000), as well as many other publications.

Hal Levin, B.Arch., ASHRAE Fellow

Hal Levin, B.Arch., ASHRAE Fellow, is a Research Architect with Building Ecology Research Group, Santa Cruz, California, and Scientist, Indoor Environment Department, Lawrence Berkeley National Laboratory. Mr. Levin has conducted research on the impact of buildings on occupant health and comfort as well as on the larger environment. For more than 26 years, he has been involved in research that includes the integration of knowledge about indoor and outdoor air pollution and other risk factors into the design of residential, educational, and commercial buildings and communities. He has been involved in many efforts to design buildings with minimal negative impact on occupants or the larger environment from ventilation design, building materials selection, energy consumption, and total environmental quality. He has been a strong proponent of life-cycle analysis and risk assessment as indicators of the sustainability of alternative designs, practices and buildings.

In addition to his academic and research activities, Mr. Levin has been active in professional education workshops and short courses on topics that include pollution prevention and indoor environmental quality management for schools, offices, and residences. He is a contributor to chapters in several books including *Indoor Air Quality Handbook* (McGraw-Hill, 2001). He is an Associate Editor of the journal *Indoor Air*, and serves on the Editorial Board of the journal *Building Research and Information*. He served as Vice-President (1997–2000) of the International Society of Indoor Air Quality and Climate (ISIAQ) and was founding chairman (1984–present) of American Society for Testing and Materials (ASTM) Subcommittee D22.05 on Indoor Air. He was the founding editor of the newsletter *Indoor Air Quality Update* and the founding editor and publisher of the newsletter *Indoor Air Bulletin*.

Mr. Levin is a member of the Air & Waste Management Association, the International Society of Indoor Air Quality and Climate (founding member), the International Society of Exposure Analysis (founding member), the American Chemical Society, the North American Solar Energy Society, and Society for Environmental Toxicology and Chemistry. Currently, Mr. Levin is chairman of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)'s Guideline Project Committee 10P, Criteria for Achieving Acceptable Indoor Environments, and a member of ASHRAE Standing Standard Project Committee (SSPC) 55, Thermal Conditions for Human Occupancy. Mr. Levin served for 10 years as a member of ASHRAE SSPC62, Ventilation and Indoor Air Quality, and for two 4-year terms as a member of ASHRAE's Environmental Health Committee. He also serves as a voting member of ASHRAE Technical Committee 2.1, Physiology and the Human Environment. He serves as a consultant to European Regional Office for Health of the World Health Organization on Children's Health and the Environment. He has consulted to government agencies in Denmark, Canada, and Australia among others, and he has lectured extensively in North America, Europe, Japan, and Australia.

Mr. Levin was chosen by the International Academy of Indoor Air Sciences to serve as President of the 9th International Conference on Indoor Air Quality and Climate, Indoor Air 2002, held in Monterey, California. He also organized and serves as President of the non-profit Indoor Air 2002 Inc. which, in addition to being responsible for administration of Indoor Air 2002, has also prepared and is publishing five post-conference journal special issues or supplements with papers expanded from the Indoor Air 2002 conference papers. He has served as an international advisor to Indoor Air '90, Indoor Air '93, Indoor Air '96, and Indoor Air '99. He has also served on the advisory committees of several "Healthy Buildings" conferences including HB2006 (Lisbon) and Indoor Air 2005 (Beijing), and is Convener for the Indoor Environment section of Sustainable Buildings 2005 (Tokyo).

Mr. Levin received a B.A. degree in English and a B. Architecture degree from the University of California, Berkeley. From 1978 to 1989, he was Research Specialist at the College of Environmental Design, and from 1978 to 1983, Lecturer in the Department of Architecture, University of California, Berkeley. From 1979 to 1983, he was Lecturer in the Board of Studies in Environmental Studies, University of California, Santa Cruz.

Vivian Loftness, B.S., M.Arch., F.A.I.A.

Vivian Loftness, B.S., M.Arch., FAIA, is Professor of Architecture at Carnegie Mellon University, Pittsburgh, PA, and recently completed 10 years as Head of the School of Architecture. She also serves as Senior Researcher of the Center for Building Performance and Diagnostics at Carnegie Mellon. She is an internationally renowned researcher, author, and educator with over 30 years of focus on environmental design and sustainability, advanced building systems and systems integration, and climate and regionalism in architecture, as well as design for performance in the workplace of the future.
Supported by a university-building industry partnership, the Advanced Building Systems Integration Consortium, she is a key contributor to the development of the Intelligent Workplace, a living laboratory of commercial building innovations for performance. She has authored a range of publications on international advances in the workplace. She has served on six National Academy of Science panels, is a member of the Academy's Board on Infrastructure and the Constructed Environment, and has given three Congressional testimonies on sustainable design. Her work has influenced both national policy and building projects, including the Adaptable Workplace Lab at the U.S. General Services Administration and the Laboratory for Cognition at Electricité de France.

Over the past 5 years, Ms. Loftness has led the BIDS™ (Building Investment Decisions Support) research effort, with over 150 case studies linking environment, health, and productivity to life-cycle decision-making and the quality of the built environment. As a result of her research, teaching, and professional consulting, she received the 2002 National Educator Honor Award from the American Institute of Architecture Students and a 2003 "Sacred Tree" Award from the U.S. Green Building Council (USGBC).

Ms. Loftness has Bachelors of Science and Masters of Architecture degrees from the Massachusetts Institute of Technology. She is on the National Board of the USGBC, American Institute of Architects Committee on the Environment (AIACOTE) (2005 national chair), Technical and Scientific Advisory Committee (TSAC), Advanced Research and Technology Institute (ARTI), International Design Center for the Environment (IDCE), and the Department of Energy's Federal Energy Management Advisory Council (FEMAC). She is a Leadership in Energy and Environmental Design (LEED)-accredited registered architect, and a Fellow of the American Institute of Architects.

Clifford S. Mitchell, M.S., M.D., M.P.H.

Clifford S. Mitchell, M.S., M.D., M.P.H., is an Associate Professor of Environmental Health Sciences at the Johns Hopkins Bloomberg School of Public Health. A graduate of Williams College, he attended medical school at Case Western Reserve University and holds Masters degrees in Technology and Policy from MIT and in Public Health from Johns Hopkins University. He is board certified in both Internal Medicine and Preventive (Occupational) Medicine and has been on the faculty of the School of Public Health since 1992. He currently serves as Director of the Occupational Medicine Residency, and his research and clinical practice focus on the health effects of indoor environmental exposures.

Thomas A. E. Platts-Mills, M.D., Ph.D.

Thomas A. E. Platts-Mills, M.D., Ph.D., is the Oscar Swineford Jr. Professor of Medicine and Head of the Asthma and Allergic Disease Center at the University of Virginia. Dr. Platts-Mills is vice president of the American Academy of Allergy Asthma and Immunology (AAAAI) and has been active in educational efforts nationally for 20 years. He has published over 300 papers and has been a member of the Editorial Board of more than 10 journals. In addition, he was a member of the Immunological Sciences Study Section for the National Institutes of Health and in 2003 was chairman of the special interest study section on Asthma and Allergic disease for the National Institute of Allergy and Infectious Diseases (NIAID).

Dr. Platts-Mills has also served on the National Asthma Education and Prevention Program (NAEPP) for the National Heart, Lung, and Blood Institute (NHLBI). He has trained more than twenty specialists in Allergic Disease and has supervised eight Ph.D. candidates. He received his degree in Animal Physiology from Oxford University (1963) and received an M.D. degree from St. Thomas Hospital. In 1981 he was made a member of the Royal College of Physicians in London and become a fellow in 1982. He did his training in Allergy and Immunology with Dr. Ishizaka and Dr. Lichtenstein at Johns Hopkins (1971–1974) and in 1983 received a Ph.D. in Immunology from London University.

Dr. Platts-Mills has carried out research in many different aspects of the role of indoor allergens in asthma. Starting with the characterization of the major dust mite allergen (Der p 1) his group developed the first assays for mite allergen and defined the form in which dust mite allergen becomes airborne. In addition, their assays were used to define the evidence for allergen exposure in the development of asthma and the scientific basis for allergen avoidance in the treatment of asthma. Those studies have been extended to the investigation of risk factors for acute episodes of asthma, focusing on emergency room and hospitalized patients. The results provided better evidence about the relevance of indoor allergens and also about the relevance of different allergens in different communities.

CAPT Stephen C. Redd, M.D.

Captain Stephen C. Redd, M.D., is Chief of the Air Pollution and Respiratory Health Branch of the National Center for Environmental Health, Centers for Disease Control and Prevention. Since assuming this position in 1997, Captain Redd has overseen development of a three-part branch strategy to reduce the health burden from asthma in the United States. The components of the strategy call for improving asthma tracking activities, implementing scientifically proven programs, and working in partnership. Captain Redd also serves as Co-chair of the Asthma Priority Area Workgroup, President's Task Force on Environmental Health Risks and Safety Risks to Children. He is a member of the National Advisory Council for two asthma initiatives sponsored by the Robert Wood Johnson Foundation: Improving Asthma Care for Children, and Allies Against Asthma. Over the past several years, the Air Pollution and Respiratory Health Branch has become increasingly involved in indoor air issues, particularly examining the health effects of exposure to indoor mold.

Jonathan M. Samet, M.D., M.S.

Jonathan M. Samet, M.D., M.S., is Professor and Chairman of the Department of Epidemiology of the Johns Hopkins University Bloomberg School of Public Health and the Jacob I. and Irene B. Fabrikant Professor in Health, Risk, and Society. Dr. Samet received a Bachelors degree in Chemistry and Physics from Harvard College, an M.D. degree from the University of Rochester School of Medicine and Dentistry, and a Master of Science degree in Epidemiology from the Harvard School of Public Health. He is trained as a clinician in the specialty of Internal Medicine and in the subspecialty of Pulmonary Diseases. From 1978 through 1994, he was a member of the Department of Medicine at the University of New Mexico.

At the Johns Hopkins University Bloomberg School of Public Health, he is Director of the Institute for Global Tobacco Control and Co-Director of the Risk Sciences and Public Policy Institute. His research has addressed the effects of inhaled pollutants in the general environment and in the workplace. He has written widely on the health effects of active and passive smoking and has served as Consulting Editor and Senior Editor for Reports of the Surgeon General on Smoking and Health and the National Cancer Institute's Monographs on Tobacco Control. He has edited books on the epidemiology of lung cancer and on indoor and outdoor air pollution, including *Indoor Air Pollution: A Health Perspective* (1991) and *The Indoor Air Quality Handbook* (2000). He has served on the Science Advisory Board for the U.S. Environmental Protection Agency and was Chairman of the Biological Effects of Ionizing Radiation Committee VI and the Committee on Research Priorities for Airborne Particulate Matter of the National Research Council. He presently chairs the Board on Environmental Studies and Toxicology of the National Research Council. He was elected to the Institute of Medicine of the National Academy of Sciences in 1997.

Dr. Samet is a member of the Society for Epidemiologic Research (President 1989–90), the American Thoracic Society, the American College of Epidemiology (President 2000–01), the International Society of Indoor Air Quality and Climate, the International Epidemiological Association, and the American Public Health Association. He also served as Chair of the Working Group on Smoking and Involuntary Smoking for the International Agency for Research on Cancer of the World Health Organization. He served as Chairman of the Epidemiology Cancer Study Section of the National Institutes of Health from 2002–2004 and is presently an Editor for *Epidemiology*. Dr. Samet serves as a member of the Awards Assembly of the General Motors Cancer Research Foundation and the Epidemiology Review Board of the I.E. duPont de Nemours and Company, Inc. Dr. Samet served as an expert witness in tobacco litigation brought by the state of Minnesota against the tobacco industry and recently served as an expert witness for the U.S. Department of Justice in the government's case against the tobacco industry. Dr. Samet served as the Senior Scientific Editor, as well as a chapter author, on the 2004 *Report of the Surgeon General: The Health Consequences of Smoking*. He is also serving as Senior Scientific Editor for the upcoming Surgeon General's Report on secondhand smoke.

Dr. Samet has received numerous awards for his research and public health service, including the Surgeon General's Medallion (1990), the Alumni Award of Merit, Harvard School of Public Health (2001), the Joseph W. Cullen Memorial Award from the American Society of Preventive

Oncology (2002), and the Dr. William Cahan Distinguished Professor Award from the Flight Attendant Medical Research (2003).

John D. Spengler, Ph.D.

John D. Spengler, Ph.D., is the Akira Yamaguchi Professor of Environmental Health and Human Habitation in the Exposure, Epidemiology and Risk Program, Department of Environmental Health, at Harvard University's School of Public Health, Boston, Massachusetts.

Professor Spengler has conducted research in the areas of personal monitoring, air pollution health effects, aerosol characterization, indoor air pollution and air pollution meteorology. More recently, he has been involved in research that includes the integration of knowledge about indoor and outdoor air pollution as well as other risk factors into the design of housing, buildings and communities. Several new efforts are underway to investigate housing design and its effects on ventilation rates, building materials selection, energy consumption, and total environmental quality in homes. The tools of life-cycle analysis and risk assessment and activity-based costing are being used as indicators to measure the sustainable attributes of alternative designs, practices and community development.

Professor Spengler has been active in professional education workshops and short courses on topics that include pollution prevention and indoor environmental quality management for schools, offices and hospitals, and distance learning courses (http://courses.dce.harvard.edu/~environment/). He is co-editor of three books: *Indoor Air Quality Handbook* (McGraw-Hill, 2001); *Particles in Our Air: Concentrations and Health Effects* (distributed by Harvard University Press, 1996); and *Indoor Air Pollution: A Health Perspective* (Johns Hopkins University Press, 1991). He is on the editorial board of the journal *Indoor Air*, and he is the President (2002–2005) of the International Academy of Indoor Air Sciences.

Professor Spengler is a member of the Air & Waste Management Association, the International Society of Indoor Air Quality and Climate (founding member), the International Society of Exposure Analysis (founding member), the American Meteorological Society, and the American Chemical Society. Currently, Professor Spengler is a member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)'s Environmental Health Committee. Recently, he served as a member of the National Research Council/National Academy of Sciences' Committee on Air Quality in Passenger Cabins of Commercial Aircraft (2000–2001). He has also served on the American Lung Association's National Air Conservation Commission (1997–1998) and on the Scientific Advisory Panel of the Mickey Leland National Urban Air Toxics Research Center (1995–1998). He serves as an advisor to the World Health Organization on indoor air pollution, personal exposure and air pollution epidemiology, and he has served as either a member or consultant on various U.S. Environmental Protection Agency Science Advisory Board committees. In 2003, Professor Spengler received a Heinz Award for the Environment.

Along with Dr. Douglas Dockery, Professor Spengler was a co-organizer of the international 1998 ISEE/ISEA Conference, held in Boston, MA (August 1998). From 1981, when the first

International Conference on Indoor Air Quality and Climates was held in Amherst, MA, to the present, Professor Spengler has served as a chair or co-chair for various technical sessions.

Professor Spengler received a B.S. degree in physics (1966) from the University of Notre Dame, a Ph.D. degree in atmospheric sciences (1971) from the State University of New York-Albany, and a M.S. degree in environmental health sciences (1973) from Harvard University.

Eileen Storey, M.D., M.P.H.

Eileen Storey, M.D., M.P.H., is the Co-Director of the Center for Public Health and Health Policy at the University of Connecticut, Chief of the Division of Occupational and Environmental Medicine, and Director of the Center for Indoor Environments and Health at the University of Connecticut Health Center. An occupational medicine physician and internist, she works with a team of physicians, nurses, industrial hygienists, and environmental health specialists to evaluate the impact of indoor environments on health, particularly respiratory conditions. Her research focuses on the spectrum of respiratory disease associated with indoor environments, with particular interest in the relationship between building-related upper respiratory syndromes (rhinitis, sinusitis) and the development of lower respiratory syndromes (asthma, hypersensitivity pneumonitis). Her team is working to develop exposure assessment tools that will help to better characterize indoor risk factors. The Center for Indoor Environments and Health provides support and consultation to employees, employers, building owners, school districts, and public health agencies to promote efforts at prevention and remediation in buildings.

Dr. Storey was a Fellow with the Oak Ridge Institute for Science and Education (ORISE), assigned to the Division of Respiratory Disease Studies at the National Institute for Occupational Safety and Health (NIOSH) in 2001–2002. She is Co-Leader of the National Occupational Research Agenda (NORA) Indoor Environment Team. She serves on the Executive Committee of the Asthma Regional Council in New England.

Dr. Storey provides clinical services for individuals with concerns about occupational and environmental exposure. Her group recently published a book in cooperation with the U.S. Environmental Protection Agency (EPA): *Guidance for Clinicians on the Recognition and Management of Health Effects Related to Mold Exposure and Moisture Indoors*. (oehc.uchc.edu/clinser/indoor.atm)

Dr. Storey completed her medical degree at the Harvard Medical School (1978), a Master of Public Health at the Harvard School of Public Health (1978), and Internal Medicine training at West Virginia University in Morgantown, WV (1981). She is board certified in Internal Medicine and Occupational Medicine.

RADM Robert C. Williams, P.E., DEE

Rear Admiral Robert C. Williams has more than 25 years of experience in environmental engineering. He is the Chief Engineer of the U.S. Public Health Service, providing advice and consultation on public health engineering matters to the Surgeon General and to over 1200

engineers in the Public Health Service. He is also is the Chief of Staff, Office of the Surgeon General (OSG). Prior to his assignment to the OSG in 2004, he served as the Director, Division of Health Assessment and Consultation of the Agency for Toxic Substances and Disease Registry (ATSDR) since 1989. He received his B.S. in Civil Engineering and M. Eng. in Environmental Engineering from Texas A&M University and has continued his postgraduate education with courses in public health.

Rear Admiral Williams is a Registered Professional Engineer and serves, or has served, as an officer and member of national committees for several professional organizations including American Water Works Association, Water Environment Federation, American Society of Civil Engineers (ASCE Fellow Grade), Society of American Military Engineers (SAME Fellow) and the Commissioned Officers Association of the U.S. Public Health Service. He has been a Diplomate since 1992 and has served in various positions with the American Academy of Environmental Engineers (AAEE), including the Board of Trustees and his current position on the Certification by Eminence Committee. Rear Admiral Williams served on the Governing Board of the ASCE Environmental and Water Resources Institute from its inception until 2004. He currently serves on the Board of Directors of the Society of American Military Engineers.

He is an Adjunct Associate Professor at the Texas A&M University School of Rural Public Health and a member of the Emory University Academic Advisory Council, responsible for developing the University's environmental health curriculum. He has authored and presented more than 100 publications on a wide variety of environmental health issues, including the co-editing of four books.

Rear Admiral Williams received the Stanley Kappe Award from the AAEE in 2004. He has received the CFEE Federal Environmental Engineer of the Year, USPHS Engineer of the Year, and NSPE Top Ten Federal Engineers. He received the Gorgas Medal from the Association of Military Surgeons of the United States and the ASCE Government Engineer of the Year in 2003. He is the recipient of the USPHS Meritorious Service Medal, two Outstanding Service Medals, three Commendation Medals, an Achievement Medal, Crisis Response Service Award, and ten Unit Commendation Medals. He has received several group awards including the DHHS Secretary's Distinguished Service Award, SAME Cumming Plaque, and ATSDR/CDC Honor Awards for Public Health Practice. He has also received several awards from professional organizations (e.g., ASCE Best Practice Paper) for his efforts in environmental engineering.

Samuel H. Wilson, M.D.

Samuel H. Wilson, M.D., is Deputy Director of the National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health (NIH), Research Triangle Park, NC. A biochemist, he began his career as a Principal Investigator in 1970 at the NIH and remained there until 1991 when he moved to the extramural community to found a center focused in the area of genetic toxicology, structural biology, and functional genomics. Dr. Wilson moved to NIEHS as Deputy Director in 1996, where he has been instrumental in helping develop NIEHS programs in genetic susceptibility, functional genomics, children's health, minority institutions' research, health disparities research, and community involvement. Dr. Wilson has strengthened partnerships between NIEHS and other federal agencies concerned with environmental health and with

the private sector. He has worked with the Institute of Medicine, National Academies of Science, to develop a Roundtable promoting discussions on long-term planning and a broader definition of environmental health, and he has worked with the National Research Council to develop a Committee addressing issues relevant to the applications of toxicogenomics.

Dr. Wilson has a long-term research interest in mammalian DNA metabolism. Over the past 15 years, he and his associates have focused their efforts on the mammalian base excision DNA repair pathway. Their work has improved our understanding of maintenance of genomic stability in mammalian cells. Dr. Wilson has authored and co-authored 300 research publications and has been editor of four reference volumes.

Dr. Wilson's recent activities include membership on numerous federal agency advisory groups. He has served as a scientific advisor to several private foundations involved in biomedical research. He was chair of the 2001 Mammalian DNA Repair Gordon Research Conference and co-chair of the 2002/2004 US-Japan and 2003 US-EU international conferences on DNA Repair. He is Associate Editor of *DNA Repair* and a member of the editorial board of the *Annual Review of Medicine*.

Dr. Wilson received a Bachelor of Arts degree in Chemistry from the University of Denver in 1961. He received his graduate and postdoctoral training in medicine and biochemistry at Harvard Medical School and the NIH, respectively.

James E. Woods, Ph.D., P.E., ASHRAE Fellow

James E. Woods, Ph.D., P.E., is the Executive Director of The Building Diagnostics Research Institute, Inc., in Chevy Chase, Maryland. In 1997 he retired as the William E. Jamerson Professor of Building Construction at Virginia Polytechnic Institute and State University. Previously, he served as Senior Engineering Manager and Senior Staff Scientist at Honeywell, and was Professor of Mechanical Engineering and Architecture at Iowa State University. He has over 40 years of experience in energy and environmental analyses and has been responsible for more than 25 research projects and 200 investigations related to indoor environmental quality and human responses in residences, office buildings, public assembly and monumental buildings, hospitals, schools, laboratories, and commercial aircraft.

Dr. Woods has authored or co-authored six books and more than 200 technical papers and is the co-holder of two patents. He has served as a consultant or advisor to many private and public agencies, including design engineering and architectural firms, insurance companies, law firms, utility companies, state energy agencies, the U.S. General Services Administration, the U.S. Department of Energy, the National Institute of Standards and Technology, the U.S. Environmental Protection Agency, the U.S. Department of State, the Architect of the Capitol, the National Energy Management Institute, the National Center for Energy Management and Building Technology, the American Hospital Association, the American Lung Association, and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

Dr. Woods is an ASHRAE Fellow and Life Member. He has chaired and served on numerous ASHRAE committees related to indoor air quality, environmental health, industrial air condition-

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A Founding Member of the International Society of Indoor Air Quality and Climate (ISIAQ), Dr. Woods chaired the Organizing Committee for the international conference *Healthy Buildings/Indoor Air Quality 97* at Natcher Center, and is a Member of the International Academy of Indoor Air Sciences. He has served on the Science Advisory Board for the EPA, on the Technical Advisory Committee for the American Lung Association, on the Science Advisory Board for the Center for Indoor Air Research, and on several committees of the National Research Council.

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Appendix C

Acknowledgments

Surgeon General's Workshop on Healthy Indoor Environment

The Surgeon General expresses his sincere appreciation to all who contributed time, experience, and knowledge to support the development of the Surgeon General's Workshop on Healthy Indoor Environment and this report. The Surgeon General would especially like to acknowledge the following:

THE ENGINEER PROFESSIONAL ADVISORY COMMITTEE

The Engineer Professional Advisory Committee (EPAC) provides advice and consultation to the U.S. Public Health Service (PHS) Chief Engineer, who in turn reports to the Surgeon General on matters relating to professional engineering issues. As part of its efforts to advance public health engineering and improve the health status of Americans, the various members of the Building and Design Subcommittee, EPAC, have worked diligently for several years to foster the development of this workshop. Their dedication to this initiative truly reflects the PHS Engineering Category motto of *Machinatores Vitae* (Engineering for Life).

THE PUBLIC

Approximately 300 people attended the Surgeon General's Workshop on Healthy Indoor Environment. The participants provided valuable insight concerning the indoor environment, which help guide the development of this report.

GOVERNMENT AGENCIES

The Surgeon General's Workshop on Healthy Indoor Environment was sponsored by the following government agencies in the Department of Health and Human Services:

- Agency for Toxic Substances and Disease Registry
- Centers for Disease Control and Prevention
- National Institutes of Health

In addition, the following federal agency and federal council sponsored the workshop:

- U.S. Environmental Protection Agency
- National Science and Technology Council

PLANNING AND COORDINATION GROUP

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