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 housing: 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 standardized 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), communicable 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 inter-related 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).