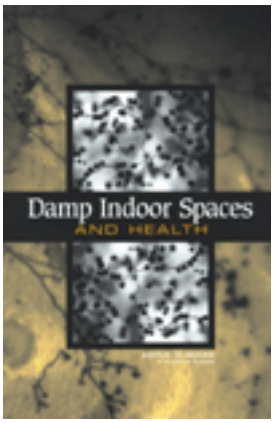
Free Executive Summary



Damp Indoor Spaces and Health

Committee on Damp Indoor Spaces and Health
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Almost all homes, apartments, and commercial buildings will experience leaks, flooding, or other forms of excessive indoor dampness at some point.Not only is excessive dampness a health problem by itself, it also contributesto several other potentially problematic types of situations. Molds and othermicrobial agents favor damp indoor environments, and excess moisture mayinitiate the release of chemical emissions from damaged building materialsand furnishings. This new book from the Institute of Medicine examines thehealth impact of exposures resulting from damp indoor environments andoffers recommendations for public health interventions.Damp Indoor Spaces and Health covers a broad range of topics. The booknot only examines the relationship between damp or moldy indoor environmentsand adverse health outcomes but also discusses how and wherebuildings get wet, how dampness influences microbial growth and chemicalemissions, ways to prevent and remediate dampness, and elements ofa public health response to the issues. A comprehensive literature reviewfinds sufficient evidence of an association between damp indoor environmentsand some upper respiratory tract symptoms, coughing, wheezing,and asthma symptoms in sensitized persons. This important book will be ofinterest to a wide-ranging audience of science, health, engineering, andbuilding professionals, government officials, and members of the public.

Executive Summary

A damp spot appears in a ceiling after an intense rainstorm; a hose loosens from a washing machine, spilling gallons of water onto a basement floor; weeks after a moldy odor is detected, a plumber finds a slow leak behind a wall. There are over 119 million housing units in the United States and nearly 4.7 million commercial buildings (U.S. Census Bureau, 2003), and almost all of them experience leaks, flooding, or other forms of excessive indoor dampness at some time.

Excessive indoor dampness is not by itself a cause of ill health, but it is a determinant of the presence or source strength of several potentially problematic exposures. Damp indoor environments favor house dust mites and microbial growth, standing water supports cockroach and rodent infestations, and excessive moisture may initiate chemical emissions from building materials and furnishings.

Indoor microbial growth—especially fungal growth—has recently received a great deal of attention in the mass media. It is a prominent feature of the breakdown of dampness control; its many possible causes include a breach of the building envelope, failure of a water-use device, and excessive indoor water-vapor generation. Occupants, health professionals, and others have wondered whether indoor exposure to mold and other agents might have a role in adverse health outcomes experienced by occupants of damp buildings. Prominent among these health outcomes is acute idiopathic pulmonary hemorrhage in infants, cases of which were reported in Cleveland, Ohio in the 1990s. Residence in homes with recent water dam-

age and in homes with visible mold (including *Stachybotrys chartarum*) was among the risk factors identified in the case infants.

Against that backdrop, the Centers for Disease Control and Prevention (CDC) asked the Institute of Medicine to convene a committee of experts. CDC provided the following charge to that committee:

> The Institute of Medicine will conduct a comprehensive review of the scientific literature regarding the relationship between damp or moldy indoor environments and the manifestation of adverse health effects, particularly respiratory and allergic symptoms. The review will focus on the non-infectious health effects of fungi, including allergens, mycotoxins and other biologically active products. In addition, it will make recommendations or suggest guidelines for public health interventions and for future basic science, clinical, and public health research in these areas.

FRAMEWORK AND ORGANIZATION

Figure ES-1 describes the path by which water or moisture sources may lead to excessive indoor dampness and to exposures that may result in adverse health outcomes. The elements of this framework are reflected in the major topics addressed in the report:

- How and where buildings become wet, the signs of dampness, how dampness is measured, the risk factors for moisture problems, and what is known about their prevalence, severity, location, and duration (Chapter 2).
- How dampness influences indoor microbial growth and chemical emissions, the various agents that may be present in damp environments, and the influence of building materials on microbial growth and emissions (Chapter 2).
- The means available for assessing exposure to microorganisms and microbial agents that occur in damp indoor environments (Chapter 3).
- The experimental data on the nonallergic biologic effects of molds and bacteria, including the bioavailability of mycotoxins and toxic effects seen in cellular (in vitro) and animal (in vivo) toxicity studies of mycotoxin and bacterial toxin exposure (Chapter 4).
- The state of the scientific literature regarding health outcomes and indoor exposure to dampness and dampness-related agents (Chapter 5).
- Dampness prevention strategies, published guidelines for the removal of fungal growth (remediation), remediation protocols, and research on the effectiveness of various cleaning strategies (Chapter 6).
- The public health implications of damp indoor environments and the elements of a public health response (Chapter 7).

The committee faced a substantial challenge in conducting its review of these topics—research on fungi and other dampness-related agents is bur-

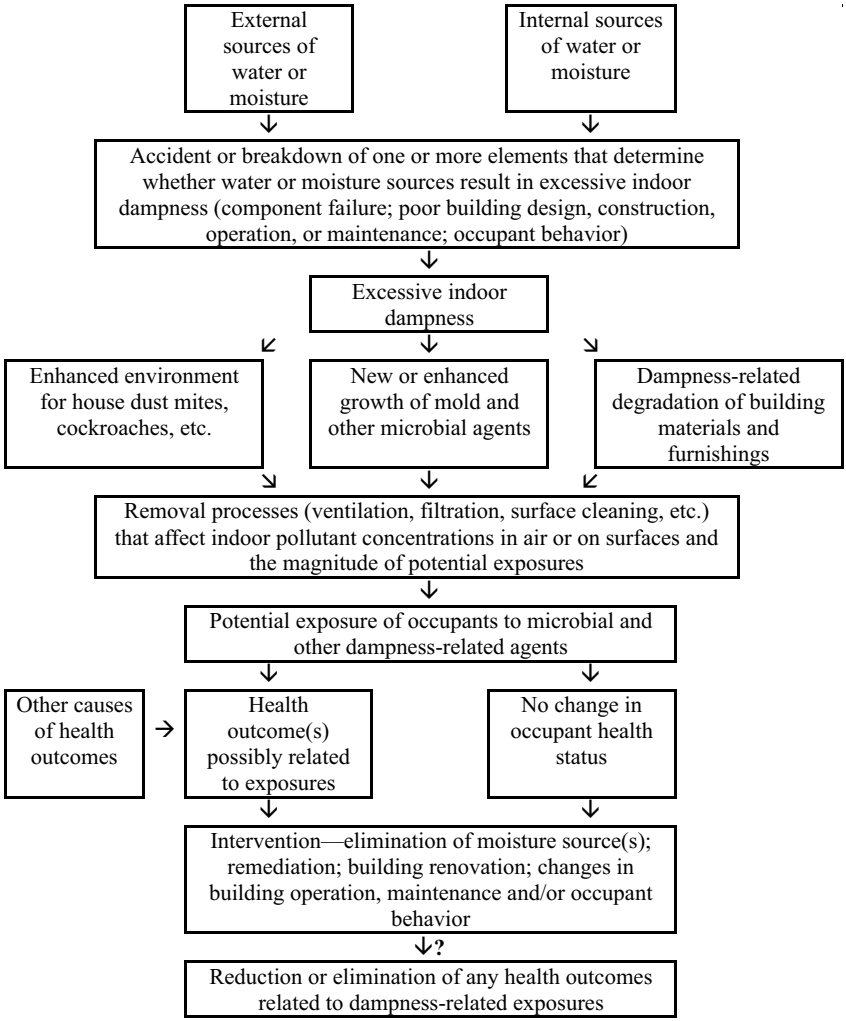

FIGURE ES-1 A framework describing the potential for water and moisture sources to lead to excessive indoor dampness and to exposures that may result in adverse health outcomes.

geoning, and important new papers are constantly being published. Although the committee did its best to paint an accurate picture of the state of the science at the time its report was completed in late 2003, it is inevitable that research advances will extend beyond the report's findings.

The sections below are a synopsis of the committee's major findings and recommendations, and the research needs they identified. Chapters 2–7 detail the reasoning underlying these and present the committee's complete findings.

THE COMMITTEE'S EVALUATION

Damp Buildings

The term *dampness* has been used to define a variety of moisture problems in buildings, including high relative humidity, condensation, water ponding, and other signs of excess moisture or microbial growth. While studies report that dampness is prevalent in residential housing in a wide array of climates, attempts to understand its scale and significance are hampered by the fact that there is no generally accepted definition of *dampness* or of what constitutes a "dampness problem."

There is no single cause of excessive indoor dampness, and the primary risk factors for it differ across climates, geographic area, and building types. Although the prevalence of dampness problems appears to increase as buildings age and deteriorate, the experience of building professionals suggests that some modern construction techniques and materials and the presence of air-conditioning also increase the risk of dampness problems. The prevalence and nature of dampness problems suggest that what is known about their causes and prevention is not consistently applied in building design, construction, maintenance, and use.

One consequence of indoor dampness is new or enhanced growth of fungi and other microbial agents. The fungi have (eukaryotic) cells like animals and plants, but are a separate kingdom. Most consist of masses of filaments, live off of dead or decaying organic matter, and reproduce by spores. Visible fungal colonies found indoors are commonly called mold or sometimes mildew. This report, following the convention of much of the literature on indoor environments, uses the terms *fungus* and *mold* interchangeably to refer to the microorganisms.

Mold spores are regularly found in indoor air and on surfaces and materials—no indoor space is free of them. There are a large number of species and genera, and those most typically found indoors vary by geographic area, climate, season, and other factors. The availability of moisture is the primary factor that controls mold growth indoors, since the nutrients and temperature range they need are usually present. While much attention is focused on mold growth indoors, it is not the only dampness-related microbial agent. Mold growth is usually accompanied by bacterial growth. Some research on fungi and bacteria focuses on specific compo-

nents that may be responsible for particular health effects: spores and hyphal fragments of fungi, spores and cells of bacteria, allergens of microbial origin, structural components of fungal and bacterial cells, and such products as microbial volatile organic compounds (MVOCs) and mycotoxins. Release of these components varies, depending on many physiologic and environmental factors. Dampness can also damage building materials and furnishings, causing or exacerbating the release of chemicals and nonbiologic particles from them.

Given the present state of the literature, the committee identified several kinds of research needs. Standard definitions of dampness, metrics, and associated dampness-assessment protocols need to be developed to characterize the nature, severity, and spatial extent of dampness. Precise, agreed-on definitions will allow important information to be gathered about the determinants of dampness problems in buildings and the mechanisms by which dampness and dampness-related effects and exposures affect occupant health. More than one definition may be required to meet the specific needs of health researchers (epidemiologists, physicians, and public-health practitioners) in contrast with those involved in preventing or remediating dampness (architects, engineers, builders, and those involved in building maintenance). However, definitions should be standardized to the extent possible. Any efforts to establish common definitions must be international in scope because excessive indoor dampness is a worldwide problem and research cooperation will promote the generation and dissemination of knowledge.

Research is also needed to better characterize the dampness-related emissions of fungal spores, bacteria, and other particles of biologic origin and their role in human health outcomes; the microbial ecology of buildings, that is, the link between dampness, different building materials, microbial growth, and microbial interactions; and dampness-related chemical emissions from building materials and furnishings, and their role in human health outcomes. Studies should be conducted to evaluate the effect of the duration of moisture damage of materials and its possible influence on occupant health and to evaluate the effectiveness of various changes in building designs, construction methods, operation, and maintenance in reducing dampness problems. Increased attention should be paid to heating, ventilation, and air conditioning (HVAC) systems as a potential site for the growth and dispersal of microbial contaminants that may result in adverse health effects in building occupants. And research should be performed to develop designs and construction and maintenance practices for buildings and HVAC systems that reduce moisture problems; building materials that are less prone to microbial contamination when moist; and standard, effective protocols for clean-up after flooding and other catastrophic water events that will minimize microbial growth.

Exposure Assessment

The lack of knowledge regarding the role of microorganisms in the development and exacerbation of diseases found in occupants of damp indoor environments is due largely to the lack of valid quantitative exposure-assessment methods and knowledge of which specific microbial agents may primarily account for the presumed health effects. Very few biomarkers of exposure to or dose of biologic agents have been identified, and their validity for exposure assessment in the indoor environment is often not known. The entire process of fungal-spore aerosolization, transport, deposition, resuspension, and tracking—all of which determine inhalation exposure—is poorly understood, as is the significance of exposures to fungi through dermal contact and ingestion.

There are several methods for measuring and characterizing fungal populations, but methods for assessing human exposure to fungal agents are poorly developed and are a high-priority research need. Part of the difficulty is related to the large number of fungal species that are measurable indoors and the fact that fungal allergen content and toxic potential vary among species and among morphologic forms within species. In addition, the most common methods for fungal assessment—counting cultured colonies and identifying and counting spores—have variable and uncertain relationships to allergen, toxin, and irritant content of exposures.

Based on their review of the literature, the committee recommends that existing exposure assessment methods for fungal and other microbial agents be subjected to rigorous validation and that they be further refined to make them more suitable for large-scale epidemiologic studies. This includes standardization of protocols for sample collection, transport of samples, extraction procedures, and analytical procedures and reagents. Such work should result in concise, internationally accepted protocols that will allow measurement results to be compared both within and across studies.

The committee also identified a need to develop improved exposure assessment methods, particularly methods based on nonculture techniques and techniques for measuring constituents of microorganisms—allergens, endotoxins, $\beta(1\rightarrow3)$-glucans, fungal extracellular polysaccharides, fungal spores, and other particles and emissions of microbial origin. These needs include further improvement of light and portable personal airborne exposure measurement technology, more rapid development of measurement methods for specific microorganisms that use DNA-based and other technology, and rapid and direct-reading assays for bioaerosols for the immediate evaluation of potential health risks. Application of the improved or new methods will allow more valid exposure assessment of microorganisms and their components, which should facilitate more-informed risk assessments.

Because only sparse data are available on variation in exposure to biologic agents in the home environment, it is not possible to recommend how many samples should be taken to produce an accurate assessment of risk-relevant exposure.

Toxic Effects of Fungi and Bacteria

Although a great deal of attention has focused on the effects of bacteria and fungi mediated by allergic responses, these microorganisms also cause nonallergic responses. Toxicologic studies, which examine such responses using animal and cellular models, cannot be used by themselves to draw conclusions about human health effects. However, animal studies are important in identifying hazardous substances, defining their target organs or systems and their routes of exposure, and elucidating their toxicokinetics and toxicodynamics, the mechanisms that account for the biologic effects, metabolism, and excretion of toxic substances. Animal studies are also useful for generating hypotheses that can be tested through studies of human health outcomes in controlled exposures, clinical studies, or epidemiologic investigations, and they are useful for risk assessment that informs regulatory and policy decisions.

Research reviewed in Chapter 4 shows that molds that can produce mycotoxins under the appropriate environmental and competitive conditions can and do grow indoors. Damp indoor spaces may also facilitate the growth of bacteria that can have toxic and inflammatory effects. Little information exists on the toxic potential of chemical releases resulting from dampness-related degradation of building materials, furniture, and the like.

In vitro and in vivo studies have demonstrated adverse effects—including immunotoxic, neurologic, respiratory, and dermal responses—after exposure to specific toxins, bacteria, molds, or their products. Such studies have established that exposure to microbial toxins can occur via inhalation and dermal exposure and through ingestion of contaminated food. Animal studies provide information on the potency of many toxins isolated from environmental samples and substrates from damp buildings, but the doses of such toxins required to cause adverse health effects in humans have not been determined. In vitro and in vivo research on *Stachybotrys chartarum* suggests that effects in humans may be biologically plausible, although this observation requires validation from more extensive research before conclusions can be drawn.

Among the other research needs identified in the chapter is further development of techniques for detecting and quantifying mycotoxins in tissues in order to inform questions of interactions and the determination of exposures resulting in adverse effects. The committee also recommends that animal studies be initiated to evaluate the effects of long-term (chronic)

exposures to mycotoxins via inhalation. Such studies should establish dose-response, lowest-observed-adverse-effect levels, and no-observed-adverse-effect levels for identified toxicologic endpoints in order to generate information for risk assessment that is not available from presently-available studies of acute, high-level exposures.

Human Health Effects Associated with Damp Indoor Environments

The committee used a uniform set of categories to summarize its conclusions regarding the association between health outcomes and exposure to indoor dampness or the presence of mold or other agents in damp indoor environments, as listed in Box ES-1. The distinctions among categories reflect the committee's judgment of the overall strength, quality, and persuasiveness of the scientific literature evaluated. Chapter 1 details the methodologic considerations underlying the evaluation of epidemiologic evidence and details the definitions of the categories.

BOX ES-1
Summary of the Categories of Evidence Used in This Report

Sufficient Evidence of a Causal Relationship

Evidence is sufficient to conclude that a causal relationship exists between the agent and the outcome. That is, the evidence fulfills the criteria for "sufficient evidence of an association" and, in addition, satisfies the following criteria: strength of association, biologic gradient, consistency of association, biologic plausibility and coherence, and temporally correct association.

Sufficient Evidence of an Association

Evidence is sufficient to conclude that there is an association. That is, an association between the agent and the outcome has been observed in studies in which chance, bias, and confounding can be ruled out with reasonable confidence.

Limited or Suggestive Evidence of an Association

Evidence is suggestive of an association between the agent and the outcome but is limited because chance, bias, and confounding cannot be ruled out with confidence.

Inadequate or Insufficient Evidence to Determine Whether an Association Exists

The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence of an association. Alternatively, no studies exist that examine the relationship.

Tables ES-1 and ES-2 summarize the committee's findings. The conclusions are not applicable to persons with compromised immune systems, who are at risk for fungal colonization and opportunistic infections.

Conclusions regarding exposure to agents associated with damp indoor environments are limited by the means used to assess exposure in the epidemiologic studies reviewed by the committee. For the most part, studies have relied on occupants' observations of the presence of "mold" or "moldy odor." Relatively few research efforts have used trained observers or measurements to attempt to discern which microbial agents are present, the extent of their growth, or whether there are specific common potential exposures (other than dampness). When the committee is drawing a conclusion about the association between exposure to a damp indoor environment and a health outcome, it is not imposing the assumption that the outcome is necessarily a result of exposure to a particular mold or to microbial agents in general. In some circumstances, a paper addresses the association between a particular indoor dampness-related exposure and a health outcome. However, even in those cases, it is likely that people are being exposed to multiple agents.

The committee has drawn conclusions about the state of the scientific literature regarding associations of health outcomes with two circumstances:

TABLE ES-1 Summary of Findings Regarding the Association Between Health Outcomes and Exposure to Damp Indoor Environments[a]

Sufficient Evidence of a Causal Relationship	
(no outcomes met this definition)	
Sufficient Evidence of an Association	
Upper respiratory (nasal and throat) tract symptoms	Wheeze
Cough	Asthma symptoms in sensitized asthmatic persons
Limited or Suggestive Evidence of an Association	
Dyspnea (shortness of breath)	Asthma development
Lower respiratory illness in otherwise-healthy children	
Inadequate or Insufficient Evidence to Determine Whether an Association Exists	
Airflow obstruction (in otherwise-healthy persons)	Skin symptoms
Mucous membrane irritation syndrome	Gastrointestinal tract problems
Chronic obstructive pulmonary disease	Fatigue
Inhalation fevers (nonoccupational exposures)	Neuropsychiatric symptoms
Lower respiratory illness in otherwise-healthy adults	Cancer
Acute idiopathic pulmonary hemorrhage in infants	Reproductive effects
	Rheumatologic and other immune diseases

[a]These conclusions are not applicable to immunocompromised persons, who are at increased risk for fungal colonization or opportunistic infections.

TABLE ES-2 Summary of Findings Regarding the Association Between Health Outcomes and the Presence of Mold or Other Agents in Damp Indoor Environments[a]

Sufficient Evidence of a Causal Relationship	
(no outcomes met this definition)	
Sufficient Evidence of an Association	
Upper respiratory (nasal and throat) tract symptoms	Wheeze
Asthma symptoms in sensitized asthmatic persons	Cough
Hypersensitivity pneumonitis in susceptible persons[b]	
Limited or Suggestive Evidence of an Association	
Lower respiratory illness in otherwise-healthy children	
Inadequate or Insufficient Evidence to Determine Whether an Association Exists	
Dyspnea (shortness of breath)	Skin symptoms
Airflow obstruction (in otherwise-healthy persons)	Asthma development
Mucous membrane irritation syndrome	Gastrointestinal tract problems
Chronic obstructive pulmonary disease	Fatigue
Inhalation fevers (nonoccupational exposures)	Neuropsychiatric symptoms
Lower respiratory illness in otherwise-healthy adults	Cancer
Rheumatologic and other immune diseases	Reproductive effects
Acute idiopathic pulmonary hemorrhage in infants	

[a]These conclusions are not applicable to immunocompromised persons, who are at increased risk for fungal colonization or opportunistic infections.
[b]For mold or bacteria in damp indoor environments.

exposure to a damp indoor environment, and the presence of mold or other agents in a damp indoor environment. As already noted, the term *dampness* has been applied to a variety of moisture problems in buildings. Most of the studies considered by the committee did not specify which agents were present in the buildings occupied by subjects, and this probably varied between and even within study populations.

The committee found **sufficient evidence of an association** between exposure to damp indoor environments and some respiratory health outcomes: upper respiratory tract (nasal and throat) symptoms, cough, wheeze, and asthma symptoms in sensitized asthmatic persons. Epidemiologic studies also indicate that there is sufficient evidence to conclude that the presence of mold (otherwise unspecified) indoors is associated with upper respiratory symptoms, cough, wheeze, asthma symptoms in sensitized asthmatic persons, and hypersensitivity pneumonitis (a relatively rare immune-mediated condition) in susceptible persons.

Limited or suggestive evidence was found for an association between exposure to damp indoor environments and dypsnea (the medical term for

shortness of breath), lower respiratory illness in otherwise-healthy children, and the development of asthma in susceptible persons. It is not clear whether the latter association reflects exposure to fungi or bacteria or their constituents and emissions, to other exposures related to damp indoor environments, such as dust mites and cockroaches, or to some combination thereof. The responsible factors may vary among individuals. For the presence of mold (otherwise unspecified) indoors, there is limited or suggestive evidence of an association with lower respiratory illness in otherwise-healthy children.

Inadequate or insufficient information was identified to determine whether damp indoor environments or the agents associated with them are related to a variety of health outcomes listed in Tables ES-1 and -2. Included among these is acute idiopathic pulmonary hemorrhage in infants (AIPHI). The committee concluded that the available case-report information constitutes inadequate or insufficient information to determine whether an association exists between AIPHI and the presence of *Stachybotrys chartarum* or exposure to damp indoor environments in general. AIPHI is a serious health outcome, and the committee encourages the CDC to pursue surveillance and additional research on the issue to resolve outstanding questions.

The committee considered whether any of the health outcomes listed above met the definitions for the categories "sufficient evidence of a causal relationship" and "limited or suggestive evidence of no association" defined in Chapter 1, and concluded that none did.

It offers some additional observations on research needs and recommendations for action:

- Indoor environments subject occupants to multiple exposures that may interact physically or chemically with one another and with the other characteristics of the environment, such as humidity, temperature, and ventilation rate. Few studies to date have considered whether there are additive or synergistic interactions among these factors. The committee encourages researchers to collect and analyze data on a broad range of exposures and factors characterizing indoor environments in order to inform these questions and possibly point the way toward more effective and efficient intervention strategies.
- The committee encourages the CDC to pursue surveillance and additional research on acute pulmonary hemorrhage or hemosiderosis in infants to resolve questions regarding this serious health outcome. Epidemiologic and case studies should take a broad-based approach to gathering and evaluating information on exposures and other factors that would help to elucidate the etiology of acute pulmonary hemorrhage or hemosiderosis in infants, including dampness and agents associated with damp indoor

environments; environmental tobacco smoke (ETS) and other potentially adverse exposures; and social and cultural circumstances, race/ethnicity, housing conditions, and other determinants of study subjects' health.

- Concentrations of organic dust consistent with the development of organic dust toxic syndrome are very unlikely to be found in homes or public buildings. However, clinicians should consider the syndrome as a possible explanation of symptoms experienced by some occupants of highly contaminated indoor environments.
- Greater research attention to the possible role of damp indoor environments and the agents associated with them in less well understood disease entities is needed to address gaps in scientific knowledge and concerns among the public.

Prevention and Remediation of Damp Indoor Environments

Homes and other buildings should be designed, operated, and maintained to prevent water intrusion and excessive moisture accumulation when possible. When water intrusion or moisture accumulation is discovered, the source should be identified and eliminated as soon as practicable to reduce the possibility of problematic microbial growth and building-material degradation. The most effective way to manage microbial contaminants, such as mold, that are the result of damp indoor environments is to eliminate or limit the conditions that foster its establishment and growth. That also restricts the dampness-related degradation of building materials and furnishings.

Information is available on the sources of excessive indoor dampness and on the remediation of damp indoor conditions and its adverse consequences. Chapter 6 summarizes several sources of guidance on how to respond to various indoor microbial contamination situations. However, as the committee observes, determining when a remediation effort is warranted or when it is successful is necessarily subjective because there are no generally accepted health-based standards for acceptable concentrations of fungal spores, hyphae, or metabolites in the air or on surfaces.

There is a great deal of uncertainty and variability in samples of mold and other microbial materials taken from indoor air and surfaces, but the information gained from a careful and complete survey may aid in the evaluation of contamination sources and remediation needs. Visible surfaces and easily accessible spaces are not the only source of microbial contaminants, however, and the potential for exposure from sources in spaces such as attics, crawl spaces, wall cavities, and other hidden or seldom-accessed areas is poorly understood.

When microbial contamination is found, it should be eliminated by means that not only limit the possibility of recurrence but also limit expo-

sure of occupants and persons conducting the remediation. Disturbance of contaminated material during remediation activities can release microbial particles and result in contamination of clean areas and exposure of occupants and remediation workers. Containment during clean-up (through the erection of barriers, application of negative air pressure, and other means) has been shown to prevent the spread of microbial particles to noncontaminated parts of a contaminated building. The amount of containment and worker personal protection and the determination of whether occupant evacuation is appropriate depend on the magnitude of contamination.

Notwithstanding the interest in the topic, very few controlled studies have been conducted on the effectiveness of remediation actions in eliminating problematic microbial contamination in the short and long term or on the effect of remediation actions on the health of building occupants. In addition, the available literature addresses the management of microbial contamination when remediation is technically and economically feasible. There is no literature addressing situations where intervening in the moisture dynamic or cleaning or removing contaminated materials is not practicable.

Among the research needs identified by the committee are studies that better characterize the effectiveness of remediation assessment and remediation methods in different contamination circumstances, the dynamics of movements of contaminants from colonies of mold and other microorganisms in spaces such as attics, crawl spaces, exterior sheathing, and garages, and the effectiveness of various means of protection of workers and occupants during remediation activities. Standard methods should be formulated to assess the potential of new materials, designs, and construction practices to cause or exacerbate dampness problems. And research should be performed to address the other data gaps discussed above and to determine

- How free of microbial contamination a surface or building material must be to eliminate problematic exposure of occupants and in particular, how concentrations of microbial contamination left after remediation are related to those found on ordinary surfaces and materials in buildings where no problematic contamination is present.
- Whether and when microbial contamination that is not visible to the naked eye but is detectable through screening methods should be remediated.
- The best ways to open a wall or other building cavity to seek hidden contamination while controlling the release of spores, microbial fragments, and the like.
- The effectiveness of managing contamination in place by using negative air pressure, encapsulation, and other means of isolation.
- How to measure the effectiveness and health effects of a remediation effort.

The Public Health Response

On the basis of its review of the scientific papers and other information summarized above and detailed in the report, the committee concludes that excessive indoor dampness is a public-health problem. An appropriate public health goal should thus be to prevent or reduce the incidence of potentially problematic damp indoor environments, that is, environments that may be associated with undesirable health effects, particularly in vulnerable populations. However, there are serious challenges associated with achieving that goal. As the report indicates, there is insufficient information on which to base quantitative recommendations for either the appropriate level of dampness reduction or the "safe" level of exposure to dampness-related agents. The relationship between dampness or particular dampness-related agents and health effects is sometimes unclear and in many cases indirect. Questions of exposure and dose have not, by and large, been resolved. It is also not possible to objectively rank dampness-related health problems within the larger context of threats to the public's health because there is insufficient information available to confidently quantify the overall magnitude of the risk resulting from exposures in damp indoor environments.

Institutional and social barriers may hinder the widespread adoption of technical measures and practices that could prevent or reduce problematic indoor dampness. Economic factors, for example, encourage poor practice or impede remediations; they may also create incentives to forgo or limit investment in maintenance that might help to prevent moisture problems.

Given these challenges, the committee identifies seven areas of endeavor that deserve discussion in the formulation of public health mechanisms to prevent or reduce the incidence of damp indoor environments:

- Assessment and monitoring of indoor environments at risk for problematic dampness.
- Modification of regulations, building codes, and building-related contracts to promote healthy indoor environments; and enforcement of existing rules.
- Creation of incentives to construct and maintain healthy indoor environments; and financial assistance for remediation where needed.
- Development, dissemination, and implementation of guidelines for the prevention of dampness-related problems.
- Public-health-oriented research and demonstration projects to evaluate the short-term and long-term effectiveness of intervention strategies.
- Education and training of building occupants, health professionals, and people involved in the design, construction, management, and mainte-

nance of buildings to improve efforts to avoid or reduce dampness and dampness-related health risks.

- Collaborations among stakeholders to achieve healthier indoor environments.

Among the recommendations the committee offers for implementing the actions it suggests are these:

- CDC, other public-health-related, and building-management-related funders should provide new or continuing support for research and demonstration projects that address the potential and relative benefit of various strategies for the prevention or reduction of damp indoor environments, including data acquisition through assessment and monitoring, building code modification or enhanced enforcement, contract language changes, economic and other incentives, and education and training. These projects should include assessments of the economic effects of preventing building dampness and repairing damp buildings and should evaluate the savings generated from reductions in morbidity and gains in the useful life of structures and their components associated with such interventions.
- Carefully designed and controlled longitudinal research should be undertaken to assess the effects of population-based housing interventions on dampness and to identify effective and efficient strategies. As part of such studies, attention should be paid to definitions of dampness and to measures of effect; and the extent to which interventions are associated with decreased occurrence of specific negative health conditions should be assessed when possible.
- Government agencies with housing-management responsibility should evaluate the benefit of adopting economic-incentive programs designed to reward actions that prevent or reduce building dampness. Ideally, these should be coupled with independent assessments of effectiveness.
- HUD or another appropriate government agency with responsibility for building issues should provide support for the development and dissemination of consensus guidelines on building design, construction, operation, and maintenance for prevention of dampness problems. Development of the guidelines should take place at the national level and should be under the aegis of either a government body or an independent nongovernment organization that is not affiliated with the stakeholders on the issue.
- CDC and other public-health-related funders should provide new or continuing support for research and demonstration projects that:
  - — Develop communication instruments to disseminate information derived from the scientific evidence base regarding indoor dampness, mold

and other dampness-related exposures, and health outcomes to address public concerns about the risk from dampness-related exposures, indoor conditions, and causes of ill health.

— Foster education and training for clinicians and public-health professionals on the potential health implications of damp indoor environments.

- Government and private entities with building design, construction, and management interests should provide new or continuing support for research and demonstration projects that develop education and training for building professionals (architects, home builders, facility managers and maintenance staff, code officials, and insurers) on how and why dampness problems occur and how to prevent them.
- Those formulating the education and training programs discussed above should include means of evaluating whether their programs are reaching relevant persons and, ideally, whether they materially affect the occurrence of moisture or microbial contamination in buildings or occupant health.

REFERENCE

U.S. Census Bureau. 2003. Statistical Abstract of the United States 2002. United States Department of Commerce.

Damp Indoor Spaces AND HEALTH

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

Cover: The images for the cover design were provided by Terry Brennan. The image at the center of the design is *Stachybotrys chartarum* and the border image is *Cladosporium* on paint.

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

INSTITUTE OF MEDICINE
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Reviewers

This report has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following for their review of this report:

Diane R. Gold, MD, MPH, Harvard Medical School and Harvard School of Public Health
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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by **Robert B. Wallace, MD**, University of Iowa, and **John C. Bailar III, MD, PhD**, University of Chicago. Appointed by the National Research Council and Institute of Medicine, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Acknowledgments

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Sincere thanks go to all the participants at the workshops convened on March 26, June 17, and October 8, 2002. The intent of the workshops was to gather information regarding issues related to damp indoor spaces, health effects attributed to microbial agents found indoors, and mold- and moisture-related research. The speakers, who are listed in Appendix A, gave generously of their time and expertise to help inform and guide the committee's work.

We are deeply indebted to two hard-working people—Terry Brennan and Jeroen Douwes—who served as consultants and made major contributions to the content of this report. Special thanks are also extended to Harriet Burge, chair of the committee from its inception through October 2002, for her exceptional commitment and guidance during her tenure. The committee also thanks Ulla Haverinen-Shaughnessy and Anne Hyvärinen, who permitted excerpting of text from their doctoral dissertations. Institute of Medicine staff members Michelle Catlin, Ben Hamlin, and Michael Schneider provided valuable input and help over the course of the study. The Committee on Damp Indoor Spaces and Health, of course, takes final responsibility for all content in the report.

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Finally, the committee would like to thank the chair, Noreen Clark, for her outstanding work, leadership, and dedication to this project.

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