MICROBIOMES OF THE BUILT ENVIRONMENT

A RESEARCH AGENDA FOR INDOOR MICROBIOLOGY, HUMAN HEALTH, AND BUILDINGS

SUMMARY FOR PUBLIC HEALTH PROFESSIONALS

A report from the National Academies of Sciences, Engineering, and Medicine evaluates research on the complex interactions among indoor environments, the microbial communities inside buildings, and human health. The time people spend in homes and workplaces is shared with diverse microorganisms—viruses, bacteria, fungi, and protozoa—that are found in the air that circulates in buildings, in the plumbing systems that supply water and remove waste, and on surfaces from the most inaccessible space behind a wall to a doorknob that is touched every day. New microorganisms and microbial components are constantly introduced into built environments through pathways such as pets, plants, rodents, an open window, a leaky roof, and dirt tracked indoors on an occupant's shoes.

Built environments and the microorganisms they contain impact public health. For decades, for example, research has explored the release of droplets into indoor air through coughing and sneezing and the contributions of aerosol and contact factors to the development of colds and flu. More recently, the switch in water supply and changes to water chemistry in Flint, Michigan resulted in a 2014 outbreak of Legionnaires' disease. Other examples of how microorganisms in indoor environments impact human health include the unfavorable respiratory consequences of mold growth in damp settings, as well as potential protective effects on allergic disease from childhood exposure to certain microorganisms such as those associated with dogs or with traditional farm environments.

While research has begun to offer insights on the topic, the characteristics of "healthy" indoor environments remain largely undefined. We don't currently know how to modify features of indoor environments—such as building ventilation systems and the chemistry of building materials—in ways that will best promote human health via their impact on indoor microbial communities. Many questions remain in understanding the factors that control the abundance, diversity, persistence, and other characteristics of the indoor microbial communities to which people are exposed and in linking such indoor microbial exposures to positive and negative health effects.

The report proposes a **systematic research agenda with 12 priority areas** to address identified knowledge gaps. This agenda aims to achieve the five goals of characterizing built environment interrelationships, assessing effects of exposures on health outcomes, exploring non-health impacts of indoor microbial communities, advancing tools and research infrastructure, and translating research into practice. There are a number of ways in which public health professionals can play a role in the effective pursuit of such a research agenda (see Box on back).

Selected knowledge gaps impeding advancement in this field include the need to:

- *Improve understanding of the transmission and impacts of infectious microorganisms within the built environment,* including modes of transmission for emerging respiratory pathogens; for pathogens with evolving patterns of hosts; and for pathogens with problematic characteristics, such as drug resistance.
- *Clarify the relationships between microbial communities that thrive in damp buildings and negative allergic, respiratory, neurocognitive, and other health outcomes,* including how building conditions and maintenance result in dampness that leads to the proliferation of communities of microbes that can adversely affect respiratory health; distinguishing among the microbial and non-microbial effects of dampness; understanding the relationships among microbes, building materials, and chemicals within damp buildings; and assessing how human health is impacted when dampness is reduced.
- *Elucidate the immunologic, physiologic, or other biologic mechanisms through which microbial exposures in built environments may influence human health,* including how the composition of the microbial communities, stage of life, route of exposure, and other factors affect

human biologic responses and potential health outcomes.

- *Gain further understanding of the beneficial impacts of exposures to microbial communities* on human health, including further longitudinal studies of the effects of early-life microbial exposures on subsequent child and adult health; and additional data on the beneficial impacts of exposures to specific microbial communities to clarify such factors as the extent to which impacts vary with the characteristics of a building's occupants, stage of life, and the routes through which the occupants are exposed.
- *Develop an improved understanding of complex, mixed exposures in the built environment,* such as exposures to multiple microorganisms and to combinations of microorganisms and chemicals that occur routinely in built environments.
- *Design studies to test health-related hypotheses, drawing on the integrated expertise of health professionals, microbiologists, chemists, building scientists, and engineers,* to ensure that the experiments are reproducible and produce results that can be translated into actionable outcomes.

Furthering the proposed research agenda and achieving an improved understanding of the nexus of built environments, their associated microbial communities, and their human occupants can help define and promote healthful indoor environments in the future.

PUBLIC HEALTH COMPONENTS OF THE RESEARCH AGENDA

Public health researchers can contribute to addressing the knowledge gaps identified in the report by supporting or conducting research that is aimed at further characterizing the roles of human occupants and at assessing the influences of the built environment and indoor microbial exposures on the composition and function of the human microbiome, on human functional responses, and on human health outcomes. Examples include studies that:

- Incorporate the social and behavioral sciences to analyze the roles of people who occupy and operate buildings.
- Use complementary study designs–observational, animal model, and intervention–to develop and test health-specific hypotheses.
- Clarify effects of timing (stage of life), dose, and differences in human sensitivity on relationships among microbial exposures and health.
- Develop exposure assessment approaches to address how combinations of exposures (microbial agents, chemicals, and physical materials) influence human functional responses and health outcomes.

This document is based on the report *Microbiomes of the Built Environment: A Research Agenda for Indoor Microbiology, Human Health, and Buildings.* The study was sponsored by the Alfred P. Sloan Foundation, the Gordon and Betty Moore Foundation, the National Aeronautics and Space Administration, the National Institutes of Health, and the U.S. Environmental Protection Agency, with additional support from the National Academy of Sciences Cecil and Ida Green Fund.

Copies of the report are available from the National Academies Press at **http://www.nap.edu.**

For more information, visit: **http://nas-sites.org/builtmicrobiome**