Microbiomes of the Built Environment: From Research to Application

Meeting 1
Washington, D.C. - April 11, 2016
2101 Constitution Avenue NW

The National Academies of
SCIENCES • ENGINEERING • MEDICINE
Committee on Microbiomes of the Built Environment: From Research to Application

**TABLE OF CONTENTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGENDA</td>
<td>Meeting agenda, Sponsor and speaker biographies</td>
</tr>
<tr>
<td>TASK / TIMELINE</td>
<td>Project prospectus and statement of task, Study timeline</td>
</tr>
<tr>
<td>COMMITTEE MEMBER &amp; STAFF INFO</td>
<td>Study committee roster, Study committee biographies</td>
</tr>
<tr>
<td>TRAVEL</td>
<td>Directions to NAS building, Building layout</td>
</tr>
</tbody>
</table>
Microbiomes of the Built Environment: From Research to Application - Meeting 1
Public Agenda

National Academy of Sciences Building
2101 Constitution Avenue NW
April 11, 2016
Room 120

Monday, April 11

10:30am Welcome Public Observers and Study Sponsors
Committee Member Introductions

What are microbiomes of built environments and why is the study topic a compelling one to address?
Joan Bennett, Committee Chair

10:45 Discussion of Statement of Task with Study Sponsors
Sponsoring organizations will provide perspectives on the context for the study, how the study relates to their missions, and what they see as key needs and challenges for understanding microbiomes in built environments. Invited speakers will each provide 10 minutes of opening remarks.

Paula Olsiewski, Alfred P. Sloan Foundation
Tina Bahadori and Laura Kolb, Environmental Protection Agency
David Tomko, National Aeronautics and Space Administration
Lisa Chadwick, NIEHS, National Institutes of Health (remotely)

Committee Discussion with Sponsors

12:15 Lunch

1:30 Setting the Stage for the Study
Presentations will highlight developments and challenges in several background areas. Invited speakers will each give 15 minute presentations.

1:40 Built environment microbiome interfaces: Why is improving our understanding of these interactions an exciting topic and perspective on the field?
Gary Andersen, Lawrence Berkeley National Laboratory and University of California, Berkeley

2:00 Understanding and modeling building systems: What's known and how might these parameters impact indoor microorganisms?
Jelena Srebric, University of Maryland

2:20 Example of built environment microbiome studies and their potential human health links
Benjamin Kirkup, Naval Research Laboratory
2:40  **Understanding microbes in water systems**  
Amy Pruden, Virginia Polytechnic Institute and State University

3:00  **Committee Discussion with Speakers**

3:30  **Break**  
Light snack will be provided

3:50  **Further Discussion: Major Issues Relevant to the Study**  
Opportunity for committee members, sponsors, speakers, and meeting participants to further discuss points raised during the presentations and to identify additional topical areas, gaps, or needs that may be relevant to the study's statement of task.

4:30  **Public Comment Period**  
Opportunity for meeting participants to share additional information or ideas they would like the committee to consider.

5:00  **Meeting Adjourns**
SPONSOR REPRESENTATIVE BIOGRAPHIES

Paula Olsiewski, Alfred P. Sloan Foundation
Paula J. Olsiewski, PhD joined the Alfred P. Sloan Foundation as a Program Director in 2000. Dr. Olsiewski created and directs the Foundation’s programs in Microbiology of the Built Environment and Synthetic Biology. Dr. Olsiewski led Sloan’s Biosecurity program until its conclusion in 2011. Dr. Olsiewski sits on numerous advisory committees and boards, including serving as the chair of the Board of Scientific Counselors Homeland Security Research Subcommittee at the U.S. Environmental Protection Agency. She is a consultant to the National Counterproliferation Center (2009 - present). She previously served on the advisory board for the National Consortium for the Study of Terrorism and Responses to Terrorism (START), a Center of Excellence of the U.S Department of Homeland Security based at the University of Maryland (2005- 2012). She served on the Board of Advisors for the WMD Center’s Bio-Response Report Card in 2001. She was a member of the MIT Corporation (2003-2009), was President of the MIT Alumni Association (2003-2004), and served on the MIT Initiative on Faculty Race and Diversity Advisory Committee (2008-2009). She was a member of the NRC Committee on Advances in Technology and the Prevention of Their Application to Next Generation Biowarfare Threats, which produced the “Globalization, Biosecurity, and the Future of Life Sciences” report (2006). Dr. Olsiewski received a Bachelor of Science in chemistry from Yale College in 1975 and a Doctorate in biological chemistry from MIT in 1979.

Tina Bahadori, U.S. EPA
Dr. Tina Bahadori leads EPA’s Chemical Safety for Sustainability research program. She is an exposure scientist with extensive expertise developing and managing research programs that integrate exposure with health sciences. Prior to coming to EPA, Dr. Bahadori was Managing Director for the American Chemistry Council’s Long Range Research Initiative. She is a past president of the International Society of Exposure Science and is an associate editor of the Journal of Exposure Science and Environmental Epidemiology. She has also served on several committees for the National Academy of Sciences, the Centers for Disease Control and Prevention, and the National Children’s Study. Dr. Bahadori holds a PhD in Environmental Health from the Harvard School of Public Health and a master’s degree from the Technology and Policy Program in Chemical Engineering from MIT.

Laura Kolb, U.S. EPA
Laura Kolb has been with the U.S. Environmental Protection Agency (EPA) for more than 22 years. She currently manages the science group at EPA, Indoor Environments Division (IED). The IED is a non-regulatory program that covers indoor air issues such as mold and moisture control, radon, environmental tobacco smoke, particulate matter, volatile organic compounds (VOCs), indoor asthma triggers, and indoor air quality in schools. Recent examples of key guidance documents available from IED include Moisture Control Guidance for Building Design, Construction, and Maintenance and Energy Savings Plus Health: Indoor Air Quality Guidelines for Multifamily Building Upgrades.

David Tomko, NASA
Dr. David Tomko is Program Scientist for Space Biology in the Space Life and Physical Sciences Division of HEOMD at NASA Headquarters. In this 30 years with NASA, he was a bench scientist working on the physiology of the balance organs and the Science Director of the Vestibular Research Facility at Ames Research Center (1986-1998), Acting Chief and Deputy Chief of the Gravitational
Research Branch at Ames, (1994-1998), Lead Scientist for the Biomedical Program at NASA Headquarters (1998-2003), Headquarters Chief Scientist for the Human Support Research and Technology Program (2003-2005) and currently Program Scientist for Space Biology. He has had numerous administrative roles at Ames and at NASA Headquarters. He has had responsibility for managing peer review of multiple NASA Life Sciences Research Programs, and served as an interface with advisory committees and a resource for legislative affairs. Prior to joining NASA, he was a researcher and teacher and Associate Professor of Physiology (Neuroscience) at the University of Pittsburgh School of Medicine, from which he obtained a PhD degree in 1971, and where he served on the faculty from 1972-1986. While there, he was the recipient of numerous NIH and NASA grants in support of his research, and is the author of numerous peer reviewed scientific papers and book chapters.

Lisa Chadwick, NIEHS, NIH
Lisa Helbling Chadwick, PhD, joined the Division of Extramural Research and Training in 2008. Chadwick is one of the program directors of the NIH Roadmap Epigenomics Program, and is one of the scientific contacts for NIEHS-funded epigenetics studies. In addition, she directs extramural research programs in transgenerational inheritance, aryl hydrocarbon receptor biology, microbiome/environment interaction, and the development of non-mammalian model systems for environmental health research. She represents NIEHS in a number of trans-NIH programs, including the Human Microbiome Project, the Knockout Mouse Program, and the Trans-NIH Zebrafish Coordinating Committee. Chadwick’s scientific background is in complex trait genetics, epigenetics, and chromatin biology. She received her Ph.D. in genetics from Case Western Reserve University for her work on identifying genetic modifiers of X chromosome inactivation. Prior to joining the Division of Extramural Research and Training, she completed a postdoctoral fellowship in Division of Intramural Research at NIEHS, studying the role of chromatin remodeling complexes in the maintenance of heterochromatin.
SPEAKER BIOGRAPHIES

Gary Andersen, Lawrence Berkeley National Laboratory and University of California, Berkeley
Gary Andersen serves as Head of the Ecology Department and Senior Scientist, Earth Sciences Division (ESD), Lawrence Berkeley National Laboratory (LBNL) and is an adjunct professor, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA since 2012. His microbiome and microbial-oriented research focuses on phylogenetic diversity and the dynamics of microbial community structure under changing environmental conditions for which he has developed award-winning new methods (R&D 100 Award for Berkeley PhyloChip (2008); Overall Bronze Medal winner, and Environment category winner, Wall Street Journal Technology Innovation Awards (2008). The long-term goal of this research is to integrate different fields of biology (i.e., genomics, ecology, molecular biology, proteomics and bioinformatics) to provide insight into the interactions of environmental microorganisms under stressful conditions. He also holds patents for innovative tools, including one for nucleotide sequences specific to the strategically important microbe, Bacillus anthracis. He joined the Alfred P. Sloan Foundation Scientific Advisory Board, Microbiology of the Environment in 2009.

Jelena Srebric, University of Maryland
Dr. Srebric is a Professor of Mechanical Engineering and Director of the Cluster for SustainabilitTY in the Built Environment at the University of Maryland (CITY@UMD). She earned a Ph.D. degree from the Massachusetts Institute of Technology in 2000. The focus of Srebric's research is on multi-scale modeling of built infrastructure to provide reliable assessments of how these systems affect occupant population, energy consumption, and associated CO2 emissions. She teaches and develops new courses on energy and environmental systems in the built environment with more than several thousands of students who took her courses at University of Maryland, Penn State, and Harvard. She presented more than thirty guest lectures at different universities including Stanford, Princeton, MIT, and Columbia. Dr. Srebric is the author and co-author of roughly two hundred publications, including the “Indoor Environment” chapter in the newest edition of the Mechanical Engineers’ Handbook. The International Academy of Indoor Air Sciences recognized her work on indoor air quality with the 2005 Yaglou award. She was an invited speaker at the National Academy of Engineering’s (NAE) 2011 U.S. Frontiers of Engineering Symposium. Dr. Srebric was elected an international member of the Serbian National Academy of Engineering in 2013.

Benjamin Kirkup, Naval Research Laboratory
Benjamin C. Kirkup, PhD, is a microbial ecologist in the Center for Biomolecular Science and Engineering at the Naval Research Laboratory. He is the principal investigator of a program on bacterial population biology. He is also an Army Reservist. Formerly he was the Deputy Director of the Department of Wound Infections at the Walter Reed Army Institute of Research; in that role, he was principal investigator on several projects related to the microbial ecology of wounds and medical facilities. He has been a Lecturer and Postdoctoral Associate in the Department of Civil and Environmental Engineering at MIT; holds a PhD from Yale University in Ecology and Evolutionary Biology, and an AM and AB from Harvard University.
Amy Pruden, Virginia Tech
Amy Pruden is the W. Thomas Rice Professor of Civil & Environmental Engineering at Virginia Tech in Blacksburg, VA USA. Her primary expertise is on tracking pathogens and antibiotic resistance genes through environmental systems and developing engineering control strategies for protecting public health. Her broad research mission is to advance the sustainability and health of our water systems through integrating a microbiome perspective to water engineering. Dr. Pruden received the Presidential Early Career Award in Science and Engineering in 2007 and the Paul L. Busch Award in 2014. Her 2014 article “Balancing Water Sustainability and Public Health Goals in the Face of Growing Concerns about Antibiotic Resistance,” was recognized as the Editor’s Choice Best Feature Article in Environmental Science and Technology. Dr. Pruden’s research has been funded by the National Science Foundation, Water Research Foundation, Water Environment Research Foundation, Department of Energy, the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, and The Alfred P. Sloan Foundation.
Humans spend roughly 90 percent of each day indoors in environments built for shelter and environmental control. Recent research has shown that within these built environments there exist a vast number and diversity of species of bacteria, viruses, fungi and protozoa in the air, water, and heating, ventilation, and air conditioning (HVAC) systems, and on surfaces. These constitute dynamic microbial communities or “microbiomes.” The nature, composition, diversity, evolution, and growth of these microbiomes are influenced by interactions with humans, animals and plants, and by factors such as air flow, temperature, humidity, chemical exposures and building materials. These factors are, in turn, shaped by the design, construction, operation, occupation, and use of the built environments.

Although the world of living things is dominated by microbes, very little is known about the vast majority of them. Until recently there have been few systematic efforts to collect and describe the microbes living in or on soil, seawater, freshwater lakes and streams, plants, in the guts and on the bodies of humans and other animals, and in the constructed environments in which we spend most of our time. Our ability to move from identification of genes to a functional understanding of microbial communities and their interaction with ecological conditions remains limited.

Microbial communities in built environments have been shown to affect human health both positively and negatively, influencing our susceptibility to allergies and infectious diseases. The potential health effects from exposure to mold growing in damp environments, for example, are well-recognized. Until relatively recently, most microorganisms in built environments were regarded as pollutants that should be reduced or eliminated from indoor reservoirs. It is now understood, however, that the vast majority of the millions of microbes contained in every glass of water we pour or every breath of air we inhale indoors is non-pathogenic. Many questions remain about the ways in which human occupants shape complex indoor microbiomes and, reciprocally, how the indoor microbiomes to which we are exposed influence the formation and composition of our own internal microbiome and what that might mean.

Similarly, “building science” to inform the dynamic between microbiomes and built environments is itself underdeveloped. For example, building materials are poorly characterized in terms of physical structure and chemical composition, factors believed to influence the nature of resident microbial communities and their growth rates. Accordingly, our understanding of how microbial communities respond to changes in building environmental conditions, materials, operation, and maintenance practices is even more limited. We are beginning to understand that microbiomes can have positive and negative effects on the longevity, energy efficiency, and maintenance of the built environments they inhabit, accelerating or decelerating corrosion and degradation of materials, structures, and infrastructural systems. For example, it is estimated that U.S. industries spend $276
billion per year repairing damage to water infrastructure and approximately 50 percent of this cost can be attributed to corrosion influenced by microorganisms. Yet it is believed that the majority of microbes in water systems do no physical harm, and some microbial communities might actually protect pipes from chemical and physical stresses.

A number of investigations are being carried out to better understand microbiomes in buildings such as homes, workplaces, and hospitals, in transit systems, and in unusual environments such as those that support human space exploration. But it is not always obvious which types of complex biological, chemical, and physical data are most important to collect to help answer key research questions, how to design and standardize methods and data interpretation, and which tools from diverse disciplines are available to help address these challenges. For example, information on microbial metabolic activity or factors linked to allergenicity or pathogenicity may be needed to supplement measures of overall composition and diversity such as 16S sequencing. Further discussion may be useful on the types of building data that can be collected and the spatial and temporal resolution that is required from environmental sampling.

Currently, standards pertaining to microbes in the built environment are limited and focus on specific adverse human and material effects or, to some extent, performance. A building’s performance can be measured in terms of its indoor environmental quality (e.g., quality of air, ventilation, lighting, comfort of occupants), its use of materials, energy, and other natural resources, and its emissions into the air and water. In some cases, voluntary consensus and other widely recognized standards have been adopted for the design of mechanical and other building systems (e.g., HVAC systems) or for their performance (e.g., energy efficiency standards). Some infrastructure design takes into account positive chemical reactions, such as oxidation on weathering steel, which develops a “patina” of rust to produce a protective barrier that impedes further access of oxygen and moisture. However, there is, in general, limited knowledge on the complex effects of microbes for in-situ construction materials or design.

Integrating expertise from microbial ecologists, building scientists and engineers, and environmental and public health researchers may help refine the design of studies on microbiomes in diverse built environments, enabling results to more effectively inform our understanding of the indoor habitats in which we spend the majority of our time, how these interactions affect us, and whether we can use the results of such investigations to inform improved design and operation of built environments or to support occupant health and well-being. The question facing us is not whether or not we will shape the microbiomes of built environments, but whether we will do so intentionally and in a manner that is socially responsible, applying new knowledge as it becomes available and as its systemic and health implications are more clearly understood.

The purposes of the proposed study are to assess the current state of knowledge regarding microbiomes of the built environment; identify the scientific, technical, engineering, and
health-related knowledge gaps; map out basic and applied research agendas and priorities to guide practical and actionable knowledge to facilitate improving the microbiome/built environment interface; and provide information for government agencies considering whether to include research on the microbiome/built environment interface in their research plans, with the research agenda developed by the study serving as a guide to key issues and questions. The 20-month project will be overseen by an ad hoc committee of approximately 12-14 experts representing various disciplinary and sectoral perspectives.

STATEMENT OF TASK

The National Academies’ Board on Life Sciences, working in partnership with the NAE, IOM, and Board on Infrastructure and the Constructed Environment will assess the current state of knowledge regarding microbial communities (bacteria, viruses, fungi, etc.), or “microbiomes” of the built environment, and the implications for human health, sustainability, security, and the design, construction, and operation of physical infrastructural systems and other elements of built environments. The committee will:

• Assess needs, opportunities, and challenges for the practical application of what is currently known about microbiome/built environment interactions.
• Determine if the knowledge developed to date is adequate to assess the impacts of existing policies and practices (e.g., energy efficiency, air quality, building standards and regulations, standards for the design of infrastructural systems, voluntary systems for rating green buildings, etc.) on the microbiomes of the built environment; the resulting implications for human health, sustainability and security; and in cases where the knowledge is found to be adequate, summarize the impacts and implications.
• Identify the scientific, technical, engineering, and health-related knowledge gaps and map out basic and applied research agendas and priorities for built environments with regard to microbiome and microbial-oriented research, building and infrastructure-oriented research, health-oriented research, and tools and method development.
• Consider the economic, legal, and regulatory implications of intentional design and maintenance of built environments to influence microbiomes, as well as social, ethical, and public engagement dimensions thereof.

The committee may also recommend additional actions to advance understanding of microbiome-built environment interactions and accelerate the application of existing and new knowledge in this area to improve the design of built environments for human health, economy, sustainability, and other dimensions of built environment performance.
<table>
<thead>
<tr>
<th>Date</th>
<th>Primary Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015</td>
<td><strong>Study initiation</strong>; committee nominations obtained</td>
</tr>
<tr>
<td>January 2016</td>
<td>Committee appointed</td>
</tr>
<tr>
<td>February 2016</td>
<td>• Data-gathering and preparations for subsequent meetings</td>
</tr>
<tr>
<td></td>
<td>• Discussion and development of preliminary statements of work for topical</td>
</tr>
<tr>
<td></td>
<td>white papers in key areas</td>
</tr>
<tr>
<td>March 2016</td>
<td>• Data-gathering and preparations for subsequent meetings</td>
</tr>
<tr>
<td></td>
<td>• Discussion and development of preliminary statements of work for topical</td>
</tr>
<tr>
<td></td>
<td>white papers in key areas</td>
</tr>
<tr>
<td>April 2016</td>
<td>• <strong>Meeting #1</strong> (April 11-12, Washington, DC)</td>
</tr>
<tr>
<td></td>
<td>• Development of initial report outline</td>
</tr>
<tr>
<td>May 2016</td>
<td>Further data-gathering and workshop planning, including development of</td>
</tr>
<tr>
<td></td>
<td>agenda and invitation of speakers</td>
</tr>
<tr>
<td>June 2016</td>
<td>• <strong>Meeting #2 and public workshop</strong> (June 20-21, location TBD)</td>
</tr>
<tr>
<td></td>
<td>• Identify and make plans to address remaining data and speaker gaps</td>
</tr>
<tr>
<td>July 2016</td>
<td>• Working group assignments and development of draft report</td>
</tr>
<tr>
<td></td>
<td>• Identify and address remaining data and speaker gaps</td>
</tr>
<tr>
<td>August 2016</td>
<td>• Working group assignments and development of draft report</td>
</tr>
<tr>
<td></td>
<td>• Identify and address remaining data and speaker gaps</td>
</tr>
<tr>
<td>September 2016</td>
<td>• Working group assignments and development of draft report</td>
</tr>
<tr>
<td></td>
<td>• Identify and address remaining data and speaker gaps</td>
</tr>
<tr>
<td>October 2016</td>
<td><strong>Meeting #3 and public workshop</strong> (October 17-18, location TBD)</td>
</tr>
<tr>
<td>November 2016</td>
<td>Working group assignments and development of draft report</td>
</tr>
<tr>
<td>December 2016</td>
<td>• <strong>Meeting #4</strong> (December 1-2, location TBD)</td>
</tr>
<tr>
<td></td>
<td>• Completion of draft report with findings and recommendations</td>
</tr>
<tr>
<td>January - March 2017</td>
<td>• Completion of draft report with findings and recommendations</td>
</tr>
<tr>
<td></td>
<td>• Report undergoes National Academies report review process and committee</td>
</tr>
<tr>
<td></td>
<td>responds to review comments</td>
</tr>
<tr>
<td>March - April 2017</td>
<td>• Institutional sign-off and <strong>report release</strong></td>
</tr>
<tr>
<td></td>
<td>• Publication through National Academies Press</td>
</tr>
<tr>
<td></td>
<td>• Report dissemination to stakeholder audiences</td>
</tr>
<tr>
<td>April - May 2017</td>
<td>Report dissemination to stakeholder audiences</td>
</tr>
</tbody>
</table>
STUDY COMMITTEE

JOAN WENNSTROM BENNETT, PHD (Chair)
Distinguished Professor of Plant Biology and Pathology
Rutgers University

JONATHAN ALLEN, PHD
Bioinformatics Scientist
Lawrence Livermore National Laboratory

JEAN COX-GANSSER, PHD
Research Team Supervisor, Field Studies Branch
Respiratory Health Division
National Institute for Occupational Safety and Health

JACK GILBERT, PHD
Professor, Department of Surgery
University of Chicago

DIANE GOLD, MD
Professor, Department of Environmental Health
Harvard T. H. Chan School of Public Health

JESSICA GREEN, PHD
Alec and Kay Keith Professor of Biology
Founding Director, Biology and the Built Environment (BioBE) Center
University of Oregon

CHARLES HAAS, PHD
LD Betz Professor of Environmental Engineering
Head, Department of Civil, Architectural and Environmental Engineering
Drexel University

MARK HERNANDEZ, PHD, PE
Professor
Department of Civil, Environmental and Architectural Engineering
University of Colorado, Boulder

ROBERT HOLT, PHD
Eminent Scholar
Arthur R. Marshall, Jr. Chair in Ecological Studies
University of Florida

RONALD LATANISION, PHD
Senior Fellow
Exponent

HAL LEVIN, BAch
Research Architect
Building Ecology Research Group

VIVIAN LOFTNESS, MA, FAIA, LEED AP
University Professor
School of Architecture
Carnegie Mellon University

KAREN NELSON, PHD
President
J. Craig Venter Institute

JORDAN PECCIA, PHD
Associate Professor of Chemical and Environmental Engineering
Yale University

ANDREW PERSILY, PHD
Chief, Energy and Environment Division
National Institute of Standards and Technology

JIZHONG ZHOU, PHD
George Lynn Cross Research Professor
Department of Microbiology and Plant Biology
Director, Institute for Environmental Genetics (IEG)
University of Oklahoma
NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE STAFF

KATHERINE BOWMAN (Study Director)
Senior Program Officer
Board on Life Sciences
(P) (202) 334-2638
(E) kbowman@nas.edu

JENNA OGILVIE
Research Associate
Board on Life Sciences
(P) (202) 334-1348
(E) jogilvie@nas.edu

ELIZABETH BOYLE
Program Officer
Board on Environmental Studies and Toxicology
(P) (202) 334-2228
(E) eboyle@nas.edu

CAMERON OSKVIG
Director
Board on Infrastructure and the Constructed Environment
(P) (202) 334-2663
(E) coskvig@nas.edu

DAVID BUTLER
Scholar
Institute of Medicine
(P) (202) 334-2524
(E) dbutler@nas.edu

PROCTOR REID
Director
National Academy of Engineering Program Office
(P) (202) 334-2467
(E) preid@nae.edu

ANDREA HODGSON
Christine Mirzayan Fellow (until 4/9/2016)
Board on Life Sciences
(P) (202) 334-3142
(E) ahodgson@nas.edu

FRANCES SHARPLES
Director
Board on Life Sciences
(P) (202) 334-2187
(E) fsharples@nas.edu
STUDY COMMITTEE BIOGRAPHIES

Joan Wennstrom Bennett, PhD (Committee Chair) has been a Distinguished Professor of Plant Biology and Pathology at Rutgers University since 2006. Prior to coming to Rutgers, she was on the faculty at Tulane University, New Orleans, Louisiana, for over thirty years. The Bennett laboratory studies the genetics and physiology of filamentous fungi. In addition to mycotoxins and other secondary metabolites, research focuses on the volatile organic compounds (VOCs) emitted by fungi. These low molecular weight compounds are responsible for the familiar odors associated with molds and mushrooms. Some VOCs function as semiochemicals for insects while others serve as developmental signals for fungi. The Bennett lab has tested individual fungal VOCs in model systems and found that 1-octen-3-ol (“mushroom alcohol”) is a neurotoxin in Drosophila melanogaster and causes growth retardation in Arabidopsis thaliana. It also inhibits growth of the fungus that causes “white nose syndrome” in bat populations. In other studies, the Bennett lab has demonstrated that VOCs from living cultures of Trichoderma, a known biocontrol fungus, can enhance plant growth. Investigations on the mechanistic aspects of fungal VOC action are underway using a yeast knock-out library. Dr. Bennett also has an active interest in fungal genomics and has been involved in genome projects for Aspergillus flavus, A. fumigatus, A. oryzae and Penicillium expansum. Dr. Bennett was Associate Vice President for the Office for the Promotion of Women in Science, Engineering, and Mathematics (“SciWomen”) at Rutgers from 2006-2014. She is a past Editor-in-Chief of Mycologia; a past Vice President of the British Mycological Society and the International Union of Microbiological Societies; as well as past president of the American Society for Microbiology and the Society for Industrial Microbiology and Biotechnology. She was elected to the National Academy of Sciences in 2005.

Jonathan E. Allen, PhD is a Bioinformatics Scientist at the Lawrence Livermore National Laboratory. His research focuses on the development and application of new software tools to address various genome sequence analysis problems, including prediction of genetic virulence markers in viruses, detecting genetic engineering in bacteria, and characterizing microbial communities. Dr. Allen is currently working on developing software tools such as the Livermore Metagenomic Analysis Toolkit and has collaborated on projects using the Lawrence Livermore Microbial Detection Array, which is capable of comparing the DNA of microorganisms in a specific location or environment with a vast library of stored viral, bacterial, and fungal genetic sequences.

Jean Cox-Ganser, PhD is the Research Team Supervisor for the Field Studies Branch, Respiratory Health Division, National Institute for Occupational Safety and Health (NIOSH). For the past 15 years, she has been principal investigator for research studies on the respiratory health effects of dampness and mold in office buildings and schools and is author or co-author on over 35 peer-reviewed publications, book chapters and reports resulting from this research. Of special interest is her many years of experience in guiding and participating in detailed and technically rigorous health hazard investigations of buildings.

Jack A. Gilbert, PhD earned his PhD from Unilever and Nottingham University, UK in 2002, and received his postdoctoral training at Queens University, Canada. He subsequently returned to the UK in 2005 to Plymouth Marine Laboratory at a senior scientist until his move to Argonne National Laboratory and the University of Chicago in 2010. Currently, Professor Gilbert is in Department of Surgery at the University of Chicago, and is Group Leader for Microbial Ecology at Argonne National Laboratory. He is also Associate Director of the Institute of Genomic and Systems Biology, Research Associate at the Field Museum of Natural History, and Senior Scientist at the Marine Biological Laboratory. Dr. Gilbert uses molecular analysis to test fundamental hypotheses in microbial ecology. He has authored more than 200 peer reviewed publications and book chapters on metagenomics and approaches to ecosystem ecology. He is currently working on generating observational and mechanistic models of microbial communities in natural, urban, built and human ecosystems. He is on the advisory board of the Genomic Standards Consortium (www.gensc.org), and is the founding Editor in Chief of mSystems journal. In 2014 he was recognized on
Crain’s Business Chicago’s 40 Under 40 List, and in 2015 he was listed as one of the 50 most influential scientists by Business Insider, and in the Brilliant Ten by Popular Scientist.

**Diane Gold, MD** is a Professor in the Department of Environmental Health at the Harvard T. H. Chan School of Public Health. Her research focuses on the relationships between environmental exposures and the incidence or severity of respiratory diseases, including asthma. The environmental exposures considered include indoor allergens, including fungi, smoking, outdoor ozone and particles. She investigates the environmental exposures which may explain socioeconomic, cultural and gender differences that have been observed in asthma severity. These include perinatal exposures and family stress as well as exposure to the allergens and pollutants mentioned above. She is also interested in the cardiopulmonary effects of particles on the elderly.

**Jessica Green, PhD** is an Alec and Kay Keith Professor of Biology at the University of Oregon, where she is Founding Director of the Biology and the Built Environment (BioBE) Center, and External Faculty at the Santa Fe Institute. Her lab applies theoretical, computational, and empirical approaches to the study of microbial systems. She is the recipient of the Blaise Pascal International Research Chair, John Simon Guggenheim Memorial Foundation Fellowship, and TED Senior Fellowship. She earned an MS in Civil/Environmental Engineering and PhD in Nuclear Engineering, both at the University of California, Berkeley.

**Charles Haas, PhD** is the L.D. Betz Professor of Environmental Engineering and Head of the Department of Civil, Architectural and Environmental Engineering at Drexel University. His broad research interests include the estimation of human health risks from environmental exposures to pathogens and their control using engineering interventions and drinking water treatment. Specific research activities include assessment of risks from exposures to deliberately released agents; engineering analysis and optimization of chemical decontamination schemes; microbiological risks associated with pathogens in drinking water, biosolids, and foods; novel kinetic models for disinfection processes and process control; and use of computational fluid dynamics for process modeling. Dr. Haas was co-director of the Center for Advancing Microbial Risk Assessment that was jointly funded by the U.S. Department of Homeland Security and the U.S. Environmental Protection Agency, and has received funding from various sources including NSF, EPA, research foundations and local government agencies. He received his MS from the Illinois Institute of Technology and his PhD in environmental engineering from the University of Illinois at Urbana-Champaign.

**Mark Hernandez, PhD, PE** is a Professor in the Department of Civil, Environmental and Architectural Engineering at the University of Colorado, Boulder. His research interests lie at the cusp of molecular biology and civil engineering, focusing on the characterization and control of biological air pollution, both natural and anthropogenic. His recent work has focused on engineering disinfection systems for airborne bacteria and viruses and on tracking bioaerosols through natural weather patterns and catastrophic events (such as Hurricane Katrina.) He is a registered professional civil engineer and an active technical consultant in the commercial waste treatment and industrial hygiene sectors. Dr. Hernandez serves as an editor of *Aerosol Science and Technology* and is the director of the Colorado Diversity Initiative. He received his PhD and MS in environmental engineering and his BS in civil engineering from the University of California at Berkeley.

**Robert Holt, PhD** is an Eminent Scholar and the Arthur R. Marshall, Jr. Chair in Ecological Studies at the University of Florida. Dr. Holt’s research focuses on theoretical and conceptual issues at the population and community levels of ecological organization, and the task of linking ecology with evolutionary biology. He focuses on basic research as well as bringing modern ecological theory to bear on significant applied problems, particularly in conservation biology. He approaches ecology by moving beyond traditional analyses of single species or interacting species pairs by focusing on an immediate level of complexity (community modules), which are small sets of interacting species, patterns of interactions found across many ecosystems. (e.g., how predators influence infectious disease dynamics in host populations that are also prey.)
Ronald M. Latanision, PhD is a Senior Fellow at Exponent. Prior to joining Exponent, Dr. Latanision was the Director of the H.H. Uhlig Corrosion Laboratory in the Department of Materials Science and Engineering at MIT, and held joint faculty appointments in the Department of Materials Science and Engineering and in the Department of Nuclear Engineering. He led the School of Engineering’s Materials Processing Center at MIT as its Director from 1985 to 1991. He is now an Emeritus Professor at MIT. In April 2015, he was appointed an Adjunct Professor in the Key Laboratory of Nuclear Materials and Safety Assessment of the Institute of Metal Research of The Chinese Academy of Sciences. In addition, he is a member of the National Academy of Engineering and a Fellow of ASM International, NACE International, and the American Academy of Arts and Sciences. From 1983 - 1988, Dr. Latanision was the first holder of the Shell Distinguished Chair in Materials Science. He hosted the annual Siemens Science and Technology Competition on the MIT campus for more than ten years. Dr. Latanision was a founder of Altran Materials Engineering Corporation, established in 1992. Dr. Latanision’s research interests are focused largely in the areas of materials processing and in the corrosion of metals and other materials in aqueous (ambient as well as high temperature and pressure) environments. He specialized in corrosion science and engineering with a particular emphasis on materials selection for contemporary and advanced engineering systems and in failure analysis. His expertise extends to electrochemical systems and processing technologies, ranging from fuel cells and batteries to supercritical water power generation and waste destruction. Dr. Latanision’s research interests include environmentally-assisted cracking of metals and ceramics, water and ionic permeation through thin polymer films, photoelectrochemistry, and the study of aging phenomena/life prediction in engineering materials and systems. Dr. Latanision is a member of the International Corrosion Council and serves as Co-Editor-in-Chief of Corrosion Reviews, with Professor Noam Eliaz of Tel-Aviv University. He is Editor-in-Chief of the NAE Quarterly, The Bridge. Dr. Latanision has served as a science advisor to the U.S. House of Representatives Committee on Science and Technology in Washington, DC. He has also served as a member of the Advisory Committee to the Massachusetts Office of Science and Technology, an executive branch office created to strengthen the Commonwealth’s science and technology infrastructure with emphasis directed toward future economic growth. Dr. Latanision has served as a member of the National Materials Advisory Board of the National Research Council and now serves as a member of the NRC’s Standing Committee on Chemical Demilitarization. In June of 2002, Dr. Latanision was appointed by President George W. Bush to membership on the U.S. Nuclear Waste Technical Review Board, and was reappointed for a second four-year term by President Barack Obama.

Hal Levin, BArch is a Research Architect with Building Ecology Research Group, Santa Cruz, California. Mr. Levin has conducted research and provided consultation in the areas of buildings’ impacts on occupant health and comfort, as well as on the larger environment. For almost 40 years, he has been involved in research and consulting that include the integration of knowledge about indoor and outdoor air pollution as well as other risk factors into the design of residential, educational, and commercial buildings and communities. His work includes many efforts to design buildings with minimal negative impacts on occupants or the larger environment, including the design of its ventilation, 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.

Vivian Loftness, MArch, FAIA, LEED AP, is a University Professor and former Head of the School of Architecture at Carnegie Mellon University. She is an internationally renowned researcher, author, and educator with over thirty years of focus on environmental design and sustainability, advanced building systems integration, climate and regionalism in architecture, and design for performance in the workplace of the future. She has served on ten National Academy of Sciences panels, and NAS Board on Infrastructure and the Constructed Environment and has given four Congressional testimonies on sustainability. Vivian is the recipient of the National Educator Honor Award from the American Institute of Architecture Students and the Sacred Tree Award from the U.S. Green Building Council (USGBC). She received her BS and MS in Architecture from MIT and served on the National Boards of the USGBC, AIA Committee on the Environment, Green Building Alliance, Turner Sustainability, and the Global Assurance Group of
the World Business Council for Sustainable Development. She is a registered architect and a Fellow of the American Institute of Architects.

**Karen E. Nelson, PhD** is the President of the Rockville Campus of the J. Craig Venter Institute (JCVI) where she has worked for the past 15 years. She was formerly the Director of Human Microbiology and Metagenomics in the Department of Human Genomic Medicine at the JCVI. Dr. Nelson has extensive experience in microbial ecology, microbial genomics, microbial physiology, and metagenomics. Since joining the JCVI legacy institutes, Dr. Nelson has led several genomic and metagenomic efforts, was involved in the analysis of the microbiota of the human stomach and gastrointestinal tract, and led the first human metagenomics study on fecal material derived from three individuals which was published in 2006. Additional ongoing studies in her group include metagenomic approaches to study the ecology of the gastrointestinal tract of humans and animals, reference genome sequencing and analysis, studies with non-human primates, and studies on the relationship between the microbiome and various human and animal disease conditions. She has authored or co-authored over 100 peer reviewed publications and edited three books, and is currently Editor-in-Chief of the journals *Microbial Ecology* and *Advances in Microbial Ecology*. She also serves on the editorial boards of *BMC Genomics*, *GigaScience*, and the *Central European Journal of Biology*. She was also a member of the NRC Standing Committee on Biodefense for the U.S. Department of Defense, and is a member of the Board on Life Sciences. She is also a Fellow of the American Society for Microbiology. Dr. Nelson received her undergraduate degree from the University of the West Indies, and her PhD from Cornell University.

**Jordan Peccia, PhD** is an associate professor of environmental engineering at Yale University and the director of Yale Environmental Engineering undergraduate studies. His research group applies classical and molecular biology to solve environmental problems. The current research thrusts in his laboratory include: (i) applying molecular biology techniques to investigate the diversity, origin, and fate of airborne biological material, (ii) development of functional genomic approaches for controlling microalgae growth in biodiesel production, (iii) understanding human pathogen exposure and in vitro toxicity responses associated with land applied biosolids.

**Andrew Persily, PhD** has performed research into indoor air quality and ventilation since the late 1970s. His work has included the development and application of measurement techniques to evaluate airflows and indoor air contaminant levels in a variety of building types, including large, mechanically ventilated buildings and single-family dwellings. These evaluation procedures include tracer gas techniques for measuring air change rates and air distribution effectiveness, contaminant concentrations measurements, and envelope airtightness. He has contributed to the development and application of multi-zone airflows and contaminant dispersal models. Dr. Persily was a vice-president of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) from 2007 to 2009, and is past chair of ASHRAE SSPC 62.1, responsible for the revision of the ASHRAE Ventilation Standard 62. He is currently chair of Standard 189.1, Design of High-Performance Green Buildings. He is a past chair of ASTM Subcommittee E6.41 on Air Leakage and Ventilation Performance and past vice-chair of subcommittee D22.05 on Indoor Air Quality. He was named an ASTM Fellow and an ISIAQ Fellow in 2002, and an ASHRAE Fellow in 2004.

**Jizhong Zhou, PhD** is a George Lynn Cross Research Professor in the Department of Microbiology and Plant Biology and Director for the Institute for Environmental Genomics, University of Oklahoma, Norman, OK; Adjunct Senior Scientist at Lawrence Berkeley National Laboratory; and Adjunct Professor at Tsinghua University, Beijing, China. His expertise is in microbial ecology and genomics with current research focused on: (i) molecular community ecology and metagenomics, particularly in terrestrial soils and groundwater ecosystems important to climate change, bioenergy and environmental remediation; (ii) experimental evolution and functional genomics of microorganisms important to environment and bioenergy; (iii) pioneering development of high throughput metagenomic technologies, particularly functional gene arrays for biogeochemical, environmental, and ecological applications; and (iv) theoretical ecology, particularly ecological theories and network ecology. He has authored more than 470
publications, with total citations of >24,000 and H-index of 82, on microbial genomics, genomic technologies, molecular biology, molecular evolution, microbial ecology, bioremediation, bioenergy, global change, bioinformatics, systems biology, and theoretical ecology. He received the Presidential Early Career Award for Scientists and Engineers in 2001, the R&D 100 Award in 2009, and the Ernest Orlando Lawrence Award in 2014 - the Department of Energy’s highest scientific recognition. He is an Editor for *mBio* and a former Editor for *Applied and Environmental Microbiology*. He is a Fellow of the American Academy of Microbiology and the American Association for the Advancement of Science.
Getting to the National Academy of Sciences Building
2101 Constitution Ave. NW, Washington, DC 20418

The National Academy of Sciences Building is located at 2101 Constitution Ave. NW in the Foggy Bottom area of Washington, DC.

**Building Entrances, Security, and Directions:**

If you are arriving by cab or by Metro, the main entrance is located at 2101 Constitution Ave. and an alternate entrance is located at 2100 C St. NW.

If you are *driving* to the meeting, the *garage* entrance is located off 21St. Before entering the garage, stop at the security check point. You will be asked the nature of your business and to show ID before entering. If you are planning to drive, please let a staff member know in advance, so your name can be provided to security personnel. Limited guest parking is available for meeting participants. Please be aware that parking is allocated on a first come basis and staff cannot reserve spaces for guests.

**Arriving by Metro:**

Take Metro's Blue/Orange/Silver Line to the *Foggy Bottom-GWU* station. Exit the station and turn RIGHT on 23rd St. Walk SOUTH on 23rd St. for approximately 7 blocks. Turn LEFT on C St. just past the State Department. Cross 22nd St. and the next building on your right will be the NAS Building (C St. entrance). The main entrance is located at 2101 Constitution Ave. NW. **Note:** Ronald Reagan Washington National Airport is located on the *Blue Line.*