AAAS SYMPOSIUM

Microbiomes of the Built Environment

SPONSORED BY THE ALFRED P. SLOAN FOUNDATION

27 MARCH 2014 • AAAS HEADQUARTERS
1200 NEW YORK AVENUE, NW • WASHINGTON, DC 20005

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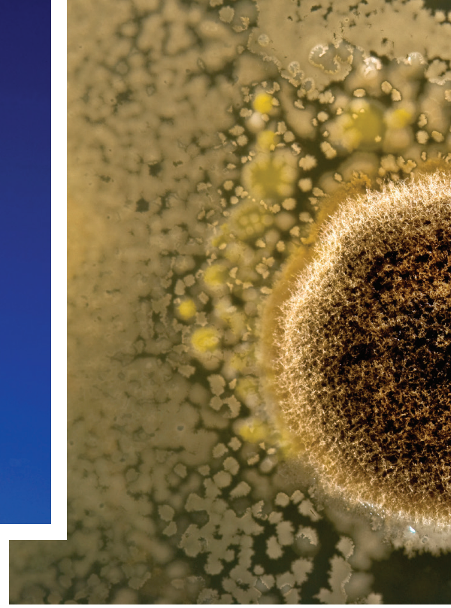


Program

8:15 – 8:45 A.M. **Coffee, Check-in, and Networking.** *2nd floor Mezzanine*

8:45 – 9:00 A.M. **Welcome and Introduction.** *Auditorium*

Edward Derrick, Chief Program Director, Center of Science, Policy and Society Programs, American Association for the Advancement of Science

Paula J. Olsiewski, Program Director, Alfred P. Sloan Foundation

9:00 – 9:30 A.M. **Plenary: Microbiomes and Worker Health: The Need for More Research.** *Auditorium*
John Howard, Director, National Institute for Occupational Safety and Health; Administrator, World Trade Center Health Program, CDC

9:30 – 10:30 A.M. **Panel 1: Indoor Microbiomes: the Diverse Microbial Communities Existing within our Buildings.** *Auditorium*

Moderator: **Donald Milton,** Professor and Director, Maryland Institute for Applied Environmental Health, University of Maryland School of Public Health, College Park, and Professor of Medicine, University of Maryland School of Medicine, Baltimore

The Recent Field of Microbiomes of the Built Environment, and Potential Impacts on Building Design and Human Health
Jessica Green, Director, Biology of the Built Environment Center, University of Oregon

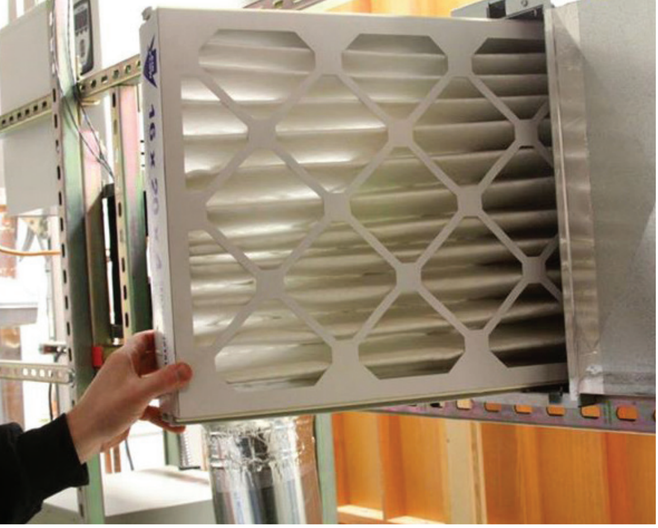
Drinking Water Microbiology and the Built Environment of Water Distribution Systems
Norman Pace, Distinguished Professor, Department of Molecular, Cellular and Developmental Biology, University of Colorado

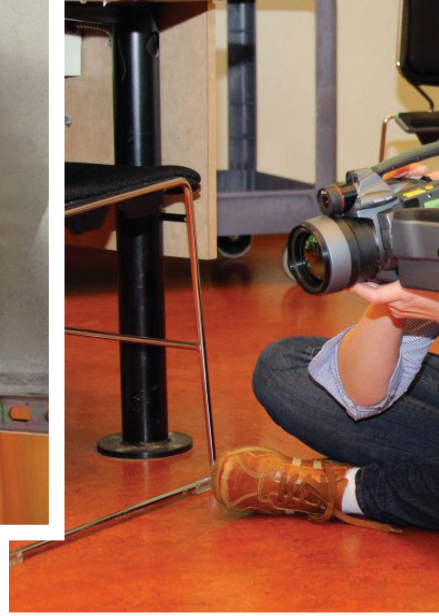
MicroBEnet: the Microbiology of the Built Environment Network
Jonathan Eisen, Professor, Department of Evolution and Ecology, Department of Microbiology and Immunology, and UC Davis Genome Center, University of California, Davis

10:30 – 11:00 A.M. **Coffee and Networking Break.** *2nd floor Mezzanine, Abelson-Haskins, Revelle, and Room 207*

11:00 – 12:00 P.M. **Panel 2: How do Microbiomes Differ Across Environments, and What are Their Impacts?** *Auditorium*

Moderator: **Ryan Colker,** Director of the Consultative Council and Presidential Advisor, National Institute of Building Sciences





Globalization of the Microbiome: Tracking Microbes in Mobile Built Environment
Scott Kelley, Professor, Department of Biology, San Diego State University

Microbially Induced Corrosion and the Accelerated Deterioration of Critical Infrastructure
Mark Hernandez, Professor, Department of Civil, Environmental, and Architectural Engineering, University of Colorado

Microbes across Human Cultures
Maria Gloria Dominguez-Bello, Professor, Department of Biology, University of Puerto Rico; New York University Langone Medical Center

12:00 – 12:45 P.M. **Lunch and Networking.** *2nd floor Mezzanine, Abelson-Haskins, Revelle, and Room 207*

12:45 – 1:30 P.M. **Keynote Address: The International Space Station as a Microbial Observatory: Benefits for Long-Duration Spaceflight and our Understanding of Microbiomes on Earth.**
C. Mark Ott, Senior Microbiologist, Johnson Space Center, National Aeronautics and Space Administration

1:30 – 2:30 P.M. **Panel 3: Microbes and Human Health: the Direct Effects of these Communities on our Health.** *Auditorium*

Moderator: **Gary Roselle,** Professor of Clinical Medicine, Division of Infectious Diseases, University of Cincinnati; Chief, Medical Service, Cincinnati Veterans Affairs Medical Center; and Director, National Infectious Diseases Service, Veterans Affairs Central Office, Washington, DC

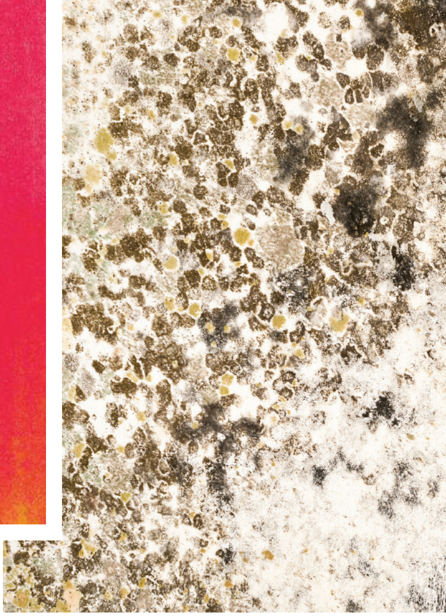
Overview of the NIH Human Microbiome Project
Lita Proctor, Program Director, Human Microbiome Project, National Institutes of Health

The Respiratory Effects of Dampness, Mold, and Dampness-Related Agents in Buildings: What do We Know? What can We do?
Mark Mendell, Staff Scientist/Epidemiologist, Indoor Environment Group, Lawrence Berkeley National Laboratory, and Air Pollution Research Specialist, Indoor Air Quality Section, California Department of Health

Communities Enriched by the Ill: The Hospital Microbiome
Jack Gilbert, Environmental Microbiologist, Argonne National Laboratories and Associate Professor, Department of Ecology and Evolution, University of Chicago

and

Major Ben Kirkup, Deputy Director, Department of Wound Infections, Walter Reed Army Institute of Research



2:30 – 3:00 P.M. **Coffee and Networking Break.** *2nd floor Mezzanine, Abelson-Haskins, Revelle, and Room 207*

3:00 – 4:00 P.M. **Panel 4: Understanding Microbial Communities in Order to Solve Environmental, Energy, Biosecurity, and Other Issues.** *Auditorium*

Moderator: **Todd Anderson,** Director, Biological Systems Science Division, Office of Biological & Environmental Research, Department of Energy

The Nexus of Sustainable Water Infrastructure and Public Health: Can Microbiome Research Reveal New Ways to Keep Antibiotics Working?
Amy Pruden, Professor of Civil and Environmental Engineering, Virginia Tech

What Zero-energy and Prebiotic Buildings have in Common
Jeffrey Siegel, Associate Professor, Department of Civil Engineering, University of Toronto

Critical Capabilities for Biosurveillance and Monitoring Building Health
Jayne Morrow, Environmental Engineer, Biochemical Science Division, National Institute of Standards and Technology

4:00 – 4:15 P.M.	**Break.** *2nd floor Mezzanine, Abelson-Haskins, Revelle, and Room 207*
4:15 – 5:00 P.M.	**Panel 5: State of the Field, and the Future.** *Auditorium.* **Summary:** Microbiomes and Built Environments **Richard Corsi, Ph.D.;** Chair and ECH Bantel Professor for Professional Practice, Department of Civil, Architectural and Environmental Engineering, University of Texas at Austin. **Panel discussion:** Future directions Moderator: **Dr. Richard Corsi** Invited Panelists: **Jessica Green, Norman Pace, Gary Roselle, Jeffrey Siegel, Jayne Morrow,** and **Donald Milton** **Open Discussion and Q&A**
5:00 P.M.	**Adjournment**
5:00 – 7:00 P.M.	**Reception**

Speaker and Moderator Biographies

Plenary Speaker

John Howard, M.D., M.P.H., J.D., LL.M. john.howard@cdc.hhs.gov

John Howard is the Director of the National Institute for Occupational Safety and Health in the U.S. Department of Health and Human Services. Dr. Howard also serves as the Administrator of the World Trade Center Health Program.

Prior to his appointment as NIOSH Director, Dr. Howard served as Chief of the Division of Occupational Safety and Health in the California Labor and Workforce Development Agency from 1991 through 2002.

Dr. Howard received a Doctor of Medicine degree from Loyola University of Chicago, a Master of Public Health degree from the Harvard School of Public Health, a Doctor of Law degree from the University of California at Los Angeles, and a Master of Law degree in Administrative Law and Economic Regulation from the George Washington University in Washington, D.C.

Dr. Howard is board-certified in internal medicine and occupational medicine. He is admitted to the practice of medicine and law in the State of California and in the District of Columbia, and he is a member U.S. Supreme Court bar. He has written numerous articles on occupational health law and policy.

Keynote Speaker

C. Mark Ott, Ph.D. c.m.ott@nasa.gov

Dr. C. Mark Ott is a Senior Microbiologist at the Johnson Space Center, National Aeronautics and Space Administration (NASA). Dr. Ott received his B.S. in Chemical Engineering from the University of Texas at Austin in 1982, his M.B.A. from Louisiana State University in 1989, and his Ph.D. in Microbiology from Louisiana State University in 1998. He has published extensively in the areas of microbial ecology in spacecraft, human and microbial responses to spaceflight, and the development of advanced tissue culture models to investigate infectious disease. In his current position with NASA Johnson Space Center, Dr. Ott serves as a technical lead in the Johnson Space Center Microbiology Laboratory, which is responsible for mitigating infectious disease risk during human spaceflight. His responsibilities include the assessment of microbial risk based on vehicle and mission architecture as well as crewmember, food, and environmental monitoring. These assessments are used to develop requirements for NASA and commercial spaceflight vehicles, including the International Space Station. In addition, Dr. Ott is a scientist for the NASA Human Research Program where he performs research investigations that focus on environmental monitoring and control.

Symposium Moderators and Speakers

Todd Anderson, Ph.D. Todd.Anderson@science.doe.gov

Dr. Anderson is the Director of the Biological Systems Science Division within DOE's Office of Biological and Environmental Research (BER). The division manages a portfolio of programs within BER including the DOE Bioenergy Research Centers, the Genomic Science Program, the Joint Genome Institute (a DOE National Scientific User Facility), the DOE Systems Biology Knowledgebase (KBase) and, programs in the Radiological Sciences and Structural Biology end stations at the DOE Synchrotron Light Sources. Dr. Anderson holds a bachelor's degree in chemistry from the University of Virginia, a master's degree in environmental engineering from the Johns Hopkins University and a Ph.D. in environmental engineering from the University of Massachusetts.

Richard Corsi, Ph.D., P.E.

Richard L. Corsi is Chair of the Department of Civil, Architectural and Environmental Engineering and the ECH Bantel Professor for Professional Practice at the University of Texas at Austin (UT). He received his B.S. degree in Environmental Resources Engineering from Humboldt State University, and his M.S. and Ph.D. degrees in Civil Engineering from the University of California, Davis. Dr. Corsi and his students study sources of, and human exposure to, indoor air pollution. Focus areas of research include indoor surface chemistry and innovative low-energy strategies for improving indoor air quality. Dr. Corsi's work has previously been featured in *National Geographic, The Economist, Business Week, National Wildlife, Prevention, Men's Health,* National Public Radio's Science Friday, Science Studio, and the Academic Minute, amongst other print, media, and television outlets. Dr. Corsi is previous Director of a highly successful and interdisciplinary NSF IGERT program entitled Indoor Environmental Science and Engineering, which supported Ph.D. students from seven academic departments and six colleges at UT. He is currently Co-Director of the Center for Sustainable Development in the School of Architecture at UT. Dr. Corsi has served as research advisor to 19 Ph.D., 48 M.S., and 47 undergraduate students. He is also faculty advisor to the UT Student Chapter of Engineers for a Sustainable World. Dr. Corsi teaches undergraduate courses in fluid mechanics and indoor air quality, and graduate courses on indoor chemistry and human exposure to indoor air pollution. He has received 15 major awards for teaching and mentoring, including the 2013 Lockheed-Martin Aeronautics Company Award for Excellence in Engineering Teaching for the entire Cockrell School of Engineering. He is a member of the prestigious International Society of Indoor Air Quality and Climate's Academy of Fellows, a 2006 Distinguished Alumnus of Humboldt State University, and past President of Indoor Air 2011.

Ryan Colker, J.D. rcolker@nibs.org
Ryan M. Colker is Director of the Consultative Council and Presidential Advisor at the National Institute of Building Sciences where he is responsible for leading the development of findings and recommendations on behalf of the entire building community and for transmitting those recommendations to Congress and the Administration. He also serves as staff director of the Council on Finance, Insurance and Real Estate; the National Council of Governments on Building Codes and Standards; and the Sustainable Building Industry Council. Prior to joining the Institute, he served as Manager of Government Affairs for the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), where he contributed to the development of a robust government affairs program. While at ASHRAE, he assisted in the formation of the High-Performance Building Congressional Caucus and contributed to the development and piloting of the Building Energy Quotient, ASHRAE's building energy labeling program. Previously, Colker served as the Program Director of the Renewable Natural Resources Foundation. A graduate of the George Washington University Law School with a Juris Doctor, Colker is a licensed member of the Maryland Bar.

Maria Gloria Dominguez-Bello, Ph.D.
Maria.Dominguez-Bello@nyumc.org
Dr. Maria Gloria Dominguez-Bello is a Professor at the University of Puerto Rico and recently became an Associate Professor at the New York University School of Medicine. Her research has focused for the last several years on the microbiota function in vertebrate animals and humans, including microbiota development and the impact of modern practices, and the integration of data from microbiology, genomics/metagenomics, ecology, physiology, anthropology, architecture, environmental engineering and biostatistics, in order to address broad questions on host-microbial interactions in different environments. Dr. Dominguez-Bello received her B.S. in 1983 from the University Simon Bolivar, Caracas, Venezuela and her M.S. in 1987 and Ph.D. in 1990 from the University of Aberdeen, Aberdeen, Scotland. She is a Fellow of the Infectious Disease Society of America, and Fellow of the American Academy of Microbiology.

Jonathan Eisen, Ph.D. jaeisen@ucdavis.edu
Jonathan A. Eisen is an evolutionary biologist and a Professor at the University of California, Davis. His research focuses on the mechanisms underlying the origin of novelty (how new processes and functions originate). Most of his work involves the sequencing of the genomes of microorganisms and the development and use of "phylogenomic" methods to analyze the genome data. Previously, he applied this phylogenomic approach to cultured organisms, such as those from extreme environments. Currently he is using phylogenomic methods to study microbes in their

natural habitats, including symbionts living inside host cells and planktonic species in the open ocean. Dr. Eisen's lab is in the U. C. Davis Genome Center and he holds appointments in the Section on Evolution and Ecology and the Department of Medical Microbiology and Immunology. Dr. Eisen is also a vocal advocate for "Open Access'" to scientific publications and is the Academic Editor in Chief of PLoS Biology. He is also a active blogger at http://phylogenomics.blogspot.com and a co-author of a new Evolution textbook (http://evolution-textbook.org). Prior to moving to U. C. Davis he worked at The Institute for Genomic Research (TIGR) in Rockville, MD. He earned his PhD in Biological Sciences from Stanford University where he worked on the evolution of DNA repair processes in the lab of Philip C. Hanawalt and his undergraduate degree in Biology from Harvard College.

Jack A. Gilbert, Ph.D. gilbertjack@anl.gov

Dr. Jack A Gilbert earned his Ph.D. from Nottingham University, UK in 2002, and received his postdoctoral training in Canada at Queens University. He subsequently returned to the UK in 2005 and worked for Plymouth Marine Laboratory at a senior scientist until his move to Argonne National Laboratory and the University of Chicago in 2010. Dr. Gilbert is an Environmental Microbiologist at Argonne National Laboratory, Professor in the Department of Ecology and Evolution at University of Chicago, and senior fellow of the Institute of Genomic and Systems Biology. Dr. Gilbert is currently applying next-generation sequencing technologies to microbial metagenomics and metatranscriptomics to test fundamental hypotheses in microbial ecology. He has authored more than 90 publications and book chapters on metagenomics and approaches to ecosystem ecology (www.gilbertlab.com). He has focused on analyzing microbial function and diversity, with a specific focus on nitrogen and phosphorus cycling, with an aim of predicting the metabolic output from a community. He is currently working on generating observational and mechanistic models of microbial communities associated with aquatic and terrestrial ecosystems. He is on the board of the Genomic Standards Consortium (www.gensc.org), is an academic editor for PLoS ONE and senior editor for the ISME Journal, and is PI for the Earth Microbiome Project (www.earthmicrobiome.org), the Home Microbiome Project (www.homemicrobiome.com) and the Hospital Microbiome Project (www.hospitalmicrobiome.com).

Jessica Green, Ph.D. jlgreen@uoregon.edu

A professor at both the University of Oregon and the Santa Fe Institute, Dr. Jessica Green is an engineer and ecologist who specializes in biodiversity theory and microbial systems. She co-founded the Biology and the Built Environment (BioBE) Center with Brendan Bohannan and G.Z. (Charlie) Brown, creating a team that bridges biology and architecture. Dr. Green envisions a future with genomic-driven approaches to architectural design that promotes sustainability, human health and well-being. She is spearheading efforts to model urban spaces as complex ecosystems that house trillions of diverse microorganisms interacting with each other, with humans, and with their environment. This framework uses next-generation sequencing technology to characterize the "built environment microbiome" and will contribute to design solutions that minimize the spread of infectious disease and maximize building energy efficiency.

Dr. Green is internationally recognized for over 40 publications including articles in *Nature, Science,* and the *Proceedings of the National Academy of Sciences*. Her work has been featured in *Time,* ABC, NBC, NPR, *Forbes,* the *LA Times, Scientific American* and *Discover.* She has been honored with an American Association of University Women Selected Professions Fellowship, a National Science Foundation Postdoctoral Fellowship, a TED Senior Fellowship, and a Guggenheim Foundation Fellowship. She completed a Ph.D. in nuclear engineering at University of California (UC), Berkeley, and earned a M.S. and B.S. in civil and environmental engineering from UC, Berkeley, and UC, Los Angeles, respectively.

Mark Hernandez, Ph.D. Mark.Hernandez@colorado.edu
Dr. Mark Hernandez received all his degrees from and served a postdoctoral tenure in the Civil and Environmental Engineering Department at the University of California, Berkeley. After several years of civil engineering practice, he joined the University of Colorado faculty in 1996, where he is now a professor. Dr. Hernandez's research has consisted of characterizing the microbiology of our built environment. He remains a registered professional engineer, and is an expert on the remediation of bioaerosols and microbially induced corrosion. His research group has recently focused on determining novel designs for large-scale aerosol disinfection systems, as well as on inhibiting corrosion with novel concrete formulation. With respect to environmental investigations, Dr. Hernandez's work has focused on large-scale disasters, including bioaerosols generated by major metropolitan floods, the quarantined City of New Orleans following Hurricane Katrina, and coastal Louisiana following the Deepwater Horizon oil spill.

Dr. Hernandez's research group is based in an environmental microbiology laboratory that houses one of the largest bioaerosol chambers in the United States. Since its commissioning, this laboratory has been active in BL2/3 aerobiology research supported by the National Science Foundation, the National Institutes of Health (CDC/NIOSH), the U.S. Environmental Protection Agency, and various private and public companies. Dr. Hernandez was a recipient of the Robert Canham Award from the Water Environmental Federation, received a National Science Foundation's Early Career Award, and recently was awarded the 2012 Educator of the Year by the Great Minds in STEM Foundation. He holds several patents, is a founding principal of Environmental Forensics LLC, a remediation consulting firm, and helped found Tusaar Inc., a maturing technology company focusing on heavy metal remediation processes. Dr. Hernandez recently served on the U.S. National Research Council committee to review the safety and health risks of U.S.

military biological warfare laboratories, and currently serves on the National Academy of Sciences committee to evaluate risk assessments for the U.S. Department of Homeland Security Agricultural Defense Facility.

Scott Kelley, Ph.D. skelley@mail.sdsu.edu
Dr. Kelley received his undergraduate degree at Cornell University with a B.S. in Biology, having concentrated in Neurobiology and Behavior. After a short stint in Texas as an elementary school teacher with the Teach for America program and then as a research technician, Dr. Kelley was accepted to the Ph.D. Program at the University of Colorado, Boulder. At CU-Boulder, he studied molecular phylogenetics and the population genetics of tree-killing bark beetles under Dr. Brian Farrell and Dr. Jeffry Mitton. As a post-doctoral researcher, he stayed at CU Boulder to study bioinformatics with Dr. Gary Stormo and then to learn the molecular tools for studying environmental microbiology with Dr. Norman Pace. During his time in the Pace lab, he began his studies of microbiomes in built environments with analyses of shower curtain biofilms and hospital therapy pools. In 2002, Dr. Kelley joined the Department of Biology at San Diego State University (SDSU), becoming a Professor in 2012, and he currently studies diverse indoor environments (e.g., hospitals, daycares, airplanes) and many natural environments (e.g., geothermal hot springs, the human oral cavity, marine environments) using molecular tools. He has also developed novel software approaches for analyzing the massive new high-throughput sequence data sets. He received the Outstanding Faculty Service Award by the Mortar Board National Honor Society at SDSU in 2005, and he was awarded the Alexander von Humboldt Research Fellowship for Experienced Researchers for 2009-20011.

Major B. C. Kirkup, Ph.D. benjamin.kirkup@us.army.mil
Kirkup is the Deputy Director, Department of Wound Infections, Walter Reed Army Institute of Research. His work on systems of antagonistic bacteria began with DE Dykhuizen at SUNY Stony Brook and continued through a Ph.D. at Yale University with MA Riley and as a postdoctoral associate with MF Polz at MIT. MAJ Kirkup joined the US Army in 2009 to assist the nascent Department of Wound Infections, addressing complex polymicrobial wound infections from the perspective of microbial ecology. Through the generous support of the Military Infectious Disease Research Program, the Defense Health Program, and the Congressionally Directed Medical Research Program, he initiated a program in biodebridement, a program to develop a construct-valid small animal wound infection model, and a program to understand microbial ecology within the wound and hospital. Because nosocomial infection is a critical aspect of combat wound infection, MAJ Kirkup participates in a project to characterize the hospital microbiome. It is hugely collaborative; supported by the Sloan Foundation, run jointly with Prof. Gilbert (U. Chicago, ANL), engaging numerous key collaborators including Prof.

Knight (U. Colorado), Mr. Hal Levin, the individual military treatment facilities, and the Uniformed Services University of the Health Sciences (Prof. N. Aronson, COL (ret)).

Mark J. Mendell, Ph.D., M.P.H. MJMendell@lbl.gov

Mark Mendell, Ph.D., is currently a Staff Scientist/Epidemiologist in the Indoor Environment Group at Lawrence Berkeley National Laboratory, and an Air Pollution Research Specialist in the Indoor Air Quality Section of the California Department of Public Health. He was formerly at the CDC/National Institute for Occupational Safety and Health, where he was for six years the head of the National Occupational Research Agenda Team for Indoor Environments. Dr. Mendell is on the editorial board of the journal *Indoor Air* and a member of the International Academy of Indoor Air Sciences. He holds a BA from Cornell University; a Bachelor of Landscape Architecture from the University of Oregon; and an MPH and PhD in epidemiology from the UC Berkeley School of Public Health. Dr. Mendell has worked for over 20 years in the field of environmental epidemiology, focused on health effects related to indoor environments in buildings. His work includes field research to help understand relationships between specific factors or conditions in buildings and health effects in occupants, and critical reviews of the literature on specific environment/health relationships in buildings. His research interests include the causes and prevention of building-related symptoms (also called sick building syndrome) in offices; health risks, including asthma and allergies, associated with indoor environmental factors such as ventilation systems, moisture, microbial growth, and chemical emissions; and effects of school environments on the health and performance of students.

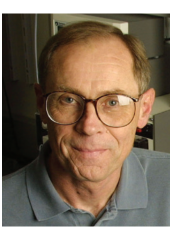
Donald Milton, Dr.P.H. dmilton@umd.edu

Dr. Milton earned a B.S. in Chemistry from the University of Maryland, Baltimore County (Cum Laude), an M.D. from Johns Hopkins University and a Dr.P.H. in Environmental Health from Harvard University. He trained in medicine at Emory and Boston Universities and in occupational and environmental medicine at Harvard. He previously served on the faculties of the Department of Environmental Health, Harvard School of Public Health and the Department of Work Environment, University of Massachusetts Lowell School of Health and Environment. He is currently Professor and Director of the Maryland Institute for Applied Environmental Health, University of Maryland School of Public Health, Professor of Medicine, University of Maryland School of Medicine, Adjunct Senior Lecturer on Occupational and Environmental Health at Harvard School of Public Health, and Honorary Professor, Department of Community Medicine, University of Hong Kong. He is board certified in internal and occupational medicine and has 20 years of experience in occupational medicine referral practice. Dr. Milton is a past chair of the ACGIH Bioaerosols committee and a member of the committee since 1988. He a member of the editorial boards of *Applied Environmental Microbiology, Indoor Air,* and *BMC Public Health*. He is a recipient of the Lloyd Hyde Research Award of Emory University, the Harriet Hardy Award for Lifetime Achievement from the New England College of Occupational and Environmental Medicine, and was elected a Fellow of the International Society for Indoor Air Quality and Climate in 2008.

Dr. Milton leads multidisciplinary investigations of the health effects of bioaerosols with three major themes: 1) investigation and prevention of airborne infection transmission, 2) exhaled breath analysis, and 3) the relationship of asthma onset and exacerbation to exposure to allergens and microbial products. His research has focused on influenza, productivity effects of rhinovirus colds in office workers and asthmatic children, as well as mathematical models, laboratory and epidemiological studies of control methods for influenza, and agents of biological warfare and terrorism.

Jayne Morrow, Ph.D. jmorrow@ostp.eop.gov

Dr. Jayne Morrow has served as an environmental engineer in the Biochemical Science Division of the National Institute of Standards and Technology since 2006, and has studied microbial adhesion and the impact of interfacial processes on bacterial transport in the built environment for nearly 20 years. Efforts have resulted in developing the conceptual framework and measurement capabilities to detect, understand and predict microbe/surface interfacial processes relevant to natural (bacterial transport in soils and aquatic microbial community adaptation dynamics) and engineered (built environment, drinking water and medical implant) systems. Dr. Morrow's current programmatic activities are focused on the detection and characterization of microbes in complex environments. She has collaborated with the academic and federal research communities to establish validated sample collection methods for suspected biothreats and developed measurement assurance approaches for innovative detection technologies. Research program activities have resulted in the development and publication of guidance on microbial detection performance evaluation for a range of microbial characterization methods including sequencing technologies which are enabling the formation of the nascent field of metrology for microbiology. Dr. Morrow received a B. S. in Civil Engineering from Montana State University, and her M.S. and Ph.D. in Environmental Engineering from the University of Connecticut.



Norman R. Pace, Ph.D. nrpace@colorado.edu

Dr. Norman Pace received an A.B. from Indiana University and his Ph.D. from the University of Illinois. He has held faculty positions at several institutions, including the National Jewish Hospital and Research Center, the University of Colorado Medical Center, Indiana University and the University of California, Berkeley. He currently is Distinguished Professor of Molecular, Cellular and Developmental Biology at the University of Colorado, Boulder.

Pace works in two scientific arenas. On one hand he is a molecular biologist, and his laboratory has made substantive contributions to our understanding of nucleic acid structure and processing. Additionally, his laboratory has led the field in the development and use of molecular tools to study microbial ecosystems independently of the traditional requirement for cultures. The results have expanded substantially the known diversity of microbial life in the environment. Efforts have ranged from high-temperature ecosystems and human disease to the microbiology of the built environment.

Pace is a member of the National Academy of Sciences; and he is a Fellow of the American Association for the Advancement of Science, the American Academy of Microbiology, and the American Academy of Arts and Sciences. He has received a number of awards, for instance the 1996 Procter and Gamble Award in Applied and Environmental Microbiology, the 2007 Lifetime Achievement Award from the American Society for Microbiology, the 2008 Lifetime Achievement in Science Award from the RNA Society, the 2008 Tiedje Lifetime Achievement Award in Environmental Microbiology from the International Society for Microbial Ecology and the 2001 Selman A. Waksman Award for Distinguished Contributions in Microbiology from the National Academy of Sciences. This is the Nation's highest award in microbiology. He also in 2001 was appointed a Fellow of the John D. and Catherine T. MacArthur Foundation.

Lita Proctor, Ph.D. lita.proctor@nih.gov

A Program Director at the National Institutes of Health, Dr. Proctor is responsible for coordination of the Human Microbiome Project (HMP). The HMP is an 8-year, $188M trans-NIH Common Fund Initiative to create a community resource for this emerging field. Dr. Proctor joined the NHGRI Division of Extramural Research in 2010. Prior to this she served as Program Director at the National Science Foundation (NSF) in the Geosciences and the Biosciences Directorates, where she managed microbiological and bioinformatics research programs. She is formally trained in microbial ecology, was a NSF Postdoctoral Fellow in molecular microbial genetics at University of California, Los Angeles and held appointments at Florida State University and University of California, Santa Cruz.

Amy Pruden, Ph.D., E.I. apruden@vt.edu

Dr. Amy Pruden is a Professor of Civil and Environmental Engineering at Virginia Tech. Dr. Pruden's broad research mission is to advance the sustainability and health of our water systems through fundamental understanding of the microbiome in the built environment. Dr. Pruden earned her B.S. in Biology in 1997 and her Ph.D. in Environmental Science in 2002 at the University of Cincinnati. She was a recipient of the prestigious Presidential Early Career Award in Science and Engineering (PECASE) in 2007. Dr. Pruden is the primary author on a landmark paper published in *Environmental Science and Technology* in 2006 establishing antibiotic resistance genes as emerging environmental contaminants. She was also a participant in an international expert workshop, *"Antimicrobial Resistance in the Environment:*

Assessing and Managing Effects of Anthropogenic Activities," aimed at bringing awareness to the Public Health community of the importance of considering human-impacted environments as sources and pathways for the spread of antibiotic resistance. Dr. Pruden has served as PI or Co-PI on several National Science Foundation, Water Research Foundation, Water Environment Research Foundation, Department of Energy, and U.S. Environmental Protection Agency sponsored research projects related to the control of emerging pathogens and also to the nano-bio interface. Currently she is PI on an Alfred P. Sloan Foundation grant entitled, *"Effect of Pipe Material, Water Chemistry, and Flow on the Building Plumbing Microbiome."* She is also serving on an expert advisory panel to the City of Flagstaff focused on Contaminants of Emerging Concern in Recycled Water. Her work has been featured in *Scientific American, Discover* magazine, *Science News, Nature News, The New York Times,* National Public Radio, and CBC's As it Happens.

Gary A Roselle, M.D., F.A.C.P.

Gary A. Roselle, M.D., FACP, is the National Director for Infectious Diseases for the Department of Veterans Affairs (VA) Central Office in Washington, DC, as well as the Chief of the Medical Service at the Cincinnati VA Medical Center. He is a professor of medicine in the Department of Internal Medicine, Division of Infectious Diseases, at the University of Cincinnati College of Medicine and Associate Chairman of the University of Cincinnati Department of Internal Medicine. Dr. Roselle serves on several national advisory groups, including the Advisory Council for the Elimination of Tuberculosis (TB), the Federal TB Task Force, the Interagency Task Force on Antimicrobial Resistance, the Health and Human Services Steering Committee to Prevent Healthcare-Associated Infections, the Executive Office of the President Sub-Interagency Policy Committees for Biosurveillance and for Pandemic Preparedness, and the Center for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee. He is a long standing member of the Institute of Medicine Forum on Microbial Threats. He has been an invited speaker at national and international meetings and has published more than 100 papers and several book chapters, and is a reviewer for numerous scientific and medical journals. Dr. Roselle received his medical degree from The Ohio State University School of Medicine. He served his residency at the Northwestern University School of Medicine and his infectious diseases fellowship at the University of Cincinnati College of Medicine.

Jeffrey Siegel, Ph.D. jeffrey.siegel@utoronto.ca

Dr. Jeffrey A. Siegel is an Associate Professor in the Department of Civil Engineering at the University of Toronto where his research focuses on sustainable and healthy buildings. Prior to joining the UofT faculty in 2013, he was an associate professor and J. Neils Thompson Centennial Teaching Fellow at the University of Texas at Austin. He received his Ph.D. in Mechanical Engineering in 2002 from the University of California, Berkeley. Dr. Siegel and his research team have ongoing research on HVAC filtration and air cleaning, portable and passive air cleaners, particle transport and deposition in HVAC systems and indoor environments, the indoor microbiome, and the connections between ventilation and indoor air quality. He is an active member of ASHRAE, AAAR, and ISIAQ, and served for nine years as a voting member of ASHRAE Standard 52.2 and as a voting member of ASHRAE Technical Committees 2.4 and 6.3. He is also active in promoting the integration of building science measurements with microbial samples for indoor microbiome research. He has received several awards for research and teaching including the Cockrell School of Engineering Award for Outstanding Teaching by an Assistant Professor in 2007 and the ISEA/ACC Early Career Award in 2004. He has recently served on the organizing committees for Indoor Air 2011 and ASHRAE IAQ 2013 and is serving on the International Scientific Committee for Indoor Air 2014.

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Abstracts

In order of presentation

Plenary: Microbiomes & Worker Health: The Need for More Research

John Howard, M.D., M.P.H., J.D., LL.M.
Director, National Institute for Occupational Safety and Health

The National Institute for Occupational Safety and Health (NIOSH) in the Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services conducts research into the causes and methods of control of both industrial and non-industrial type health risks arising from microbial agents.

For instance, "farmer's lung" is a hypersensitivity pneumonitis caused by exposure to heat-tolerant actinomycetes bacteria associated with hay dust, mold spores, or other agricultural products in industrial environments. Another industrial exposure to workers involves metalworking fluids used in machine grinding; these fluids may be contaminated with microbes and their toxic products. Aerosol exposures to metalworking fluids may cause a variety of health effects including hypersensitivity pneumonitis, chronic bronchitis, impaired lung function, and asthma. In addition, substantial evidence shows that past exposures to some metalworking fluids were associated with increased risk of some types of cancer.

NIOSH is also interested in biologic exposures occurring in indoor, nonindustrial work environments such as offices and retail —where nearly 75% of US workers are employed. Beginning in 1996, NIOSH designated indoor work environment exposures a priority research area. NIOSH has funded research into such topics as building-influenced communicable respiratory infections; building-related asthma and allergic diseases; non-specific building-related symptoms; indoor environmental science; and methods of increasing implementation of healthful building practices.

NIOSH is pleased to participate in the American Association for the Advancement of Science's Symposium on *Microbiomes of the Built Environment,* to join with others interested in the microbial ecology of the built environment.

Panel 1: The Recent Field of Microbiomes of the Built Environment, and Potential Impacts on Building Design and Human Health

Jessica Green, Ph.D.
Director, Biology of the Built Environment Center, University of Oregon

Every person has a distinctive and unseen universe of microorganisms living in, on, and around them. These unique "microbiomes," consisting of trillions of tiny creatures, help define who we are and can exert a significant influence on our health. Yet we are only just beginning to understand how our microbes interact with the people around us, our buildings, and the urban environment. How can a deeper understanding of the built environment microbiome help us create healthier buildings, sustainable cities, and more robust green spaces? In an effort to begin answering these questions, the Biology and Built Environment (BioBE) Center at the University of Oregon is training a new generation of innovators and practitioners at the architecture-biology interface. Here I share some key BioBE Center findings about the microbiomes of a diverse array of built environments: a health care facility, a university multi-use facility, and an experimental climate chamber. I illustrate how humans have a guiding impact on the microbiology of buildings, both directly through the impact of human microbial “shedding”, and more indirectly through the effects of building design. I discuss the possibility of a new field of design, one that is focused on selecting indoor microbes that promote health and well-being. I close by highlighting major areas of research that are essential for linking building design and human health.

Panel 1: Drinking Water Microbiology and the Built Environment of Water Distribution Systems

Norman Pace, Ph.D.
Distinguished Professor, Department of Molecular, Cellular and Developmental Biology, University of Colorado

Every society depends on the delivery of safe drinking water; failure of water distribution systems can result in major disease epidemics. Until recently, remarkably little has been known about the bacteria that are delivered with drinking water. The public commonly views municipal drinking waters as “sterile,” but in fact the typical municipal water load is 10-100 million bacteria per liter. Federal regulations establish monitoring standards for “coliform” bacteria as indicators of potential fecal contamination in distributed waters, but, beyond the absence of coliforms, few generalities are known about the microbiology we interact with and consume daily. What are those mostly unknown organisms?

Although municipal drinking water microbiology has long been studied using cultures, this technique detects usually <1% of the actual microbial content. To side-step the requirement for culturing, we use “metagenomics,” a technique in which the DNA of resident microbes is isolated directly from any environment, such as point-of-use municipal drinking waters, and then is gene-sequenced to determine the kinds of microbes that are present. Different culture studies had indicated considerable variation in microbiology among municipal systems, so a broad survey of different systems is necessary to extract generalities in the microbiology consumed in public drinking waters and, perhaps, trends that might indicate impacts of land-use on the microbiology.

Results from one analysis will be described as an example, with multiple samples from 17 communities in the Arkansas and lower Mississippi River valleys. Results highlight many specific generalities as well as some interpretable variations based on land-use and disinfectant regimens. Microbes encountered generally are innocuous, but results point to some potential problems with some distribution and storage systems, such as variably high loads of “opportunistic pathogens,” environmental organisms that infect humans but are not considered communicable.

Panel 1: microBEnet: the Microbiology of the Built Environment Network

Jonathan Eisen, Ph.D.
Professor, Department of Evolution and Ecology, Department of Microbiology and Immunology, and UC Davis Genome Center, University of California, Davis

New fields, especially ones that are highly interdisciplinary, can be limited by issues unrelated to whether or not the field is important. Examples of such limiting issues include difficulty in communicating across disciplines, a lack of historical information and context relative to other fields, limited resources (e.g., data, tools, and ideas) for practitioners, and a lack of awareness of the field by practitioners, policymakers and the public. Our goal for the microbiology of the Built Environment network (microBEnet) project (http://microbe.net) is to circumvent these limitations and to carry out activities to catalyze advancement and innovation in the new field of "microbiology of the built environment." In its first three years, our microBEnet project met a number of needs by: (1) organizing sessions, presentations, and key international scientific conferences, (2) creating, curating and sharing key needed resources and information (e.g., we have curated a freely available reference collection on the topic http://tinyurl.com/microBEnet), (3) creating and leveraging a social media presence for the field (e.g., http://www.microbe.net/microbenet-blog/), (4) enabling more openness in activities in the field and (5) engaging students and the public via undergraduate research projects and citizen science activities (e.g., see http://spacemicrobes.org). I will also discuss some of the future needs within the field and then our revised plan for microBEnet going forward, which includes these same activities, as well as more emphasis on longevity and sustainability, teaching and spreading openness, and research, education and outreach.

Panel 2: Globalization of the Microbiome: Tracking Microbes in Mobile Built Environments

Scott Kelley, Ph.D.
Professor, Department of Biology, San Diego State University

Worldwide, approximately 90,000 passenger-carrying airplanes take off and land every day of the year. These airplanes fly distances ranging from hundreds to tens of thousands of kilometers, and flight times can range from less than an hour to twenty hours at a stretch. In addition to their human cargo, airplanes also carry aboard the many trillions of invisible passengers that comprise the human microbial ecosystem. Airplanes likely also carry microbes from soils and other environmental sources brought on with the passengers. I discuss my lab's previous research using molecular tools to investigate the sites and sources of the most microbially contaminated portions of airplanes. I also present our recent work on the rapid development of microbial assemblages in built environments, namely restrooms, and how this work may help us understand similar patterns in airplane settings. Finally, I review some of the novel software approaches that should help us determine the environmental sources of airplane microbial assemblages. A better understanding of the contamination sources and dynamism of microbial assemblages in airplanes and other environments will help us better determine how airplane travel may or may not facilitate "microbial globalization" and what might be the potential risks to human health.

Panel 2: Microbially Induced Corrosion and the Accelerated Deterioration of Critical Infrastructure

Mark Hernandez, Ph.D.
Professor, Department of Civil, Environmental, and Architectural Engineering, University of Colorado

Concrete is the most utilized man-made material on the planet. Many public agencies and private organizations now recognize that microbially induced concrete corrosion (MICC) is emerging as one of the most serious problems plaguing the world's wastewater infrastructure. MICC occurs as a result of microbially mediated sulfur cycling within wastewater collection systems. Microbes forming anoxic biofilms below the waterline oxidize the sulfate present in wastewater to sulfide. This sulfide partitions into the pipe headspace as hydrogen sulfide gas, which serves as a substrate for acidogenic sulfur-oxidizing bacteria above the waterline. These bacteria produce sulfuric acid, which dissolves cement and severely weakens the concrete pipe, often reducing their design life by many years.

The domestic perspective of our American Society of Civil Engineers currently gives our national wastewater infrastructure a letter grade of "D". The US EPA estimates that more than 8,000 miles of sewers are in need of rehabilitation - in large part because of accelerated corrosion – and the agency projects a $300 billion in investment over the next 20 years, three-quarters of which will be needed to address piping problems. The Congressional Budget Office has similar estimates, suggesting that the cost of restoring wastewater infrastructure to proper function in the future will be at least $12 billion per year for the foreseeable future. In response to this problem, we present a national survey of microbes associated with severely corroding sewer systems, using modern phylogenetic characterization methods. We compare these results to classical culture-based studies and their use in conventional corrosion models. We also present the development of novel cement formulations, which may offer economical material-based approaches to inhibiting the biogenic sulfur oxidation process in wastewater conveyance systems.

Panel 2: Microbes across Human Cultures

Maria Gloria Dominguez Bello, Ph.D.
Associate Professor, Department of Biology, University of Puerto Rico; Associate Professor, New York University Langone Medical Center

An animal's microbiome shows phylogenetic signals that provide evidence of coevolution with the host and also of the exclusive transfer of genes within microbial species. Modern practices, such as the use of antimicrobial products, disrupt the microbiota, however. Evidence shows that Westernized peoples have less diverse microbiota than those in less modernized societies. But the microbiota of peoples living with low exposure to antimicrobial practices has not been well characterized. We are studying different microbiomes across cultures, to determine environmental and microbiota changes that might relate to antimicrobial practices. The microbiota of peoples unimpacted by the modern environment presumably provide a picture of the microbiota of our ancestors, which will be useful to identify the modern life microbiota "extinctions", potentially recover them, design human probiotics, and use them in therapies and prevention.

Keynote: The International Space Station as a Microbial Observatory: Benefits for Long-Duration Spaceflight and our Understanding of Microbiomes on Earth

C. Mark Ott, Ph.D.
Senior Microbiologist, Johnson Space Center, National Aeronautics and Space Administration

Human presence in space, whether permanent or transient, is accompanied by the presence of microorganisms. Historically, the approach to microbial control on spacecraft has been to minimize the number of detectable organisms, relying heavily on preventative measures, including appropriate vehicle design, crew quarantine prior to flight, and extensive microbial monitoring. Pre-flight monitoring targets have included the astronauts, spaceflight foods, potable water systems, the vehicle air and surfaces, and the cargo carried aboard the spacecraft. This approach has been very successful for earlier missions; however, the construction and habitation of the International Space Station (ISS) has created the need for additional in-flight monitoring of the environment and potable water systems, using hardware designed for both in-flight microbial enumeration and collection and for the return to Earth.

In addition to enhancing our knowledge in maintaining healthy habitats for future space exploration, the ISS is also providing a unique research platform to enhance our knowledge of microbiomes of both the spacecraft and the inhabitants within. The environmental conditions within the ISS are routinely monitored, and the activities and diets of the crew are likewise well documented. Additional information is available on crewmembers, who are also participants in various spaceflight experiments to better understand their medical status. Adding to the research possibilities of the ISS platform are multiple reports of changes in microbial gene expression and phenotypic responses, including virulence and biofilm formation, in response to spaceflight culture. To fully understand the potential of the ISS research platform, the National Research Council specifically recommended that NASA utilize the ISS as a microbial observatory. Collectively, the information from this effort and from current monitoring activities is expected to mitigate microbial risks for future long-duration spaceflight, as well as increase our understanding of microbiomes in built environments on Earth.

Panel 3: Overview of the NIH Human Microbiome Project

Lita Proctor, Ph.D.
Program Director, The Human Microbiome Project, National Institutes of Health

The human microbiome is the full complement of microbial life, to include viruses, bacteria, fungi and protozoa (along with their genes and genomes) which live in and on the human body. Though we have known for centuries that microbes are a part of the human body, the extent and diversity of these microbial communities, their natural history and the crucial roles they play in human health is only just being recognized. The NIH Human Microbiome Project (HMP) is an 8-year, $188M program to produce microbiome data, computational tools and scientific approaches as community resources for this emerging field. An overview of the HMP and other human microbiome studies will provide the audience with a broad understanding of the human microbiome and its role in human health and disease.

Panel 3: The Respiratory Effects of Indoor Dampness, Mold, and Dampness-Related Agents in Buildings: What do We Know? What can We do?

Mark Mendell, Ph.D., M.P.H.
Staff Scientist/Epidemiologist, Indoor Environment Group, Lawrence Berkeley National Laboratory, and Air Pollution Research Specialist, Indoor Air Quality Section, California Department of Health

Many studies have shown consistent associations between evident, subjectively assessed indoor dampness or mold and respiratory or allergic health effects. Causal links remain unclear because objectively measured microbiologic organisms, components, or products (referred to here as “agents”) have shown little consistent relationship with health outcomes. This talk will broadly summarize current epidemiologic evidence on relationships of specific health outcomes with two types of environmental risk factors: *qualitatively/subjectively* assessed dampness or mold and *quantitative* measurements of microbiologic agents Evident indoor dampness or mold have been associated consistently with many adverse respiratory outcomes: increased asthma (both development and exacerbation), respiratory infections, bronchitis, allergic rhinitis, and various upper and lower respiratory tract symptoms. Studies suggest both allergic and non-allergic mechanisms. For quantified microbiologic agents, only suggestive and often contradictory evidence of association with any health outcome is available for a few measured agents. Both adverse and protective associations of indoor microbiomes with health are apparent, including protective associations of early and diverse microbial exposures against later development of allergies, and adverse associations of microbiomes in air-conditioning systems with respiratory symptoms. Overall, evidence suggests health benefits of remediating evident, subjectively assessed indoor dampness and mold, but does not yet support measuring specific indoor microbiologic factors to guide health-protective actions. Evidently, we do not yet know what to measure. It is important to identify which specific or aggregate indoor microbial exposures have adverse human health effects, and which have protective effects. Recent findings using molecular methods of microbial identification demonstrate the promise of these methods for developing health-relevant measurements of indoor microbiologic exposures.

Panel 3: Communities Enriched by the Ill: The Hospital Microbiome

Jack Gilbert, Ph.D.
Environmental Microbiologist, Argonne National Laboratories and Associate Professor, Department of Ecology and Evolution, University of Chicago
and
Major Benjamin Kirkup, Ph.D.
Deputy Director, Department of Wound Infections, Walter Reed Army Institute of Research

Decades of culture-based surveillance of the microbes of patients and hospitals have put a spotlight on certain organisms, especially within particular growth states, but leave the medical community ill-informed about the larger systems of transmission and of reservoirs of infection in the healthcare setting. The hospital is a complex system of unusually vulnerable hosts (i.e., patients), healthy providers and visitors, and the physical plant, including ventilation systems, cleaning products, sealed surfaces, fabrics and so on. The intuitions based on classic microbiology have misled the earnest attempts to control hospital-acquired infections. Recent findings demonstrate that 1) hospital infections - once thought to be clonal outbreaks - are actually co-infections and super-infections of more than one variety or species, and 2) organisms have been found persisting in the hospital in novel niches. As a result, hospital epidemiology, infection control and operations require a new foundation in modern microbial ecology. The Hospital Microbiome Project encompasses a growing range of observational and interventional studies to characterize and comprehend the pattern and process of microbial ecology in hospitals. Two efforts already yielding data include an observational study in Chicago and a second at the Walter Reed National Military Medical Center (WRNMMC). In Chicago, a newly constructed private hospital has provided a special opportunity for numerous sampling events both prior to and following the official opening of the hospital. Over 15,000 microbiological samples are being taken and building environmental measurements (ventilation rates, temperature, relative humidity, light intensity, and human occupancy) are being combined with the microbiological data to describe microbial community composition and to hypothesize about ecological processes. The second observational study has been conducted in conjunction with the Centers for Disease Control and the Uniformed Services University of the Health Sciences at WRNMMC. A third study is currently planned in conjunction with the staff of the Landstuhl Regional Medical Center (LRMC), Germany, to study the impact of the patient on his own hospital room.

Panel 4: The Nexus of Sustainable Water Infrastructure and Public Health: Can Microbiome Research Reveal New Ways to Keep Antibiotics Working?

Amy Pruden, Ph.D., E.I.
Professor of Civil and Environmental Engineering, Virginia Tech

Imagine a world without antibiotics. Now imagine a world without access to clean water. A century ago, it was not necessary to imagine these things: they were a reality of everyday life. Scientists, engineers, and architects worked together to conceive and bring to fruition the built environment that supports the quality of life that we enjoy today. A vital component of the built environment is the delivery of clean, potable water to homes and businesses, while eliminating resulting sewage. However, today, our water infrastructure faces new challenges, with important implications for water sustainability and public health. One growing concern is that the manner in which we treat, deliver, and return our water to the environment could contribute to the proliferation of emerging pathogens, especially antibiotic resistant bacteria. When people take antibiotics, bacteria that are resistant to those antibiotics are able to survive, end up being excreted to sewage treatment plants and, ultimately, can be released into water bodies. Already, antibiotic resistance rates are increasing among dangerous pathogens, such as Enterococcus, MRSA, tuberculosis, and Klebsiella. Routine surgeries, such as hip replacements, are becoming riskier because secondary infections may be untreatable. At the same time, due to growing pressure on our water resources, we are forging new territory with innovations such as water conservation features in green buildings and systems for reusing treated sewage for irrigation and other purposes. New products also continually emerge on the market, such as nanomaterials, which also have the potential to stimulate antibiotic resistance. Such innovations are vital to advancing water sustainability and our economic prosperity, yet research is critically needed to fill in and address knowledge gaps with respect to potential drawbacks to human health. Standard methods for assessing water quality are limited and overlook the vast majority of microbes in our water. The latest advances in next-generation DNA sequencing technology and microbiome research, however, provide the ideal avenue to crystalize our understanding of how the water cycle may contribute to the spread of antibiotic resistance, and how we might best design our built environment to keep people healthy.

Panel 4: What do Zero-energy and Prebiotic Buildings have in Common?

Jeffrey Siegel, Ph.D.
Associate Professor, Department of Civil Engineering, University of Toronto

Buildings consist of a complex set of dynamic, interacting features: (1) physical systems including the mechanical systems, the interior and its contents, the exterior, and the structure; and (2) biological systems including the human and non-human organisms that inhabit them. Air, water, pollutants, energy, and organisms continuously move through these systems. Truly healthy and efficient buildings need to acknowledge and embrace this complexity. One desirable aspect of sustainable buildings is the presence of a diverse and healthy indoor microbiome. With increasing research and exploration of indoor microorganisms, there is an oft-stated goal of engineering, or of at least encouraging, healthy and diverse indoor microbial communities – AKA, prebiotic buildings. The purpose of this talk is to provide, from the perspective of building science, a framework for thinking about this goal, and to establish appropriate precautionary principles for applying indoor microbial research to the design and operation of buildings. Many of the potential challenges to prebiotic buildings arise directly from the inherent complexity of buildings, and this talk will explore approaches to resolve this complexity in ways that are relevant to the indoor microbiome. Ongoing efforts to make buildings more energy efficient, and ultimately to consume no net energy (AKA, zero-energy buildings) offer many instructive lessons. The ultimate goal of this presentation is to provide a building science context for the future of indoor microbiome research and application.

Panel 4: Critical Capabilities for Biosurveillance and Monitoring Building Health

Jayne Morrow, Ph.D.
Environmental Engineer, Biochemical Science Division, National Institute of Standards and Technology

Efforts to characterize the indoor microbiome and to understand the role of the microbial communities on the health of buildings have led to critical changes in how we see our environment and baseline health. The microbial colonization of our buildings and ourselves can be both advantageous when kept in balance and problematic when the community shifts toward conditions that are favorable for pathogen survival. Our ability to detect subtle aberrations from the norm is fundamental to establishing the health of an organism or environment and is critical to recognizing when and how problematic conditions arise. Rapidly emerging sequencing methods are new tools to characterize the baseline microbial community and the results can inform our understanding of the norm. Traditional methods for organism identification are fundamentally linked to the organisms' function within the host environment. Genomic and metagenomic techniques provide unique insight into what functions are possible in a community, but often lack corresponding observational data of true mechanistic behavior. Critical to the successful emergence of sequence technologies for characterizing complex microbial communities is the ability to accurately and reliably identify microorganisms. This talk will present the technical challenges of accurately characterizing microbiomes and detecting pathogenic organisms, as well as the standards development needed to foster maturation of the field. This talk will further discuss the value of developing reliable microbiome characterization in order to establish baseline and healthy norms for the built environment, and, subsequently, to provide biosurveillance capabilities that will increase our ability to detect, respond to and recover from biological threats.

Humans spend approximately 90% of each day indoors within environments built for shelter. However, recent research has revealed that, even in our "controlled" built environments, tremendous numbers and diverse species of bacteria, viruses, fungi, and protozoa exist in the air, in water systems, and on surfaces, forming microbial communities or "microbiomes."

All built environments contain microbiomes: houses, offices, stores, hospitals, modes of transportation, and more. Microbiomes affect our built structures through mold and corrosion. They also influence our health – both positively and negatively.

Understanding microbiomes will help us improve our building designs, and thus our energy use, health, and security. The AAAS Symposium on Microbiomes of the Built Environment, organized in collaboration with the Alfred P. Sloan Foundation, brings together the wide community of stakeholders for a discussion on the field's potential impacts and next steps.

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