Microbial Genomics of the Global Ocean System

A Joint Colloquium Hosted by the Gulf of Mexico Research Initiative, the American Society for Microbiology, and the American Geophysical Union

April 9 & 10, 2019
Washington DC

Welcome Statement

On behalf of the Gulf of Mexico Research Initiative Research Board, the American Geophysical Union and the American Society for Microbiology, we thank you for your willingness to participate in this colloquium. Microorganisms drive biogeochemical cycles in the global ocean and play a critical role in the response of marine ecosystems to disturbance, such as that resulting from a major oil spill. Next generation sequencing technologies and the rapid advance in genomics approaches revolutionized the capability to interrogate structure and functioning of microbial communities. The Deepwater Horizon oil spill was the first large scale environmental disaster to which genomics techniques were applied to track the microbial response to perturbation. This colloquium brings together the world's leading experts in microbial genomics and related fields to develop a broad research synthesis. The goal is to generate foundational ideas to advance marine microbiology and enhance understanding of microbial response to major disturbances in the ocean.

Thank you for spending your valuable time on this important effort.

Sincerely,

Mandy Joye and Joel Kostka on behalf of the Colloquium Steering Committee

Special Thanks

Thank you to the partner organizations who contributed to the success of this event: the American Geophysical Union, the American Society for Microbiology, and the Gulf of Mexico Research Initiative. A special thanks to AGU for generously hosting in their wonderful newly renovated meeting space. This event was possible due to the dedicated effort of the Steering Committee: Rita Colwell, Brooks Hanson, Ken Halanych, Mandy Joye and Joel Kostka. Many thanks!

Safety Considerations

Parts of the building are still under construction, so please be aware of contractor traffic in and around the building. Scaffolding is protecting the front entrance and building perimeter; please take care when entering and exiting the building.

Should there be an emergency that requires evacuation, audible alarms & flashers will alert meeting attendees accordingly. There are two emergency exits from the Lobby Level (front doors, at the main entrance and loading dock doors, just past the restrooms); all exits are marked with lighted signs. Please exit quietly and promptly. Once outside the building, please gather at the corner of Connecticut and Florida Avenues, so we can ensure that all have evacuated safely.

Should you have any questions or concerns, or should you see anything that looks suspicious or out-of-place, please contact the security guard at the front desk, or any of the AGU Conference Center staff.

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Colloquium Schedule

Tuesday April 9

State of the Science Before and After the Deepwater Horizon Discharge

7:30 Arrive/Continental Breakfast

8:30 Welcome and workshop introduction – Janice Lachance and Rita Colwell

8:45 Meeting Charge – Mandy Joye and Joel Kostka

9:00 Plenary - Janet Jansson – Microbial dynamics on a global scale, drivers of community assembly, techniques/approaches

10:00 Coffee Break

10:30-12:45 GoMRI-enabled Science Advances I: Omics and microbiology overview

10:30 Overview of Research Advances Since 2010

11:15 Breakout Groups – Research Advances Since 2010

Group 1) What is the current knowledge on using genomics to characterize microbially mediated ecosystem functions?

Group 2) How do we quantify and characterize the indicators of microbially-mediated ecosystem functions, such as biodegradation?

Group 3) What is the current knowledge of incorporating microbial data into models?

12:45 Breakout Group Report Out

1:00 Lunch

2:00 Charge for the Afternoon

2:15-3:30 Breakout Groups – Research Advances Since 2010

Group 4) What are the most translational advances and discoveries in ocean systems made since 2010?

Group 5) How much baseline data is enough? How do we achieve the necessary amount of baseline data and support long-term and in situ studies? What new technologies are needed?

Group 6) How does the knowledge gained in the wake of the Deepwater Horizon advance microbial biology in general?

3:30 Coffee Break

4:00 ~5-minute report out from each working group

4:15-5:30 Breakout Groups – Research Advances Since 2010

Group 7) How do the unique aspects of particle-mediated microbial dynamics (e.g. MOSSFA) fit into the larger portfolio of marine microbiology?

Group 8) What are the major remaining knowledge gaps with respect to fundamental knowledge regarding the role of microorganisms in ecosystem function?

Group 9) How can we improve the current knowledge of incorporating microbial data into models?

5:30 Summary

6:15 Dinner

8:00 Informal working groups after dinner

Wednesday, April 10

Translation of Science into New Understanding and Improved Practice

7:30 Arrive/Continental Breakfast

8:30 Plenary - Kostas Konstantinidis- How has metagenomics advanced knowledge of the microbial response to disturbance?

9:30-12:00 Breakout Groups – Knowledge gaps and challenges

Group 10) What tools and standards need to be (further) developed (i.e. sequencing approaches vs. bioinformatic analysis) to better understand the role of microorganisms in ecosystem function?

Group 11) What governs community assembly in response to perturbation? Can we constrain microbial feedbacks and ecosystem consequences?

Group 12) How do we better characterize genotype-phenotype relationships and incorporate into assessment of ecosystem function?

10:30 Coffee Break

12:00 Short report out from each breakout group – brief questions

12:30 Lunch

1:30 -3:00 Breakout Groups – Application of GoMRI-enabled knowledge

Group 13) How can we build expertise in the community – e.g. build the necessary workforce with the appropriate training and access to tools – and facilitate communication between groups using common language and common approaches to advance microbial genomics?

Group 14) How can lessons learned from DWH research as well as the broader microbial genomics community be translated into improved strategies for quantitative prediction and mitigation of ecosystem disturbance (e.g. better oil spill preparedness and response and restoration)?

Group 15) Is the Gulf-based knowledge translatable to other regions? Why or why not? Can we develop indices and indicators of ecosystem functions (e.g. microbial hydrocarbon degradation) and use genomics to prioritize sites for emergency response to disturbance?

3:00 Coffee Break

3:30 5-minute report out from afternoon breakout groups

3:45 Meeting Summary - Overview, summarize writing goals/objectives

4:45 Adjourn official meeting

5:30 Closing Session (public lecture) - Dave Karl – Station Aloha: A Proving Ground for Microbial Oceanography

6:30 Reception

7:30 *End of Workshop*

Questions to guide breakout group discussion

1) What is the state of the field with respect to characterizing microbially mediated ecosystem functions and the response of marine ecosystems to disturbance such as that during a major oil spill, and/or development or application of tools to assess ecosystem functions and their response to disturbance (from microbiology to activity).

2) What have we learned relative to the 2010 baseline? What are the most important lessons learned in marine microbiology and genomics within the past 10 years from GoMRI-supported microbial research as well as the from the broader microbial genomics community? What are the most translational improvements and discoveries in ocean systems made since 2010?

3) What are the major remaining knowledge gaps with respect to basic information versus tools to assess/evaluate (i.e. omics data generation vs bioinformatics analysis of those data) the role of microorganisms in ecosystem function and impacts of disturbance on ecosystem function?

4) How can what has been learned from DWH research, as well as from research of the broader microbial genomics community, be translated into improved strategies for quantitative prediction and mitigation of ecosystem disturbance, such as better oil spill preparedness, response, restoration. Is the Gulf-based knowledge translatable to other regions? Why or Why not?

5) What steps are required to advance application of DWH-based microbiological and genomic findings? What were/are primary impediments to research progress and how can these be prevented/overcome in the future?

Public Lecture

The Microbial Genomics of the Global Ocean System Joint Colloquium will close on 10 April with a public lecture, "Station ALOHA: A Proving Ground for Microbial Oceanography," presented by David M. Karl. The lecture, including Q&A, will begin at 5:30 p.m., followed by a reception at 6:30 p.m.

STATION ALOHA: A PROVING GROUND FOR MICROBIAL OCEANOGRAPHY

David M. Karl
Daniel K. Inouye Center for Microbial Oceanography: Research and Education, University of Hawaii at Manoa, Honolulu, HI, USA

Microbial oceanography is a relatively new discipline that integrates the principles of marine microbiology, microbial ecology and oceanography to study the role of microorganisms in the biogeochemical dynamics of natural marine ecosystems. A general goal of microbial oceanography is to observe and understand microbial life in the sea well enough to make accurate ecological predictions, for example, of the impact of climate variability on microbial processes in the global ocean. Since Oct 1988, interdisciplinary teams of scientists from the University of Hawaii and around the world have conducted research at Station ALOHA (22.75 N, 158 W), a site chosen to be representative of the expansive North Pacific Subtropical Gyre. Numerous scientific discoveries from Station ALOHA, including novel microorganisms, unprecedented metabolic pathways and complex interactions, have transformed our understanding of microbial life in the sea. The uncertain nature of future climate change and the potential impacts on the structure and function of marine ecosystems demands a comprehensive description and understanding of the sea around us. Sustained research of marine microbes is vital, so continued field observations and experimentation at Station ALOHA, and at selected locations elsewhere including the Gulf of Mexico, is both timely and important. After three decades of intensive study at Station ALOHA, we now have a new view of an old ocean, with revised paradigms built on the strength of high-quality time-series data, insights from the application of –omics techniques and observations from autonomous gliders. The pace of new discovery, and the importance of integrating this new understanding into predictive models is an enormous contemporary challenge with great scientific and societal relevance.

Karthik Anantharaman is an Assistant Professor in the Department of Bacteriology at the University of Wisconsin-Madison. He received his Ph.D. in Earth and Environmental Sciences from the University of Michigan in 2014 studying the geomicrobiology of deep-sea hydrothermal plumes and conducted his postdoctoral research at the University of California-Berkeley studying biogeochemistry and microbial ecology. He is an expert in environmental microbiology and virology, high throughput 'omics approaches to studying microbiomes, and biogeochemistry. His interdisciplinary research program focuses on understanding the cycling of sulfur and nutrients, with a strong emphasis on the microbial and viral processes that transform them in environmental and human systems. His current research uses a combination of cultivation-independent, cultivation-dependent, and field-based approaches to investigate the interplay between the microbiome, virome, and chemistry in hydrothermal plumes, oxygen minimum zones, and the deep oceans.

Brett J. Baker completed his undergraduate and M.S. at the University of Wisconsin Milwaukee. Before doing his Ph.D. at the University of Michigan (Geosciences Dept.) with Gregory Dick, he spent 10 years as a research associate in Dr. Jillian Banfield lab at University of California Berkeley. For the last 4 years Brett has led his own research program in the Department of Marine Science at University of Texas Austin. Dr. Baker's team employs metagenomic and in situ activity techniques (BONCAT, DNA-SIP, and transcriptomics) to study a variety of microbial systems; resolving hydrocarbon cycling in the Deepwater Horizon oil spill (Dombrowski et al. 2016), ecological interactions in deep sea hydrothermal sediments (Dombrowski et al. 2017 and 2018), estuary biogeochemical cycling (Baker et al. 2015 and 2016, Lazar et al. 2015 and 2016), and the role of archaea in the evolution of cellular complexity (Seitz et al. 2016, Spang et al. in press, Zaremba-Niedwiedzka et al. 2017).

Iliana Baums studies the molecular ecology and evolution of marine invertebrates at the Penn State University department of biology. The Baums lab at Penn State studies ecological and evolutionary processes that shape populations of reef-building corals. She develops and applies molecular tools to understand the influence of population structure, mating patterns and climate change on the survival and evolution of corals and other marine organisms. Baums in 2004 received the Smith Prize, awarded for the most original piece of research at the Rosenstiel School of Marine & Atmospheric Science at the University of Miami. Prior to joining Penn State in August, 2006, as an assistant professor of biology, Baums was an assistant researcher to Dr. Rob Toonen at the University of Hawaii since 2005. Prior to that, she was a postdoctoral researcher to Dr. Jack Fell at the University of Miami from 2004 to 2005. She earned her doctorate degree at the University of Miami in 2003 and her Diploma in marine biology from the University of Bremen in Germany in 2000.

Annalisa Bracco is a Professor of Physical Oceanography in the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. She received her Ph.D. in 2000 from the University of Genoa (Italy) in Geophysics and Oceanography. Before coming to Georgia Tech, she was a Junior scientist at the International Center for Theoretical Physics in Trieste (Italy) and an Assistant Scientist at the Woods Hole Oceanographic Institution in Woods Hole, MA. Her expertise covers the ocean mesoscales and submesoscales with a focus on their impact on

circulation and biology. Her research aims at integrating data and model simulations, linking physical advective processes to the distribution of tracers and pollutants in the ocean. She was the recipient of the 2011 Nicholas Fofonoff Award by the American Meteorological Society. Currently, she is the co-chair of the Scientific Steering Committee of CLIVAR (Climate and Ocean Variability, Predictability and Change), a core project of the World Climate Research Programme.

Jennifer Brum is an Assistant Professor in the Department of Oceanography and Coastal Sciences at Louisiana State University. She has a bachelor's degree in Marine Science from Hawaii Pacific University, and both a M.S. and Ph.D. in Oceanography from the University of Hawaii. Dr. Brum's research focuses on marine viruses, including studying their ecology and effects on microbial ecology and biogeochemical cycles using field sampling, metagenomics, and microscopy. Her current projects include examining viral ecology and their effects on biogeochemical cycling in seven globally-distributed oxygen minimum zones, as well as in hydrothermal vent systems on the Mid-Atlantic Ridge.

Barbara Campbell earned a Ph.D. in Microbiology from Cornell University. Before coming to Clemson University, she was a Research Assistant Professor at the University of Delaware for five years specializing in Marine Microbial Ecology. She is currently an Associate Professor at Clemson University, and has graduated three master's and one Ph.D. student and now has two graduate students and nine undergraduate students in her lab. She has 38 publications, the most recent one published in ISME on clam symbiont diversity, and two more submitted or in revision. She or her students have presented at regional, national and international venues, including estuarine microbial ecology research most recently at Xiamen University, China and in San Juan, Puerto Rico at ASLO. She has one current grant funded by NSF on lucinid clam symbiont diversity and one from the DOE for sequencing services for her estuarine microbial ecology research. Her main focus is on how marine microbes respond to spatial, temporal and environmental change using a combination of field work, metagenomics and metatranscriptomics. She serves on the editorial board or is a review editor for five journals and was the Chair of Division N of the American Society for Microbiology in 2015.

Carl Childs is a biological oceanographer with experience in biogeochemistry and marine microbial ecology. He is the SCAT (Shoreline Cleanup Assessment Technique) program coordinator for NOAA where he has been working for the last 15 years. He has provided on-scene and remote scientific support for numerous oil spills, hazardous materials releases and natural disasters. He has coordinated and served on several interagency panels on oil spill science and has served as a SCAT Coordinator and Technical Advisor on numerous responses. He received his Ph.D. in Oceanography from Florida State University in 2004 and holds undergraduate degrees in history and chemistry and a master's degree in Whole Systems Design.

Victoria Coles earned a B.S, in Physics from the University of California at San Diego. She then completed a Ph.D. in Physical Oceanography working with Donald B. Olson at the University of Miami Rosenstiel School of Marine and Atmospheric Science on observations and models of abyssal circulation of Antarctic Bottom Water and its climate variability. Coles then completed a postdoc working at the NASA Goddard Space Flight Center. She began coupled physical-biological

modeling with funding from the NSF to understand the interactions between dust, river runoff, circulation and mixing, and the role of nitrogen fixation in the tropical Atlantic. She joined the faculty at University of Maryland Center for Environmental Science in 2001, where she works on coupled biological and physical processes. Her present work includes novel methodologies for modeling ecosystems with a direct representation of genes and transcription (GENOME model) as well as coupling Eulerian and Lagrangian models to represent Sargassum macroalgae. She also serves on steering committees for US CLIVAR and the Ocean Carbon and Biogeochemistry program. Her work on climate assessment for the state of Maryland lead to receiving the 2008 UMCES president's award for excellence in application of science.

Rita Colwell is Distinguished University Professor at the University of Maryland at College Park and President of CosmosID, Inc. Her interests are focused on global infectious diseases, water, and health. She has authored or co-authored 19 books and more than 800 scientific publications. Dr. Colwell served as 11th Director of the National Science Foundation and Co-chair of the Committee on Science, National Science and Technology Council. Dr. Colwell is a member of the National Academy of Sciences, Royal Swedish Academy of Sciences, Royal Society of Canada, Royal Irish Academy, American Academy of Arts and Sciences, and American Philosophical Society. Dr. Colwell has been awarded 63 honorary degrees from institutions of higher education and is the recipient of the Order of the Rising Sun, Gold and Silver Star - Japan, 2006 National Medal of Science, 2010 Stockholm Water Prize, and the 2018 Lee Kuan Yew Water Prize of Singapore.

Annette Summers Engel is the Donald H. Jones Professor of Aqueous Geochemistry at the University of Tennessee in the Department of Earth and Planetary Sciences. She obtained her Ph.D. in geochemistry and geomicrobiology from The University of Texas at Austin (2004), after receiving separate M.Sc. degrees in biology and geology from the University of Cincinnati, and a B.A. from Wittenberg University. She previously held a joint-faculty position at Louisiana State University in the Departments of Geology & Geophysics and the Biological Sciences. Living in Louisiana allowed Dr. Engel to expand her interests from caves, aquifers, and the subsurface to marine and coastal environments. Her research accomplishments in microbial diversity and ecology now include beach, marsh, and seagrass habitats, and her work has advanced our understanding of bivalve chemosymbiosis. Dr. Engel is currently on two non-profit conservancy boards and serves on advisory committees for the international societies for Subsurface Microbiology and for Environmental Biogeochemistry. She has received university research and service awards, as well as a Charles A. and Anne Morrow Lindbergh Foundation award, the Science Award from the National Speleological Society, and she is a Fellow of the National Speleological Society, Geological Society of America, and the Explorers Club.

John W. Farrington is Dean *emeritus* Woods Hole Oceanographic Institution (WHOI). B. S. (1966) and M. S. (1968) in Chemistry, Southeastern Massachusetts Technological Institute (now UMass-Dartmouth) and a Ph. D. (January, 1972) in Oceanography from the Graduate School of Oceanography, URI. He retired from WHOI in 2006 after a thirty-five-year career of successive positions there as Postdoctoral Investigator through Senior Scientist and Dean/Vice President for Academic Programs, 1990-2005. He is a member of the Research Board, Gulf of Mexico Research

Initiative. His research interests are the biogeochemistry of organic compounds in the marine environment, including biogenic chemicals, industrial chemicals of environmental concern and oil chemicals. He has published 125 scientific publications in refereed scientific journals, books and reports, 45 publications related to education, policy, or science- policy interactions. He has participated as a member or Chair in several U. S. National Academies Committees issuing reports about oil pollution in the marine environment and remediation of polluted sediments. Among the honors he has received are National Associate (life appointment) of the U. S. National Academies; Fellow of the American Association for the Advancement of Science; Fellow of the American Geophysical Union; and Doctor Honoris Causa the University of Concepcion, Chile.

Tony Gutierrez is an Associate Professor of Environmental Microbiology & Biotechnology at Heriot-Watt University in Edinburgh, Scotland. Since obtaining his Ph.D. in Environmental Microbiology at The University of New South Wales he did a postdoc in the UK investigating the ecology and commercial use of marine bacterial biosurfactants. Whilst at the University of North Carolina at Chapel Hill as a Marie Curie Fellow, he became involved on research to do with the Deepwater Horizon oil spill. His current research interest includes the taxonomy and ecology of oil-degrading bacteria in the ocean, the microbial response to the Deepwater Horizon spill, including the formation of marine oil snow (MOS) and its role in oil fate, and research to predict the microbial response and MOS formation at other sites at sea. Current work focuses on the microbiology of sea surface and deepwater provinces, such as in the northeast Atlantic where oil exploration is expanding. Another major focus is on bio-prospecting marine microorganisms for discovering novel types of bio-molecules, such as surface-active agents (bio-surfactants and bio-emulsifiers) for biotechnological applications.

Ken Halanych is the Schneller Endowed Chair of Biological Sciences at Auburn University. His research is focused on understanding extensive morphological variation by exploring time scales and different types of genomic information. He combines a molecular systematic and/or genomic approach with information on organismal evolution to study diverse topics, such as the origin of major animal lineages and the biogeographic history of commercially important species. He earned his Ph.D. from the University of Texas.

Casey Hubert leads the Geomicrobiology Group at the University of Calgary, in Canada. He joined the U of C in 2014 after starting as a faculty member in Geosciences at Newcastle University, UK, following a post doc at the Max Planck Institute for Marine Microbiology in Bremen, Germany. The Geomicrobiology Group in Calgary is a team of students, post docs and staff pursuing field-based marine microbiology research aimed at better understanding various aspects of petroleum systems. In collaboration with geoscientists and oceanographers from industry and academia, both in Canada and internationally, this approach to geomicrobiology combines genomics, cultivation, biogeochemistry and metabolomics to understand the biogeography and ecophysiology of oil-associated microbial communities in the ocean and in the subsurface. In recent years members of the Geomicrobiology Group have participated in Arctic research expeditions aboard the Canadian Coast Guard's research icebreaker and on other smaller ships, sampling sediment, seawater and sea ice to assess hydrocarbon biodegradation potential. Dr.

Hubert currently leads the large-scale Genome Canada funded project "*GENICE: Microbial Genomics for Oil Spill Preparedness In Canada's Arctic Marine Environment*."

Janet Jansson is Chief Scientist for Biology and a Laboratory Fellow at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington. Jansson has more than 30 years of experience in microbial ecology. She obtained her Ph.D. in microbial ecology at Michigan State University (1984-1988). Jansson was a senior staff scientist at Lawrence Berkeley National Laboratory from 2007-2014 and an adjunct professor at the University of California, Berkeley and at the University of Copenhagen, Denmark from 2012-2014. She moved to PNNL in 2014 and is currently coordinating several large research projects at PNNL that are focused on the use of molecular approaches (omics) to study complex microbial communities, such as those residing in soil and the human gut. Relevant to the current talk, she carried out a variety of omics experiments to determine the impact of the Deepwater Horizon oil spill on indigenous microbes in the water column and sediments of the Gulf of Mexico. Jansson recently served as President of the International Society of Microbial Ecology and on several national panels at the White House and the National Academy. She is a Fellow of the American Academy of Microbiology and the Washington State Academy of Science.

Samantha Joye is a microbiologist and oceanographer at the University of Georgia where she holds the Athletic Association Professorship in Arts and Sciences and is a Professor in the Department of Marine Sciences. She received her B.Sc. in Biology (1987) and Ph.D. in Marine Sciences (1993) from the University of North Carolina at Chapel Hill. She is an expert in microbial geochemistry, focusing on hydrocarbon and trace gas dynamics, and works in both blue water and nearshore ocean ecosystems. Her work is highly interdisciplinary, bridging the fields of analytical chemistry, microbiology, and geology. She has published 170 peer-reviewed papers and 18 book chapters. She is a Fellow of the American Association for the Advancement of Science, the Association for the Sciences of Limnology and Oceanography, the American Geophysical Union, the American Academy of Microbiology and The Explorers Club.

David Karl is the Victor and Peggy Brandstrom Pavel Chair of Oceanography, and Director of the Center for Microbial Oceanography at the University of Hawaii. In spring 1973, Karl participated in his first oceanographic research expedition and since that time he has spent more than 1,000 days conducting research at sea including 23 expeditions to Antarctica. In 1988, he co-founded the Hawaii Ocean Time-series (HOT) program that has conducted sustained physical, biogeochemical and microbial measurements at Station ALOHA for the past 30 years. In 2006, he led a team of scientists in the establishment of a new NSF Science and Technology Center, C-MORE, that conducts collaborative research on the dynamics of marine microorganisms from "genomes to biomes," and in 2014 he helped to create the Simons Collaboration on Ocean Processes and Ecology (SCOPE) program. His research interests focus on marine microbial ecology and biogeochemistry, including various aspects of the major element cycles (C, N, O, P, H), controls on phytoplankton and bacterial production, and the impacts of climate variability on microbial processes in the sea. He is a fellow of the American Geophysical Union and the American Academy of Microbiology, a member of the U.S. National Academy of Sciences, and was a lead author for the IPCC 5th Climate Assessment (*Ocean Systems*, chapter 6, WG-II).

David Kirchman is the Harrington Professor of Marine Bioscience in the School of Marine Science and Policy at the University of Delaware. He has been at Delaware since 1986 after completing postdocs at the University of Georgia and the University of Chicago. He received a B.A. from Lawrence University in 1976 and the Ph.D. from Harvard University in 1982. In the past, he has worked on several topics in the microbial oceanography of the upper water column, focusing on the role of heterotrophic and photoheterotrophic bacteria in the carbon and nitrogen cycles. He is currently interested in the hypoxia problem in the northern Gulf of Mexico and elsewhere.

Kostas Konstantinidis joined the School of Civil and Environmental Engineering at Georgia Institute of Technology as an Assistant Professor in November 2007 and holds the Maulding Faculty Fellow Chair in Environmental Engineering since July 2018. His education and research interests are at the interface of environmental microbiology with engineering, genomics and computational biology. The overarching goal of his research is to broaden our understanding of the genetic and metabolic diversity of the smallest organisms on the planet, the bacteria and archaea, and the role of this diversity for ecosystem function and resilience to natural as well as anthropogenic perturbations. He is also interested in the biotechnological applications of microbial diversity in the bioremediation of environmental pollutants and the assessment of water quality. Dr. Konstantinidis has published >100 peer-reviewed articles, ten in PNAS alone, and six book chapters in these research areas, which have received >10,000 citations (Google Scholar). He received several national and international distinctions for his work, including the 2010 Skerman Award from the World Federation for Culture Collection for the ANI work, the 2012 Sigma Xi Young Faculty Research Award, and a 2014 Kavli Frontiers of Science Fellowship.

Joel E. Kostka is Professor and Associate Chair for Research in the Schools of Biological Sciences and Earth & Atmospheric Sciences at Georgia Institute of Technology. B.S. in Biology (1985), Western Illinois University; M.S. in Marine Biology (1988), College of Charleston; Ph.D. in Marine Science(1993), University of Delaware. He was an NSF Postdoctoral Fellow at the University of Wisconsin (1994-1995) and a visiting scientist at the Max Planck Institute for Marine Microbiology in Bremen, Germany (1995-1996). His research group specializes in characterizing the role of microorganisms in ecosystem functioning, especially in the context of bioremediation and climate change. He has published 106 refereed journal publications and achieved an h-index of 55 with >9,948 citations. He has served as a co-PI of the C-IMAGE and Deep-C consortia within the Gulf of Mexico Research Initiative. In 2011, he coauthored a report from the American Academy of Microbiology entitled, “Microbes and Oil Spills: Frequently Asked Questions.” He served as editor of the journal of Applied and Environmental Microbiology (2011-2017). Currently, Dr. Kostka serves as a Distinguished Lecturer for the American Society for Microbiology as well as Chair Elect for the Gordon Research Conference in Applied and Environmental Microbiology. He is a member of the American Academy of Microbiology.

Elizabeth Kujawinski is a Senior Scientist in the Marine Chemistry & Geochemistry Department. She earned a bachelor’s degree in Chemistry from MIT in 1994, followed by a Ph.D. in Chemical Oceanography from the MIT/WHOI Joint Program in 2000. She completed postdoctoral research at The Ohio State University in the Chemistry Department from 2000 to 2002. Dr. Kujawinski was

an Assistant Professor of Environmental Science at Barnard College from 2002 to 2004, at which time she moved to WHOI. Her research program is centered on the characterization of dissolved molecules in aquatic systems, with a particular focus on detecting and identifying the molecules within microbial community networks. She has been involved in numerous educational and research initiatives at WHOI and has served on external advisory boards.

Karen G. Lloyd is an Associate Professor in the Microbiology Department at the University of Tennessee. She got her Bachelor's in Biochemistry from Swarthmore College and her M.S. and Ph.D. in Marine Sciences from the University of North Carolina. Her research focuses on the biogeochemistry of the subsurface in marine and terrestrial systems. Karen employs whole-sample biomolecular approaches to reconstruct microbial physiologies from uncultured groups of bacteria and archaea, in marine sediments, Arctic fjords, temperate estuaries, and hot springs from subduction zones.

Alexander Loy is Professor for Microbial Communities at the Centre for Microbiology and Environmental Systems Science (University of Vienna, Austria), deputy operational director of the Joint Microbiome Facility (JMF, University of Vienna and Medical University of Vienna), managing director of the Austrian Microbiome Initiative (AMICI), and faculty member of the Austrian Polar Research Institute (APRI). He received his Ph.D. in Microbiology at the Technical University of Munich in Germany. In 2003, he was awarded a Marie Curie postdoctoral fellowship to join the newly founded Department of Microbial Ecology at the University of Vienna in Austria, where he established his own research group in 2006 based on third-party grants and was Assistant Professor from 2009 to 2013 and Associate Professor from 2013 to 2017. He received his Habilitation (*venia docendi*) and the Young Scientist Award of the City of Vienna in 2012. Research of the Loy group focuses on evolution and ecology of sulfur microorganisms, the function of the complex symbiotic microbiota of animals and humans in health and disease, and the development of molecular and isotope-labeling methods for studying uncultivated microorganisms in their natural environment. Since 2002, he has published 79 papers in peer-reviewed journals (including one paper each in *Nature*, *Science* and *PloS Biology*, and two in *PNAS*) and 9 book chapters, and has edited a book on Geomicrobiology.

Olivia Mason is an Assistant Professor at Florida State University, studying how microbial communities respond to respond to ecosystem perturbations, such as oil spills and low oxygen conditions, and the ecological impact of this response. Her research uses methods that do not rely on culturing microorganisms in the lab to discern their physiologies, such as multi-omics techniques to determine what microbes were abundant, active, and what oil constituents the dominant uncultured microorganisms were able to degrade during the Deepwater Horizon oil spill, to provide better resolution on microbial processes and to link these processes in situ geochemistry. She earned her Ph.D. in Oceanography from Oregon State University and a M.S. in Environmental Science from Portland State University.

Kelly McFarlin has been studying oil biodegradation and oil spill response for the past 11 years. She obtained her M.S. in Environmental Engineering and her Ph.D. in Biological Sciences from the

University of Alaska Fairbanks. Most of her work has focused on characterizing the effects of crude oil, chemically dispersed oil, and individual surfactant compounds on indigenous microbial communities and quantifying biodegradation rates under realistic environmental conditions (i.e. using freshly collected seawater with indigenous microbial communities, natural temperatures and nutrient concentrations). She has also performed various molecular analyses to characterize baseline microbial communities and functional potentials (including nutrient cycling) in an offshore Arctic oil lease area. After completing her Ph.D., Dr. McFarlin worked at SINTEF (Trondheim, Norway) as a Research Scientist. Dr. McFarlin is currently an Environmental Scientist at ExxonMobil.

Beth N. Orcutt is a Senior Research Scientist at the Bigelow Laboratory for Ocean Sciences in Maine, USA. Orcutt earned her Ph.D. in Marine Sciences in 2007 from the University of Georgia, Athens, following her research on methane and sulfur cycling in Gulf of Mexico sediment and gas hydrate habitats with Dr. Samantha B. Joye. She also received a B.S. degree in Interdisciplinary Studies from the University of Georgia, Athens, in 2002. Orcutt's research focuses on figuring out how microbial life survives in "extreme" environments in the deep sea and other aquatic environments and determining the roles that those microbes play in global chemical cycles. Orcutt's specializes in the use of *in situ* observatory experiments in the environment coupled with geochemical, electromicrobiological, and single cell-level genomic techniques to track the activity of microbes and identify the mechanisms they use to survive.

Edward B. Overton is a Professor Emeritus in the Department of Environmental Sciences, School of Coast and the Environment at LSU. He received his B.S. (1965) and Ph.D. (1970) degrees from the University of Alabama, Tuscaloosa. His research interests include understanding the fates and distributions of hydrocarbons following an oil spill, the environmental chemistry of hazardous chemicals, and the detection of environmental pollutants at the site of sample collection. He has been active in understanding the fate and effects of petroleum hydrocarbons in marine environments from oil spills since the 1978 Well blowout at the US DOE Strategic Petroleum Reserve West Hackberry Site, followed by the Amoco Cadiz Tanker wreck and the IXTOC 1 blowout in 1979, the Exxon Valdez wreck in 1989, and currently the Deepwater Horizon fire and blowout in 2010. Dr. Overton held the Clairborne Chair in Environmental Toxicology and Air Quality prior to his retirement, was honored as an LSU Distinguished Faculty in 2008, elected the 1996 Louisiana Technologist of the Year, and the 2010 Louisiana Communicator of the Year. He recently received a 2017 Stewardship Award from the Coalition to Restore Coastal Louisiana.

Martin Polz is a professor at the Massachusetts Institute of Technology (MIT) in the Parsons Laboratory for Environmental Science and Engineering. His research interests are focused on the evolution and ecology of microbes with major focus on genomics and population-level processes. He obtained his M.S. degree in Zoology from the University of Vienna and his Ph.D. in Organismic and Evolutionary Biology from Harvard University. Polz joined the faculty at MIT in 1998 where he teaches microbial ecology and evolution at both the undergraduate and graduate level. He is former chair of the Joint Program in Biological Oceanography and co-chair of the MIT Microbiology program. Polz is a Fellow of the American Academy for Microbiology and recipient of the Eli Lilly and the Company Elanco Research Award, the oldest prize awarded by the

American Society for Microbiology. At MIT, he has received the Frank E. Perkins Award for excellence in graduate advising. Polz has also served as editor for Environmental Microbiology and Microbiology and Molecular Biology Reviews and is on the editorial board of Microbiome.

Joseph M. Suflita joined the faculty of the University of Oklahoma (OU) as an environmental microbiologist in 1982 following post-doctoral and Ph.D. studies at Michigan State and Penn State University, respectively. He progressed through the ranks, was tenured in 1988, promoted to full professor in 1992, and appointed a George Lynn Cross Research Professor in 1998. A unifying thread in his research is his concern over the metabolic fate of important environmental contaminants, particularly under anaerobic conditions. He currently provides leadership for important institutes/centers at OU, including the Institute for Energy and the Environment as well as the OU Biocorrosion Center. Dr. Suflita was elected into the American Academy of Microbiology (1991) and is a past recipient of the *DuPont Industrial Bioscience Award in Applied and Environmental Microbiology* (2016). He served for 26 years as an Associate Editor for *Environmental Science and Technology* and recently agreed to serve in the same capacity for *International Biodeterioration and Biodegradation Journal*. He seeks to provide the basic scientific foundation upon which the solution to applied environmental problems may be built.

Andreas Teske is a professor in the Department of Marine Sciences at the University of North Carolina in Chapel Hill, USA. Initially trained as a biochemist at Hannover University in Germany, Andreas obtained his Ph.D. with Bo B. Jørgensen at the Max-Planck-Institute for Marine Microbiology and Bremen University in 1995, on the microbial ecology of the sulfur cycle in microbial mats. As a postdoctoral fellow with H.W. Jannasch, and subsequently as assistant scientist at the Woods Hole Oceanographic Institution, he developed a taste for the microbiology of extreme marine habitats, especially the deep marine biosphere and hydrocarbon seeps. After joining the faculty of the Marine Sciences Dept. of UNC Chapel Hill in 2002, Teske continues to investigate the microbial ecology of the sulfur and methane cycle in hydrothermal vents, methane seeps and the deep sedimentary subsurface, most recently via multidisciplinary studies of the microbial ecosystems of hydrocarbon seeps in the Gulf of Mexico and in Guaymas Basin in the Gulf of California, with multiple Atlantis cruises and Alvin dives. Upcoming work focuses on deep subsurface exploration of Guaymas Basin with deep-sea drill ship JOIDES Resolution, as proponent and co-chief scientist of Expedition 385 "Guaymas Basin Tectonics and Biosphere.

J. Cameron Thrash is an Assistant Professor of Biological Sciences at the University of Southern California. His laboratory focuses on investigating the ecology and metabolism of aquatic microorganisms by integrating cultivation, physiology, and comparative (meta)genomics. He has a B.S. in Biology from UC San Diego, and a Ph.D. in Microbiology from UC Berkeley. His dissertation research in the lab of Dr. John Coates included bioelectrochemical stimulation and isolation of microorganisms that could reductively respire perchlorate as well as microbial anaerobic oxidation of Fe(II) and U(IV). Thrash received an NSF Postdoctoral Fellowship to work with Dr. Stephen Giovannoni at Oregon State University on the evolution and genomics of SAR11, the most abundant marine bacteria. He was an Assistant Professor at Louisiana State University 2013-2018 where his laboratory investigated the microbial ecology of hypoxia in the northern

Gulf of Mexico, the Mississippi River, and Louisiana coastal sites. Using high-throughput dilution-based cultivation, the Thrash laboratory has isolated hundreds of marine and estuarine microorganisms. Beginning at USC in 2019, his laboratory continues to study the roles of microorganisms in coastal and open ocean systems, and cultivation work has begun anew from the San Pedro Ocean Time series.

Tina Treude received a diploma in biological oceanography from the University of Kiel. During her Ph.D. thesis at the Max Planck Institute for Marine Microbiology she studied anaerobic oxidation of methane in marine sediments. After completing a postdoctoral fellowship at USC, Tina was a professor at the GEOMAR Helmholtz Centre for Ocean Research for seven years, where she studied the effect of climate change on marine gas hydrates, microbial petroleum degradation, microbe-mineral interactions, and biogeochemical processes in oxygen minimum zones (OMZs). In 2014 she joined UCLA, and has since then been working on different projects, including the historic development of the OMZ in the Santa Monica Basin, methane production and consumption in salt marshes, sulfate reduction in the water column of the Peruvian OMZ, gas bubble transport of methanotrophic microbes at seeps, and the temperature limit of the deep biosphere in the Nankai Trough. Tina's research focusses on the activity of microorganisms and related biogeochemical processes in marine environments and how they are related to element cycling. She uses experiments and radioisotope labeling to quantify microbial activity and couples these with other techniques (geochemical analyses and cell identification) to understand biogeochemical processes in sediments and in the water column. Her research often connects with many other disciplines from geophysics to molecular biology and numerical modeling.

Jonathan Zehr is Distinguished Professor of Ocean Sciences at the University of California, Santa Cruz. He received his B.S in Biology from Western Washington University in 1981 and his Ph.D. in Ecology from the University of California, Davis, in 1985. Dr. Zehr did postdoctoral work in nitrogen cycling at the State University of New York, Stony Brook and Brookhaven National Laboratory, and in molecular biology at New England Biolabs, Inc. in Beverly, Massachusetts. He joined the faculty of Biology at Rensselaer Polytechnic Institute in 1992. In 1999, Dr. Zehr began his current position as Professor of Ocean Sciences at the University of California. He was elected Fellow of the Academy of Microbiology in 2009 and of the American Association for the Advancement of Science (AAAS) in 2018. His research has focused on nitrogen cycling by aquatic microorganisms, although he has publications spanning topics in microbial diversity in freshwater and hypersaline systems, organic matter metabolism, selenium metabolism in estuarine sediments, and nitrogen metabolism in oligotrophic oceans. His major focus is oceanic nitrogen fixation. Dr. Zehr is the Editor-in-Chief for "Frontiers in Aquatic Microbiogy" and co-Editor of the Journal of Phycology.

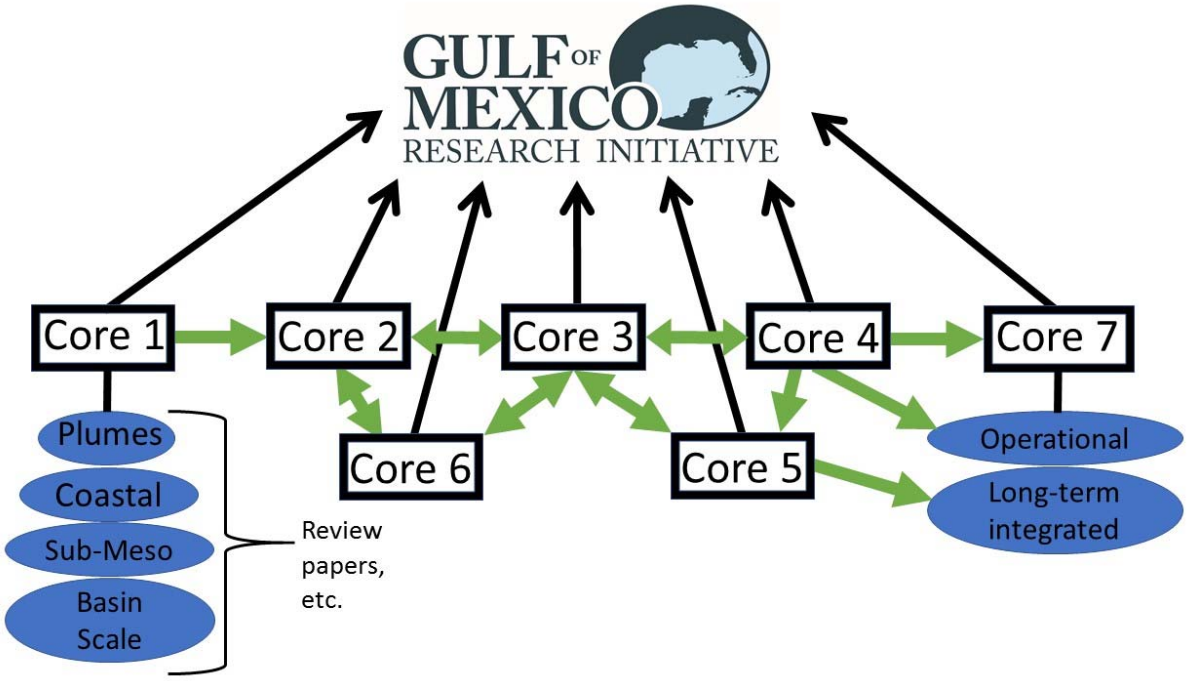
Karsten Zengler is an Associate Professor at UC San Diego and has more than 20 years of experience in the fields of microbiology and systems biology. After receiving his Ph.D. at the Max Planck Institute for Marine Microbiology (Bremen, Germany), he worked for seven years in the biotechnology industry where he led a team of scientists to pioneer the high-throughput

cultivation for the isolation and recovery of previously unculturable microorganisms. His work has focused on understanding of interactions of microorganisms with their environment and host organisms. He spearheaded the field of community systems biology where he combined his knowledge in microbial physiology and molecular biology with computational biology to discover new physiological capabilities, regulatory effects, and novel multidimensional interspecies interactions. His lab has been on the forefront of developing new protocols for ultra-low input omics approaches to unravel the role of the microbiome in health and disease. This interdisciplinary approach allows for a deeper understanding of microbial interactions and the unraveling of mechanisms in microbiome research. Dr. Zengler is author and co-author of more than 80 research articles and reviews. He is the co-founder of several companies and is on the advisory board of different companies and institutions.

GoMRI's Synthesis Efforts

The Gulf of Mexico Research Initiative (GoMRI) will come to an end in 2020 after 10 years of dedicated research efforts to understand the impacts of the Deepwater Horizon oil spill. GoMRI is synthesizing knowledge to ensure that GoMRI's scientific achievements and advances will be available to scientists, the user community, and responders. To best capture a comprehensive scientific synthesis, eight Core Areas of focus were identified along with a set of guiding principles to maintain consistency throughout the entire synthesis effort. Learn more about GoMRI's synthesis efforts, the eight Core Areas and the series of workshops that have already occurred and will continue in the coming year, at gulfresearchinitiative.org/gomri-synthesis/.

This colloquium, *Microbial Genomics of the Global Ocean System* will contribute significantly to GoMRI Synthesis Core Area 6 – Microbiology, Metagenomics & Bioinformatics.



This diagram illustrates the interrelated nature of the GoMRI Core Areas. The green arrows indicate critical lines of communication. Each Core Area has multiple subtopics, as shown here in the Core Area 1 example. The Core Area 8 advisory group will play a unique and crucial role throughout all the Core Areas promoting the effective application and communication of GoMRI funded science between the research and user communities. Products from the subtopics, designed for a scientific audience within that specific field, will help inform a product for each Core Area that is written for scientific audiences in all fields. Eventually, all Core Area products will inform synthesis products for the general public.

GoMRI findings, including the data and peer reviewed publications, are publicly available. This data and information legacy will promote continual scientific discovery and public awareness of the Gulf of Mexico ecosystem. Visit data.gulfresearchinitiative.org and research.gulfresearchinitiative.org to learn more!

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AGU Goes Net Zero Energy

Working together to advance science and communicate its power to ensure a sustainable future, we believe in leveraging new discoveries to benefit all of humanity.

It was that principle that drove us to transform AGU's headquarters building into a living representation of our mission that embodies the spirit and values of scientific discovery.

With the goal of leading by example and catalyzing the incorporation of similar approaches and designs into new and existing facilities throughout Washington, D.C. and beyond, we embarked on the first-ever net zero energy renovation of an existing commercial building in our nation's capital.

The project incorporates numerous innovative technologies that focus on four key engineering principles—reduction, reclamation, absorption, and generation…

Garage Level

- **Huber Sewer Heat Exchange System**
  The first to be installed in the United States, it works by pumping screened wastewater from the outdoor wet well to a heat exchanger, where energy is exchanged with a separate closed-loop system of clean water for use in the building's heating and cooling system. That allows us to leverage the natural thermal energy flowing through the sewer system to heat and cool our building more efficiently.
- **Wet Well**
  The wet well connects to Washington, D.C.'s existing 1890s-era sewer line, which lies 30 feet below Florida Avenue, just outside the building, via one supply and one return pipe. Stabilizing and safely excavating around the building and sewer line were major challenges, requiring the existing sewer line to be completely reinforced with concrete before supply and return lines could be installed.

Garage Level

- **Water Filtration System**
  Once pumped to the below-ground 11,300 gallon tank, captured rainwater and reclaimed condensate water is filtered, chemically treated, and conditioned before it is recirculated for non-potable use throughout the building.
- **Hy-Phy Water Treatment**
  The Nedlaw hy-phy skid is a pumping station for the hy-phy wall. The computer can detect which walls are hydrated sufficiently and which aren't and redirect the water accordingly; it can also shut water off if one wall is in danger of overflowing and monitor the tank to desalinate it when salt builds up. Water for the hy-phy wall comes from the water reclamation cistern, which collects rainwater from the roof as well as condensate water from the building's dedicated outdoor air system. Once filtered and treated, this water is continuously pumped throughout the individual green walls to keep the plants irrigated and hydrated. The plants themselves grow their root structures around a mesh-like material inlaid behind the hy-phy wall and the reclaimed water is constantly circulating through the plant roots, giving the system its hydroponic moniker.

Lower Level

- **Net Zero Tour Orientation**
  AGU's Net Zero Tour gives you an inside look at the technologies and strategies used in the first-ever net zero energy renovation of a commercial building in our nation's capital. The tour demonstrates our commitment to science, our staff, the environment, and humanity while fulfilling our goal to educate the public and those working in the built environment.
- **Command Center**
  Here, engineers collect data from various systems and technologies, including data on air quality, energy consumption, and usage at individual workstations, as well as solar power generation from the rooftop solar array, to help ensure the building is meeting its net zero energy goals.
- **Reuse Materials**
  Nearly 96% of the existing walls, floors, and roof materials were reused, and more than 85% of construction waste was recycled. Specifically, more than 5,000 bricks were carefully removed from the outside of the building, carefully cleaned, and replaced during construction. In addition, the old windows, broken bricks, and even the sinks and toilets were crushed to make the terrazzo used on the floors of the building and the surface of the Board room table.
- **Hy-Phy wall**
  The hydroponic phytoremediation wall system—or hy-phy wall—is actually six distinct green walls featuring more than 400 plants. The plants are all non-pollen producing, ranging from multiple species of Ficus and Dracaena to Philodendron, and reclaimed rainwater irrigates the entire system. The hy-phy wall works with our dedicated outdoor air system (DOAS) to act as a bio-filter, recycling indoor air, filtering it through the root systems of the plants and removing contaminants, and recirculating clean air throughout the building.
- **Mechanical Room**
  The mechanical room houses a water-to-water heat pump. This pump is a critical part of our municipal sewer heat exchange system, which extracts thermal energy from screened and filtered wastewater pumped in from the city's sewer system 30 feet below street level. This water-to-water pump then pumps that clean water from the heat exchanger and uses it to produce either chilled or hot water for use in the building and for the radiant cooling systems.
- **Radiant Panels in the Ceilings**
  By circulating chilled water through a network of pipes installed in the ceiling, the hydronic cooling system will maintain spaces at comfortable temperatures using less energy than a forced-air system.

Lobby

- **Earth and Space Science Exhibit**
  The Exhibit highlights several of the discoveries, innovations, and solutions in Earth and Space Science from the last 100 years and those who contributed to the field, while exploring some of the scientific grand challenges facing the future. The exhibit features artifacts from the field, as well as a multitude of tactile and digital interactives.
- **Compass Rose**
  Pointing north, our marble and granite compass rose remained untouched throughout the net zero energy renovation as part of our strategy to reuse as many existing materials and features as possible.
- **Members Lounge**
  By providing accessible, state-of-the-art meeting and conference space, as well as informal gathering/work space for members to use while they are in the neighborhood, AGU's headquarters will become a place for members to feel welcome and to collaborate with each other. It will become a home away from home for all AGU members while they are visiting the nation's capital. Ad-hoc meetings that are scheduled within one week are complimentary to members, contingent upon availability.

Roof

- **Solar Photovoltaic Array**
  The solar photovoltaic (PV) array will generate enough energy to supply power for all the building's electrical needs on an annual basis and allow any surplus power to be fed back into the city's grid. Nearly 700 PV panels are laid out horizontally above the penthouse roof and more than 20 south-facing panels are installed vertically. Altogether, there are more than 13,000 square feet of PV panels.
- **Electrical Room**
  This room contains equipment supporting the solar photovoltaic array and direct current power distribution system. A rectifier helps AGU recognize if and when the building is using more power than it is creating and will automatically switch to the city's power grid.
- **Made in the Sage**
  AGU replaced more than 900 windows with dynamic, triple-paned, electrochromic SageGlass, which helped to limit the use of our heating and cooling systems and save even more energy. These windows use sensors to measure sun levels and tint automatically to reduce glare and heat transmission. The windows are connected to the building's interior lights; as the windows grow darker, the lights will glow brighter.
- **Just Venting**
  The dedicated outdoor air system (DOAS) works with our hy-phy wall to provide a dedicated means of ventilation for the building. While the DOAS conditions and delivers outside air into the building, the hy-phy wall works to filter and purify inside air of any contaminants, recycling it throughout the building. The DOAS also recovers energy from outgoing exhaust air and uses it to either heat (in the winter) or cool (in the summer) the outside air before delivering it inside.