NATIONAL ACADEMIES Sciences Engineering Medicine

The Role of Plant Agricultural Practices on Development of Antimicrobial Resistant Fungi Affecting Human Health

Health and Medicine Division
Board on Global Health
Forum on Microbial Threats

Workshop Briefing Book
June 21, 22, & 27, 2022

Contents

About the Forum

The Forum on Microbial Threats of the National Academies of Sciences, Engineering, and Medicine (National Academies) was created in 1996 at the request of the Centers for Disease Control and Prevention and the National Institutes of Health to provide a structured opportunity for discussion and scrutiny of critical, and possibly contentious, scientific and policy issues related to research on and the prevention, detection, surveillance, and responses to emerging and reemerging infectious diseases in humans, plants and animals as well as the microbiome in health and disease. The Forum brings together leaders from government agencies, industry, academia, and nonprofit and philanthropic organizations to facilitate cross-sector dialogue and collaboration through public debate and private consultation to stimulate original thinking about the most pressing issues across the spectrum of microbial threats.

Despite decades of progress, the need for the Forum on Microbial Threats remains. Emerging and persistent problems such as Ebola, Chikungunya, Zika, yellow fever, antibiotic resistance, and, in recent years, MERS and COVID-19 demonstrate how the issue of infectious threats is global and unrelenting. The drivers are ever more pervasive, and the consequences—human, social, and economic—loom larger than ever.

The Forum convenes several times each year to identify and discuss key problems and strategies in the area of microbial threats. To supplement the perspectives and expertise of its members, the Forum also holds public workshops to engage a wide range of experts, members of the public, and the policy community. All workshops are summarized in high quality scholarly workshop proceedings that are available for free download from the National Academies Press.

The Forum on Microbial Threats is part of the National Academies' Board on Global Health. For more information about the Forum, please visit our website: www.nationalacademies.org/microbialthreats.

Sponsors

- U.S. Agency for International Development
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The Forum greatly appreciates our sponsors that make intellectual and financial contributions to the Forum's work.

Highlights of Recent Publications

- Toward a Post-Pandemic World: Lessons from COVID-19 for Now and the Future: Proceedings of a Workshop (2022)
- Innovations for Tackling Tuberculosis in the Time of COVID-19: Proceedings of a Workshop (2022)
- Systematizing the One Health Approach in Preparedness and Response Efforts for Infectious Disease Outbreaks: Proceedings of a Workshop (2022)
- The Critical Public Health Value of Vaccines: Tackling Issues of Access and Hesitancy: Proceedings of a Workshop (2021)
- Vaccine Access and Hesitancy: Part One of a Workshop Series: Proceedings of a Workshop—In Brief (2020)
- Exploring the Frontiers of Innovation to Tackle Microbial Threats: Proceedings of a Workshop (2020)
- The Convergence of Infectious Diseases and Noncommunicable Diseases: Proceedings of a Workshop (2019)
- Exploring Lessons Learned from a Century of Outbreaks: Readiness for 2030: Proceedings of a Workshop (2019)
- Understanding the Economics of Microbial Threats: Proceedings of a Workshop (2018)
- Urbanization and Slums: Infectious Diseases in the Built Environment: Proceedings of a Workshop (2018)
- Combating Antimicrobial Resistance: A One Health Approach to a Global Threat: Proceedings of a Workshop (2017)

Forum's Action Collaborative – One Health

The Forum's One Health Action Collaborative (OHAC), led by Gail Hansen, D.V.M., is an ad hoc activity that engages a community of participants who are interested in contributing to ongoing exploration and information sharing related to one health topics. OHAC is committed to accelerating the implementation of a one health approach in the field to counter microbial threats. Members include a subset of forum members and a diverse range of external stakeholders from multiple sectors and disciplines such as public health, animal health, plant pathology, agriculture, environment, biotechnology, and others. Drawing from the dynamic discussions over regular conference calls, OHAC advises on one health efforts that are internal and external to the national academies, through the publication of papers and the hosting of seminars. For more info, click here.

Upcoming Events from the Forum

ADVANCES FROM COVID-19 IN DEVELOPMENT, REGULATION, AND COMMUNICATIONS OF NEW TOOLS AND TECHNOLOGIES FOR FUTURE PANDEMIC PREPAREDNESS: A WORKSHOP

On December 8-9, 2022, the Forum on Microbial Threats will host a multi-day public workshop that will broadly explore innovative approaches sparked by COVID-19 to enhancing health systems preparedness and response to emerging infectious diseases. This workshop will consider basic scientific infrastructure and essential capabilities to support rapid medical countermeasures that have made up the COVID-19 pandemic response. Workshop participants will reflect on critical infrastructure for stakeholder coordination and innovations in the regulatory environment that can facilitate rapid and effective responses to emerging threats.

Stay tuned for more details!

To receive a "Save the Date" announcement for our events, sign up for our listserv here: www.nationalacademies.org/microbialthreats

Forum Membership

Peter Daszak, Ph.D. ***(chair)***
EcoHealth Alliance

Kent E. Kester, M.D. ***(vice chair)***
International AIDS Vaccine Initiative

Emily Abraham, Dr.P.H.
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Retired

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The Role of Plant Agricultural Practices on Development of Antimicrobial Resistant Fungi Affecting Human Health

A Workshop

Objectives:

As the use of antimicrobials in agriculture has become a globally widespread and standard practice, the impacts on human, animal, and ecosystem health have become more pronounced. Antimicrobial resistance (AMR) is now one of the most pressing global health threats as microbes affecting humans, animals, and plants become less responsive to standard treatments (WHO, 2021). The use of antifungals in crop production is an area of great concern that has garnered the attention of global health entities such as the WHO and US HHS (WHO, 2021; HHS, 2021). Antifungal use in agriculture may promote the development of resistant fungi in the environment, with implications for human health. However, several questions remain as to the mechanisms that promote resistance, the effects of resistant fungi in the environment, and how this phenomenon might impact human health.

This public workshop will examine: 1) the magnitude of environmentally induced/selected AMR in agricultural practices worldwide, with a focus on plant crop production; 2) the practices that contribute to AMR in human pathogens, 3) surveillance strategies, and 4) mitigation strategies.
The public workshop series will feature invited presentations and discussions to consider:

- What is the magnitude of antifungal use in crop production in high-, middle- and low-income countries? How are such uses regulated?
- What are the mechanisms of AMR in plant pathogens and non-target environmental microbiota? How might this influence AMR in human pathogens?
- Which practices promote, prevent, or reduce the development of AMR in plant production environments, specifically in fungal pathogens? How does this affect risk of produce contamination with AMR pathogens?
- Are sampling and testing technologies for AMR surveillance in plant production systems adequate? What further evidence is needed to inform the use of antimicrobials worldwide? What further evidence is needed to understand the presence and effects of environmental AMR on human health?

A proceedings of the presentations and discussions at the webinar will be prepared by a designated rapporteur in accordance with institutional guidelines. For more information on this virtual workshop, please visit the main project page.

The Role of Plant Agricultural Practices on Development of Antimicrobial Resistant Fungi Affecting Human Health

A Workshop

TUESDAY, JUNE 21, 2022 (via Zoom; all times in EDT)

Bridging the Two Worlds: Fungal Pathogens in Plant and Human Health	
10:00 AM–10:10 AM	**Welcome Remarks, Workshop Overview, and Goals** **Paige Waterman**, Uniformed Services University of Health Sciences *Workshop co-chair*
10:10 AM–11:05 AM	**Opening Panel** **Tom Chiller**, U.S. Centers for Disease Control and Prevention *Moderator* Antifungal drug uses in human medicine **Arturo Casadevall**, Johns Hopkins University Bloomberg School of Public Health Fungicide uses in plant agriculture **Tony Dorn**, U.S. Department of Agriculture **TBD**
11:05 AM-11:20 AM	**Break**
11:20 AM-12:35 PM	**Fungal Diseases, Antifungal Resistance, and Human Health** **Tom Chiller**, U.S. Centers for Disease Control and Prevention *Moderator* Impact of invasive fungal diseases and antifungal drug resistance on human health **Andrej Spec**, Washington University at St. Louis Overview of aspergillosis and mechanisms of antifungal drug resistance **David Denning**, Global Action For Fungal Infections Overview of drug-resistant, invasive *Candida* infections **Brendan Jackson**, U.S. Centers for Disease Control and Prevention

	Current research in understanding pathogenesis and host immunity toward developing treatment options **Michail Lionakis**, National Institute of Allergy and Infectious Diseases
12:35 PM–1:15 PM	**Fungicide Resistance in Plant Protection Use** **Marin Talbot Brewer**, University of Georgia *Moderator* Genetics and mechanisms of fungicide resistance **Matthew Fisher**, Imperial College London Azole-resistant *Aspergillus fumigatus* in agronomic settings: hotspots and coldspots **Kevin Doughty**, CropLife International
1:15 PM–1:55 PM	**Discussion**
1:55 PM–2:00 PM	**Summary and Adjourn**
END OF DAY 1	

WEDNESDAY, JUNE 22, 2022 (via Zoom; all times in EDT)

Effects of Fungicide Use in Plants on Humans and the Environment	
10:00 AM–10:05 AM	**Welcome Remarks, Review of Day 1** **Jeff Lejeune**, Food and Agriculture Organization of the United Nations
10:05 AM–10:45AM	**Role of Fungicide Use in Food Safety and Security** **Phil Taylor**, Centre for Agriculture and Bioscience International (CABI) *Moderator* Case examples to illustrate (1) the role of azole fungicides in safeguarding food safety and security, and (2) potential drivers of fungicide use in the US **Tim Brenneman**, University of Georgia **Pierce Paul**, The Ohio State University
10:45 AM-12:15PM	**Dimensions of Fungicide Regulations, Use Management, and Risk Assessment** **Lynn Goldman**, George Washington University Milken Institute School of Public Health *Moderator* Documentation of azole fungicide use in plants in low- and middle-income countries **Phil Taylor**, Centre for Agriculture and Bioscience International (CABI) Registration and health threats assessment of fungicides **Nathan Mellor**, US Environmental Protection Agency **Magdalini Sachana**, Organisation for Economic Co-operation and Development Occupational exposure to environmental resistant fungi and possible implications in human health **Raquel Sabino**, Portuguese National Institute of Health Dr. Ricardo Jorge
12:15 PM-12:30 PM	**Break**
12:30 PM–1:15 PM	**Innovations in Antimicrobial Resistance Surveillance Tools and Technologies** **Jeff Lejeune**, Food and Agriculture Organization of the United Nations *Moderator* *Aspergillus fumigatus* azole resistance survey by air sampling through a citizen science approach **Wieland Meyer**, University of Sydney Westmead Institute for Medical Research Innovation in data collection tools for surveillance and mitigation: crop and environment simulation tools **Brian Bailey**, University of California, Davis

	Sampling strategies, interpretation of sampling outcomes, and evaluation of surveillance and management technologies **Karen Garrett**, University of Florida
1:15 PM–1:55 PM	**Discussion**
1:55 PM–2:00 PM	**Summary and Adjourn**
END OF DAY 2	

MONDAY, JUNE 27, 2022 (2101 Constitution Ave. NW, Washington, DC; all times EDT)

Mitigation Strategies for Fungicide/Antifungal Resistance	
8:00 AM–10:00 AM	**In-Person Networking and Breakfast**
10:00 AM–10:15 AM	**Welcome virtual attendees; Review of workshop thus far** **Paige Waterman**, Uniformed Services University of Health Sciences *workshop co-chair*
10:15 AM–11:45 AM	**One Health Approach to Antimicrobial Resistance (AMR) and Pathogen Surveillance** **Maryn McKenna** *Moderator* The necessity and benefits of taking a One Health approach in AMR surveillance and mitigation measures **Paul Verweij**, Radboud University **Bas Zwaan**, Wageningen University Genomic surveillance and epidemiology **Marin Talbot Brewer**, University of Georgia Diagnostics, resistance testing, and surveillance capabilities in local and national levels: health care systems and agricultural systems **Shawn Lockhart**, U.S. Centers for Disease Control and Prevention One Health approach to AMR and pathogen surveillance at the international level **Jorge Pinto Ferreira**, Food and Agriculture Organization of the United Nations
11:45 AM–12:15 PM	**Break**
12:15 PM–1:00 PM	**Antifungal Drug Development and Stewardship in Health Care** **Maryn McKenna** *Moderator* New antifungal drugs in development with different modes of action **David Andes**, University of Wisconsin Incentives and market for drug development and global access **John Rex**, F2G

1:00 PM–1:50 PM	**Integrated Disease Management** **Tim Widmer**, U.S. Department of Agriculture *Moderator* Precision application technologies and communication with growers and other stakeholders **Melanie Ivey**, The Ohio State University Current research toward targeted approaches and considering localized risk factors **Walt Mahaffee**, U.S. Department of Agriculture Mitigation measures in compost "hot spots" **Jianhua Zhang**, Wageninen University
1:50 PM–2:00 PM	**Summary of Workshop**
2:30 PM–4:30 PM	**Poster and Networking Session**
END OF WORKSHOP	

Workshop Planning Committee

Sally A. Miller, Ph.D. ***(co-chair)***[†]
Distinguished Professor of Food, Agricultural, and Environmental Sciences in Plant Pathology
The Ohio State University

Paige Waterman, M.D. ***(co-chair)***
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Centre for Agriculture and Bioscience International

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Planning Committee Biographies

Sally A. Miller, Ph.D., (co-chair) is a Distinguished Professor of Food, Agricultural, and Environmental Sciences in Plant Pathology at The Ohio State University in Wooster, OH and State Extension Specialist for vegetable crop disease management. She received her B.Sc. in Biology from The Ohio State University (1976), and M.S. (1979) and Ph.D. (1982) degrees in Plant Pathology from the University of Wisconsin-Madison. Dr. Miller's research is focused on plant pathogen detection and surveillance, disease diagnosis, antimicrobial resistance, and integrated disease management in vegetable crops. She has been active in long-term international agricultural development projects focused on food security and safety in South and Southeast Asia, Ukraine, West and East Africa and Central America. She is a Fellow of the American Phytopathological Society and served as President in 2015/2016. She is currently a member of National Academies of Science, Engineering and Medicine Forum on Microbial Threats and its One Health Action Collaborative, the joint FAO/WHO Expert Meetings on Foodborne Antimicrobial Resistance Roster of Experts, and the executive committee of OSU's Global One Health Initiative.

Paige Waterman, M.D., (co-chair) is a retired Army Colonel and Professor of Medicine and Vice Chair for Clinical Research, the F. Edward Hebert School of Medicine, Department of Medicine, at the Uniformed Services University of the Health Sciences, Bethesda, MD. Dr. Waterman is an infectious disease clinician, researcher, and leader in the battle against antimicrobial resistance (AMR). Throughout her career, Dr. Waterman has worked in highly collaborative national and international teams to curb rising drug resistance through the surveillance and early detection of emerging pathogens, policy creation and coordinated antimicrobial stewardship. As a military officer, Dr. Waterman served as deputy director of the then nascent Multidrug-Resistant Organism Repository and Surveillance Network (MRSN), at the Walter Reed Army Institute of Research (WRAIR), to collect pathogens for epidemiologic and molecular characterization, profiling and centralized archiving and clinical correlation. She was also detailed to the Armed Forces Health Surveillance Directorate to establish its antimicrobial resistance effort and become the deputy director of the Global Emerging Infections Surveillance (GEIS) section. Dr. Waterman deployed as the Infectious Disease Theater Consultant and Clinic Chief for the 10th Mountain 3rd Infantry Brigade Combat team in Afghanistan in 2011-12. Throughout her career, Dr. Waterman has led clinical trials, manufacturing of biologics (vaccines), AMR and antimicrobial stewardship, clinical and bacterial genomic characterization, wound infection diagnostic and therapeutic development efforts, and global infectious disease surveillance. She also led the biodefense and bioeconomy policy effort at the Office of Science and Technology Policy within the Executive Office of the President. She served for more than 4 years as the Medical Research and Development Consultant to the Army Surgeon General and is a past President of the Greater Washington area Infectious Disease Society.

Marin Talbot Brewer, Ph.D., is an Associate Professor of Mycology and Plant Pathology at the University of Georgia where she has been a faculty member since 2011. Her research focuses on the evolution and diversity of fungal threats to plants and people with interests in the genetic basis of disease emergence and host specialization, the evolution of fungicide resistance and fungal mating systems, and the taxonomy and systematics of fungi causing emerging plant diseases. She received her M.S. in Plant, Soil, and Environmental Science from the University of Maine where she studied the effects of biological and cultural controls on soil microbial ecology and Rhizoctonia disease of potato, and her Ph.D. in Plant Pathology and Plant-Microbe Biology

from Cornell University in 2011, where her dissertation focused on the phylogeography and mating system of the grape powdery mildew fungus, Erysiphe necator. Recent work in the Brewer lab is concentrated on azole resistance in the human pathogen Aspergillus fumigatus in environmental settings. Dr. Brewer was a plenary speaker at the Plant Health 2021 meeting where she presented "Does agricultural use of azole fungicides contribute to antifungal resistance of Aspergillus fumigatus in humans?" Her research has been funded by diverse agencies including the National Science Foundation, the U.S. Department of Agriculture, and the Centers for Disease Control and Prevention.

Tom Chiller, M.D., M.P.H.T.M., is Chief, Mycotic Diseases Branch at the Centers for Disease Control and Prevention. At the CDC, Tom Chiller provides leadership for fungal disease activities, which include detection, prevention and response activities, policy and advocacy, both nationally and internationally. He also serves as the associate director for global programs in the Division of Foodborne, Waterborne, and Environmental Diseases. He remains actively involved in antimicrobial resistance, healthcare associated infections, molecular epidemiology and laboratory activities for fungal diseases. Dr. Chiller is board certified in infectious diseases and is a faculty member in the Division of Infectious Diseases at the Emory School of Medicine. During the past decade with the Mycotic Diseases Branch, Dr. Chiller has led efforts to end deaths from opportunistic fungal infections in HIV, control the spread of MDR Candida auris and azole resistant Aspergillus, and identify emerging mold infections.

Julius Fajardo, Ph.D., M.S., is a Senior Plant Pathologist in the Office of Pest Management Policy (OPMP) under the Office of the Chief Economist of USDA. Dr. Fajardo joined OPMP in 2012 as a Plant Pathologist. In this capacity, Dr. Fajardo's portfolio includes policy issues involving registration reviews of fungicides, biofungicides, nematicides, and plant growth regulators as well as fungicide resistance in collaboration with EPA. He has worked on emerging diseases and pathogens through USDA-ARS' National Plant Disease Recovery System, USDA-APHIS' Multi-Agency Coordination Group for citrus greening or huanglongbing including the Federal Interagency Committee on Invasive Terrestrial Animals and Pathogens (ITAP). Dr. Fajardo provides scientific support with the Office of the Chief Scientist on the role of antibacterial and antifungal compounds in crops on foodborne antimicrobial resistance. Dr. Fajardo received his Doctor of Philosophy in Plant Pathology from Texas A&M University in 1992 and earned a Bachelor of Science in Agriculture and Master of Science degrees in Plant Pathology from the University of the Philippines at Los Banos in 1980 and 1985, respectively.

Susan Jennings, M.S., is the Senior Advisor for Public Health at EPA's Office of Pesticide Programs. She coordinates regulatory and policy issues involving pesticides used to protect public health. This work can be complex and requires the Agency to support and maximize the benefits of pesticides used to protect human health, while still ensuring that they do not pose unreasonable adverse effects to human health or the environment. Susan serves as the staff lead on OPP's emergency responses to situations such as the Zika virus, actively supports IPM and other control discussions, and participates in other public health activities as they arise. She is currently leading the efforts on antibiotic resistance for antibiotics used on crops at the Office of Pesticide Programs. Susan has a Bachelor of Science from Carnegie Mellon University and a Master of Science in Environmental Engineering from Virginia Tech.

Ramanan Laxminarayan, Ph.D., is founder and director of the Center for Disease Dynamics, Economics & Policy (CDDEP) in Washington, D.C. and New Delhi, and a senior research scholar at Princeton University. He is an affiliate professor at the University of Washington, senior associate at the Johns Hopkins Bloomberg School of Public Health, and a visiting professor at the University of Strathclyde in Scotland. Laxminarayan chairs the board of GARD-P, a global product development partnership created by the World Health Organization, that aims to

develop and deliver new treatments for bacterial infections. He is founder and board chair at HealthCubed, which works to improve access to healthcare and diagnostics worldwide. Since 1995, Laxminarayan has worked to improve the understanding of antibiotic resistance as a problem of managing a shared global resource. His work encompasses extensive peer-reviewed research, public outreach, and direct engagement across Asia and Africa through the Global Antibiotic Resistance Partnership. Through his prolific research, active public outreach (including a TED talk that has been viewed over a million times) and sustained policy engagement, he has played a central role in bringing the issue of drug resistance to the attention of leaders and policymakers worldwide and to the United Nations General Assembly in September 2016.

Jeff Lejeune, Ph.D., D.V.M., serves as Food Safety Officer, in the Food Systems and Food Safety Division of the Food and Agriculture Organization of the United Nations (FAO) and FAO Secretariat for the FAO/WHO Joint Expert Meeting on Microbiological Risk Assessment (JEMRA). His veterinary training was completed in Canada (UPEI), at the University of Prince Edward Island and his PhD (Veterinary Microbiology) at Washington State University. Before moving to FAO he served as a Professor of Food Safety and Program head at the Food Animal Health Research Program, College of Veterinary Medicine, The Ohio State University. His prior research was primarily focused on understanding the ecological mechanisms involved with the survival, dissemination, and prevention pathogen contamination of food, notably that caused by Shiga toxin-producing E. coli and antimicrobial resistant bacteria. He has served on the editorial boards of several peer-reviewed journals and participated in scientific committees, including prior work with two National Academies committees focused on food safety hazards: the Standing Committee on the Use of Public Health Data in FSIS Food Safety Programs 2008-2017. And the ad hoc Committee for Review of the Food Safety and Inspection Service Risk-Based Approach to Public-Health Attribution. 2008.

Mervalin Morant, Ph.D., received her Ph.D. in Botany and Plant Pathology from Purdue University in 1988 and her Post-doctorate from the University of Illinois, Champaign-Urbana, before joining the faculty at the University of Maryland Eastern Shore in 1990. She participated in Mali, West Africa on a US Agency for International Development (USAID), Integrated Pest Management grant program from 1998 to 2000 where she worked alongside farmers and scientists to produce pesticide-free green beans for export to France. In 2003 as the Chair of the Department of Agriculture, she was hired as a Soil Ecologist by the US Department of Agriculture as a National Program Leader (NPL) in Natural Resources and Environment and later transferred to the Institute of Food Safety, Nutrition and Health. As the co-Lead for the Nanotechnology for Agricultural and Food Systems and the NPL for Antimicrobial Resistance program, Mervalin represented the National Institute of Food and Agriculture (NIFA) on the Presidential Advisory Council on Combating Antimicrobial Resistant Bacteria (PACCARB) until 2020. She then joined the Science and Technology Directorate at the Department of Homeland Security, where she is currently the Program Manager for the Food, Agriculture and Veterinary Defense program.

Philip Taylor, Ph.D., M.Sc., gained a first class honours degree in Plant Sciences from Wye College; University of London in 1982. He then pursued an academic career path with a Ph.D. at John Innes Institute on the Downy mildew of pea and these studies led on to two post-docs one in Illinois and one in Durham UK. Subsequently he became a lecturer in molecular plant pathology at the university of Hull UK. He then gave up the academic life to become a farmer, successfully running a large commercial farm taking it into organic, and GM production as well as conventional production. He represented the National farmers union on biotechnical matters as part of their working party. Years later another change of tack took him to CABI as part of the international development group and he became the training manager for Plantwise a large donor funded programme designed to bolster extension services in developing countries. He has travelled extensively in this role.

Speaker Biographies

David Andes, M.D., is the William A. Craig Professor in the Departments of Medicine, Division Infectious Diseases and Medical Microbiology and Immunology, School of Medicine and Public Health and School of Pharmacy at the University of Wisconsin and William S. Middleton Memorial Veterans' Hospital. He is the Head of the Division of Infectious Diseases and Director of the Wisconsin Antimicrobial Discovery and Development Center. The focus of Dr. Andes' research program strives to identify strategies to combat antimicrobial drug resistance. His study tactics span from the bench to the clinic, including identifying biofilm resistance mechanisms, drug discovery and development, delineating the optimal dosing strategies for treatment of drug resistant infections using pharmacometric approaches, and clinical trial study of epidemiology and therapy of drug resistance. His research has been communicated in more than 300 publications. He is a fellow of the American Academy of Microbiology and the American Association for the Advancement of Science and member of the American Society for Clinical Investigation and Association of American Physicians.

Brian Bailey, Ph.D., comes from an interdisciplinary background that spans the fields of engineering, computer science, and plant biology. He received his PhD in mechanical engineering, which focused on better understanding the physics of turbulence and energy transfer in plant systems. Prior to joining the Department of Plant Sciences at the University of California, Davis in 2016, he worked at the U.S. Department of Agriculture's Agricultural Research Service in Corvallis, OR on the development of improved biophysical models of grape powdery mildew spread. His current research program has focused on merging his interests in biometeorology and plant physiology in order to develop the next-generation of physically-based crop models that predict system-level responses to management practices and environmental variability. Dr. Bailey recently received a National Science Foundation Early Career award to apply these models to study whether and how plants have evolved to optimize efficiency through simultaneous variation of structure and function.

Tim Brenneman, Ph.D., is currently professor of plant pathology at the University of Georgia where he has served since 1986. His primary appointment is research on diseases of peanuts and pecans, and he has worked extensively with fungicide resistance issues in both of those crops. Among other recognitions, he is a Fellow of both the American Phytopathological Society and the American Peanut Research and Education Society. He received his Ph.D. from Virginia Tech in 1986 where he worked on dicarboximide resistance in Sclerotinia minor.

Arturo Casadevall, M.D., Ph.D., is a Bloomberg Distinguished Professor and Alfred and Jill Summer Chair of the Molecular Microbiology and Immunology at Johns Hopkins School of Public Health. He received his M.D. and Ph.D. degrees from New York University. He completed his internship/residency in internal medicine at Bellevue Hospital and specialized in Infectious Diseases at the Albert Einstein College of Medicine. The author of over 900 papers, books and chapters, his major research interests are in fungal pathogenesis and the mechanisms of antibody action. He is editor-in-chief of mBio, Deputy Editor of the Journal of Clinical Investigation and serves on several editorial boards. He has served on the National Science Board for Biosecurity and the National Commission on Forensic Science. He is currently chair of the Board of Governors of the American Academy of

Microbiology, the honorific arm of the American Society for Microbiology. He has received numerous honors including election to the American Society for Clinical Investigation, American Academy of Physicians, American Academy of Microbiology, Fellow of the American Academy for the Advancement of Science, American Academy of Arts and Sciences and the National Academy of Medicine and was recently elected to the National Academy of Science.

Tim Corrigan, M.Sc., is a Technical Officer covering antimicrobial resistance (AMR) and One Health at the World Health Organization (WHO) in Geneva, Switzerland. He also serves as the WHO Liaison Officer to the Quadripartite (Food and Agriculture Organization of the United Nations/United Nations Environmental Program/World Organization on Animal Health/WHO) Joint Secretariat on AMR. Tim has worked for over 13 years in the global health arena covering AMR, One Health, food safety, sanitary and phytosanitary regulations, political advocacy and capacity building in positions at the World Trade Organization, Gavi, the Vaccine Alliance and WHO. He holds a M.Sc. in Public Management from the Scuola di Direzione Aziendale School of Public Management in Milan, Italy.

Tony Dorn, M.S., is the Branch Chief of the Environmental, Economics, and Demographics Branch of the U.S. Department of Agriculture National Agricultural Statistics Service (NASS). In this role he is responsible for analysis and publication of environmental, economic and demographics releases including the *Census of Agriculture, Farm Numbers and Land in Farms*, *Agricultural Prices*, *Agricultural Chemical Use*, and more. Tony has been with NASS since the beginning of its Chemical Use Program in 1991 and has worked in the NASS field offices in South Carolina, Wisconsin, Puerto Rico, and North Carolina. In the past, Tony was the inaugural team leader of the NASS Information Management Group and was previously the section head in the Poultry and Special Commodity and Economics Sections. He previously won the Secretary of Agriculture's Honor Award for modernizing the agricultural prices received index methodology and for analysis and publication of the Tenure, Ownership and Transition of Agricultural Land. Tony is a member of the Agricultural and Applied Economics Association. He holds a M.S. in Economics from South Dakota State University.

Kevin Doughty, Ph.D., is a Senior Stewardship Manager working from Bayer AG's Crop Science Division Headquarters in Monheim, Germany. Prior to joining Bayer, Dr. Doughty trained as a plant pathologist and spent ten years working as a field and laboratory research scientist at the Rothamsted Research Institute in the United Kingdom. He holds a Ph.D. in Plant Pathology from the University of Wales.

David Denning, M.B.B.S., is an infectious diseases clinician with expertise in fungal diseases. He serves as the Chief Executive of Global Action For Fungal Infections and Professor of Infectious Diseases and Global Health at the University of Manchester, UK. Dr. Denning managed the National Aspergillosis Centre, Manchester from 2009-2020. He has published extensively (>700 academic papers) and has a citation H-index of 123. He leads Leading International Fungal Education, which is focused on improving patient outcomes through online education and the Aspergillus Website (www.Aspergillus.org.uk). He is also a member of the World Health Organization South-East Asia Regional Office Task Force on Antimicrobial Resistance.

Jorge Pinto Ferreira, Ph.D., D.V.M., M.S., is a Doctor of Veterinary Medicine, originally from Portugal, with five years of clinical experience; a Masters in Food Safety; a Ph.D. (as Fulbright scholar) in Population Medicine (with a graduate certificate in public policy). Doctoral studies were conducted in a partnership between the College of Veterinary Medicine of North Carolina State University and the medical school of Duke University and were

dedicated to the epidemiological aspects of the transmission of Methicilin-resistant Staphylococcus aureus. In 2017 he also got a diploma from the European College of Veterinary Public Health. Between 2012-2017 he worked as a consultant in Switzerland for SAFOSO AG, and from October 2017 until June 2021 worked for the World Organisation for Animal Health, as the Deputy Head of the Antimicrobial Resistance and Veterinary Products Department. He joined the Food and Agriculture Organization of the United Nations, in July 2021, as Food Safety Officer.

Matt Fisher, Ph.D., works on emerging pathogenic fungi and leads a research group in the Medical Research Council Centre for Global Infectious Disease Analysis within the Imperial College London School of Public Health. His research is focused on developing genomic, epidemiological and experimental tools to uncover the factors driving fungal infections, and to develop new methods of diagnosis and control. He leads a Wellcome Trust Collaborative award investigating the emergence of antifungal resistance in the pulmonary pathogen Aspergillus fumigatus and has an interest in how anthropogenic processes are changing human exposures to fungal bioaerosols. He is currently a co-lead of the Imperial College Microbiome network, co-Director of the Georgina Mace Centre for the Living Planet and is a member of the Defra Air Quality Expert Group. He is a fellow of the American Academy of Microbiology and the Canadian Institute for Advanced Research 'Fungal Kingdoms' program. Fisher has a Ph.D. and B.Sc. in Zoology, University of Edinburgh.

Karen Garrett, Ph.D., M.S., M.S., is a Preeminent Professor in the Plant Pathology Department, Food Systems Institute, and Emerging Pathogens Institute at the University of Florida. Her work addresses epidemiology, systems analysis, and analyses for decision support, including machine learning approaches. Recent work includes analysis of strengths and vulnerabilities of crop seed systems for agricultural development and corresponding crop breeding networks. Other work addresses the translation of microbiome analyses for improved agricultural management. These projects address systems in Florida, the US more broadly, and several countries in Latin America, Africa, and Asia. Garrett is advancing a new platform, impact network analysis, for evaluating the effects of management strategies in linked socioeconomic and biophysical networks, to formulate strategies for helping new technologies achieve impact. Garrett is on the editorial committee for Annual Review of Phytopathology, recent Senior Editor for Phytopathology, and an elected American Association for the Advancement of Science Fellow. Prior to joining the University of Florida, Dr. Garrett was a professor in the Department of Plant Pathology at Kansas State University. Garrett received her PhD in Plant Pathology from Oregon State University, MS in Statistics and MS in Plant Pathology from Colorado State University, and BS in International Agronomy from Purdue University.

Lynn Goldman, M.D., M.S., M.P.H., a pediatrician and an epidemiologist, is the Michael and Lori Milken Dean and Professor of Environmental and Occupational Health at the Milken Institute School of Public Health at the George Washington University. She was previously Professor of Environmental Health Sciences at the Bloomberg School of Public Health; Assistant Administrator for Toxic Substances at the U.S. Environmental Protection Agency, where she directed the Office of Chemical Safety and Prevention; and Chief of the Division of Environmental and Occupational Disease Control at the California Department of Public Health. She completed a BS and MS from UC Berkeley, an MD from UC San Francisco; an MPH from Johns Hopkins University; and pediatric residency at the UCSF Benioff Oakland Children's Hospital. She is a member of the National Academy of Medicine; a Trustee of the Environmental Defense Fund; immediate past chair of the board for the Association of Schools and Programs of Public Health; member of the National Institutes of Health's National Advisory Environmental Health Sciences Council; and member of the Centers for Disease Control and Prevention's

Advisory Committee to the Director. She serves on the National Academy of Sciences, Engineering and Medicine Environmental Health Matters Initiative and Committee on Managed Retreat in the U.S. Gulf Coast Region.

Melanie Lewis Ivey, Ph.D., M.Sc., is an associate professor in the Department of Plant Pathology, The Ohio State University, Wooster, with responsibility for research, extension and teaching in fruit crop diseases and fresh produce safety. Lewis Ivey investigates plant disease and food safety risks that occur in the production of horticulture food crops and identifies economically and environmentally sustainable practices to mitigate these risks. Her research addresses new and reemerging fruit, hop, and culinary nut diseases, microbial food safety hazards (Salmonella, Listeria monocytogenes) in hydroponic leafy green production, fungicide resistance in phytopathogens, and Global One Health issues that impact plant and human health, including antimicrobial resistance in microbe populations in the production environment, and food safety. Dr. Lewis Ivey is a member of the American Phytopathological Society and the International Association of Food Protection. Dr. Lewis Ivey received her Master of Science from The University of Western Ontario, London Ontario, Canada and her PhD from the Ohio State University.

Brendan Jackson, M.D., M.P.H., is a medical epidemiologist at the Centers for Disease Control and Prevention (CDC) and lead of the Mycotic Diseases Branch epidemiology team, which is dedicated to investigating and preventing a wide range of fungal diseases. During his time at CDC, he has investigated dozens of outbreaks and published widely on the epidemiology of fungal and foodborne diseases, including a recent paper describing potential risks from growing agricultural fungicide use. He is a graduate of the University of Georgia, the Yale School of Medicine, and the Emory Rollins School of Public Health. He completed residencies in internal medicine at the Yale Primary Care Internal Medicine program and preventive medicine at CDC, where he served at a local health department in Georgia. He joined CDC in 2010 through its Epidemic Intelligence Service. He is currently serving as the Principal Deputy Incident Manager of the CDC COVID-19 response.

Michael Lionakis, M.D., Sc.D., is a physician-scientist and Head of the Fungal Pathogenesis Section in the National Institute of Allergy and Infectious Diseases's (NIAID) Laboratory of Clinical Immunology and Microbiology where he is Deputy Chief. He obtained his MD and ScD from the University of Crete, Greece. He did postdoctoral research training at MD Anderson Cancer Center, followed by Internal Medicine Residency at Baylor College of Medicine, and Infectious Disease Fellowship at NIAID/National Institutes of Health (NIH). He established his own laboratory in 2012 at NIAID and received tenure in 2017. Dr. Lionakis' laboratory bench-to-bedside research focuses on 1) better understanding the genetic and immune defects that underlie susceptibility to fungal infections in humans and on 2) cellular and molecular factors that regulate the immune response against fungi in clinically relevant animal models. His work has defined precise genetic, biochemical, immunologic, and cellular disease mechanisms that have led to targeted immunotherapies. Dr. Lionakis has published >200 peer-reviewed papers in journals such as Science, Science Translational Medicine, Science Immunology, Nature Immunology, Journal of Clinical Investigation, Journal of Experimental Medicine, Cell Host Microbe, and Cancer Cell. He has been elected in the American Society for Clinical Investigation and the Association of American Physicians and is a Fellow of the American Academy of Microbiology, the American Association for the Advancement of Science, and the Infectious Diseases Society of America (IDSA). He has received several awards including the NIH Director's award, the IDSA Oswald Avery Award for Early Achievement, the Junior Investigator Award from the Immunocompromised Host Society, and the American College of Physicians Walter J. McDonald Award for Early Career Physicians.

Shawn Lockhart, Ph.D., is the Senior Clinical Laboratory Advisor for the Mycotic Diseases Branch and the Senior Advisor for Antimicrobial Resistance at the Centers for Disease Control and Prevention. He has been studying infectious fungi for almost 30 years with an emphasis on antimicrobial resistant fungi over fifteen years. Dr. Lockhart is board certified in Clinical Microbiology and he is a Fellow of the American Academy of Microbiology. He received his Ph.D. from the University of Kentucky and did his Clinical Microbiology Fellowship at the University of Iowa.

Walt Mahaffee, Ph.D., M.S., is a Research Plant Pathologist with the United States Department of Agriculture's Agricultural Research Service in Corvallis, Oregon and a Courtesy Faculty with the Department of Botany and Plant Pathology at Oregon State University. His team's research spans numerous disciplines to develop sustainable methods for managing diseases of horticulture crops and has resulted in the commercial implementation of several biological control agents, disease forecasting models, and cultural practices for disease management in horticulture crops. Current projects include inoculum detection and quantification, fungicide resistance monitoring and mitigation, disease forecasting and epidemiology, turbulent airflow modeling and pathogen dispersion, pathogen ecology, germicidal ultraviolet light for management of grape diseases, and developing a cyber-physical system for risk management in agricultural systems.

Nathan Mellor, has been at the Environmental Protection Agency for six years working in the Registration Division. During this time, he served on several committee's and work groups, including the Child-Resistant Packaging team, the small business waiver committee, and as the Reduced Risk coordinator. Nate completed a detail as Acting Project Manager in the Fungicide Branch last fall as is excited to be returning. Nate began his government career at U.S. Department of Agriculture's Agricultural Research Service in Lincoln, NE as a Lab and Field Technician. The team studied agricultural management effects on soil carbon and nitrogen cycling, including greenhouse gas emissions. Prior to that, he spent three years working in agriculture in Fort Collins, CO, as a Lab and Greenhouse Manager growing disease-free starter plants and seed potatoes and working at an organic farm. Nate has a degree in Biology from Bradley University and attended graduate courses at Colorado State University.

Wieland Meyer, Ph.D., M.Sc., is Deputy Head of the Curtin Medical School and Associate Dean Biomedical Science/Pharmacy/Medical Radiation Science at Curtin University, Perth, Australia, Prof. for Molecular Medical Mycology at Sydney Medical School, University of Sydney, Australia, and Guest Prof. at Fundação Oswaldo Cruz, Rio de Janeiro, Brazil. Dr. Meyer is also President of International Mycological Association. His research focuses on phylogeny, speciation, population genetics, genomics, molecular epidemiology, strain typing, development of molecular identification techniques for human pathogenic fungi, antifungal resistance, impact of mycoses on global heath, public health preparedness to respond to fungal disease outbreaks, and fungal pathogenesis. He is conducting global epidemiological studies in the Cryptococcus neoformans/C. gattii species complex and whole genome sequencing of Candida auris, etc. He is leading an international team establishing quality-controlled sequence databases (its.mycologylab.org) for fungal DNA barcoding, bringing metagenomics as a diagnostic tool to the patient's bedside. He is leading the LatAsp Centers for Disease Control and Prevention funded study investigating the presence of Aspergillus fumigatus azole resistance in the environment in Latin America. He is a Fellow of the Australian Society for Microbiology, a member of International Society for Human and Animal Mycology and the American Society of Microbiology. He obtained his PhD in Genetics in 1992 from the Humboldt University of Berlin, Berlin, Germany.

Maryn McKenna, M.S., is a senior writer at WIRED, where she covers public health, global health, and medicine, and a Senior Fellow at the Center for the Study of Human Health at Emory University, where she teaches health and science writing and storytelling. She is the author of the 2017 bestseller BIG CHICKEN: The Incredible Story of How Antibiotics Created Modern Agriculture and Changed the Way the World Eats, which received the 2018 Science in Society Award and was named a best book of 2017 by Amazon, Smithsonian, Science News, Wired, Civil Eats, and other publications (and is published in the UK and other territories under the title Plucked) as well as the award-winning books Superbug and Beating Back the Devil. She appeared in the 2020 Vox+ Netflix documentary “Coronavirus: Explained”; the 2019 documentary Resistance Fighters, which won top prizes at the Vancouver and Paris film festivals; and the 2014 documentary Resistance. Her 2015 TED Talk, "What do we do when antibiotics don't work anymore?" has been viewed 1.9 million times and translated into 34 languages. She has written for The New York Times Magazine, The New Republic, National Geographic, Smithsonian, Scientific American, The Atlantic, and The Guardian, among other publications. She has received the 2019 American Association for the Advancement of Science-Kavli Gold Award for magazine writing, the 2019 John P. McGovern Award for Excellence in Biomedical Communication, the 2014 Leadership Award of the Alliance for the Prudent Use of Antibiotics, and the 2013 Byron H. Waksman Award for Excellence in the Public Communication of Life Sciences, among many other honors.

Pierce Paul, Ph.D., M.S., is a Professor, Plant Disease Epidemiologist, and State Extension Specialist in the Department of Plant Pathology at The Ohio State University, with more than 20 years of experience in epidemiology, risk assessment, and integrated management of foliar fungal diseases of corn and wheat, particularly those caused by the toxigenic, necrotrophic fungus, Fusarium graminearum. His primary interest is the use of statistical and computer models to describe plant disease dynamics in the field and make economically sound, risk-based disease management decisions. He is a leading member of several teams of researchers developing and validating weather-based risk assessment models and integrated management programs for corn and wheat diseases and mycotoxin contamination of grain. He was the recipient of the 2016 American Phytopathological Society (APS) Syngenta Award, the 2016 Ohio Agricultural Research and Development Center Distinguished Junior Faculty Research Award, and the 2008 APS William Boright Hewitt and Maybelle Ellen Ball Hewitt Award. Dr. Paul holds a B.S in Agronomy and M.S. in Plant Pathology from the Federal University of Viçosa, Brazil, and a Ph.D. in Plant Pathology (with a minor in Statistics) from Iowa State University.

John Rex, M.D., F.A.C.P., is a physician and drug developer with more than 30 years of development and policy experience focused on antimicrobial agents. He is currently Chief Medical Officer for F2G, Ltd. (an antifungal biotech), is an operating partner with a venture capital group (Advent Life Sciences), is Chair of the Scientific Advisory Board of the $1b Antimicrobial Resistance Action Fund, and was (2015-2019) a voting member on the US Presidential Advisory Council on Combating Antibiotic Resistant Bacteria. He also blogs regularly at http://amr.solutions/blog.html. His experience includes moving compounds from preclinical development through all development phases via academic positions (National Institutes of Health, Bethesda, MD; McGovern Medical School-Houston) and Vice President-level roles at a multinational pharmaceutical firm (AstraZeneca). Other past activities include advancing novel regulatory paradigms for antibacterials, publications on novel reimbursement models for antibiotics, co-founding of a public-private partnership (CARB-X), co-founding the New Drugs for Bad Bugs program of Europe’s Innovative Medicines Initiative, and a 4-year term as Industry Representative on the Food and Drug Administration’s Anti-Infective Drugs Advisory Committee (2007–2011).

Raquel Sabino, Ph.D., F.E.C.M.M., graduated in biology at the University of Lisbon and earned a Ph.D. in Biological Sciences, Mycology at Minho University. Dr. Sabino completed her Posdoc in the molecular epidemiology of Aspergillus, in collaboration with Stanford University and California Institute of Medical Research, California. Currently, she works on diagnosis, surveillance and molecular epidemiology of fungal infections and fungal exposure at the Reference Unit for Parasitic and Fungal Infections at the National Institute of Health Dr. Ricardo Jorge and Institute of Environmental Health. Dr. Sabino has several publications and communications, including scientific papers published in international and national peer-reviewed journals, book chapters, workshops, scientific meetings, lectures, and is also editor of two books in the field of mycology. She is fellow of the European Confederation of Medical Mycology, the President of the Portuguese Society of Medical Mycology, and the Portuguese Ambassador of the Global Action for Fungal Infections.

Magda Sachana, Ph.D., M.Sc., is a Policy Analyst within the Environment Health and Safety Division of the Organisation for Economic Co-operation and Development (OECD) Environmental Directorate since 2015. She manages the development and implementation of policies in the field of chemical safety and contributes to the OECD Test Guidelines, Pesticide and Hazard Assessment Programmes. She has over 10 years of experience in academic research and scientific project management, having served as a Lecturer at the University of Liverpool in the United Kingdom and as an Assistant Professor at the Aristotle University of Thessaloniki in Greece. Dr. Sachana is a trained veterinarian with a M.Sc. in Biotechnology and a Ph.D. in toxicology.

Andrej Spec M.D., M.S.C.I., earned his MD in University of Illinois in Chicago, and did his internal medicine training at Rush University Medical Center. He came to Washington University in St Louis for his fellowship, and concomitantly earned his Masters of Science in Clinical Investigation. He stayed on as faculty, where he has focused his research and clinical work on invasive fungal infections. He is currently an Associate Professor at Washington University in St Louis, where he also serves as the Associate Director of the Infectious Disease Clinical Research Unit and the Medical Director of the Invasive Mycoses Clinic. He has authored over 60 scientific papers and several book chapters on the topic of infectious disease, mostly focusing on invasive fungal infections. He also serves as the Interim Co-Editor-in-Chief for Open Forum Infectious Disease and was recently an Associate Editor for the journals Mycoses and Medical Mycology. Dr Spec was elected as Fellow by the European Confederation of Medical Mycologists and Infectious Disease Society of America in 2019, and 2021, respectively. Finally, he is the developer and lead editor of the Comprehensive Review of Infectious Disease, a bestselling infectious disease textbook with a focus on teaching infectious disease and preparing readers for infectious disease boards.

Paul Verweij, M.D., Ph.D., is a consultant microbiologist and professor of clinical mycology at the Radboud University Medical Centre. He is board member of the Radboudumc-CWZ Centre of Expertise for Mycology and director of the national mycology reference laboratory. Since 2020 he also has an appointment at the Dutch National Institute for Public Health and the Environment. Professor Verweij's main research interest is the management of invasive fungal diseases. Topics of interest include the diagnosis of invasive mycoses by non-cultured based methods such as biological markers and fungal DNA; the emergence of azole resistance in Aspergillus, including One-Health aspects, and clinical management; and invasive pulmonary aspergillosis associated with influenza and COVID-19. He has published >450 papers in medical journals. Professor Verweij trained in medicine at Leiden University, The Netherlands and subsequently specialized in clinical microbiology at Radboud University Medical Center.

Tim Widmer, Ph.D., is the U.S. Department of Agriculture Agricultural Research Service (USDA/ARS) National Program Leader for Plant Health. He is the point of contact for all USDA/ARS projects related to plant health and is involved also with antimicrobial resistance, soil health, and plant-related issues in Ag-biosecurity. Dr. Widmer is the ARS Principal Investigator for the Congressionally appropriated Wheat Scab, Barley Pest, and Predictive Modeling Tool Initiatives. In addition, he oversees the projects for the ARS-associated overseas biological control laboratories in France, Greece, Australia, Argentina, and China and has served as the U.S. representative on the Methyl Bromide Technical Options Committee since 2018. He has authored or co-authored over 60 peer-reviewed articles, 2 books chapters and has 1 patent. In 2000, he joined USDA/ARS as a Research Plant Pathologist until 2018, where he is in his current position. Dr. Widmer received his PhD in Plant Pathology at the University of Florida, Gainesville, Florida and did a post-doctoral study at Cornell University in Geneva, NY.

Jianhua Zhang, M.D., M.P.H., is an evolutionary microbiologist. Over the last 10 years she has worked at Wageningen University on the azole resistance of a human pathogenic fungi, Aspergillus fumigatus. Her research focuses on the evolution pattern of azole resistance, the diverse life cycles of Aspergillus fumigatus, the hotspots and cold spots of azole resistance development and so on. In May 2022 she moved to the Centre for Infectious Disease Research, Diagnostics and Laboratory Surveillance of the National Institute for Public Health and the Environment in the Netherlands, where she continues to investigate public health related fungal infections such as Aspergillus and Candida as well as associated mycobiome research.