



Integrating Exposomics into the Biomedical Enterprise

December 3-6, 2023

The Banbury Center, Lloyd Harbor, New York



Organized by:

Gary W. Miller, Columbia University

L. Michelle Bennett, Roger Schwarz & Associates, LLC

This meeting generously funded by

The Cold Spring Harbor Laboratory Corporate Sponsor Program

Columbia University

MBX Capital



'The Story' of this Banbury Conference

The genesis of this Banbury Conference occurred from interactions between Tom Maniatis, a longtime Cold Spring Harbor Laboratory faculty member, now Director of Columbia University's Precision Medicine Initiative, and Gary Miller a leading proponent of exposomics. They had worked together to host a couple of exposome-related events at Columbia. When Tom suggested to Gary that he host a meeting at the Banbury Center focused on the exposome and its importance in human health, Gary had two immediate thoughts. First was the fact that Tom saw the promise of the emerging field that Gary had been championing. The second was "what a terrific idea!" A few conversations later and with the collaboration of Dr. Rebecca Leshan, Executive Director of the Banbury Center, a Banbury Conference entitled "Integrating Exposomics into the Biomedical Enterprise" was scheduled for December 3 – 6, 2023.

December was earlier than originally anticipated, but the opportunity to take advantage of a schedule opening arose. The opportunity came with risks. Less notice would be given to the invitees, eminent scientists with calendars that fill years in advance. Furthermore, a very strong agenda needed to be put in place to be worthy of a prestigious Banbury Conference. At the same time several



Dr. Gary Miller from Columbia University, Gurdane Bhutani from MBX Capital, and Dr. Cavin Ward-Caviness from the Environmental Protection Agency. Photo: C. Brukin/CSHL

major activities were converging that highlighted the need for this event: the formation of a consortium; the appearance of journal articles marking the successful outcome of the 2022 Workshop Series *Accelerating Precision Environmental Health: Demonstrating the Value of the Exposome*; just submitted grant applications in response to an NIH RFA focused on establishing an Exposomics Coordinating Center; and strong European activity focused on the exposome where several efforts have been stood up including EIRENE, the European Scientific Infrastructure (ESFRI), and International Human Exposome Network (IHEN). The confluence of these activities signaled that it was time to formally launch the field of exposomics in the United States, with a focus on the biomedical enterprise.



Dr. Arcot Rajasekar from the University of North Carolina and Dr. Krystal Pollitt from Yale University. Photo: C. Brukin/CSHL

Readers with knowledge of the exposome and exposomics might (correctly) point out that the term exposome was coined in 2005 by Chris Wild, and ask, "Hasn't the field been in existence for almost 20 years?" That is entirely true. At the same time, the exposome did not receive much initial attention, in part due to criticisms about the impossibility of being able to identify "All exposures from conception onward, including those from lifestyle, diet and the environment." Thus, the field struggled to develop its foundation, and suffered from the lack of an agreed-upon definition that could



be shared by researchers, institutions, industry, and government agencies. Many conferences, workshops, committees, and funding announcements have featured the exposome and exposomics as topics, and yet, one common discussion at meetings was the need for common definitions that could guide all researchers.

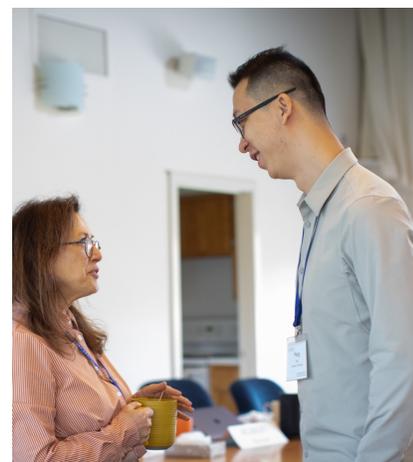
It was this confusion, specifically in the biomedical research arena, that presented itself as a major opportunity around which to center a Banbury Conference. Why Banbury? This is best answered after sharing the overarching purpose and objectives of the meeting: to move from confusion to clarity by (a) developing an operational definition for exposomics that would ground the field, (b) identifying the components of the biomedical enterprise that would benefit most from exposomics, and (c) outlining the major challenges a bonified field of exposomics would need to tackle to advance our understanding of the environmental contributors to human health and disease. To suggest that this was an ambitious agenda is an understatement. While no one admitted it to us (the organizers, Gary and Michelle), we wouldn't have been surprised if some of those who agreed to attend were a little skeptical of our optimism.

The first morning of the first day started out much like any scientific conference would, with welcomes, walk throughs of the time together, and setting the stage. A group photo, breaks, participants rolling up their sleeves, so to speak, in preparation for diving into breakout groups in the afternoon. But before that, we were scheduled to have lunch, and this was when "Why Banbury?" came into focus.

As we all joined together in a sit-down lunch around three tables, time slowed considerably. We're not sure what it is called but we will affectionately refer to it as Banbury Time. Minds busy with the things not getting done at work shifted attention to the present moment and the colleagues across the table. As people reflected on things they heard earlier, others started actively building upon them. New ideas that did not surface earlier, were shared, and extended with "what ifs." Then people shifted to sharing stories, talking about hobbies, or where they lived. The high-level conversational scientific discussions of the morning were starting to give way to deeper understanding of different disciplinary perspectives and learning about each other as people. It felt like a collective deep breath.



Dr. Chirag Patel from Harvard Medical School speaking with Dr. Thomas Metz from Pacific Northwest National Laboratory. Photo: C. Brukin/CSHL



Dr. Margaret Karagas from Dartmouth University and Dr. Peng Gao from the University of Pittsburgh. Photo: C. Brukin/CSHL



Dr. Shuzhao Li from the Jackson Laboratory and Dr. Jana Klanova from Masaryk University. Photo: C. Brukin/CSHL

We hear so much about the power of being able to quiet the mind to make space for assimilation, integration, and problem-solving. Anyone who has had a 'great idea' in the shower, while walking the dog, or doing some gardening knows the power of the alpha brainwaves. We do not typically associate achieving this state at a scientific conference. Yet, given the right environment, the alpha thinking associated with creativity, enhanced insights, and problem-solving, and that feeling of being in flow, as described by Mihaly Csikszentmihalyi, can be realized.

And so, we set into a rhythm of spending most of our time together, from early in the morning until late at night. Comfortably secluded away from the pulls and distractions of our everyday lives and without any need to venture further than we could go on foot. Coming together for meals, dispersing for a walk by the water alone in contemplation or in deep conversation with a few others, reengaging in the science, and doing it all over again. Far from what could have felt like a frantic exercise in working together, Banbury Time was almost meditative. We learned together, expanded our collective thinking, challenged each other, openly disagreed, and offered ways to reframe thinking. New connections (scientific and personal) were formed, and familiar ones reinforced. Banbury Time preserved a safe space for conversations that comfortably built upon each other over the course of the three days.

Present throughout was an awareness that we needed to deliver on the promise of substantive outputs from the meeting. Our plan going in was a white paper and a manuscript articulating the value of an operational definition for the field of exposomics for the purpose of bringing together a community of researchers with a common goal of solving the complex challenges the field has to offer. As we moved from day one to day three in the agenda, comfort levels noticeably increased, creativity seemed to have been unleashed, and a strong shared vision for what was needed to launch and then realize the promise of the exposomics field emerged.

The conference ended with personal reflections on the past several days. Specifically, we asked for one takeaway and one commitment for an action when returning to the real world beyond Banbury Time. The reflections illuminated several truths. The field of exposomics is going to thrive by having champions who are willing to spread the word, help others learn about conducting exposomics experiments, and educate the next generation of researchers and clinicians. We need a strong community of dedicated individuals who are willing to actively participate in a community of practice and recruit others to join. We are on our way.



Dr. Dana Dolinoy from the University of Michigan, Dr. Gary Miller, Dr. Pam Lein from the University of California at Davis, and Dr. L. Michelle Bennett from Roger Schwarz & Associates. Photo: C. Brukin/CSHL



DESCRIPTION

The concept of the exposome was introduced in 2005 as a way to identify the environmental contributors to human health and disease. Originally the exposome was defined as “*the totality of exposures throughout life,*” something (i) impossible to scientifically assess in any current or conceivable future setting and (ii) that does not mesh well with the U.S. biomedical enterprise, which more readily focuses on discrete cause-and-effect relationships, preventing or treating disease, and death. Yet, in the age of omic-scale biology, it is essential to study environmental factors of disease in the proper context, with all of its inherent complexity.

We propose that studying this complex phenomenon requires mapping-out and understanding the underlying exposure and biological networks to provide a scaffolding for mechanistic insight. Operationalizing this premise requires (i) having an accepted, clear, and shared operational definition, (ii) focusing on the components of the exposome that are measurable, and (iii) understanding how they impact specific aspects of human health and disease.

The purpose of this Banbury Center meeting is to develop an operational definition for exposomics that aligns with broader goals to seek fundamental knowledge and apply it. Discussions will focus on:

- Developing an operational definition* of exposomics for biomedical research;
- Identifying the components of the biomedical enterprise that will benefit most from exposomics (research, discovery, clinical trials, diagnosis, etc);
- Outlining conceptual and technical innovations that will be needed to establish exposomics a bona fide -omics discipline

We expect to develop two outputs:

- A two-page white paper that provides the rationale and utility of the operational definition
- An academic manuscript that explains how the operational definition can be used to advance the field of exposomics

Our work will provide stakeholders and the scientific community with an unambiguous definition of the exposome that can be used to advance our understanding of the environmental contributors to human disease and health.

Meeting Style

To foster a creative, highly interactive, and productive atmosphere, this meeting will combine short (~10 minutes) presentations, working breakout sessions, full group discussions, takeaways, and reports back to the full group. We will be asking you to play a highly participative role at this meeting. Interaction among scholars with different backgrounds, with integration of knowledge, ideas, and concepts will be essential for achieving our meeting goals.

**A good operational definition should: (a) be clear, specific, definable, measurable and unambiguous; (b) specify the device for measuring the factor; (c) specify the units of measurement and time frame; (d) describe the measurement method; (e) include the decision criteria.*



Participants

David Balshaw, National Institute of Environmental Health Sciences, NIH

Robert Barouki, INSERM

L. Michelle Bennett, Roger Schwarz & Associates, LLC

Gurdane Bhutani, MBX Capital

Dana Dolinoy, University of Michigan

Peng Gao, University of Pittsburgh

David Jett, National Institute of Neurological Disorders and Stroke, NIH

Margaret Karagas, Dartmouth College

Jana Klánová, Masaryk University, RECETOX

Pamela Lein, University of California, Davis

Shuzhao Li, The Jackson Laboratory

Thomas Metz, Pacific Northwest National Laboratory

Gary W. Miller, Columbia University

Yevgeniya Nusinovich, Science

Chirag Patel, Harvard University

Krystal Pollitt, Yale University

Arcot Rajasekar, University of North Carolina at Chapel Hill

Fenna Sillé, Johns Hopkins University

Anne Thessen, University of Colorado Anschutz

Sophie Thuault-Restituto, Columbia University

Roel Vermeulen, Utrecht University

Cavin Ward-Caviness, U.S. Environmental Protection Agency (EPA)

Robert Wright, Icahn School of Medicine at Mount Sinai



MEETING AT-A-GLANCE

Sunday, December 3

6:00 pm Reception, Robertson House
7:30 pm Dinner, Robertson House

Monday, December 4

7:15-8:15 am Breakfast, Robertson House
8:15-8:30 am *[optional] Prompts to Elicit Thoughts*, Conference Room
8:30-8:50 am Welcome, overview of meeting, and goals, Conference Room
8:50-9:45 am Session 1, Conference Room
9:45-10:20 am Session 2, Conference Room
10:20-10:50 am Break, Conference Room
10:50-11:30 am Session 3, Conference Room
11:30-12:05 pm Session 4A, Conference Room
12:20 pm Luncheon, Robertson House & Free Time
2:10-3:25 pm Session 4B, Conference Room
3:25-3:55 pm Break, Conference Room
3:55-5:30 pm Session 4C, Conference Room
5:30-5:40 pm Day One Wrap-up, Conference Room
6:00 pm Reception & Dinner, Robertson House

Tuesday, December 5

7:15-8:15 am Breakfast, Robertson House
8:30-9:10 am Day Two Opener, Conference Room
9:10-10:25 am Session 5A, Conference Room
10:25-10:55 am Break, Conference Room
10:55-12:30 pm Session 5B, Conference Room
12:45 pm Luncheon, Robertson House & Free Time
2:35-3:15 pm Session 6, Conference Room
3:15-3:40 pm Break, Conference Room
3:40-5:25 pm Session 7, Conference Room
5:25-5:35 pm Day Two Wrap-up, Conference Room
6:00 pm Reception & Dinner, Robertson House

Wednesday, December 6

7:15-8:15 am Breakfast, Robertson House
8:30-9:10 am Day Three Opener, Conference Room
9:10-9:50 am Session 8A, Conference Room
9:50-10:20 am Break, Conference Room
10:20-11:05 am Session 8B, Conference Room
11:05-12:10 pm Session 9, Conference Room
12:25 pm Luncheon & Participant Departures, Robertson House



MEETING AGENDA

Integrating Exposomics into the Biomedical Enterprise

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SUNDAY, DECEMBER 3, 2023

Afternoon Arrivals and check-in, Robertson House

6:00 pm Reception, Robertson House

7:30 pm Dinner, Robertson House

MONDAY, DECEMBER 4, 2023

7:15-8:15 am Breakfast, Robertson House

8:15-8:30 am [optional] Prompts to Elicit Thoughts and Comments
Sticky note exercises in the Conference Center – all invited to participate

8:30-8:40 am Rebecca Leshan, Banbury Center
Welcoming remarks

8:40-8:50 am Gary W. Miller, Columbia University, New York, NY, USA
L. Michelle Bennett, Roger Schwarz & Associates, LLC, Potomac, MD, USA
Welcome, overview of meeting, and goals



SESSION 1: Setting the Stage

Chairperson: L. Michelle Bennett, Roger Schwarz & Associates, LLC

- 8:50-9:00 am Gary W. Miller, Columbia University, New York, NY, USA
From confusion to clarity in exposomics
- 9:00-9:10 am Questions / Discussion
- 9:10-9:20 am L. Michelle Bennett, Roger Schwarz & Associates, LLC, Potomac, MD, USA
"We are here": how this workshop is situated in the context of exposomics
- 9:20-9:25 am Questions / Discussion
- 9:25-9:45 am Group Discussion with Sticky Note Exercise

SESSION 2: The Biomedical Enterprise: Definition for this Workshop

Chairperson: Pamela Lein, University of California, Davis, California

- 9:45-9:50 am Gary W. Miller, Columbia University, New York, NY, USA
Framing the biomedical enterprise from a U.S. perspective
- 9:50-9:55 am Jana Klánová, Masaryk University, RECETOX, Brno, Czech Republic
EIRENE – European infrastructure for the exposome research
- 9:55-10:20 am Questions / Discussion
- 10:20-10:50 am *Coffee Break*

SESSION 3: An Operational Definition for Exposomics is Needed

Chairperson: Chirag Patel, Harvard University

- 10:50-11:00 am L. Michelle Bennett, Roger Schwarz & Associates, LLC, Potomac, MD, USA
Criteria for an operational definition
- 11:00-11:10 am Robert Barouki, INSERM, Paris, France
The need for an operational definition
- 11:10-11:30 am Questions / Discussion

SESSION 4A: Developing an Operational Definition for Exposomics I

Chairperson: Robert Wright, Icahn School of Medicine at Mount Sinai

- 11:30-11:50 am Sticky Note Exercise
- 11:50-12:05 pm Seeding Breakout Groups
- 12:20 pm *Luncheon, Robertson House and Free Time*



SESSION 4B: Developing an Operational Definition for Exposomics I (continued)

2:10-3:25 pm Breakout Groups

3:25-3:55 pm *Coffee Break*

SESSION 4C: Developing an Operational Definition for Exposomics I (continued)

Chairperson: Cavin Ward-Caviness, U.S. Environmental Protection Agency (EPA)

3:55-4:55 pm Breakout Groups Reporting
Each breakout group: 10 minutes reporting, 5 minutes questions

4:55-5:30 pm Group Discussion

DAY ONE WRAP-UP

Chairperson: Gary W. Miller, Columbia University

5:30-5:40 pm Summary, Considerations for Day Two

6:00 pm *Reception, Robertson House*

7:00 pm *Dinner, Robertson House*



TUESDAY, DECEMBER 5, 2023

7:15-8:15 am Breakfast, Robertson House

DAY TWO OPENER

Chairperson: L. Michelle Bennett, Roger Schwarz & Associates, LLC

- 8:30-8:35 am Chirag Patel, Harvard University, Boston, NY, USA
Morning Check-in, Introduction to Day Two
- 8:35-8:45 am Group Discussion with Sticky Note Exercise
- 8:45-8:55 am David A. Jett, National Institute of Neurological Disorders and Stroke, NIH, Bethesda, MD, USA
Integrating exposomics into an NIH research portfolio – NINDS as an example
- 8:55-9:10 am Questions / Discussion

SESSION 5A: Developing an Operational Definition for Exposomics II

Chairperson: Chirag Patel, Harvard University

- 9:10-9:20 am Gary W. Miller, Columbia University, New York, NY, USA
Brief Recap, Launch Day Two
- 9:20-9:30 am Questions / Discussion
- 9:30-9:35 am L. Michelle Bennett, Roger Schwarz & Associates, LLC, Potomac, MD, USA
Preview / Guidance for Breakout Groups
- 9:35-10:25 am Breakout Groups
- 10:25-10:55 am Coffee Break

SESSION 5B: Developing an Operational Definition for Exposomics II (continued)

Chairperson: Dana Dolinoy, University of Michigan

- 10:55-11:35 am Breakout Groups Reporting
Each breakout group: 5 minutes reporting, 5 minutes questions
- 11:35-11:50 am Group Discussion
- 11:50-12:00 pm Gary W. Miller, Columbia University, New York, NY, USA
L. Michelle Bennett, Roger Schwarz & Associates, LLC, Potomac, MD, USA
Next steps on an operational definition
- 12:00-12:10 pm Thomas Metz, Pacific Northwest National Laboratory, Richland, WA, USA
Lessons from the "Decoding the Molecular Universe" meeting and initiative
- 12:10-12:30 pm Questions / Discussion



12:45 pm Luncheon, Robertson House and Free Time

SESSION 6: Identifying the Components of the Biomedical Enterprise that will Benefit Most from Exposomics

Chairperson: Roel Vermeulen, Utrecht University

(Panel Q&A, no presentations)

2:35-3:00 pm Krystal Pollitt, Yale University, New Haven, CT, USA
Dana Dolinoy, University of Michigan, Ann Arbor, MI, USA
Peng Gao, University of Pittsburgh, Pittsburgh, PA, USA
Robert Wright, Icahn School of Medicine at Mount Sinai, New York, NY, USA
Cavin Ward-Caviness, Environmental Protection Agency, Chapel Hill, NC, USA

3:00-3:10 pm Group Discussion

3:10-3:15 pm L. Michelle Bennett, Roger Schwarz & Associates, LLC, Potomac, MD, USA
Preview / Guidance for Breakout Groups

3:15-3:40 pm *Coffee Break*

SESSION 7: Identifying the Components of the Biomedical Enterprise that will Benefit Most from Exposomics

Chairperson: David Balshaw, National Institute of Environmental Health Sciences, NIH

3:40-4:25 pm Breakout Groups

4:30-4:55 pm Breakout Groups Reporting
Each breakout group: 3 minutes reporting, 3 minutes questions

4:55-5:25 pm Group Discussion

DAY TWO WRAP-UP

Chairperson: Gary W. Miller, Columbia University

5:25-5:35 pm Summary, Considerations for Day Three

6:00 pm *Reception, Robertson House*

7:00 pm *Dinner, Robertson House*



WEDNESDAY, DECEMBER 6, 2023

7:15-8:15 am Breakfast, Robertson House

DAY THREE OPENER

Chairperson: L. Michelle Bennett, Roger Schwarz & Associates, LLC

8:30-8:40 am Gary W. Miller, Columbia University, New York, NY, USA
Morning Check-in, Introduction to Day Three

8:40-8:50 am Sticky Note Exercise

8:50-9:00 am Arcot Rajasekar, University of North Carolina at Chapel Hill, NC, USA
Outlining conceptual and technical innovations that will be needed to accomplish making exposomics a bona fide -omics discipline: infrastructure and community of practice

9:00-9:10 am Questions / Discussion

SESSION 8A: Solutions for Conceptual and Technical Innovations: Developing Impossible Solutions to Solve Challenges in Measuring the Exposome

Chairperson: L. Michelle Bennett, Roger Schwarz & Associates, LLC

9:10-9:15 am Preview / Guidance for Breakout Groups

9:20-9:50 am Breakout Groups

9:50-10:20 am Coffee Break

SESSION 8B: Solutions for Conceptual and Technical Innovations: Developing Impossible Solutions to Solve Challenges in Measuring the Exposome (continued)

Chairperson: L. Michelle Bennett, Roger Schwarz & Associates, LLC

10:20-10:35 am Breakout Groups Reporting
Each breakout group: 3 minutes reporting

10:35-11:05 am Group Discussion



SESSION 9: MEETING WRAP-UP, NEXT STEPS

Chairpersons: Gary W. Miller, Columbia University; L. Michelle Bennett, Roger Schwarz & Associates, LLC

11:05-11:15 am Pamela Lein, University of California, Davis, Davis, CA, USA
Stakeholder engagement and spreading the word about exposomics in the biomedical enterprise

11:15-12:00 pm Discussion: Participants' Commitment and Next Steps

12:00-12:10 pm Gary W. Miller, Columbia University, New York, NY, USA
Closing Remarks

12:25 pm *Luncheon, Robertson House*

1:40 pm *Participant Departures*

— END OF PROGRAM —