DOE-BER Workshop: Genome Engineering for Material Synthesis (GEMS)

Seema Singh, Ph.D.
October 18, 2018
Materials- an important aspect of civilizations
Biominerals as inspiration

- Ornate and hierarchical structures;
- Mild pH;
- Ambient temperatures;
- Environmentally friendly and all-aqueous (“green”);
- Controlled;
- Involvement of organic components.
Bio-derived Inorganic Material via Synthetic Biology

https://doi.org/10.1073/pnas.1804543115
Why Genome Engineering for Inorganic/Hybrid Materials?

- **Augment current genome/metabolic design capabilities**
  - expand number and diversity platform pathways and/or organisms

- **Expand genomic engineering to inorganic materials**
  - design and/or modify new genome-based mechanisms of inorganic synthesis

- **Explore the genomic design space for organic/inorganic materials synthesis**
  - couple organic/inorganic synthesis designs
  - explore new genome-controlled materials design

- **Explore the broader potential of natural synthesis processes**
  - mining of metagenomic data for new synthesis capabilities
Genome Engineering for Material Synthesis Workshop

October 9-11, 2018
Rockville, MD
## Workshop Attendees

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caroline Ajo-Franklin</td>
<td>LBNL</td>
<td>co-chair</td>
</tr>
<tr>
<td>Michael Jewett</td>
<td>Northwestern U.</td>
<td>co-chair</td>
</tr>
<tr>
<td>Huimin Zhao</td>
<td>U. Illinois, Urbana-Champaign</td>
<td>co-chair</td>
</tr>
<tr>
<td>Brian Fox</td>
<td>U. Wisconsin, Madison</td>
<td>co-chair</td>
</tr>
<tr>
<td>Derk Joester</td>
<td>Northwestern U.</td>
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<tr>
<td>Arash Komeili</td>
<td>UC Berkeley</td>
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<tr>
<td>Claudia Schmidt-Dannert</td>
<td>U. of Minnesota</td>
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<tr>
<td>Philippe Noirot</td>
<td>ANL</td>
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<tr>
<td>Jay Keasling</td>
<td>LBNL/UCB</td>
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<tr>
<td>Filipe Natalio</td>
<td>Weizmann Institute</td>
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<tr>
<td>Arpita Bose</td>
<td>Washington U</td>
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<tr>
<td>Lance Stewart</td>
<td>U. of Washington</td>
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<tr>
<td>Kevin Morey</td>
<td>Colorado State U</td>
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<tr>
<td>Yasuo Yoshikuni</td>
<td>LBNL/JGI</td>
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<tr>
<td>P.U.P.A. Gilbert</td>
<td>U. Wisconsin</td>
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<tr>
<td>Olga Ovchinnikova</td>
<td>ORNL, Center for Nanophase Material Sciences</td>
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<tr>
<td>Oleg Gang</td>
<td>Brookhaven, Columbia</td>
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<tr>
<td>Wil Srubar</td>
<td>U. Colorado, Boulder</td>
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<tr>
<td>Laurie Gower</td>
<td>U of Florida</td>
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<tr>
<td>Nils Kröger</td>
<td>U. Dresden, Germany</td>
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<tr>
<td>John Shanklin</td>
<td>BNL</td>
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<tr>
<td>Sanat Kumar</td>
<td>Columbia U</td>
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<tr>
<td>Farren Isaacs</td>
<td>Yale U.</td>
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Multi-disciplinary beautiful minds

Biology/Synbio Expertise

Biomaterial Expertise

Plant Expertise

Enabling Technologies & Computation Expertise
### Workshop Agenda

**Tuesday, October 9, 2018**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>7.30 – 8.00AM</td>
<td>Breakfast</td>
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<tr>
<td>8.00 – 8.30AM</td>
<td>BER welcome, introductions, overview by Dr. Todd Anderson, BER</td>
</tr>
<tr>
<td>8.30 – 9.15AM</td>
<td>“GEMS: Potential Scientific Opportunities” Talk and Agenda outline for Day 1 (co-chairs)</td>
</tr>
<tr>
<td>9.15 – 9.45AM</td>
<td>Science Presentation “Biomineralization of nacre and sea urchin spicules” Speaker: Dr. Pupa Gilbert, University of Wisconsin, Madison</td>
</tr>
<tr>
<td>9.45 – 11.45AM</td>
<td>Breakout session #1 “Designer Inorganic Materials”</td>
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<tr>
<td>11:45 – 12:45PM</td>
<td>Lunch Break</td>
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<tr>
<td>12.45 – 1.15PM</td>
<td>Breakout session report prep</td>
</tr>
<tr>
<td>1:15 – 2:15PM</td>
<td>Summary and discussion of Breakout session #1 (15 Mins each group, 15 mins Q&amp;A)</td>
</tr>
<tr>
<td>2.15 – 2.30PM</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>2.30 – 3.00PM</td>
<td>Science Presentation “Synthetic Biology with Protist Biominerals: The Diatom Paradigm” Speaker: Dr. Nils Kroger, Dresden, Germany</td>
</tr>
<tr>
<td>3.00 – 3.30PM</td>
<td>Science Presentation “Towards genetically programmable biocomposites with controllable architectures, mechanical properties and bio-functionalities” Speaker: Dr. Claudia Dannert-Schmidt, University of Minnesota</td>
</tr>
<tr>
<td>5.30 – 6.00PM</td>
<td>Breakout session report prep</td>
</tr>
<tr>
<td>6.00 – 7.00PM</td>
<td>Summary and discussion of Breakout session #2 (15 Mins each group, 15 mins Q&amp;A)</td>
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<tr>
<td>7.00 – 7.30PM</td>
<td>Group Discussion on Topics 1 and 2</td>
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<tr>
<td>7.30 PM</td>
<td>Adjourn (Dinner on your own)</td>
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## Workshop Agenda

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<table>
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<tr>
<td>8.00 – 8.30 AM</td>
<td>Breakfast</td>
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<tr>
<td>8.30 – 8.45 AM</td>
<td>Agenda outline for Day 2, topics, groups, B/O schedule (co-chairs)</td>
</tr>
<tr>
<td>8.45 – 9:15 AM</td>
<td>Science Presentation “Exploring and exploiting bacterial compartments for synthetic biomineral production” Speaker: Dr. Arash Komeili, University of California, Berkeley</td>
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<td>9.15 – 9:30 AM</td>
<td>Coffee Break</td>
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<tr>
<td>9.30 – 11.30 AM</td>
<td>Breakout session #3 “Designer Cell-Inorganic Materials”</td>
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<tr>
<td>11.30 – 12.00 PM</td>
<td>Breakout session report prep</td>
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<tr>
<td>12.00 – 1.00 PM</td>
<td>Lunch Break</td>
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<tr>
<td>1.00 – 2.00PM</td>
<td>Summary and discussion of Breakout session #3 (15 Mins each group, 15 mins Q&amp;A)</td>
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<tr>
<td>2.00 – 2.30 PM</td>
<td>Science Presentation “Towards material farming: where plant biology meets material sciences” Speaker: Filipe Natalio, Weizmann Institute of Science</td>
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<tr>
<td>2:30-3:00 PM</td>
<td>Science Presentation “Next-generation synthetic biology tools” Speaker: Huimin Zhao, University of Illinois Urbana/Champaign</td>
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<td>3.00 – 5.00 PM</td>
<td>Breakout session #4 Enabling characterization technologies</td>
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<td>5.00 – 5.30 PM</td>
<td>Breakout session report prep</td>
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<tr>
<td>5.30 – 6.15 PM</td>
<td>Summary and discussion of Breakout session #4 Enabling Characterization Technologies (15 mins per group and 15 mins Q&amp;A)</td>
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<tr>
<td>6.15 – 7.00 PM</td>
<td>Group Discussion on Topics 3 and 4 (and overall)</td>
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<tr>
<td>7.00PM</td>
<td>Adjourn (Dinner on your own)</td>
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### Breakout Session #1: Designer Inorganic Materials

<table>
<thead>
<tr>
<th>1.1 (Eisenhower)</th>
<th>1.2 (Jackson)</th>
<th>1.3 (Monroe)</th>
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<tbody>
<tr>
<td>Jay Keasling</td>
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<td>Caroline Ajo-Franklin</td>
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### Breakout Session #2: Designer Hybrid Materials

<table>
<thead>
<tr>
<th>2.1 (Eisenhower)</th>
<th>2.2 (Jackson)</th>
<th>2.3 (Monroe)</th>
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<tr>
<td>Derk Joester</td>
<td>P.U.P.A. Gilbert</td>
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### Breakout Session #3: Designer Cell-Inorganic Materials

<table>
<thead>
<tr>
<th>3.1 (Eisenhower)</th>
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<th>3.3 (Monroe)</th>
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</thead>
<tbody>
<tr>
<td>Filipe Natalio</td>
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### Breakout Session #4: Techniques

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<tr>
<th>4.1 Instrumentation (Eisenhower)</th>
<th>4.2 Bio tools/Methodology (Jackson)</th>
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<tbody>
<tr>
<td>Olga Ovchinnikova</td>
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<td>Farren Isaacs</td>
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<td>Farren Isaacs</td>
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Workshop Charge Summary

- What kinds of inorganic or inorganic-organic hybrid materials can be made now?

- What other materials could you envision synthesizing biologically?

- Why would you want to do this? What for?

- How would you do it? What would you need to do it?
Biomineralization of nacre and sea urchin spicules

Pupa Gilbert
Departments of Physics (100%), Chemistry (0%), Materials Science (0%), Geoscience (0%)
UW-Madison
Nils Kröger

Synthetic Biology with Protist Biominerals:

The Diatom Paradigm
Genome Engineering for Materials Synthesis Workshop

Towards genetically programmable biocomposites with controllable architectures, mechanical properties and bio-functionalities

Claudia Schmidt-Dannert
The Making of a Magnetic Microbe

Arash Komeili
Department of Plant and Microbial Biology
University of California, Berkeley
@micromagnets
www.komeililab.org
U.S. Department of Energy’s 2018
Genome Engineering for Material Synthesis
(GEMS) workshop

biomineralization and biological fabrication

Filipe Natalio

Department of Plant and Environmental Sciences
Kimmel Center for Archaeological Sciences
Weizmann Institute of Science
Next-generation Synthetic Biology Tools

Huimin Zhao

University of Illinois at Urbana-Champaign
Agency for Science, Technology and Research, Singapore

Oligo library synthesized on chip
CHAnGE plasmid library
Transformed yeast pool
Library of yeast mutants

Assemble
Transform
Mutate

No stress
Stress

No enrichment
Enrichment of desired phenotype
Plasmid Extraction
Data visualization

NGS
## Workshop Agenda Cont’d

**Attendance by Co-Chairs and Writing Team Only**

<table>
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<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Thursday, October 11, 2018</td>
<td>Breakfast</td>
</tr>
<tr>
<td>8.00 – 8.30 AM</td>
<td>Breakfast</td>
</tr>
<tr>
<td>8.30 – 10.30 AM</td>
<td>Writing Team organization and summaries</td>
</tr>
<tr>
<td>10.30 – 10.45 AM</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>10.45 – 12.30 PM</td>
<td>Working Lunch</td>
</tr>
<tr>
<td>12.30 – 1.30 PM</td>
<td>Summary prep, additional writing assignments etc.</td>
</tr>
<tr>
<td>1.30 PM</td>
<td>Adjourn</td>
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## Draft Report Outline

**Executive Summary**

**Introduction**

**Background: Types of Genetically-Encoded Materials**

**Basic Science Opportunities for Genetically-Encoded Materials: What are current knowledge gaps?**

**Basic Science Opportunities for GEMS: What are the technology gaps?**

**Scientific Opportunities: What materials should we make and why?**

**Summary**
Stay tuned…

Report expected in December

Thank you!