

# **BSSD Workshop Report: Technologies for Characterizing Molecular and Cellular Systems Relevant to Bioenergy and Environment**

**BERAC, April 20-21<sup>st</sup> 2017**

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Division Deputy for Biosciences, Advanced Light Source

Vice President for Technology, Joint BioEnergy Institute

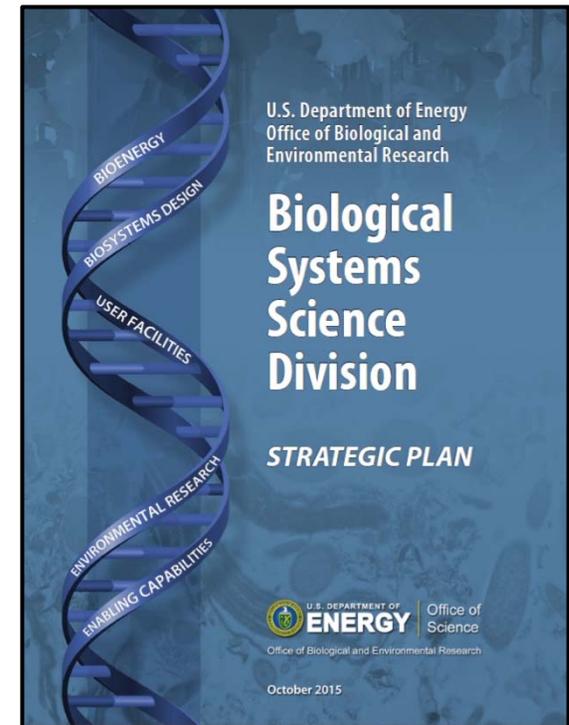
KEY

# Rationale - 2015 BSSD Strategic Plan

**Overarching Goal:** *Provide the necessary fundamental science to understand, predict, manipulate, and design biological processes that underpin innovations for bioenergy and bioproduct production and to enhance the understanding of natural environmental processes relevant to DOE.*

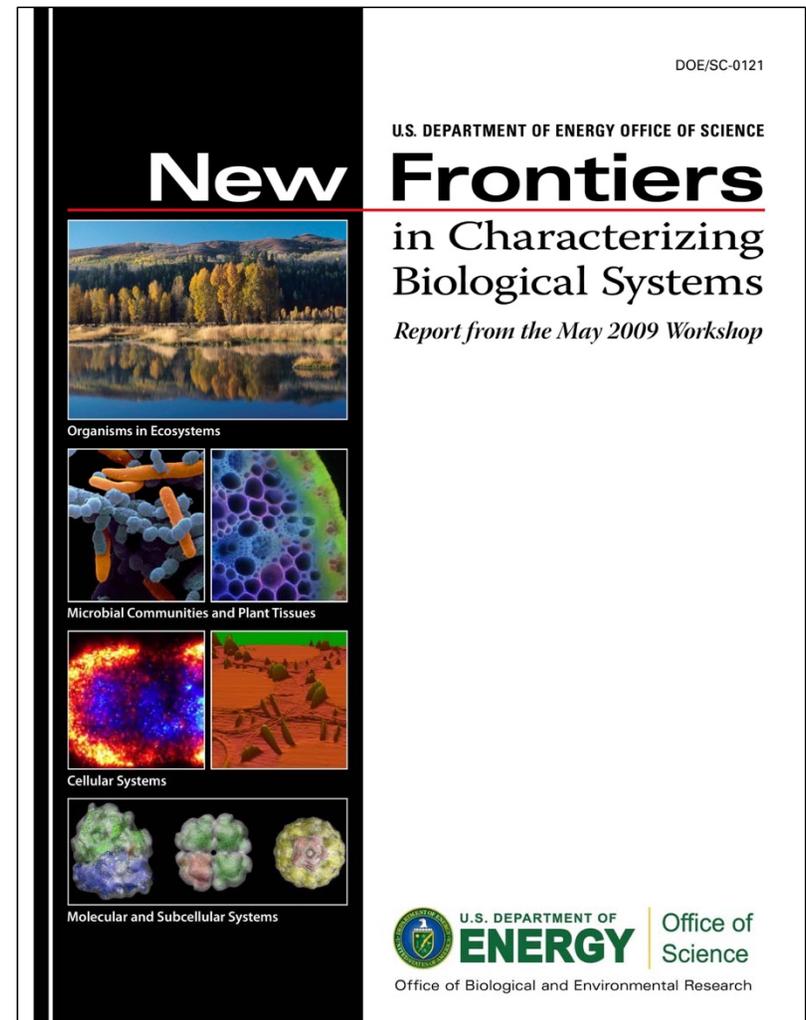
**Objective 4:** Develop the enabling computational, visualization, and characterization capabilities to integrate genomic data with functional information on biological processes.

- Workshop convened to identify and articulate the scientific basis for requesting for new resources

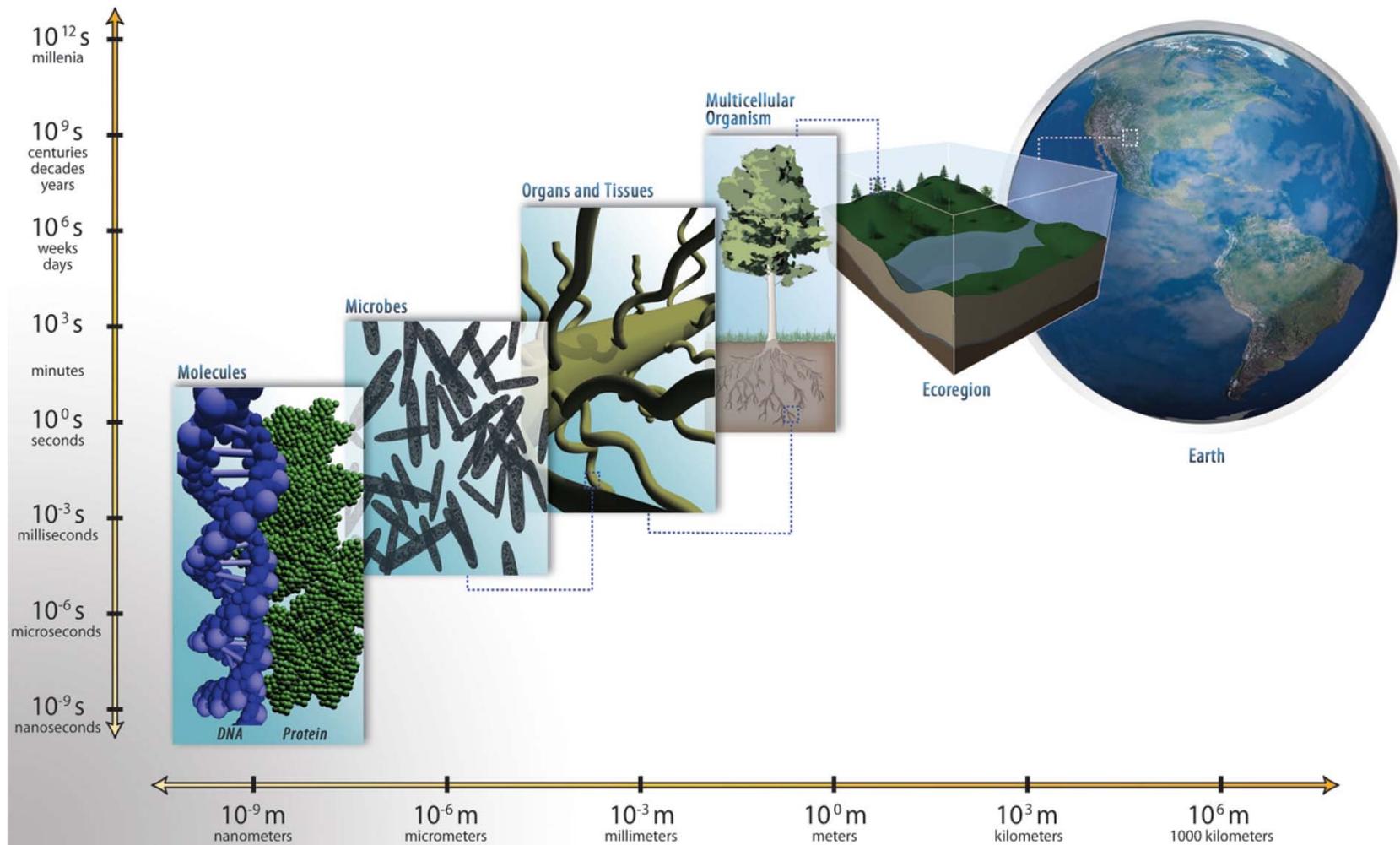


# Past Report - 2009

“Experts from scientific disciplines relevant to DOE missions and from the enabling technologies met to determine the opportunities and requirements for identifying and developing new tools and analytical approaches for characterizing cellular- and multicellular- level functions and processes that are essential to develop solutions for DOE missions. The intent of the workshop was to broadly explore future technology capabilities that are needed, not current technologies and their development.”



# BER Supported Research is Multiscale



# Integrative Technologies to Facilitate Systems Biology Research

The Biological and Systems Sciences Division is interested in gaining a predictive understanding of plant and microbial biology for a host of DOE-relevant missions including:

- Bioenergy development
- Carbon/nutrient cycling processes in the environment
- Biosystems design/synthetic biology
- Sustainability research

## ***Integrative Technologies are Needed to:***

- Understand key biological processes within and among plant and microbial cells
- Test/verify hypotheses of genome-to-function translation
- Understand the spatio-temporal nature of metabolism within/among cells
- Identify metabolic bottlenecks to pathway design or optimization
- Understand biomolecular structure-function relationships
- Improve computational descriptions and predictions of cellular processes

**Synergistic with the BERAC Grand Challenges Activity**

# Enabling Scientific Discovery in the Biological Sciences



- **Joint Genome Institute**
  - User Facility for genome sequencing and interpretation



- **Systems Biology Knowledgebase**
  - Online open source systems biology platform



- **Structural Biology Infrastructure**
  - Light and Neutron source experimental stations for structural biology and imaging



- **New Bioimaging Technologies**
  - Imaging technology development program underway



- **Environmental Molecular Science Laboratory**
  - User Facility for proteomics, microscopy, cell dynamics



- **National Energy Research Supercomputing Center**
  - Computational resources and expertise for basic scientific research

**[Joint BER/BSSD and ASCR/SciDAC session at GSP meeting]**

# September 21-23 Workshop: Technologies for Characterizing Molecular and Cellular Systems Relevant to Bioenergy and Environment

Rockville, Maryland

Organizer: Amy Swain, Biological Systems Science Division

## Co-chairs:

Paul Adams, Ph.D., Division Director, Molecular Biophysics & Integrated Bioimaging, LBNL

Elizabeth R. Wright, Ph.D., Associate Professor, Emory University



## Charge:

- Bring together biologists and technology developers to explore the current and future technology needs for BSSD research

# Workshop Participants

Chairs: Paul Adams, LBNL, Elizabeth Wright, Emory U.

<b>Participant</b>	<b>Institution</b>	<b>Participant</b>	<b>Institution</b>
Rommie Amaro	<i>UCSD</i>	Britt Hedman	<i>SLAC</i>
Parastoo Azadi	<i>U. Georgia</i>	Hoi-Ying Holman	<i>LBNL</i>
Philip Benfey	<i>Duke U.</i>	Greg Hura	<i>LBNL</i>
Joerg Bewersdorf	<i>Yale U.</i>	Farren Isaacs	<i>Yale U.</i>
Julie Biteen	<i>U. Mich.</i>	Andrzej Joachimiak	<i>ANL</i>
Wah Chiu	<i>Baylor</i>	Udaya Kalluri	<i>ORNL</i>
Bob Cottingham	<i>ORNL</i>	Ken Kemner	<i>ANL</i>
Shi-you Ding	<i>Michigan State</i>	Carolyn Larabell	<i>UCSF</i>
Jose Dinneny	<i>Carnegie Inst.</i>	Sean McSweeney	<i>BNL</i>
James Evans	<i>EMSL</i>	Michelle O'Malley	<i>UCSB</i>
Matthew Fields	<i>Montana State</i>	Hugh O'Neill	<i>ORNL</i>
Brian Fox	<i>U. Wisc.</i>	Jennifer Pett-	<i>LLNL</i>
Jamie Fraser	<i>UCSF</i>	Elizabeth Villa	<i>UCSD</i>
Sriram Ganesh	<i>U. Maryland</i>	Tuan Vo-Dinh	<i>Duke U.</i>

***A number of federal program representatives also attended***

# Workshop Charge

## Charge to Biologists:

- What are the barriers to making advances in characterizing your (representative) systems of interest?
- What are the length and time scales involved?

## Charge to Technology Experts:

- What current technical limits prevent the biological advances described above? e.g., resolution/scale, sample preparation, experimental conditions, stability, accessibility, analysis tools, etc.
- What technologies might be adapted, created, further developed, or combined to address the barriers?
- What are the obstacles to applicability or broad use of potential technological solutions?

# Biology Themes

Plenary and Breakout Sessions

- **Cellular ultrastructure and physiology**

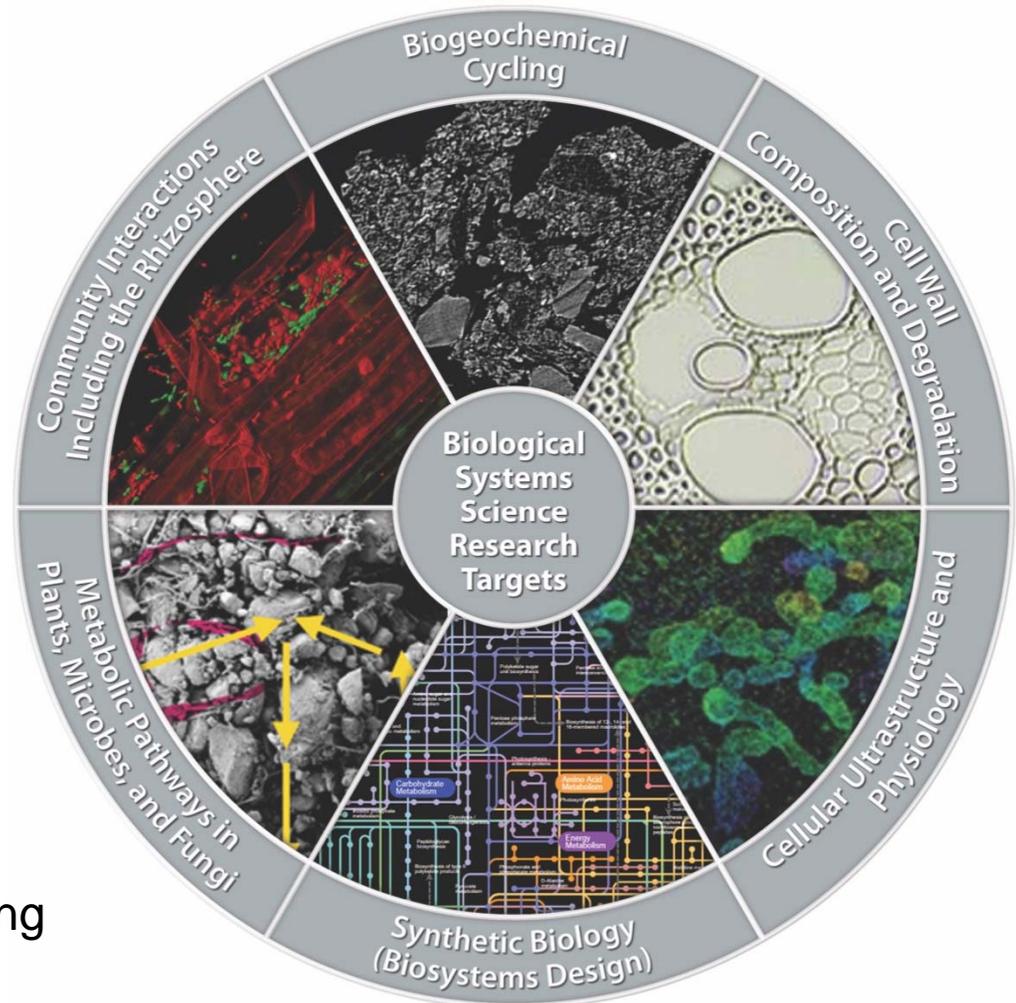
- Metabolic Pathways in Plants, microbes and fungi
- Cellular structure, organization, signalling, network

- **Bioenergy and bioproducts production**

- Cell Wall Composition and Degradation
- Synthetic Biology/Biosystems Design

- **Environmental microbiology**

- Community Interactions (including Rhizosphere)
- Biogeochemical Cycling of Elements



# Workshop Format

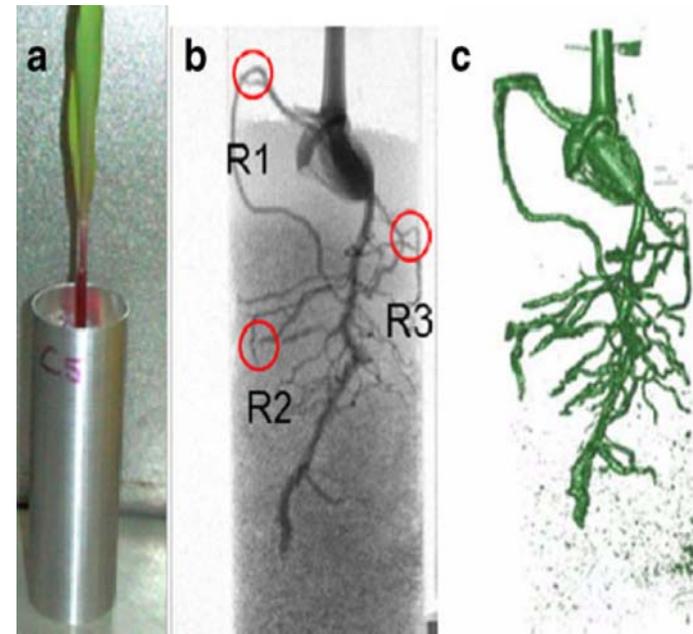
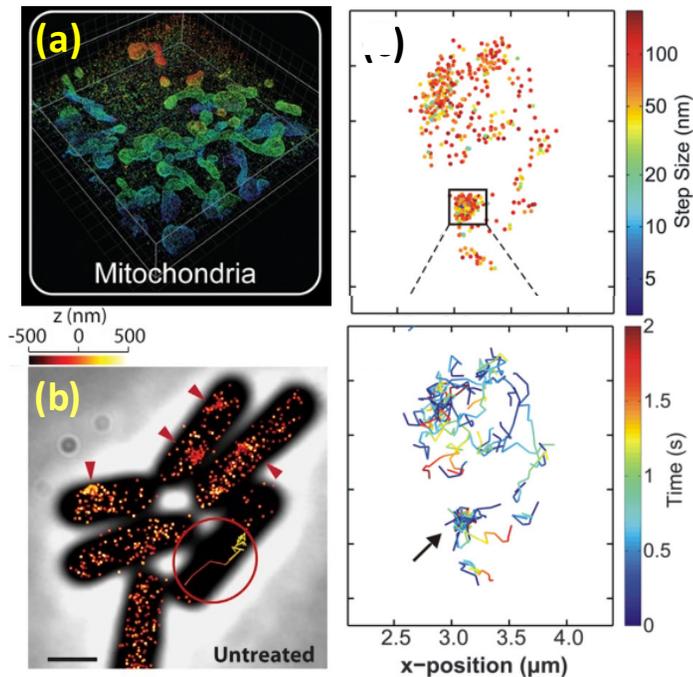
- Introductory short talks on BSSD capabilities and technology programs
- Keynote biology and technology talks with associated short talks
- Topic sessions:
  - Cellular Ultrastructure and Physiology
  - Bioenergy and Bioproducts Production
  - Environmental Microbiology
- Breakout session (moderated group discussion):
  - Metabolic pathways in plants, microbes and fungi
  - Cellular structure, organization, signaling, networks
  - Plant cell wall composition and degradation
  - Biosystems design
  - Community interactions including rhizosphere
  - Biogeochemical cycling of elements
- Community Access to Technology session
- Report writing planning session

# High Level Findings

- BER/BSSD research is multidisciplinary and covers a vast range of spatial and temporal scales
- There are needs and opportunities for improved technologies for measurement, and for *manipulation*
- Improved *computational analysis* tools are needed
- *Dissemination* of research tools and instrumentation requires continued attention
- Technical developments from other disciplines can be repurposed for BER/BSSD research
  
- What we didn't find:
  - A radically different technique on the horizon for measurement of biological systems

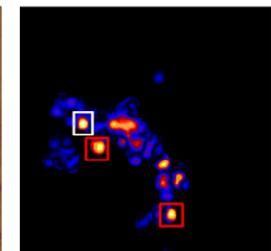
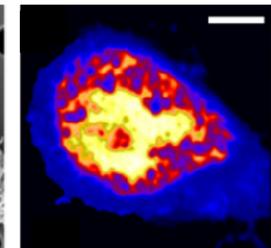
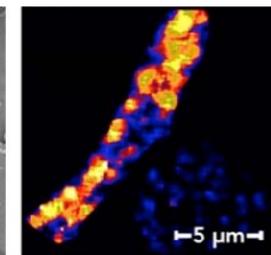
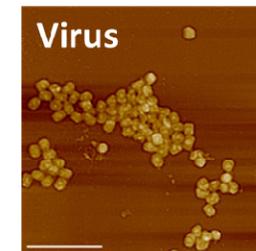
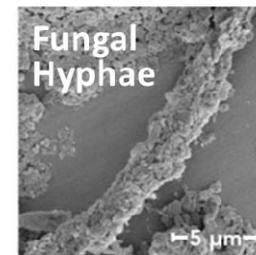
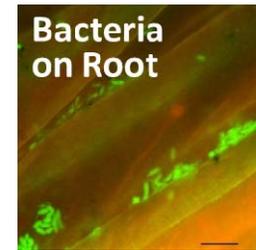
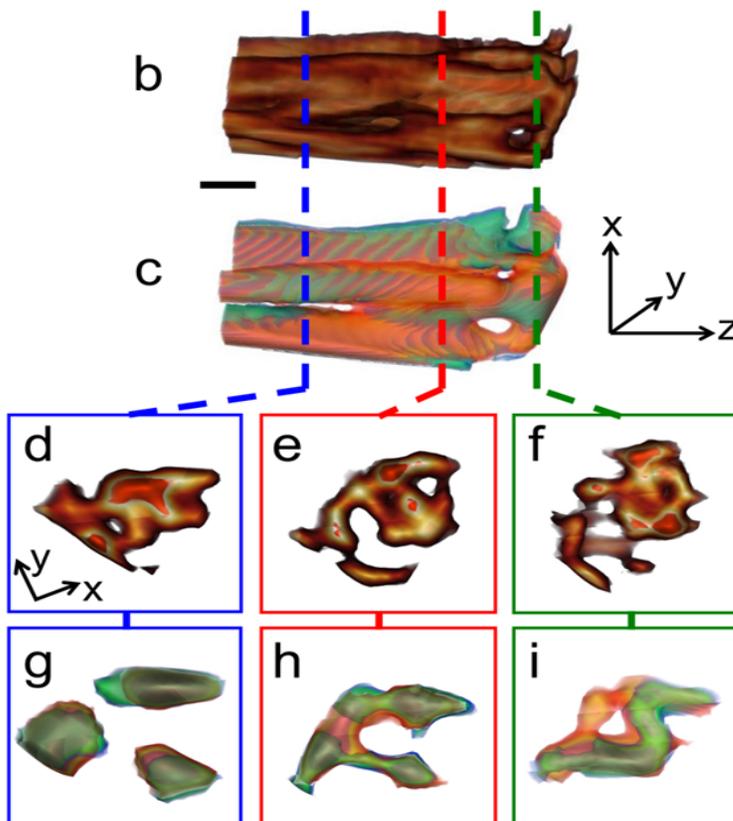
# Challenges Identified

- *In situ* and non-destructive analyses
  - Especially challenging in the environment
- Accessing timescales that probe the dynamics of biological systems
  - Coupled with high spatial resolution where possible



# Challenges Identified

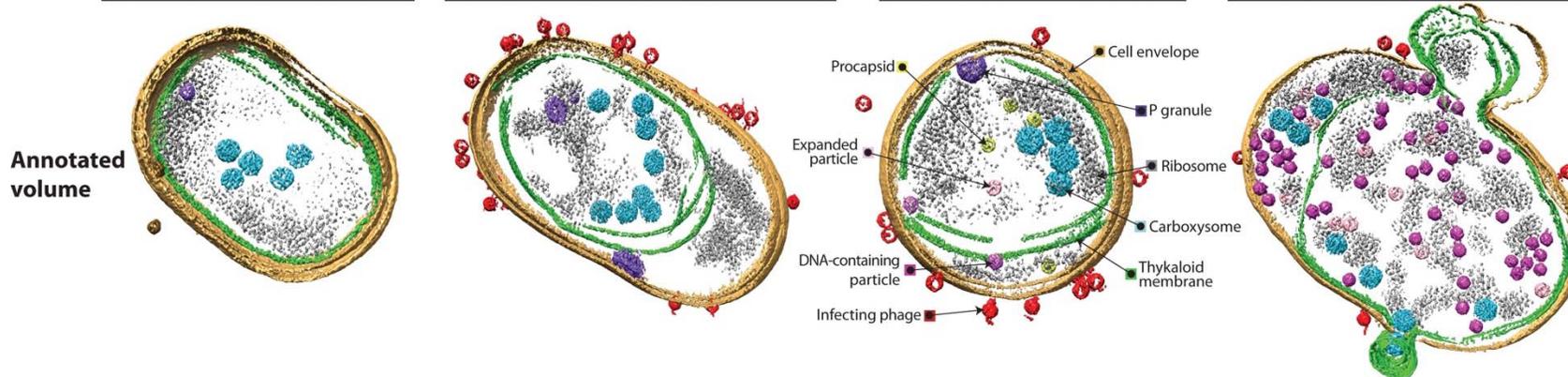
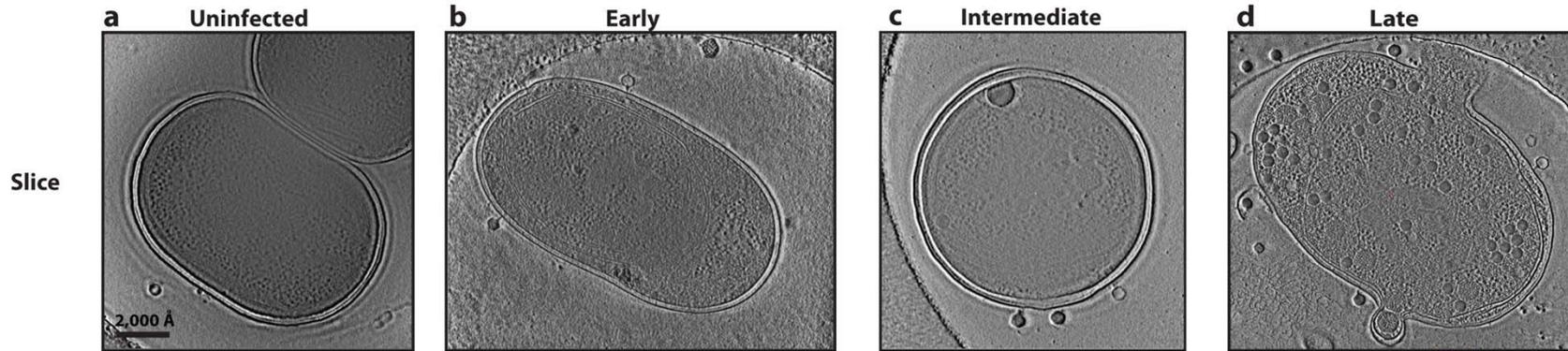
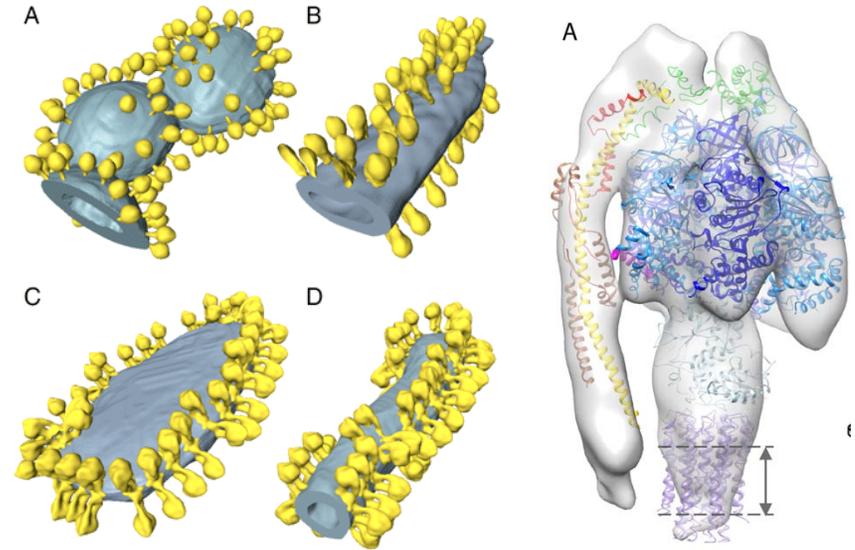
- Visualizing chemical species at high resolution in 3D
  - Combined with structural approaches



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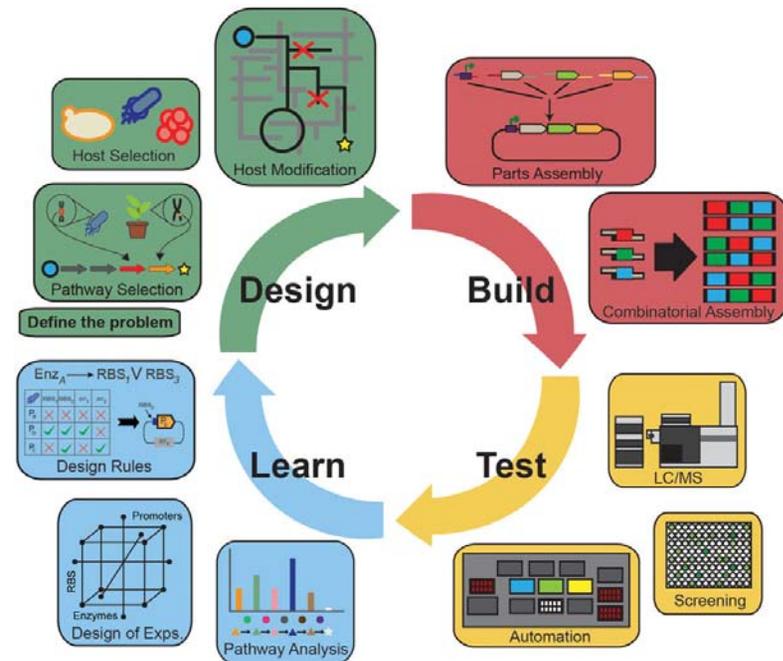
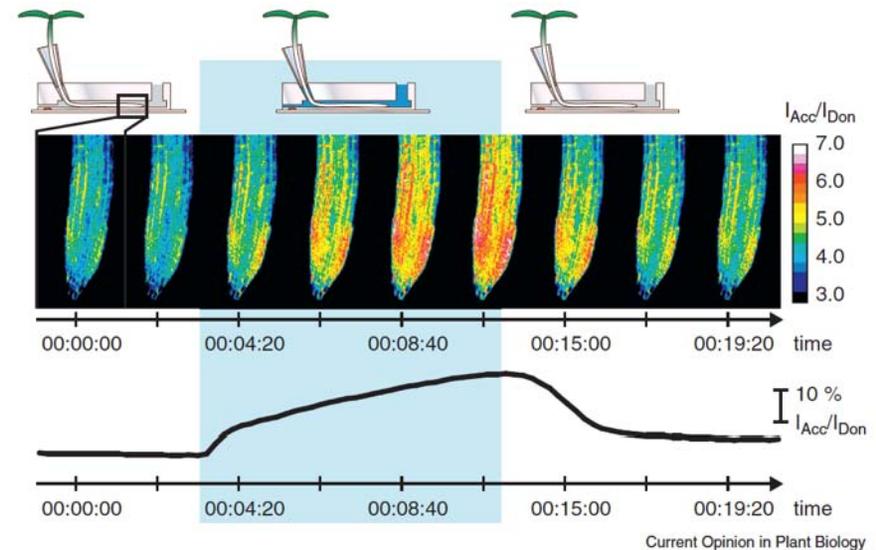
# Challenges Identified

- Harnessing cryo-EM/ET for BER research
  - Placing molecules in their cellular context



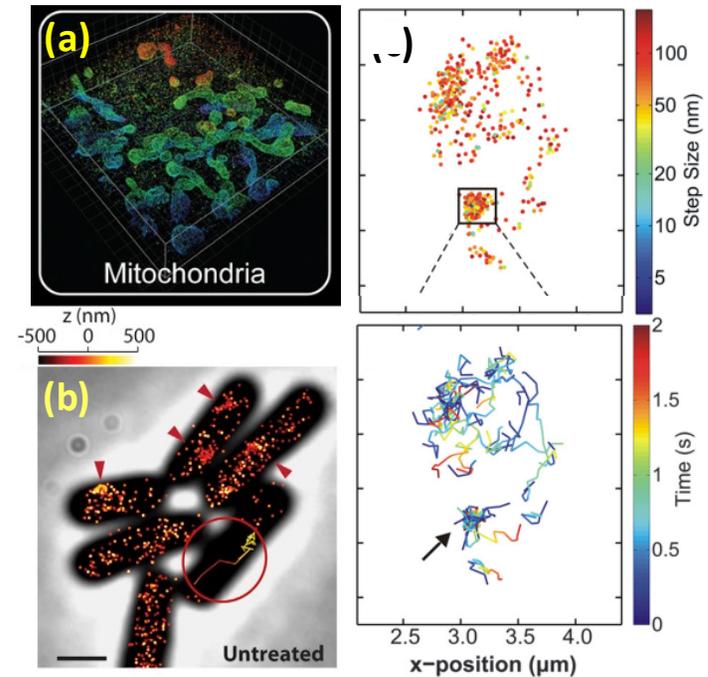
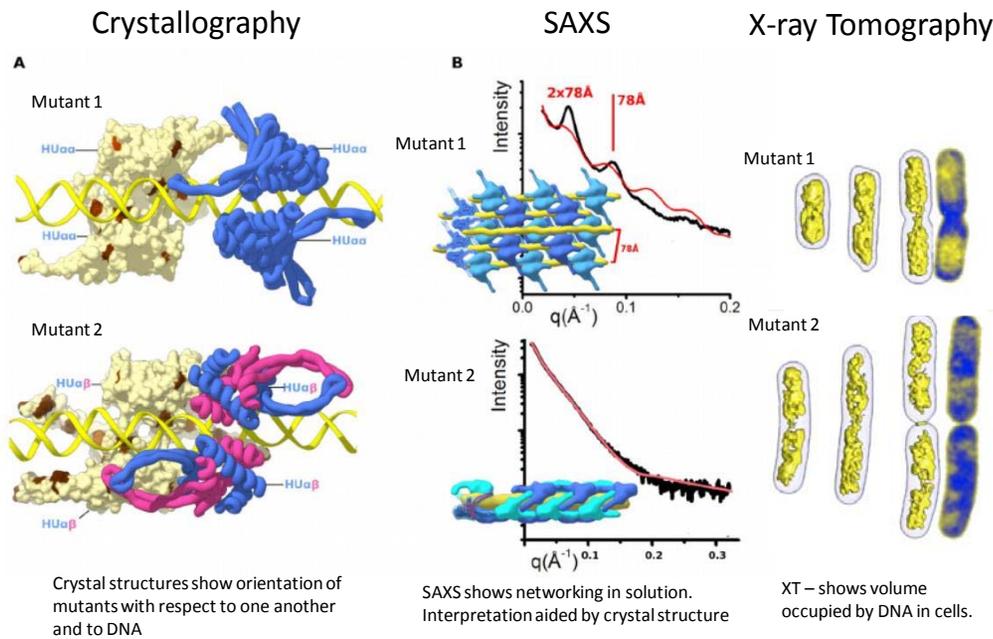
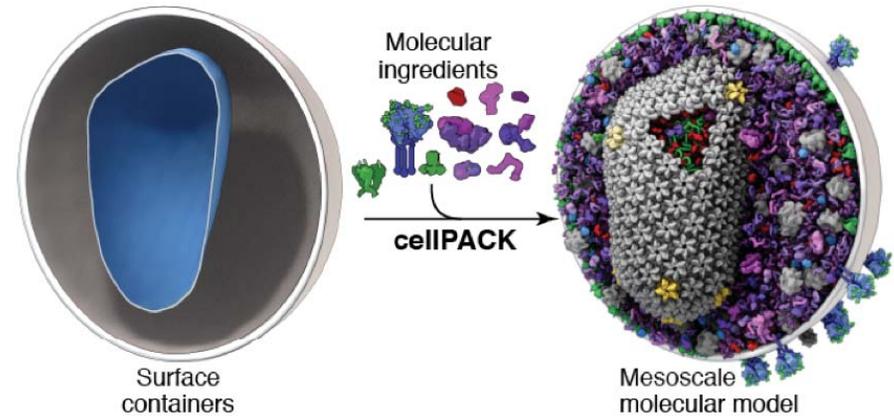
# Challenges Identified

- Metabolomics at high spatiotemporal resolution
  - Coupled with a mechanistic understanding of their synthesis, transport, degradation and perception
- Efficient tools for the precise manipulation of genomes combined with rapid measurement of phenotype
  - Enable predictive biology for biosystems design



# Challenges Identified

- Combining multiple data types
  - New approaches in computation, visualization, mathematics



# Report Writing

- Co-chairs have organized the writing by 6 session leads
  - Cellular structure: *Carolyn Larabell and James Evans*
  - Cell Wall Composition and Degradation: *Shiyu Ding and Hugh O'Neal*
  - Community Interactions: *Jennifer Pett-Ridge, Michelle O'Malley and Philip Benfey*
  - Biogeochemical Cycling: *Ken Kemner and Matthew Fields*
  - Metabolic Pathways: *José Dinneny*
  - Biosystems Design: *Farren Isaacs and Ganesh Sriram*
- Needs statements express scientific and technical needs
- Vignettes call out specific technology opportunities
- Computational section:
  - *Carolyn Larabell, James Evans, Jaime Fraser, Rommie Amaro, and Wah Chiu*
- Amy Swain and Todd Anderson contributed to the executive summary

# Report Status

- Draft report complete
- Summary and conclusions will be worked on further to bring in specific examples from the main text
- Text polishing
- Figure credits
- Anticipate final report in May, 2017

Thanks to all of the meeting participants, the breakout session leads, Amy and Todd, Betty Mansfield, Holly Haun, Marissa Mills, Kris Christen