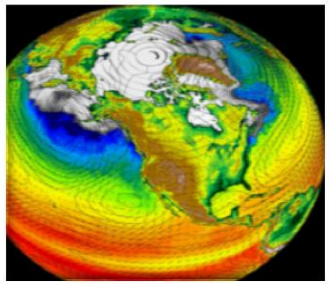
2017 Genomic Sciences Program Annual PI Meeting

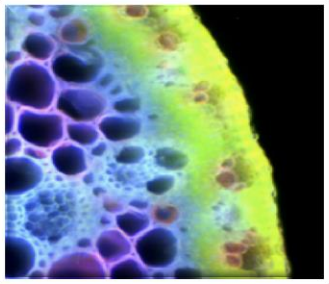
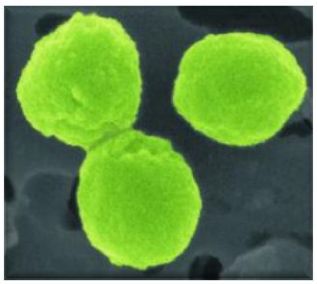
Todd Anderson, Ph.D.
Director, Biological Systems Science Division,
Department of Energy, Office of Biological &
Environmental Research

February 6, 2017

DOE Biological & Environmental Research Missions

- Understand complex biological, climatic, and environmental systems across spatial and temporal scales.
- BER provides the foundational science to:
  - Support the development of biofuels as major, secure, and sustainable national energy resources
  - Understand the potential effects of greenhouse gas emissions on Earth's climate and biosphere and the implications of these emissions for our energy future
  - Predict the fate and transport of contaminants in the subsurface environment at DOE sites
  - Develop new tools to explore the interface of biological and physical sciences



Office of Biological & Environmental Research

Sharlene Weatherwax, Associate Director

Todd Anderson, Director

Biological Systems Science

- Genomic Science
- Bioimaging Technology
- Facilities & Infrastructure
  - Joint Genome Institute
  - Structural Biology

Gary Geernaert, Director

Climate & Environmental Sciences

- Atmospheric System Research
- Environmental System Science
- Climate & Earth System Modeling
- Facilities & Infrastructure
  - Environmental Molec. Sciences Lab
  - ARM Climate Research Facility

BER FY 2017 President's Request

$661,920 ($609,000*)

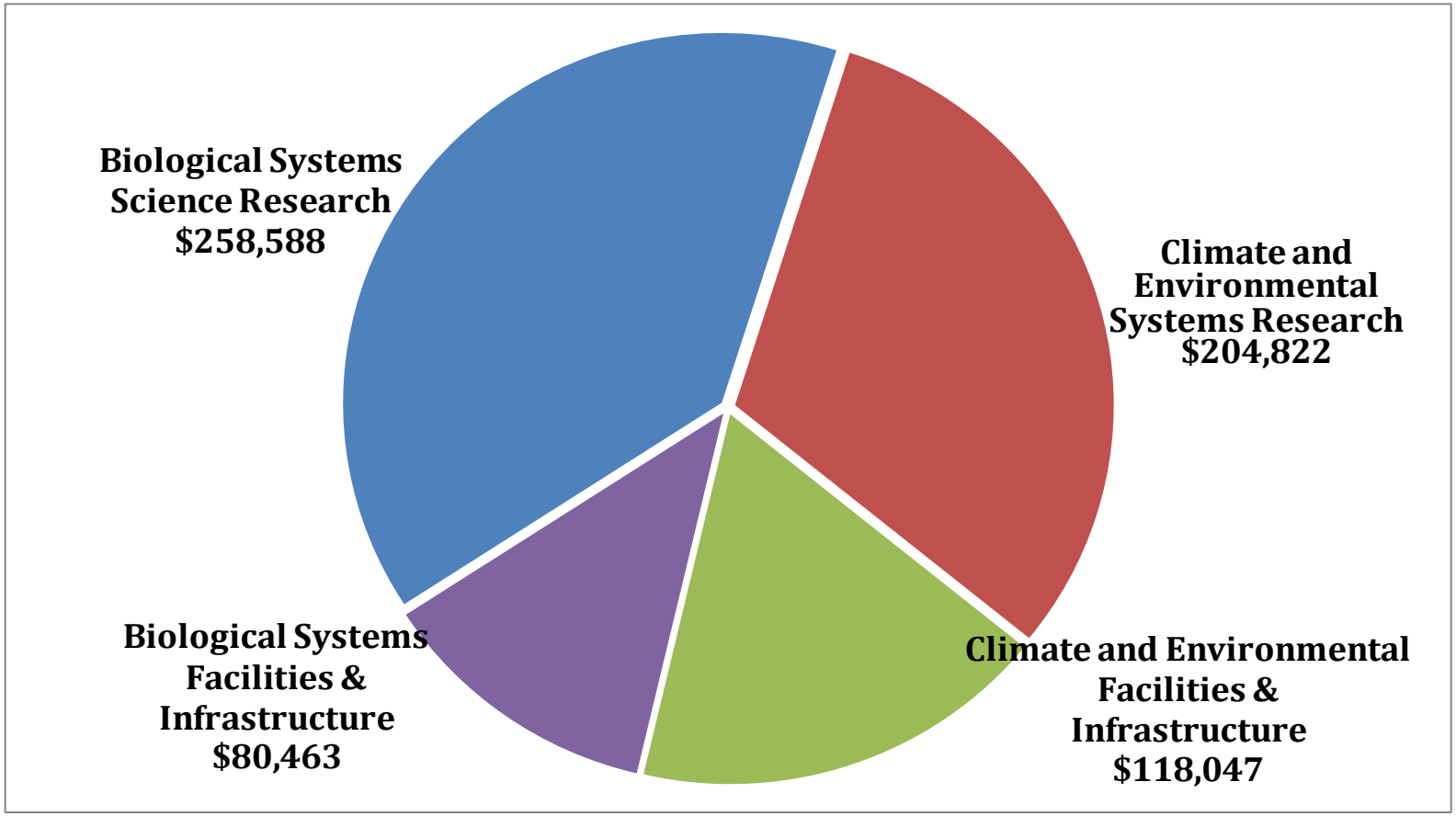
(dollars in thousands)

+ $44M

- Mission Innovation
- Microbiome
- Bioimaging

+ $8M

- Integrated Assessment



Currently operating under a Continuing Resolution (CR) at FY2016 budget till April 28th.

Biological Systems Science Division : Personnel Changes

Joe Graber – Genomic Science Program Team Lead

Meredith Rutledge – Scientific Program Specialist (Clemson University)

Funding Opportunities for FY 2017

Plant Feedstock Genomics for Bioenergy: A Joint Research Funding Opportunity Announcement USDA, DOE (DE-FOA-0001688) *

- *Continues research on plant responses to pathogens*
- *Includes a focus on oil seed crops*

BER Program Manager: Dr. Cathy Ronning

Biosystems Design to Enable Next-Generation Biofuels and Bioproducts (DE-FOA-0001650) *

- *Plant and microbial genome-scale design and engineering*
- *Expands its focus to biofuels and bioproducts*

BER Program Manager: Dr. Pablo Rabinowicz

Bioenergy Research Centers FOA (recompetition) *

- *Next steps in bioenergy research*
- *Informed by a June 2014 BER workshop on bioenergy research*

BER Program Managers : Dr. Kent Peters

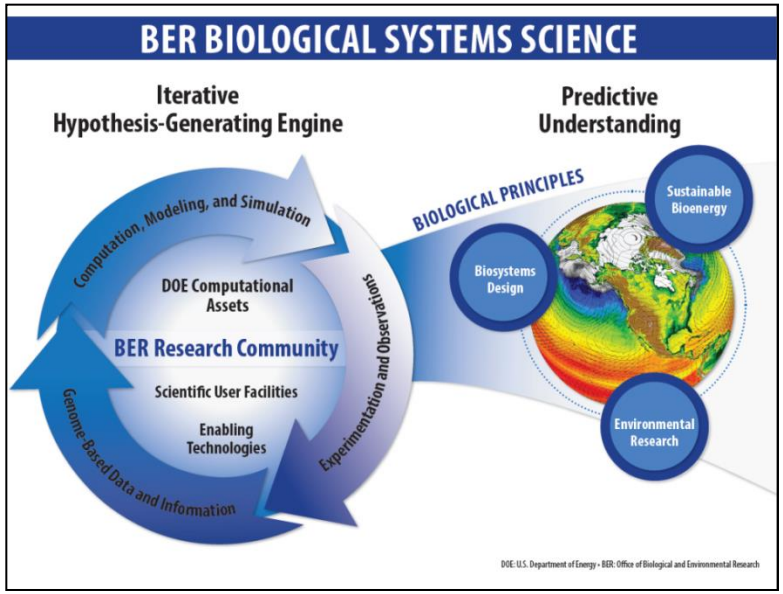
DOE National Laboratories SFA Opportunity ***Ongoing***

- *Plant Systems Biology for Bioenergy*
- *Biosystems Design for Bioenergy*
- *Soil Microbiome Research*

Systems Biology for Bioenergy FOA ***(Pending)***

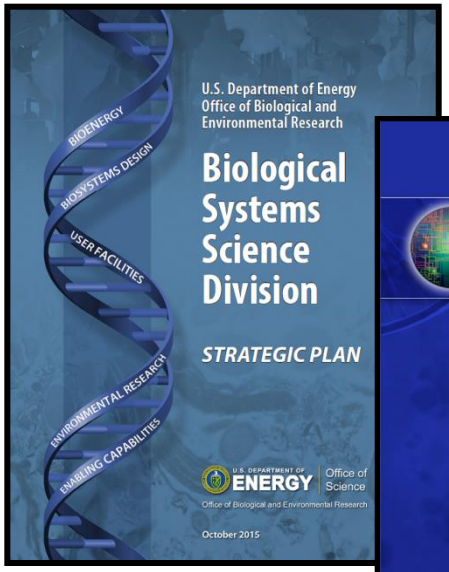
**** Closed to new submissions***

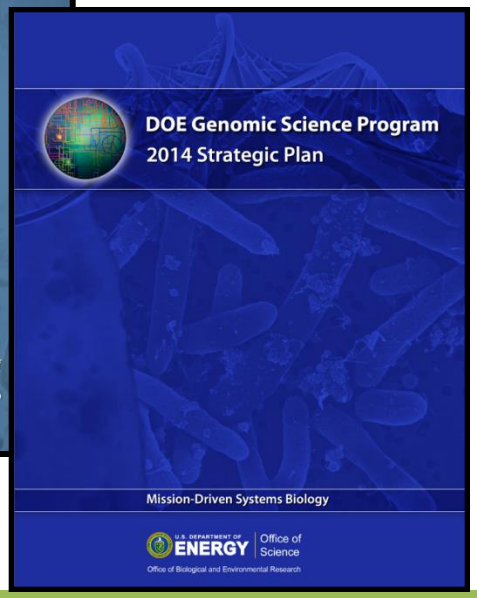
Genomic Science Program



Main Program Components

- *Bioenergy Research Centers (BRCs)*
- *Systems Biology for Bioenergy*
- *Plant Feedstocks Genomics*
- *Biosystems Design*
- *Carbon Cycle/Environmental Microbiological Research*
- *Computational Biosciences*
- *Sustainability Research for Bioenergy*



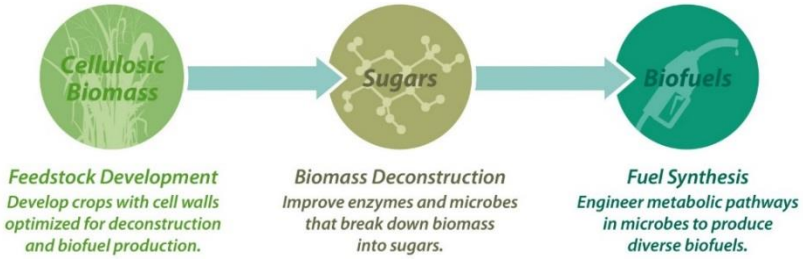


http://genomicscience.energy.gov/strategicplan/index.shtml

Bioenergy Research Centers

Multidisciplinary fundamental science guided by milestones & deliverables, targeted to key areas needed to improve production of biofuels from renewable biomass.

10th Year



- **BioEnergy Science Center** (Oak Ridge National Lab)
- **Great Lakes Bioenergy Research Center** (U. of Wisconsin, Michigan State U.)
- **Joint BioEnergy Institute** (Lawrence Berkeley National Lab)

BRC Recompetition DE-FOA-0001540

Sustainability* **Feedstock Development** **Biomass Deconstruction** **Conversion biofuels & bioproducts***

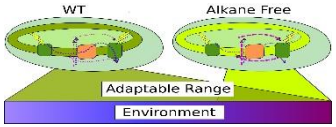
- Pre-applications due 6/17/2016
- Applications due 9/30/2016
- Selections in FY2017; centers begin in FY2018

BER Program Manager: Dr. Kent Peters

Systems Biology for Bioenergy

Fundamental, systems-level understanding of microbes and microbial communities relevant to advanced biofuels production.

- Research to advance the development of promising new model organisms relevant to biofuels production.
- Development of novel microbial functional capabilities and biosynthetic pathways relevant to the production of advanced biofuels and the development of strategies to overcome associated metabolic challenges resulting from pathway modification.
- Development of novel analytical technologies or high throughput screening approaches.



Broadens the portfolio in microbial research on advanced biofuels production

BER Program Manager: <u>Dr. Dawn Adin</u>

Genomic Science Program genomicscience.energy.gov

Systems Biology–Enabled Research for Microbial Production of Advanced Biofuels

Summary of Projects Awarded in 2014 Under Funding Opportunity Announcement DE-FOA-0001060

The U.S. Department of Energy's (DOE) Genomic Science program, managed within the Office of Biological and Environmental Research (BER), supports fundamental research to identify the foundational principles that drive biological systems. These principles govern translation of the genetic code into integrated networks of proteins, enzymes, regulatory elements, and metabolite pools underlying the functional processes of organisms. To address DOE's mission in sustainable bioenergy development, the Genomic Science program applies "omics"-driven tools of modern systems biology to challenges associated with microbial production of advanced biofuels.

Developing an increased understanding of how biological systems function and translating that knowledge to enhance the production capabilities of microbes and plants forms the basis of DOE's mission in sustainable bioenergy. To harness the microbial world's biosynthetic processing power for advanced biofuels production, an expanded set of platform organisms is needed with appropriate metabolic capabilities and stress tolerance characteristics. The DOE BER Genomic Science program supports research aimed at improving fundamental understanding of principles that govern the functional properties of bioenergy-relevant organisms at the genome scale. This knowledge will enable development of molecular genomics approaches and computational tools for the design, construction, and validation of improved biological components and systems. This highly interdisciplinary endeavor spans multiple fields in biology, systems biology, chemical and metabolic engineering, and computational biology.

Significant progress in the last decade has increased understanding of biological systems and the capabilities for manipulating them. These advances result largely from the tremendous technological leaps in developing molecular biology tools (e.g., genomic, metabolomic, and proteomic tools) to analyze and modify the functional properties of biological systems. Despite these advances, many fundamental gaps remain in understanding microbial metabolism and physiology related to the production of sustainable, efficient, and economically competitive biofuels derived from lignocellulosic plant biomass or from photosynthetic capture of carbon dioxide (CO_2).

The 2014 Funding Opportunity Announcement described herein specifically targets production of advanced biofuels, which in this context refers to biologically synthesized compounds with the potential to serve as energy-dense transportation fuels (e.g., diesel, gasoline, and aviation fuels) compatible with existing engines and fuel distribution infrastructures. Advanced biofuels production requires significant progress in the basic understanding of microbial metabolism and the conversion of photosynthetically derived carbon compounds (either via direct photosynthesis or acquired via breakdown of lignocellulosic plant biomass). Another goal is to determine how products can be efficiently shunted from central metabolism into complex products with associated rebalancing of organismal carbon allocations and redox potential.

BER solicited applications for systems biology–driven basic research in three areas of development focused on enabling advanced biofuels production:

- **Promising new model organisms relevant to biofuels production.** Proposed studies could include but are not limited to (1) advancing systems biology understanding and predictive modeling of specialist microbes or microbial consortia, (2) elucidating relevant regulatory and metabolic networks involved in product synthesis or environmental signal processing, (3) improving fundamental understanding of integrated function and compatibility of novel enzyme systems with direct applicability to lignocellulose breakdown or advanced biofuels production, and (4) developing genetic tools to facilitate study and manipulation of genetically intractable species.

Office of Biological and Environmental Research

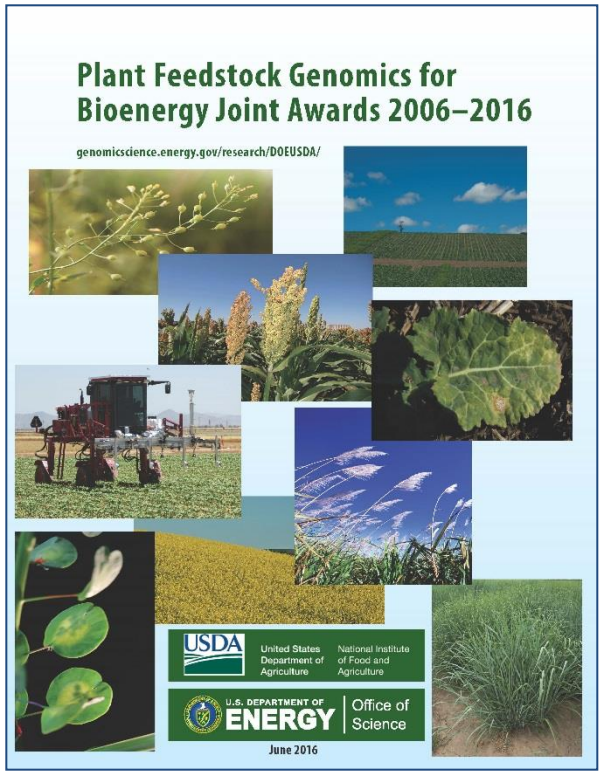
U.S. DEPARTMENT OF ENERGY | Office of Science

http://genomicscience.energy.gov/biofuels/systemsbiology/microbialbiofuelsawardsflyer.pdf

Plant Feedstocks Genomics Research for Bioenergy

Research to overcome the biological barriers to the low-cost, high-quality, scalable and sustainable production of bioenergy feedstocks using the tools of genetics and genomics

- Eleven-year collaborative effort with USDA on basic plant biology for bioenergy purposes
- Developing the scientific basis for new bioenergy crops
- Complementary with ongoing bioenergy research in BRCs and Biosystems Design
- New FOA includes plant responses to pathogens oil seed crop research



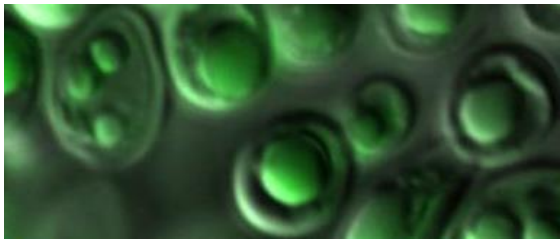
USDA NATIONAL INSTITUTE OF FOOD AND AGRICULTURE
U.S. DEPARTMENT OF AGRICULTURE

http://genomicscience.energy.gov/research/DOEUSDA/usda_doe_handout.pdf

BER Program Manager: Dr. Cathy Ronning

Biosystems Design

Systems biology and genome engineering research focused on the modeling and design of new biological systems for bioenergy and bioproduct production

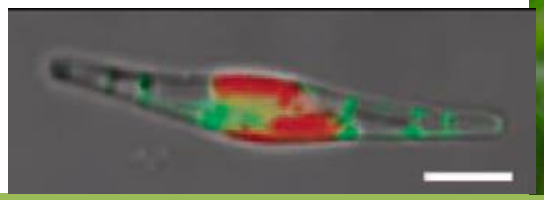


Microbial systems design for biofuels and bioproducts

- Integrated experimental and computational approaches aimed at modeling and designing flexible and tunable phototrophic or fermentative microbial systems for the production of advanced biofuels and bioproducts
- Novel *in vivo* and cell-free genome-scale engineering technologies to create new biological functions relevant to bioenergy production
- Development of new platform organisms for genome engineering and innovative high-throughput approaches for screening and testing modified strains

Plant systems design for bioenergy and bioproducts

- Systems-scale biology approaches to advance toward re-designing plants for increased photosynthesis capacity and biomass accumulation, improved nutrient and water utilization, increased non-edible oil and bio product production, and enhanced abiotic stress tolerance
- New technologies for modeling, design, and large-scale genome engineering of potential bioenergy crops to confer new or improved functions for sustainable production of biofuels and chemicals in marginal environments



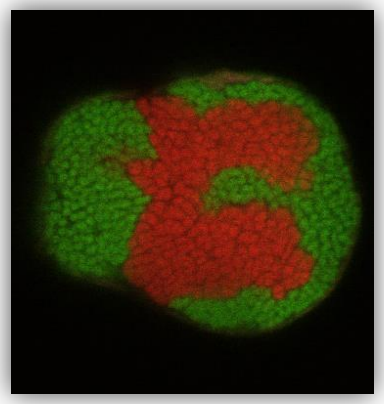
BER Program Manager: <u>Dr. Pablo Rabinowicz</u>

Environmental Microbiology

Genome enabled research linking structure and function of microbial communities with key environmental or ecosystem processes

- Systems biology of model microbes and consortia important in carbon cycle and environmental processes of relevance to DOE
- Extending systems biology approaches and understanding to integrated microbial communities and plant-microbe interactions
- Development of environmental “meta–omics” approaches to understand how shifts in environmental variables impact microbial community structure and functional processes
- High resolution, high throughput techniques for analysis of biological processes across multiple scales of spatial and temporal resolution
- Development of new techniques for in situ bioprocess analysis in terrestrial ecosystems

BER Program Manager: Dr. Dawn Adin



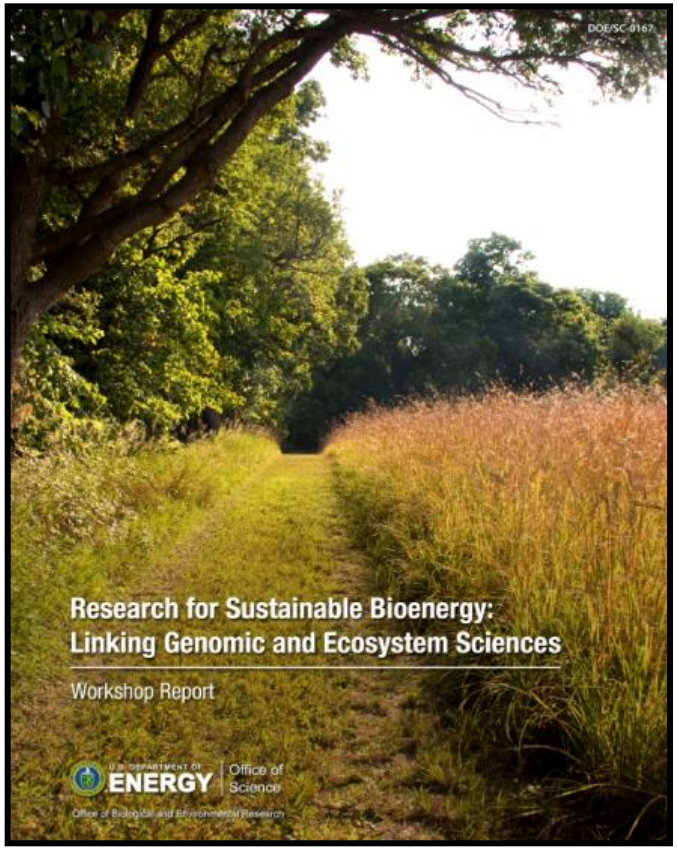
Sustainability Research for Bioenergy

Research to Advance Bioenergy Agriculture

Understanding plant/soil/microorganism interactions in field settings

- Enhance biomass productivity under changing conditions by:
  - Investigating molecular and physiological mechanisms that control bioenergy crop vigor, resource use efficiency, resilience/adaptability to abiotic stress;
  - Defining and characterizing interactions of bioenergy crop plants with the surrounding environment.

- Investigate the role(s) of microbial and microbial communities in the complex plant-soil environment in:
  - Contributing to plant performance, adaptation, and resilience under changing environmental conditions and abiotic stressors;
  - Impacts of introducing bioenergy cropping systems on the local ecosystem.



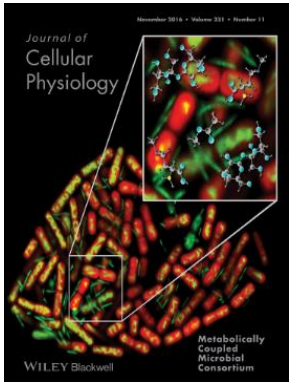
Program Manager: <u>Dr. Cathy Ronning</u>

Computational Biosciences

KBase
PREDICTIVE BIOLOGY

What's new In KBase?

- Over 60 apps spanning assembly, annotation, comparative genomics, metabolic modeling, expression analysis, RNA-seq, and more
- Enhanced RNA-seq and metabolic modeling (bold = improved, star= new)
- Upload large data objects from the web
- Upload and download select data in bulk
- Greatly enhanced tools supporting 3rd-party software tool development



➢ Modeled and predicted interactions between heterotrophic and autotrophic species in a simple community (Henry et al., *J. of Cellular Physiology*)

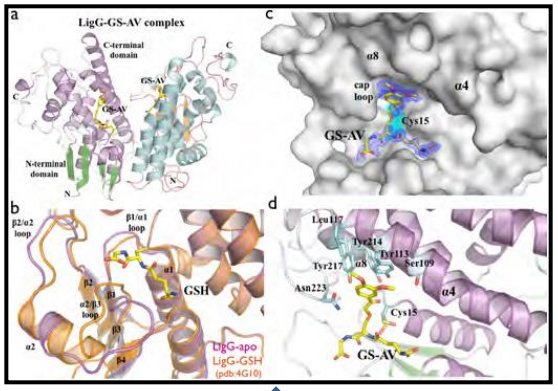
Program Manager : Dr. Ramana Madupu

Bioimaging Technologies

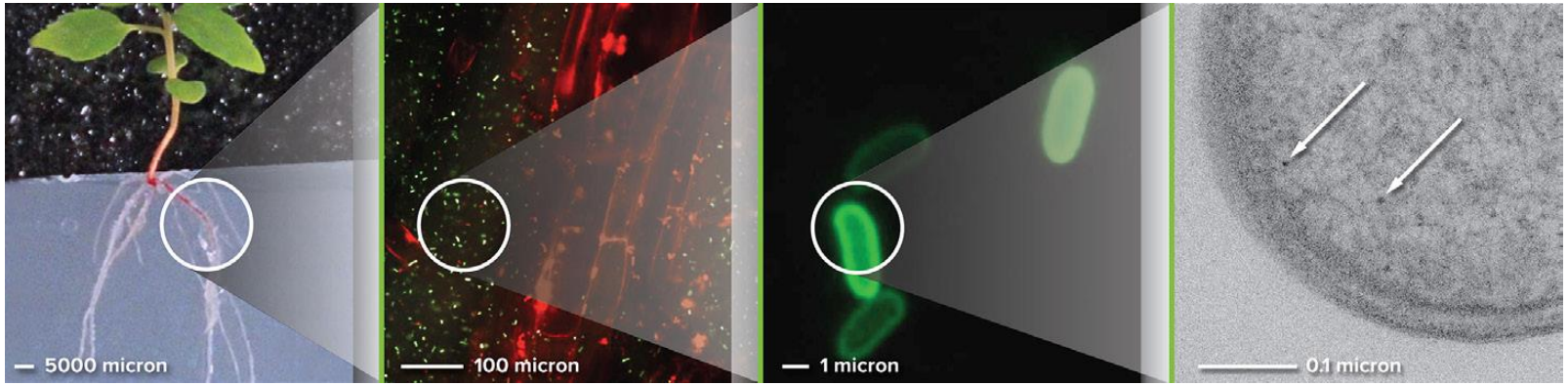
Goal: Develop the enabling computational, visualization and characterization capabilities to integrate genomic information with functional information on biological processes relevant to energy and environment.

- Combine biomolecular structural characterization with bioinformatics to infer function and improve genome annotation or design new functions.
- Visualize expressed biomolecules within living plant or microbial cells or within microbial communities.
- Develop *in situ*, dynamic, and nondestructive multifunctional imaging
- Partnerships with SC light sources and neutron sources

Characterization of energy-relevant biomolecules



Visualization across scales of observation



BER Program Manager: Dr. Prem Srivastava

DOE Joint Genome Institute

http://jgi.doe.gov/

Next Community Science Program (CSP) Call - OPEN

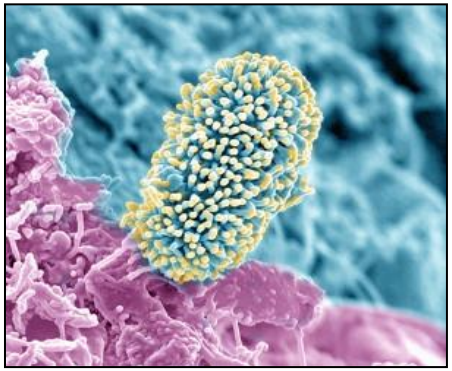
- *Letters of Intent due: March 31, 2017*
- Plant Functional Genomics and Microbiomes of DOE JGI Flagship Plants
- Inter-Organismal Interactions
- Microbiology of Extreme Environments
- Microbes and Communities Involved in Elemental Cycling in Terrestrial and Coastal Environments

FICUS (JGI-EMSL) Collaborative Science Initiative - OPEN

- *Letters of Intent due: April 3, 2017*
- Biofuels and Bioproducts
- Plant-Microbe Interactions
- Biogeochemistry
- Emerging Topics

FICUS (JGI-NERSC) Collaborative Science Initiative - OPEN

- *Letters of Intent due: March 1, 2017*



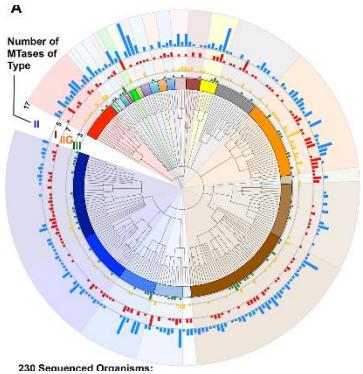
Root associated microbe

Eucalyptus grandis

A. muscaria

Setaria viridis

Updated: Tree of Life



Epigenomics

BER Program Manager: Dr. Dan Drell

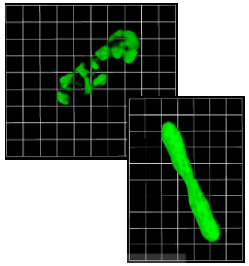
Environmental Molecular Sciences Laboratory

Advancing discovery and mechanistic understanding of molecular- to meso-scale biological, chemical and physical processes and interfaces to enable predictive understanding.

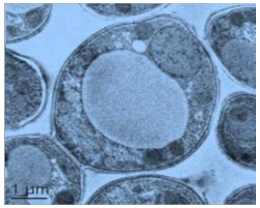
EMSL provides access to premier instruments for experimental research, high performance computing (HPC) capabilities and a variety of software codes for a range of modeling studies.

➢ Science Themes:

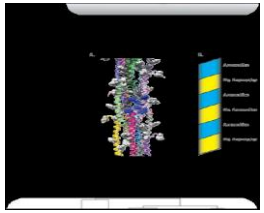
- *Biological Dynamics/Design* – understanding and optimizing biological pathways in plants, fungi and microbes.
- *Terrestrial/Subsurface Ecosystems* – understanding the dynamics of metabolites, nutrients and contaminants at biogeochemical interfaces.
- *Molecular Transformations* – understanding molecular transformations at interfaces.



Lipid production in wild type (top) and mutant (bottom) *Rhodobacter – SIM.*



Visualization of ultrastructures and whole cell reconstruction - TEM.

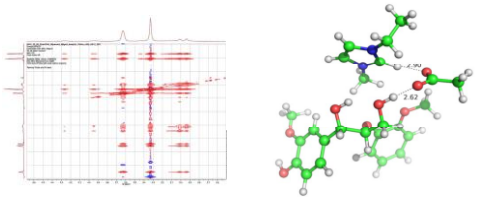


Protein structures - NMR.

➢ Proposal Opportunities:

- Science Theme Call – due February 27, 2017 ***Open***
- FICUS (JGI-EMSL) Call LOI – due April 3, 2017 ***Open***
- General and Scientific Partner – submitted anytime ***Open***

Call Info: https://www.emsl.pnl.gov/emslweb/proposal-opportunities
Capabilities: https://www.emsl.pnl.gov/emslweb/scientific-capabilities



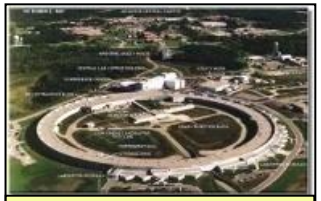
Experimentation and modeling of ionic liquid pretreatment – NMR, Spectroscopy, NWChem.

BER Program Manager – Paul Bayer

Structural Biology Infrastructure Resources

SYBYLS, NCXT,
FTIR Spectromicroscopy
X-ray tomography
SAXS
crystallography

LBNL/Advanced Light Source (ALS)
Dr. Hoi-Ying Holman
Dr. Carolyn Larabell
Dr. John Tainer

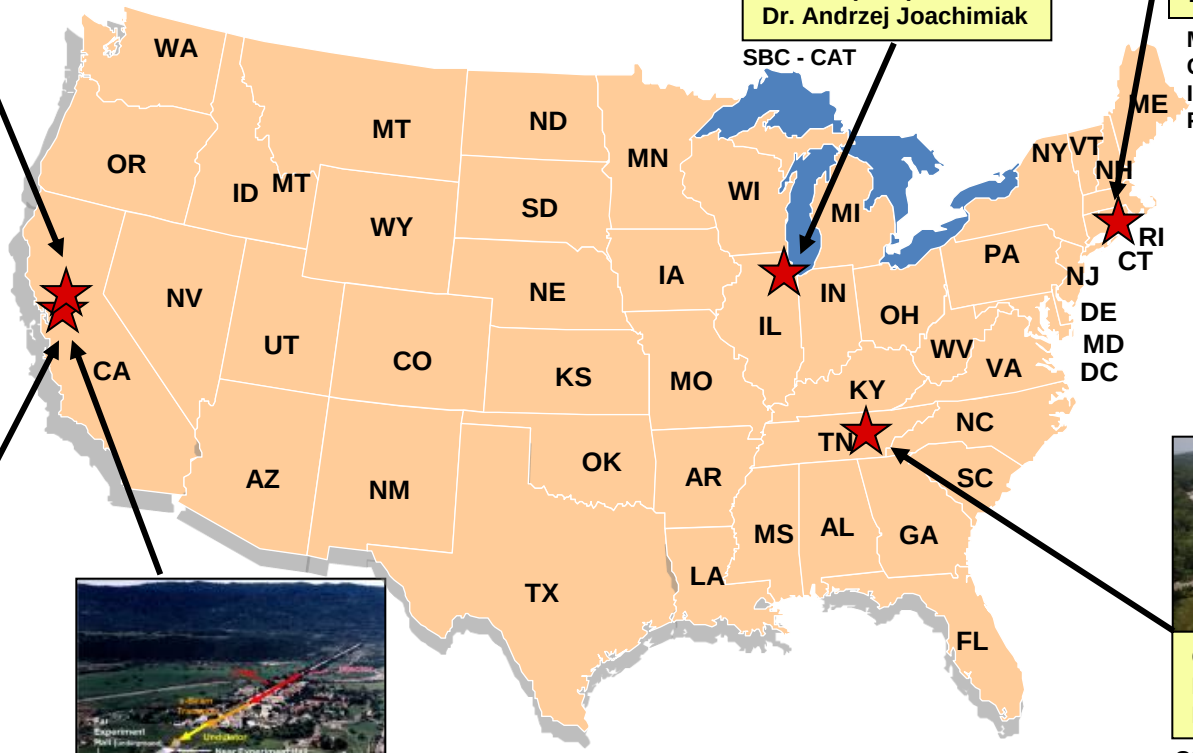


ANL/Advanced Photon Source (APS)
Dr. Andrzej Joachimiak

SBC - CAT

BNL/National Synchrotron Light Source-II
Dr. Sean McSweeney

Microfocus x-ray Crystallography, Scattering, Imaging, Footprinting



SLAC/Stanford Synchrotron Radiation Lightsource (SSRL)
Dr. Keith Hodgson

SSRL/SMB crystallography, x-ray spectroscopy and scattering

SLAC/Linear Coherent Lightsource (LCLS)
Dr. Sebastien Boutet
Dr. Soichi Wakatsuki

LCLS XFEL MFX femtosecond crystallography, scattering

ORNL/High Flux Isotope Reactor (HFIR)
Dr. Paul Langan

CSMB - BioSANS

BER Program Manager : Dr. Amy Swain

National Energy Research Scientific Computing Center

Allocations of Computer Time

6 B hours available at NERSC in 2017

- 4,800 M for DOE Production (mission computing)
- 600 M for ALCC, 600 M for NERSC Director's Reserve

Compute available to Office of Science–funded PIs

480 M hours allocated initially to BER for 2017

- 390 M for Climate/Environment
- **90 M for Bioscience**
- Additional 480 M distributed to Program Managers' reserves in spring 2017 for them to distribute at their discretion; codes must be ready to run on Xeon Phi

New requests accepted throughout the year for both production and startup

BER Program Manager : Dr. Ramana Madupu

Cori – Cray XC40
9,300 Intel Xeon Phi (KNL) nodes
2,000 Intel Xeon (Haswell) nodes
~30 PF peak

Edison – Cray XC30
5,576 Xeon (Ivy Bridge) nodes
2.57 Pflop/s peak

http://www.nersc.gov/ http://www.nersc.gov/users/accounts/allocations/first-allocation/

Complementary Research Programs within DOE

Office of Science – Basic Energy Sciences

Photosynthetic Systems focuses on natural photosynthesis and brings together biochemistry, chemistry, molecular biology, and biophysics to uncover the fundamental science of the biological capture of sunlight and its conversion to and storage as chemical energy.

Physical Biosciences combines experimental and computational tools from physical sciences with biochemistry, chemistry and molecular biology to increase basic understanding of processes to capture, convert and store energy in living systems, with an increasing emphasis on redox biochemistry.

Program managers: Dr. Robert Stack and Dr. Stephen Herbert

Advanced Research Projects agency – Energy (ARPA-E)

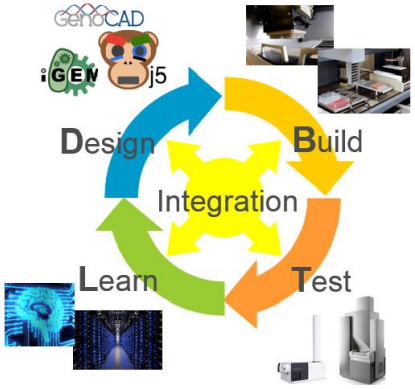
The ARPA-E Rhizosphere Observations Optimizing Terrestrial Sequestration (**ROOTS**) program seek to develop advanced technologies and crop cultivars that enable a 50 percent increase in soil carbon accumulation while reducing N_2O emissions by 50 percent and increasing water productivity by 25 percent.

Program director: Dr. Joe Cornelius

Office of Energy Efficiency and Renewal Energy (EERE)

Bioenergy Technologies Office (BETO)

Multiple outlets for basic research translation to scale in the areas of feedstocks development, biomass conversion technologies, sustainability approaches and new developments in biomanufacturing.



Agile BioFoundry

Multi-DOE Lab effort to accelerate a biomanufacturing industry

Systems science to meet DOE mission needs in bioenergy, climate and the environment.

http://science.energy.gov/ber

Thank you!

http://genomicscience.energy.gov