

Systems Biology Research in DOE's Office of Biological and Environmental

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Director, Biological Systems Science Division,
Department of Energy, Office of Biological &
Environmental Research

October 2, 2018

DOE Office of Science

Advanced
Scientific
Computing
Research

Basic
Energy
Sciences

**Biological and
Environmental
Research**

Sharlene Weatherwax,
Associate Director

High
Energy
Physics

Nuclear
Physics

Fusion
Energy

Todd Anderson, Director

Biological Systems Science

- Genomic Science
 - Bioenergy Research Centers
- Biomolecular Characterization and Imaging Science
- Facilities & Infrastructure
 - Joint Genome Institute

Gary Geernaert, Director

Climate & Environmental Sciences

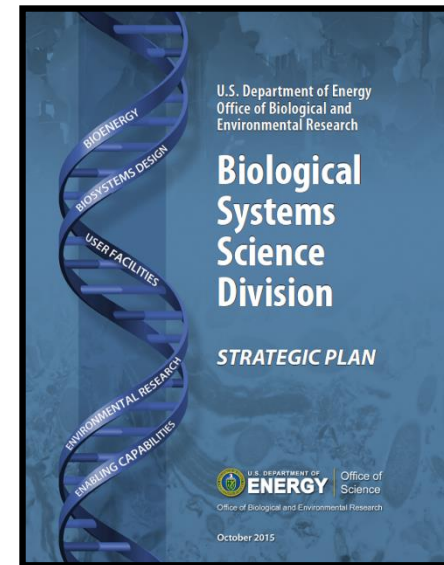
- Atmospheric System Research
- Environmental System Science
- Climate & Earth System Modeling
- Facilities & Infrastructure
 - Environmental Molec. Sciences Lab
 - ARM Climate Research Facility

Biological Systems Science Division

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.

Objectives

- Provide a basic understanding of plant and microbial biology to underpin the production of biofuels and bioproducts from sustainable plant biomass resources.
- Develop the fundamental understanding of genome biology needed to design, modify, and optimize plants, microbes, and biomes for beneficial purposes.
- Gain a predictive understanding of biological processes controlling the flux of materials (e.g., carbon, nutrients, and contaminants) in the environment and how these processes impact ecosystem function.
- Develop the enabling computational, visualization, and characterization capabilities to integrate genomic data with functional information on biological processes.
- Broaden the integrative capabilities within and among DOE user facilities to foster a more interdisciplinary approach to BER-relevant science and aid interpretation of plant, microbe, and microbial community biology.

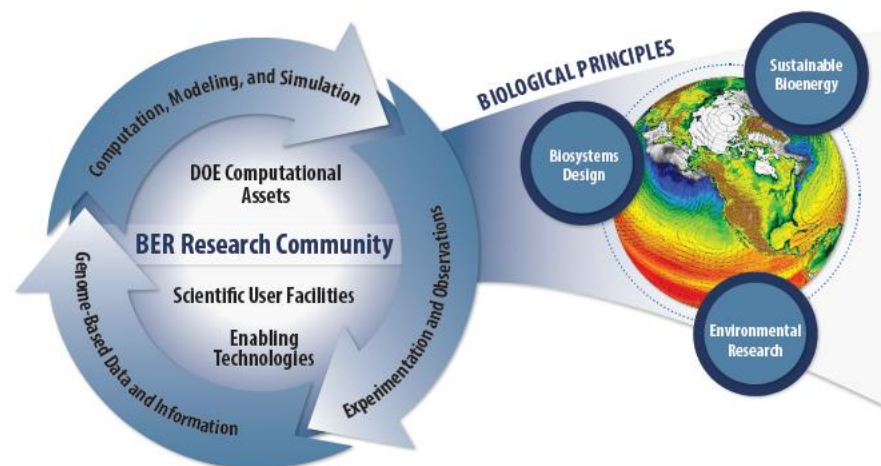
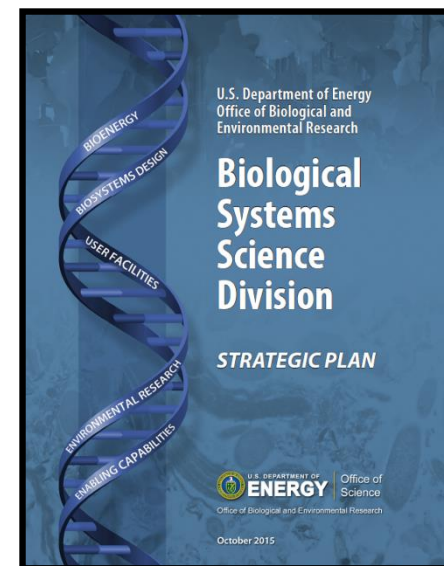


Biological Systems Science Division

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.

Objectives

- **Plant & Microbial Bioenergy Research**
- **Biosystems Design & Synthetic biology**
- **Environmental Microbiome Science**
- **Enabling Capabilities**
- **User Facility Integration**



The Biological Systems Science Division Portfolio

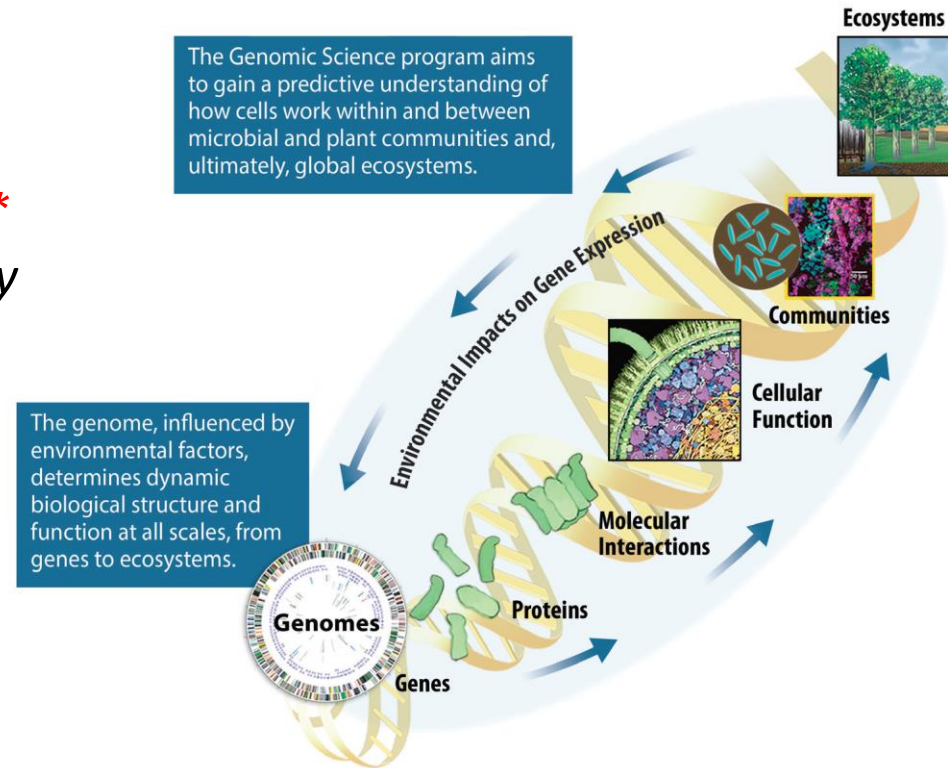
Genomic Science Program

- Bioenergy Research Centers (BRCs)
- Systems Biology for Bioenergy
- Plant Feedstocks Genomics*
- Biosystems Design
- Environmental Microbiome Science*
- Sustainability Research for Bioenergy
- Computational Biosciences*

Biomolecular Characterization and Imaging Science

Facilities & Infrastructure

- Joint Genome Institute (JGI)



Bioenergy Research Centers

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

➤ **Center for Bioenergy Innovation (CBI)**

Oak Ridge National Laboratory (<https://cbi.ornl.gov/>),



➤ **Great Lakes Bioenergy Research Center (GLBRC)**

University of Wisconsin, Michigan State University (<https://www.glbrc.org/>)



➤ **Joint BioEnergy Institute (JBEI)**

Lawrence Berkeley National Laboratory (<https://www.jbei.org/>)



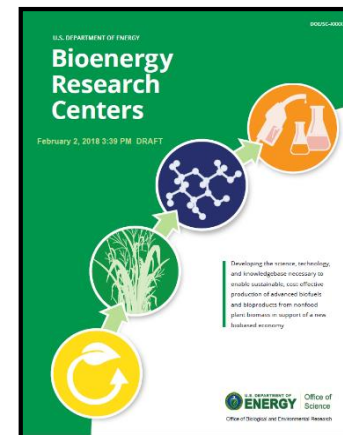
➤ **Center for Advanced Bioenergy and Bioproducts Innovation (CABBI)**

University of Illinois (UIUC) (<https://cabbi.bio/>)



BER Program Manager:
Dr. Kent Peters

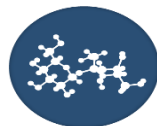
<https://genomicscience.energy.gov/index.shtml>



Sustainability



Feedstock
Development



Biomass
Deconstruction



Conversion
biofuels &
bioproducts

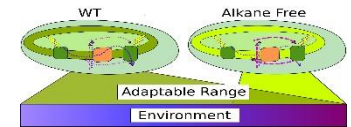
Systems Biology for Bioenergy

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: Dr. Dawn Adin



Department of Energy

Department of Energy Announces \$40 Million for Bio-Based Research

JUNE 18, 2018

[Home](#) • Department of Energy Announces \$40 Million for Bio-Based Research

31 Projects Will Help Advance Fundamental Science for Bioenergy

WASHINGTON, D.C. – Today, the U.S. Department of Energy (DOE) announced \$40 million in funding for 31 projects to advance research in the development of microbes as practical platforms for the production of biofuels and other bioproducts from renewable resources.

The projects will further the ongoing revolution in biology and biotechnology, and will increase our understanding of how nature's sophisticated production capabilities at the cellular level can be harnessed to produce sustainable, clean, and efficient fuel as well as drive other industrial production processes.

"In coming years, the revolution in biotechnology and bio-based production methods are expected to transform the face of industry," said U.S. Secretary of Energy Rick Perry. "These projects will help ensure that America continues to lead the way in developing the knowledge and expertise needed to capitalize on the many new opportunities of the emerging bioenergy fields."

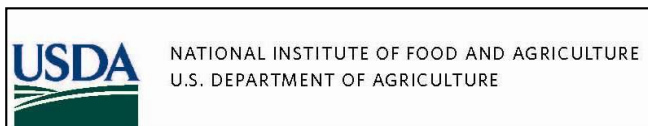
New Awards: <https://science.energy.gov/~media/4C7317A50AF94F069737C2C58B917F83.ashx>

Plant Feedstocks Genomics Research for Bioenergy

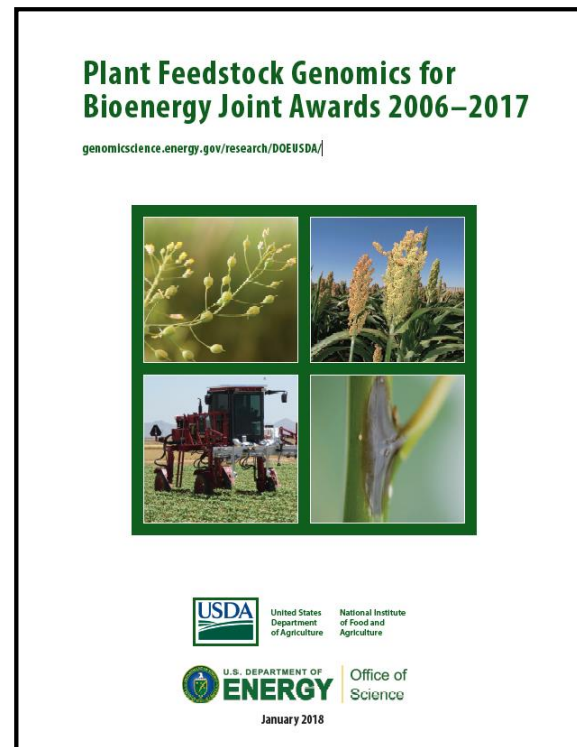
Research to overcome the biological barriers to the low-cost, high-quality, scalable and sustainable production of bioenergy feedstocks using the tools of genetics and genomics

- Twelve-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

Currently re-evaluating this effort with our USDA colleagues



BER Program Manager: Dr. Cathy Ronning



Latest Awards:

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

Biosystems Design

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

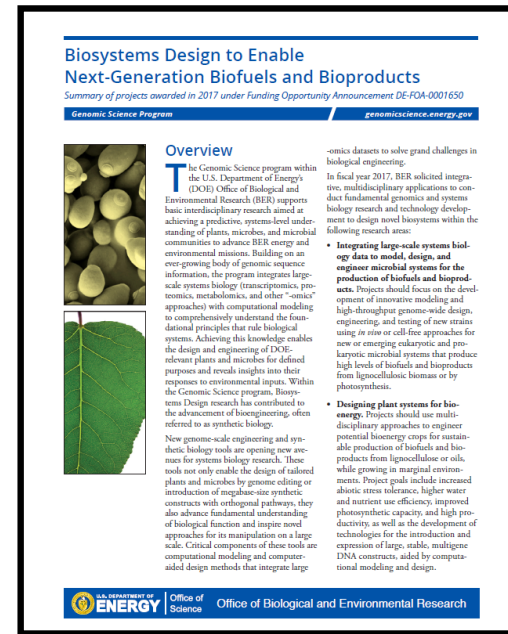
Microbial systems design for biofuels and bioproducts

- Integrated experimental and computational approaches to design 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
- New platform organisms for genome engineering and innovative high-throughput approaches for screening and testing strains

Plant systems design for bioenergy and bioproducts

- Systems-scale biology approaches to re-designing plants for increased photosynthesis capacity, yield, improved nutrient and water utilization, increased non-edible oil and bioproduct 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: Dr. Pablo Rabinowicz



Biosystems Design to Enable Next-Generation Biofuels and Bioproducts
Summary of projects awarded in 2017 under Funding Opportunity Announcement DE-FOA-0001650
Genomic Science Program | genomicscience.energy.gov

Overview
The Genomic Science program within the U.S. Department of Energy's (DOE) Office of Biological and Environmental Research (BER) supports basic interdisciplinary research aimed at achieving a predictive, systems-level understanding of plants, microbes, and microbial communities to advance BER energy and environmental missions. Building on an ever-growing body of genomic sequence information, the program integrates large-scale systems biology (transcriptomics, proteomics, metabolomics, and other "omics" approaches) with computational modeling to comprehensively understand the foundational principles that rule biological systems. Achieving this knowledge enables the design and engineering of DOE-relevant plants and microbes for defined purposes and reveals insights into their response to environmental inputs. Within the Genomic Science program, Biosystems Design research has contributed to the advancement of bioengineering, often referred to as synthetic biology.

New genome-scale engineering and synthetic biology tools are opening new avenues for systems biology research. These tools not only enable the design of tailored plants and microbes by genome editing or introduction of megabase-size synthetic constructs with orthogonal pathways, they also advance fundamental understanding of biological function and inspire novel approaches for its manipulation on a large scale. Critical components of these tools are computational modeling and computer-aided design methods that integrate large

omics datasets to solve grand challenges in biological engineering.

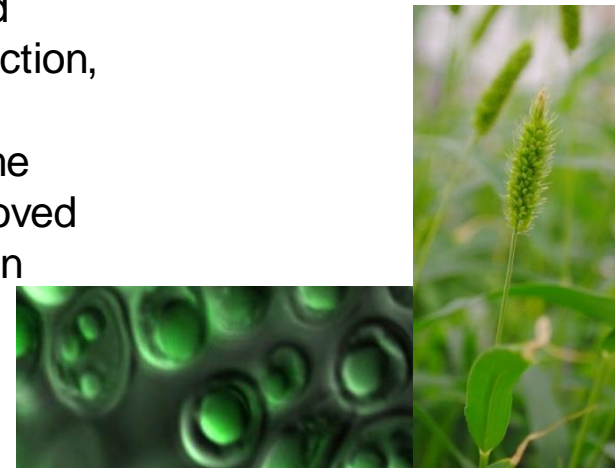
In fiscal year 2017, BER solicited integrative, multidisciplinary applications to conduct fundamental genomics and systems biology research and technology development to design novel biosystems within the following research areas:

- **Integrating large-scale systems biology data to model, design, and engineer microbial systems for the production of biofuels and bioproducts.** Projects should focus on the development of innovative modeling and high-throughput genome-wide design, engineering, and testing of new strains using *in vivo* or cell-free approaches for new or emerging eukaryotic and prokaryotic microbial systems that produce high levels of biofuels and bioproducts from lignocellulosic biomass or by photosynthesis.
- **Designing plant systems for bioenergy.** Projects should use multidisciplinary approaches to engineer potential bioenergy crops for sustainable production of biofuels and bioproducts from lignocellulose or oils, while growing in marginal environments. Project goals include increased abiotic stress tolerance, higher water and nutrient use efficiency, improved photosynthetic capacity, and high productivity, as well as the development of technologies for the introduction and expression of large, stable, multigene DNA constructs, aided by computational modeling and design.

Department of Energy | Office of Science | Office of Biological and Environmental Research

Latest Awards:

<https://genomicscience.energy.gov/biosystemsdesign/biosystemsdesign2017fundedprojects.pdf>

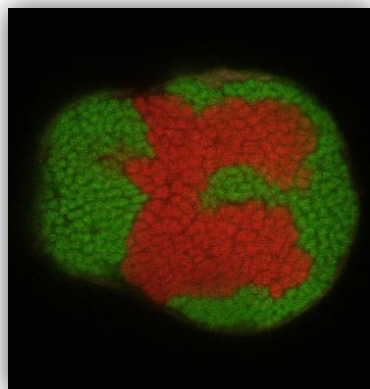


Environmental Microbiome Science

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.



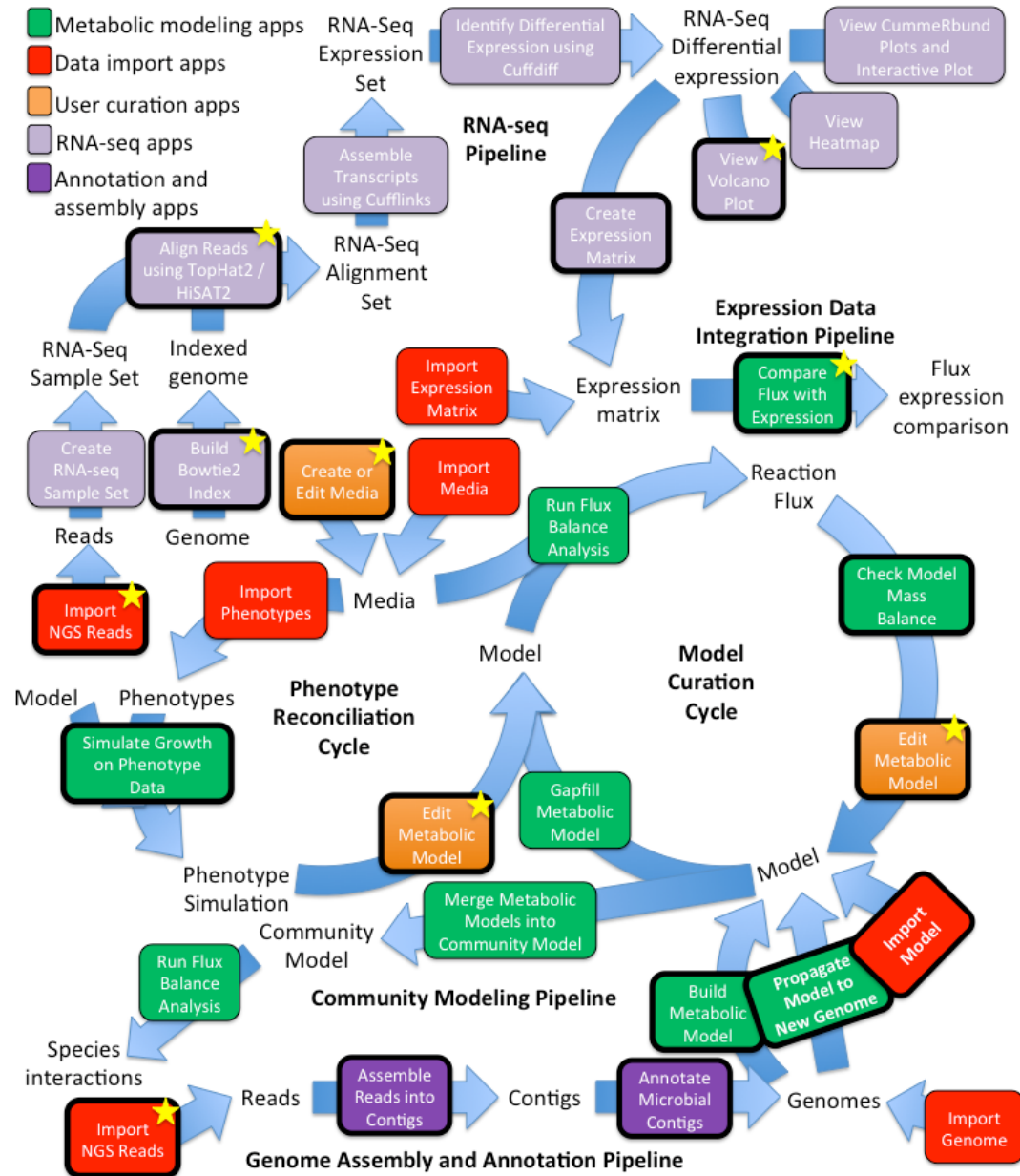
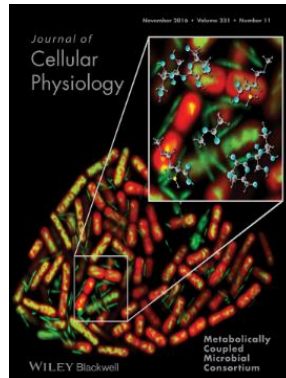
Program Manager: Dr. Cathy Ronning

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

Research highlights

- Modeled and predicted interactions between heterotrophic and autotrophic species in a simple community (Henry et al., *J. of Cellular Physiology*)
- Reconstructed 773 metabolic models of microbiome isolates (Magnúsdóttir et al., *Nature Biotech*)
- Constructed, compared and analyzed core metabolic models of over 8000 microbes (Edirisinghe et al., *BMC Genomics*)



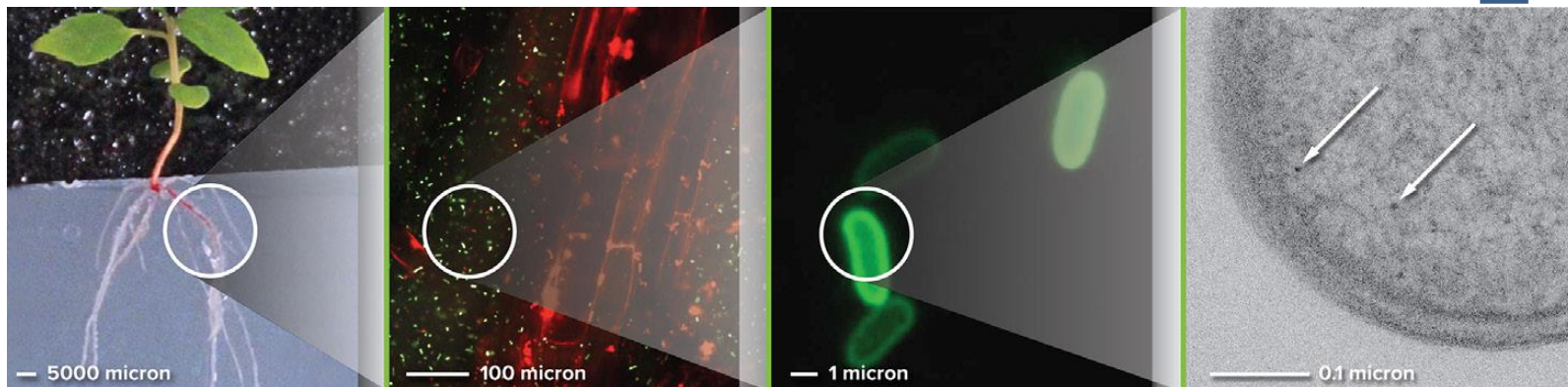
Program Manager : Dr. Ramana Madupu

Biomolecular Characterization and Imaging Science

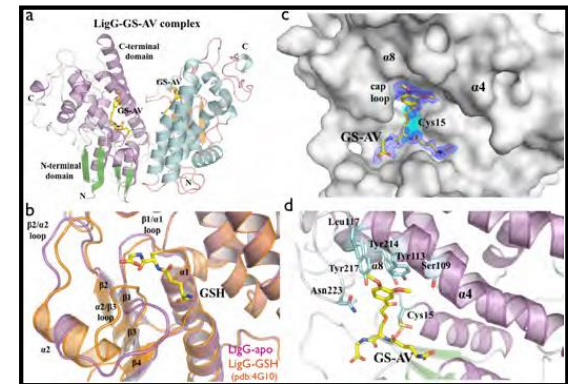
Develop the enabling computational, visualization and characterization capabilities to integrate genomic information with functional information on biological processes relevant to energy and environment.

- 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

Visualization across scales of observation



Characterization of energy-relevant biomolecules



BER Program Manager: Dr. Prem Srivastava

Biomolecular Characterization and Imaging Science



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

SSRL/SMB crystallography,
x-ray spectroscopy and
scattering

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



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



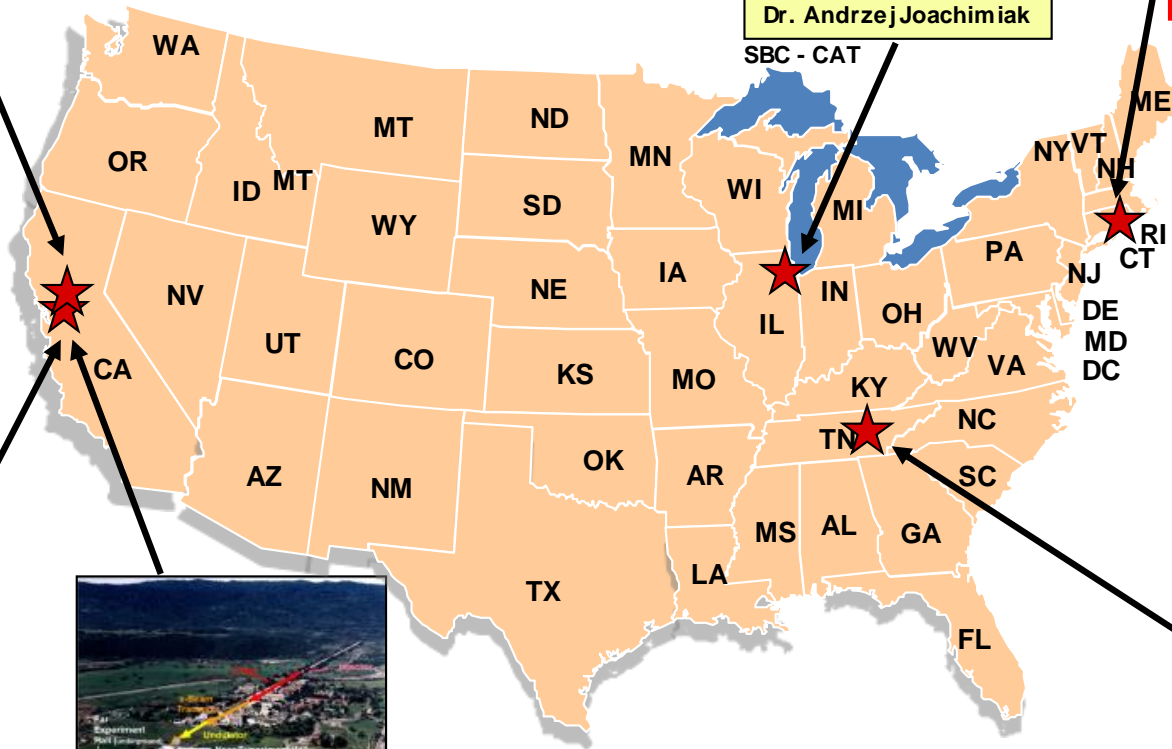
SLAC/Linear Coherent
Lightsource (LCLS)
Dr. Sebastien Boutet
Dr. Soichi Wakatsuki

LCLS XFEL MFX
femtosecond
crystallography, scattering



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

CSMB - BioSANS



***New:** Cryo-EM capabilities at SLAC, BNL

BER Program Manager : Dr. Amy Swain

DOE Joint Genome Institute



<http://jgi.doe.gov/>

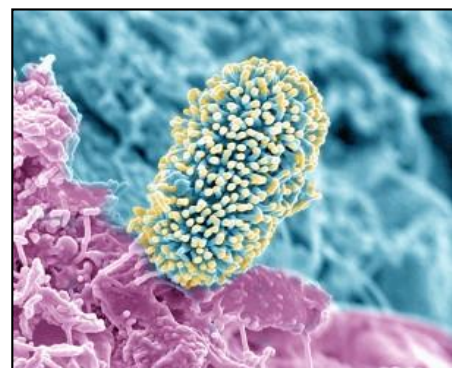
Community Science Program (CSP) Call

- 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

- Biofuels and Bioproducts
- Plant-Microbe Interactions
- Biogeochemistry
- Emerging Topics

FICUS (JGI-NERSC) Collaborative Science Initiative



Root associated microbe



Eucalyptus grandis



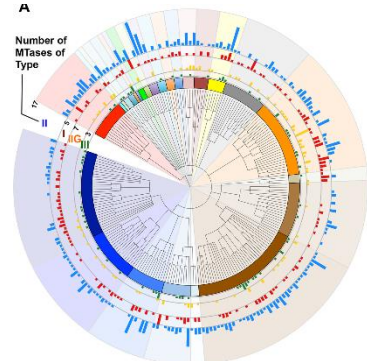
A. muscaria



Setaria viridis



Updated: Tree of Life



230 Sequenced Organisms: Epigenomics

BER Program Manager: Dr. Ramana Madupu

New Funding Opportunities Announcements for FY 2019

Genomic Science Program

- Plant Genomics Research
- Environmental Microbiome Science
- Computational Biosciences

FOAs will be posted to Grants.gov
“Department of Energy – Office of Science”

Biomolecular Characterization and Imaging Science

- Bioimaging Research

FOAs will be posted to Grants.gov
“Department of Energy – Office of Science”

Facilities & Infrastructure

- Calls for User Proposals at the Joint Genome Institute (JGI)

<https://jgi.doe.gov/user-program-info/community-science-program/how-to-propose-a-csp-project/>

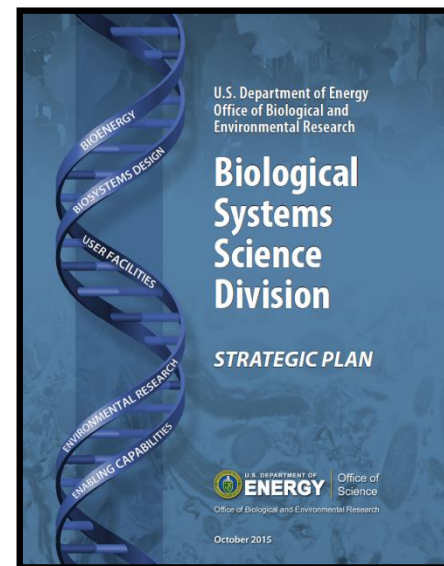
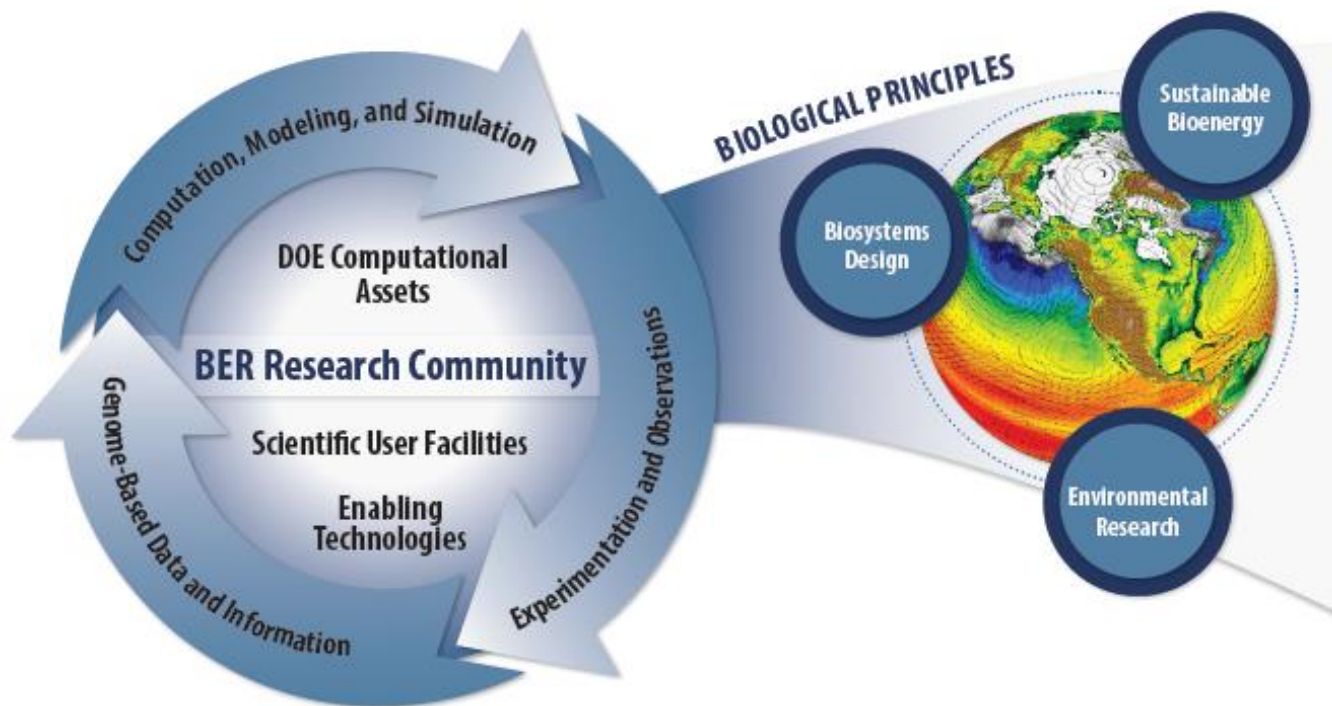
Calls for User Proposals

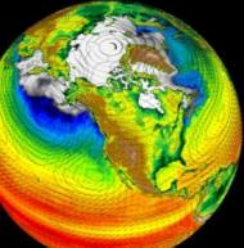
What kind of proposals can be submitted?

Proposal Call Type	Review Frequency	Next Submission Deadline	Next Review Date
CSP Annual	Annual	FY20 call to be released Spring 2019	Summer 2019
FICUS JGI-EMSL	Annual	FY20 call to be released Spring 2019	Summer 2019
FICUS JGI-NERSC-KBase	Annual	proposals due Sep 24, 2018	November 2018
CSP New Investigator	Twice yearly	proposals due Mar 1, 2019	May 2019
DNA Synthesis	Twice yearly	proposals due Jan 15, 2019	February 2019

Biological Systems Science Division

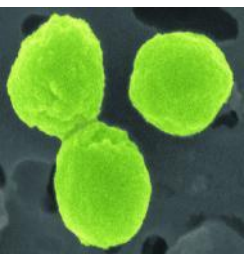
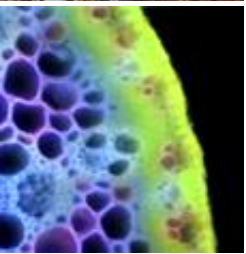
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Systems science to support DOE's energy, environment and basic research missions.

<http://science.energy.gov/ber>



Thank you!



<http://genomicscience.energy.gov>