

Office of Biological and Environmental Research

Bioenergy Systems Biology Research

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Office of Science

Science to Meet the Nation's Challenges Today and into the 21st Century

The Frontiers of Science

- Supporting research that led to over 100 Nobel Prizes during the past 6 decades—23 in the past decade alone
- Providing 45% of Federal support of basic research in the physical sciences and key components of the Nation's basic research in biology and computing
- Supporting over 27,000 Ph.D.s, students, engineers, and scientists at more than 300 institutions

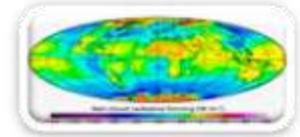
21st Century Tools of Science

- Providing the world's largest collection of scientific user facilities to over 26,000 users each year



Biological and Environmental Research (BER)

Foundational Science - integrating observations and experimental capabilities with modeling for predictive understanding



Explore frontiers of genome-enabled biology

- Sustainable bioenergy resources
- Function & organization of plant and microbial systems
- Mechanisms and regulation of carbon storage in plant biomass and microbial communities
- Biosystems design
- Systems biology via data integration and analysis within a systems biology knowledgebase

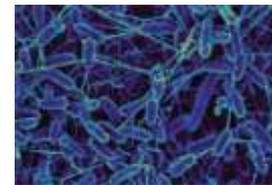
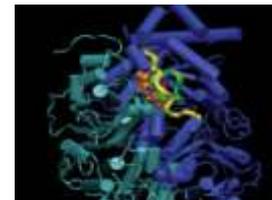
Understand the effects of greenhouse gas emissions on Earth's climate and biosphere

- World-leading capabilities in climate modeling
- Representation of clouds in climate models
- Direct/indirect effects of aerosols on climate
- Interactions of carbon cycle and climate
- Predictive understanding of terrestrial ecosystems, focus on sensitive systems, e.g., Arctic and tropics



Updates

- Bioenergy Research Centers
- Genomic Science Biodesign
- USDA-DOE Plant Feedstock Genomics for Bioenergy
- Joint Genome Institute
- Environmental Molecular Sciences Laboratory



DOE Bioenergy Research Centers

Focused, interdisciplinary, team-based transformational science with milestones:

BioEnergy Science Center (led by ORNL)

- Strategic focus on overcoming cellulosic biomass recalcitrance
- Consolidated bioprocessing

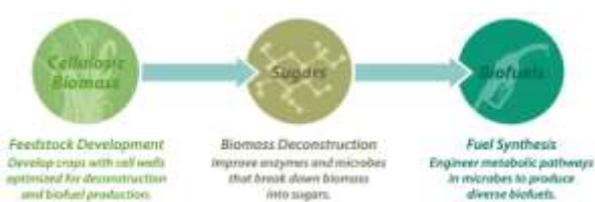
Great Lakes Bioenergy Research Center (led by U. WI, MSU)

- Re-engineering plants to produce more starches and oils
- Major research thrust on sustainability of biofuels

Joint BioEnergy Institute (led by LBNL)

- New pretreatment processes using room temperature ionic liquids
- Major research thrust on synthetic biology: re-engineering *E.coli* and yeast to produce hydrocarbons





Bioenergy Research Centers (BRCs)

Gaining a fundamental understanding of:

➤ Sustainable bioenergy crop production

- Sustainable bioenergy production from marginal lands in the US Midwest. Gelfand et al. *Nature* (2013), doi:10.1038/nature11811.

➤ Plant metabolism and techniques to decrease biomass recalcitrance

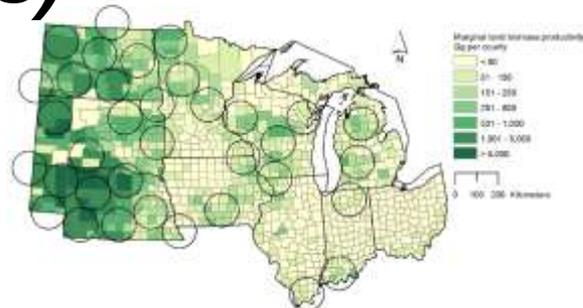
- An Arabidopsis cell wall proteoglycan consists of pectin and arabinoxylan covalently linked to an arabinogalactan protein,” Tan, et al., *Plant Cell* (2013) 25: 270-287

➤ Pretreatment methods to increase the efficiency of cellulose extraction

- How does nanoscale architecture correlate with enzymatic digestibility? Ding, et al. (2012). *Science* 338: 1055–1060.

➤ Modifications to microorganisms to combine conversion capabilities, tolerate biofuel production conditions and produce a range of biofuel compounds

- Transcription factor-based screens and synthetic selections for microbial small-molecule biosynthesis. Dietrich et al. 2012. *ACS Synthetic Biology* 2:47-58.



Over the past 5 years the BRCs have generated :

1100 journal articles,

286 Invention disclosures

146 patent applications



Industry Benefits from the Bioenergy Research Centers' Discoveries and Technologies

- All three BRCs have industry partners, collaborators, advisors, intellectual property and technology licensees, and spin-offs.
- BRCs have reached out to the bioenergy industry creating links for future commercialization.



Office of Biological and Environmental Research (BER)

Genomic Science Program

Genomic Science Program Objectives

- Determine the genomic properties, molecular and regulatory mechanisms, and resulting functional potential of microbes, plants, and biological communities central to DOE missions.
- Develop the experimental capabilities and enabling technologies needed to achieve a genome-based, dynamic system-level understanding of organism and community functions.
- Develop the knowledgebase, computational infrastructure, and modeling capabilities to advance the understanding, prediction, and manipulation of complex biological systems

FY 2014: Genomic Science for Bioenergy and the Environment (Fall 2013)
(Pending availability of funding)

<http://science.energy.gov/ber/research/bssd/genomic-science/>

Genomic Science: Biosystems Design to Enable Next-Generation Biofuels (DE-FOA-0000640)

Systems biology research applications focused on the design of new biological systems for bioenergy production.

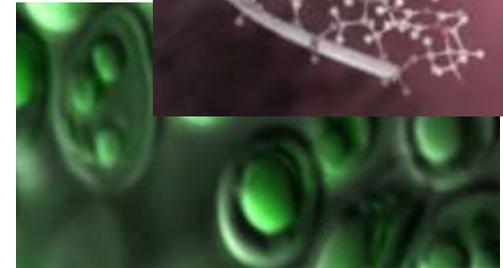
Eight awards made in FY 2012

Microbial systems design for biofuels

- ❖ Metabolic modeling and engineering an oleaginous yeast
- ❖ Next level of genome engineering in *E. coli*
- ❖ Genome-scale metabolic modeling and engineering in diatoms
- ❖ Engineer macroalgae-associated microbes

Plant systems design for bioenergy

- ❖ Modeling and engineering the shikimate and phenylpropanoid/phenylalanine pathways in *Arabidopsis*
- ❖ Engineering drought and planting density tolerance in the C4 model grass *Setaria viridis*
- ❖ Engineering CAM photosynthesis in poplar and *Arabidopsis*
- ❖ Engineering double haploid switchgrass and *Brachypodium sylvaticum* for improved drought tolerance and nutrient use efficiency.



USDA-DOE

Plant Feedstock Genomics for Bioenergy

A joint competitive grants program initiated in 2006 (DOE-BER and USDA-NIFA)

Genomics-based research leading to improved use of biomass and plant feedstocks for the production of fuels such as ethanol or renewable chemical feedstocks:

- Improve biomass characteristics, biomass yield, or sustainability;
- Systems biology approaches enabling efficient manipulation and breeding;
- Prediction of phenotype from genotype that could lead to improved feedstock characterization and sustainability.

FY2014 Solicitation pending availability of funding

Plant Feedstocks Genomics for Bioenergy (DE-FOA-0000598)



Nine Total Awards in FY 2012

- ❖ Functional understanding of genes affecting biomass yield and quality in poplar
- ❖ Abiotic stress gene networks between lowland and upland ecotypes of switchgrass
- ❖ Poplar interactome
- ❖ Genetics of Panicum grasses: developing a model system with diploid *Panicum hallii*
- ❖ **Genomics of bioenergy grass architecture [sorghum]**
- ❖ Understanding natural allelic variation in Switchgrass
- ❖ **Genetic architecture of sorghum biomass yield component traits identified**
- ❖ Genomic analysis of high-yielding triploid hybrids of willow (*Salix* spp.)
- ❖ Tubulin manipulation on *Populus* wood formation and drought tolerance



United States Department of Agriculture
National Institute of Food and Agriculture

USDA funded projects in red font

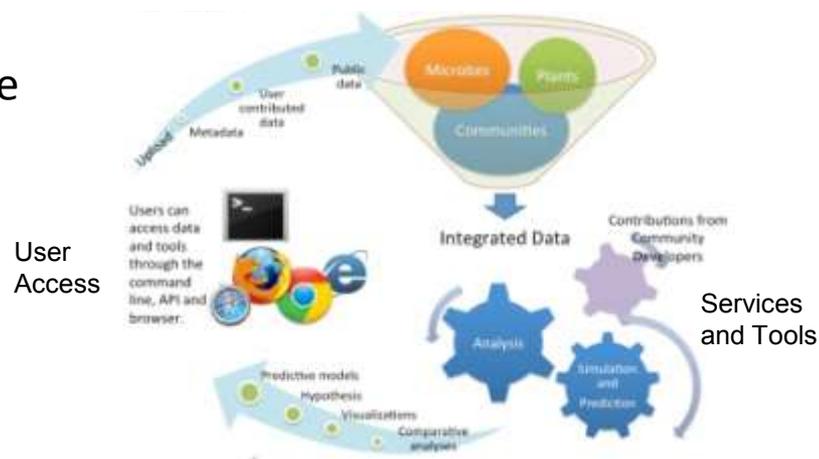


Accelerating Systems Biology Research with the Systems Biology Knowledgebase (Kbase)

Solving grand challenges in biology for energy and the environment by allowing easy access, manipulation, analysis and sharing of large scale “omics” data in new ways:

- Rapidly constructing metabolic models from genome data and integrating it with phenotypic data to accelerate microbial gene annotation studies.
- Integrating biogeochemical data with metagenomic analyses to analyze microbial community function related to C and N cycling in real environmental samples.
- Comparing hundreds of poplar genomes in a population to understand gene variation and identify beneficial bioenergy traits.
- Systems biology data, models, and information integrated for over 5870 unique genomes.
- Over 8000 researchers will have access to Kbase

- *“Takes the known biology away from the analysis (ie: known biochemistry) so the scientist can focus on new biology”*
- *“Prior to using KBase, extensive effort was expended in manual analysis (1 year of effort). The KBase workflow and analysis described here was done in 2 weeks.”*
- *“Accelerated my metagenomics research and provided a clear set of flexible tools that I can use in conjunction with my collaborators.”*



<http://www.kbase.us/>





DOE Systems Biology Knowledgebase (KBase)

An open-source and open-architecture computational environment for integrating large, diverse datasets, generated by the Genomic Sciences program and other sources, and using this information to advance predictive understanding, manipulation, and design of biological systems.

5534 unique prokaryotic, 161 archaeal, and 175 eukaryotic genomes currently included.

The Department of Energy Systems Biology Knowledgebase (KBase) is an emerging software and data environment designed to enable researchers to collaboratively generate, test and share new hypotheses about gene and protein functions, perform large-scale analyses on a scalable computing infrastructure, and model interactions in microbes, plants, and their communities. KBase provides an open, extensible framework for secure sharing of data, tools, and scientific conclusions in predictive and systems biology.

Try KBase Now
Use a web-based command-line interface—no installation necessary

Download the Tools
Install KBase command-line tools on your computer

Visit KBase Labs
Sneak a peek at KBase applications in development

KBase includes

- 925 data types
- 5695 prokaryotic genomes
- 175 eukaryotic genomes
- 4985 models
- 23 services
- 821 functions

What can KBase do?

- Efficiently annotate new microbial genomes and infer metabolic and regulatory networks.
- Transform network inferences into metabolic models and map missing reactions to genes using novel data reconciliation tools.
- Test microbial ecological hypotheses through taxonomic and functional analysis of quality-assessed metagenomic data
- Discover genetic variations within plant populations and map these to complex organismal traits

Search the database:

Learn about KBase's plans for richer user interfaces

Latest News

- KBase workshop at the 2013 Annual Great Lakes Bioenergy Research Center (GLBRC) Retreat
Posted by nfharris Jun 03, 2013 under News
- KBase at ASM 2013
Posted by nfharris May 28, 2013
- Poster and flash talk at the Genomic Standards Consortium's "Standards-enabled Research in Genomics" meeting
Posted by nfharris May 18, 2013

[View news](#)

Upcoming Events

- 2013-06-22
KBase Workshop @ FGED
- 2013-06-28
KBase webinar - Variation Service
- 2013-07-07
The Chris Henry @ Plant Metabolic Engineering Gordon Research Conference
- 2013-07-12
KBase webinar on matR (metagenome analysis)

[View calendar](#)

Rolled out in February 2013

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

Joint Genome Institute (JGI): A DOE BER USER FACILITY

- Using high throughput tools, technologies and comparative analysis, the JGI serves as a discovery platform to understand the organization and function of complex genomes for bioenergy, carbon cycle, and bioremediation.
- Genome and metagenome expression and sequencing of microbes, plants, and other complex systems, such as microbial communities or the rhizosphere.
- Genome annotation, functional analysis and verification of genome-scale biological system models. Systems-level integration and validation of genomic data from multiple sequencing and functional analyses.
- Sequencing more than 60 Terabases per year– > 2,600 projects in 2012
- Community Sequencing Program (CSP)
 - Plant genome / microbiome sequencing
 - Microbial Communities/Metagenomics sequencing
 - Gene Synthesis
- Emerging Technologies Opportunity

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



DOE Joint Genome Institute
Enabling Advances in Bioenergy & Environmental Research



Environmental Molecular Sciences Laboratory: DOE User Facility

EMSL's suite of over sixty state-of-the-art instruments enables molecular-scale experimental and theoretical research on aerosol chemistry, biological systems, geochemistry/biogeochemistry, and interfacial and surface science.

Core experimental capabilities include:

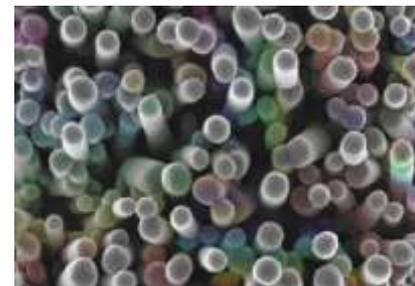
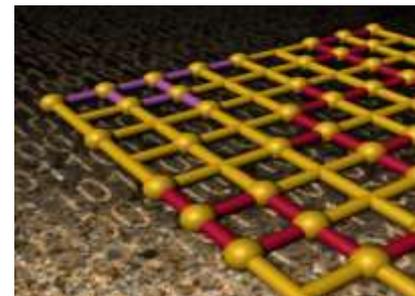
- Proteomics capabilities
- Microscopy, Deposition and Microfabrication
- NMR, EPR, Mass Spectrometry, Spectroscopy and Diffraction
- Cell Isolation and Systems Analysis
- Molecular Science Computing
- Quiet Wing for ultrasensitive microscopy instruments opened in 2012
- Radiochemistry Annex for the study of contaminated environmental materials, radionuclides and chemical signatures opens in 2013
- Over 760 users from academia, labs, and industry and over 400 peer-reviewed publications in FY 2012; over 170 patents to date.

2013 Users' Meeting August 6-7, Richland, WA

"Plants, Microbes and their Interactions"

http://www.emsl.pnl.gov/root/meetings/user_meeting2013/

<http://www.emsl.pnl.gov/emslweb/>



Joint Call for Exploratory Collaborations

➤ **First-ever call between EMSL and DOE-JGI**

➤ **Focused on plant, fungal, soil and microbial interactions and physiology related to**

- *Biofuel production*
- *Carbon cycling*

➤ **Must require capabilities from both facilities**

➤ **Schedule:**

- *Letters of Intent due February 11 – April 8*
- *Invited full proposals due May 27*
- *Approved proposals start October 1, 2013*
- *Details: <http://www.emsl.pnnl.gov/access/calls/jgi/>.*

A Call to Action

Deadline: April 8, 2013

We are now accepting letters of intent for Community Sequencing Program (CSP) large-scale sequence-based genomic projects relevant to alternative fuels, global carbon cycling, and biogeochemistry, emphasizing:

- Plant Flagship Genomes
- Microbes and microbial communities
- Collaborations with EMSL
- DNA Synthesis



How to get involved with DOE programs:

- Look for funding opportunity announcements (FOA's) on our web site <http://science.energy.gov/ber/funding-opportunities/>
- Contact a DOE scientific program manager in your area of interest
- Look for opportunities to interact with the DOE National Laboratories
- Take advantage of a DOE Scientific User Facility
- Volunteer to serve as a reviewer for a DOE peer review panel
- Participate in a DOE research needs workshop

Biological and Environmental Research information resources

•Program information

•<http://science.energy.gov/ber/>

•<http://genomicscience.energy.gov/program/aboutBER.shtml>

•Workshops: provide community input and signal new research directions

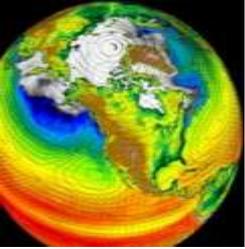
•http://www.sc.doe.gov/ober/BER_workshops.html

•Research abstracts

•<http://www.osti.gov/oberabstracts/search.adv.jsp>

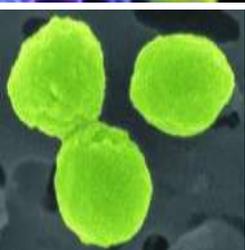
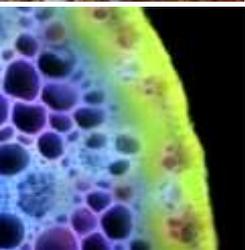
•Funding Opportunity Announcements

•<http://science.doe.gov/grants/announcements.asp>



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

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



Thank you!

