



DOE Programs in Support of Sorghum and Related Plant Biology Research

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**U.S. Department of Energy
Office of Science**

Office of Biological and Environmental Research

International Conference on Sorghum for Biofuel

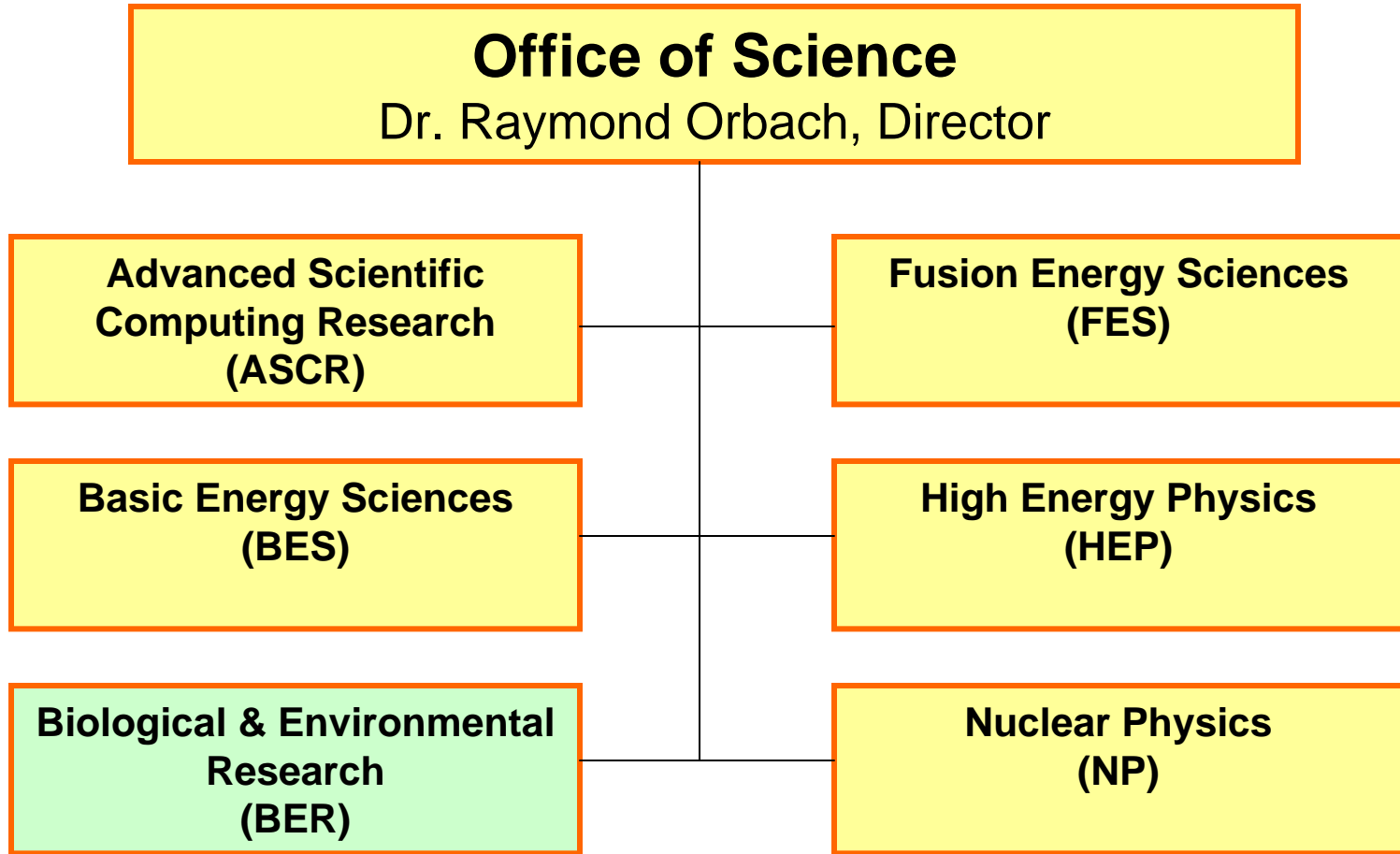
Houston, Texas

August 19, 2008





DOE Office of Science





Mission-Inspired Science

BER advances world-class biological and environmental research programs and scientific user facilities to support DOE's energy, environment, and basic research missions.

- **Develop biofuels as a major secure national energy resource.**
- **Understand relationships between climate change and Earth's ecosystems, and assess options for carbon sequestration.**
- **Predict fate and transport of subsurface contaminants at DOE sites.**
- **Develop new tools to explore the interface of biological and physical sciences**



Mission Challenges for Biological Systems Science



Cleanup

Understand microbial and plant impacts on subsurface contaminant fate to

- Develop better assessment tools.
- Design improved bioremediation methodologies.

Biofuels

Gain knowledge and tools for using microbes and plants to build a national biofuel capability to

- Develop sustainable energy crops.
- Develop biotechnologies for producing advanced biofuels

Climate Stabilization

Determine ocean and terrestrial ecosystems' contributions to the global carbon cycle to

- Improve projections of climate change and its impacts.
- Create carbon-biosequestration strategies.



DOE BER Research Programs Supporting Plant Sciences

- I. DOE Joint Genome Institute**
- II. GenomicsGTL**
- III. Joint USDA-DOE Plant Feedstock
Genomics for Bioenergy**
- IV. DOE Bioenergy Research Centers**



The Joint Genome Institute

A DOE User Facility

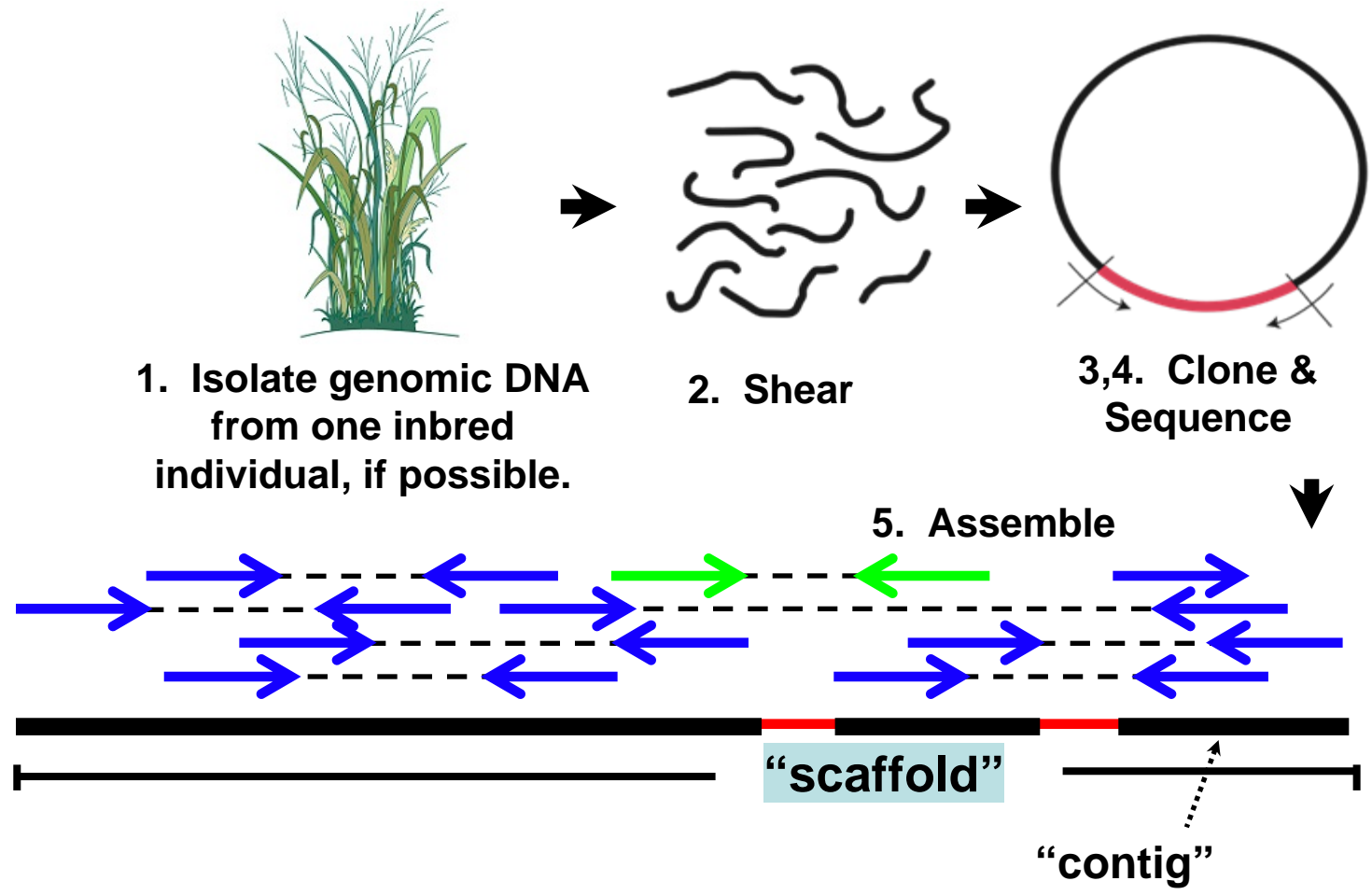
- **Sequence and analyze the genomes and metagenomes of a mission relevant organisms and communities**
 - Whole biological systems understanding required for biological applications to DOE missions of critical national needs
 - State of the art capabilities, expert staff in an array of computing and biological research disciplines, workshops, and annotation jamborees



High throughput sequencing line at DOE-JGI in Walnut Creek, CA

Sequencing more than 40 billion base pairs of DNA per year!

Whole genome shotgun sequencing strategy





The DOE Joint Genome Institute



Community Sequencing Program

provides the scientific community with access to high-throughput sequencing for projects of relevance to DOE missions.

- Whole-genome sequencing - small genomes
- Pilot-scale sequencing - large genomes
- Targeted sequencing projects
- Comparative resequencing projects
- Selected by peer review -- scientific merit and mission relevance
- Next deadline November 2008



<http://www.jgi.doe.gov/CSP/index.html>



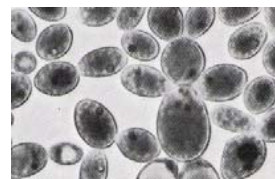
JGI and Bioenergy

Improved Feedstocks



Cellulosic Materials

- Poplar
- Maize/Corn Stover
- Switchgrass
- Brachypodium
- Sorghum



- Ethanol producing organisms**
- *Saccharomyces cerevisiae*
 - *Zymomonas mobilis*
 - *Thermoanaerobacter ethanolicus*
 - *Pichia stipitis*

Ethanol producing organisms



Saccharification

Sugars

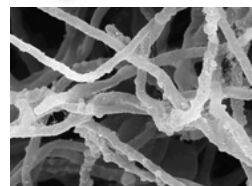
Fermentation



Improved cellulose & lignin degradation



- Termite hindgut microbiota
- White Rot Fungus
- *Clostridium thermocellum*
- *Saccharophagus degradans*
- *Acidothermus cellulolyticus*



Sorghum bicolor genome

- Demonstrates "C4" photosynthesis, resulting in more efficient carbon assimilation at high temperatures
- High water use efficiency is desirable for establishment of perennial biofuel crop growth on marginal land
- Reference genome for the study of other biofuel feedstocks and genetically-related grasses, such as maize, sugarcane and miscanthus.



Sorghum bicolor genome

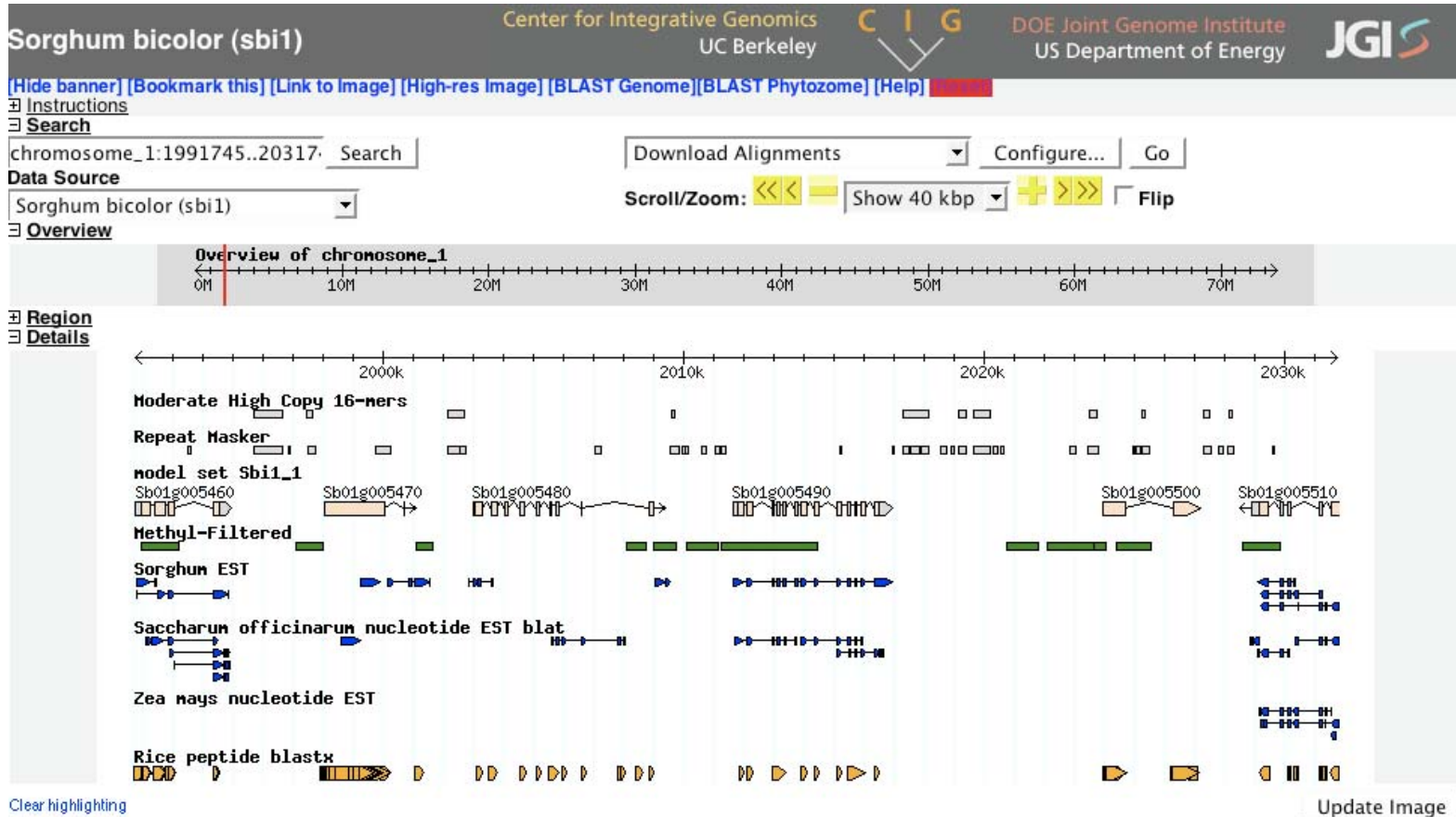
- Largest plant genome sequenced by whole genome shotgun to date
- 700-750 Mb 8X draft genome completed and posted in 2007
- Completeness >98%
- 10 chromosomes ($2n=20$) containing ~30,000 protein-coding genes
- Manuscript submitted for review



CSP project participants: Andrew Paterson (proposer), John Bowers, and Alan Gingle (U of Georgia); Thomas Hash (ICRISAT); Steve Kresovich (Cornell); Jo Messing (Rutgers); Dan Peterson (Mississippi St); and Dan Rokhsar (JGI)

Sorghum bicolor genome

- Integrate with pre-existing physical and genetic maps to reconstruct complete chromosomes with relatively minor gaps

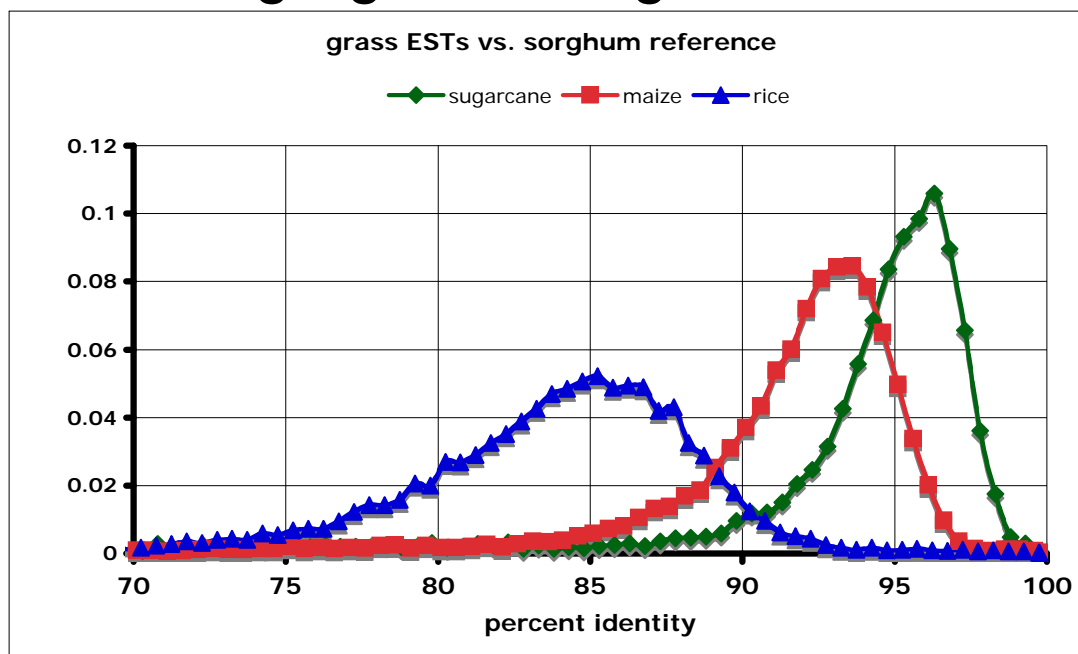


www.phytozome.net/sorghum

D. Goodstein, S. Shu, T. Mitros (JGI, UCB)

Sorghum bicolor genome-- a reference for other biofuel species

Applying new technologies to
large-genomed grasses





Genomics: GTL Goals



- **Achieve a predictive, systems-level understanding of plants, microbes, and biological communities**
- **Facilitate integration of fundamental science and technology development**
- **Enable biological solutions to DOE mission challenges in energy, environment, and climate**





Genomics: GTL Objectives

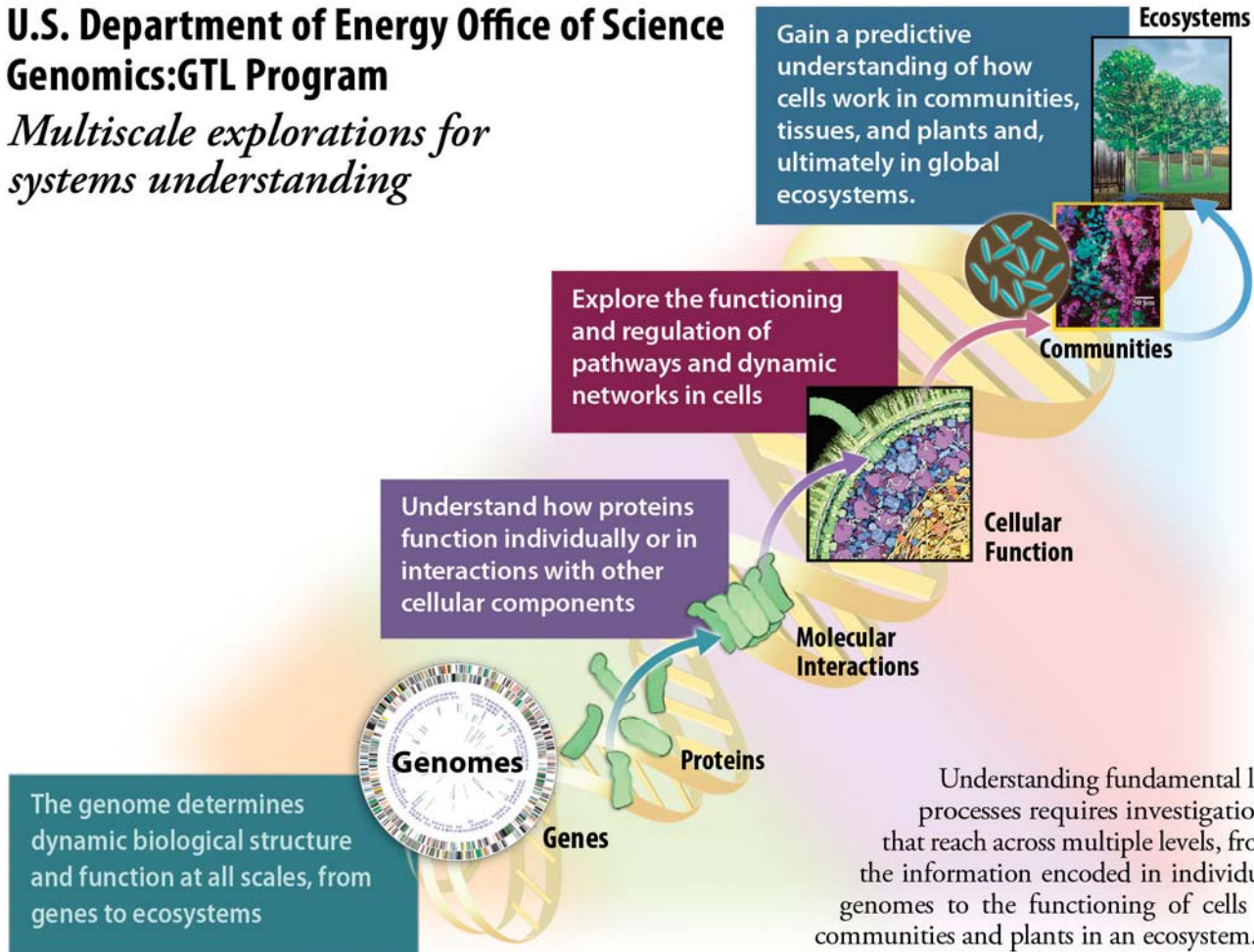


- Determine the **genomic properties**, molecular and **regulatory mechanisms**, and resulting functional potential of microbes, plants, and biological communities.
- Develop the **experimental capabilities** and **enabling technologies** needed to achieve a genome-based, dynamic systems-level understanding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

Genomics:GTL Concept

**U.S. Department of Energy Office of Science
Genomics:GTL Program**

*Multiscale explorations for
systems understanding*



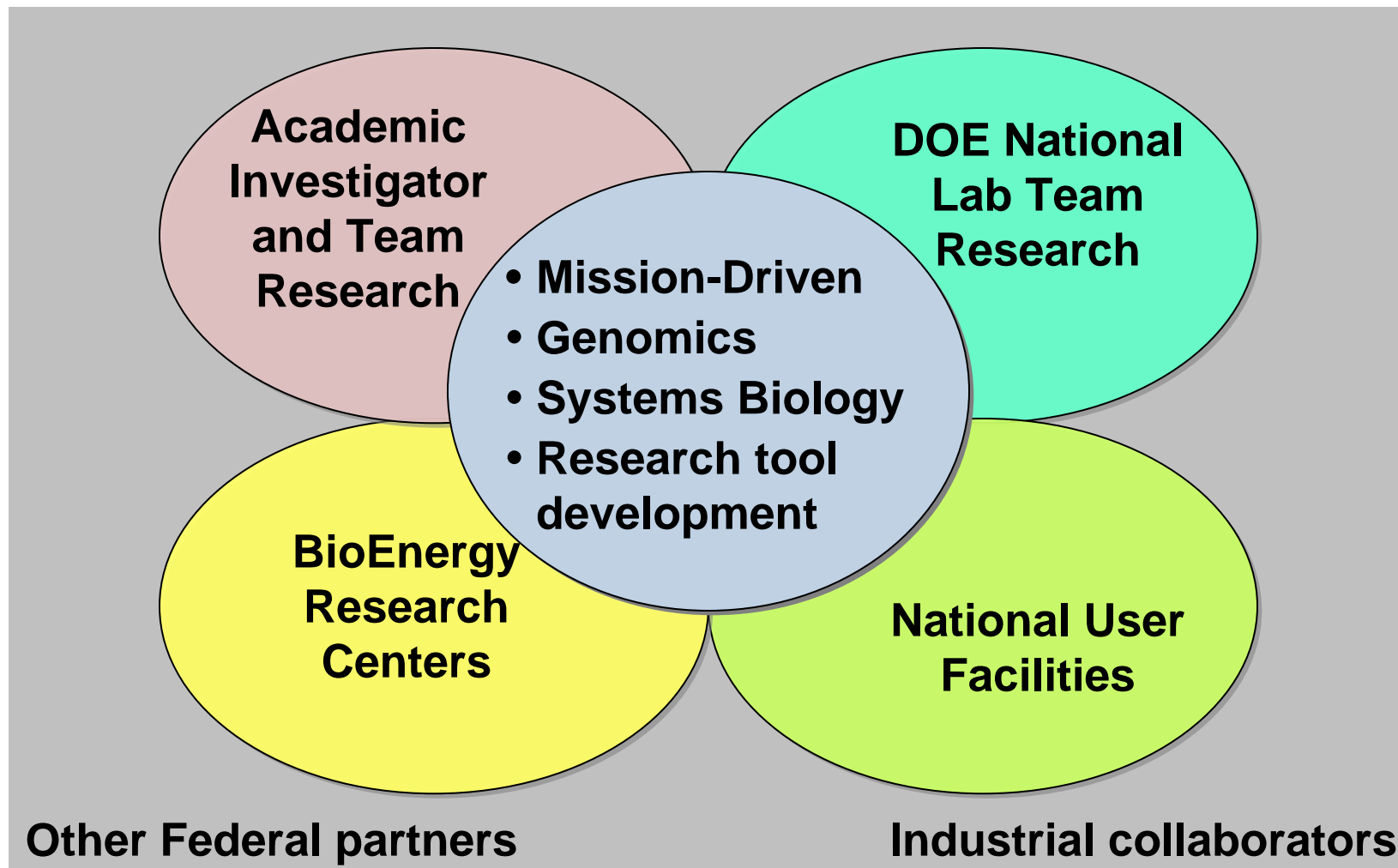


Genomics:GTL

Science at Scales

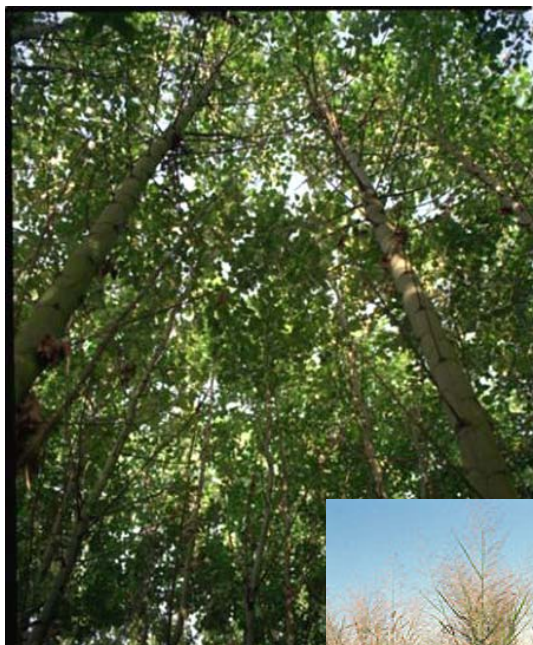
- ***Molecular:*** Focusing on genes, proteins, multicomponent protein complexes, and other biomolecules that provide structure and perform the cell's functions
- ***Whole cell:*** Investigating how dynamic molecular processes, networks, and subsystems are controlled and coordinated to enable such complex cellular processes as growth and metabolism in cells.
- ***Microbial community and higher organisms:*** Exploring how diverse cellular systems interact to carry out coordinated complex processes and both respond to and alter their environments – how cells work in communities, tissues, and plants, and ultimately in global ecosystems.

The GTL Research Enterprise





Plant Feedstock Genomics for Bioenergy



- DOE/USDA Joint Research Program
- Supports research on plants for improvement of:
 - Biomass Characteristics
 - Biomass Yield
 - Degradability of Lignocellulose

<http://genomicsgtl.energy.gov/research/DOEUSDA/index.shtml>

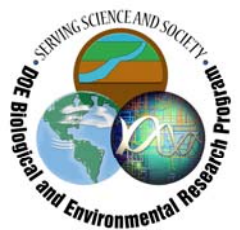
Plant Feedstock Genomics

Development of Brown Midrib Sweet Sorghum as a Dual-Source Feedstock for Ethanol Production

Wilfred Vermerris, University of Florida

- Maximize the amount of fermentable sugar in the whole sorghum plant
 - Identify and isolate genes that control the high stalk juice sugar trait and a decreased stalk lignin trait
 - Eventually combine both traits in a single germplasm
- Cloning of brown midrib (*bmr*) genes is underway
- Sorghum *bmr* material requires less pretreatment for conversion to biofuel





Plant Feedstock Genomics

Sorghum Biomass/Feedstock Genomics Research for Bioenergy

Bill Rooney, Texas A&M University

Develop bioinformatic and genome annotation resources for the study of sorghum as a bioenergy crop

SorghumCyc

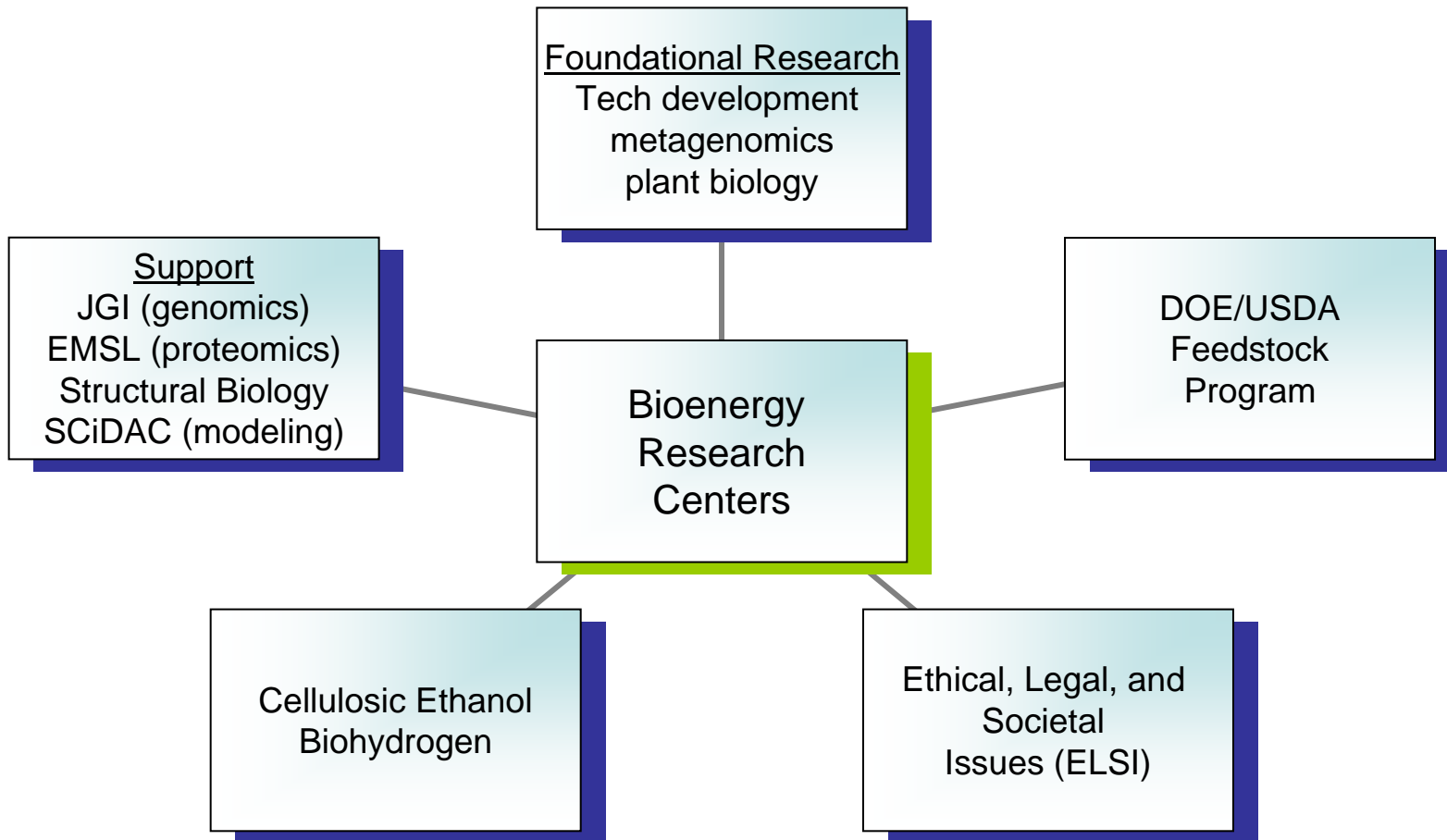
Pathway Database	SorghumCyc ver 1.0 beta Organism: <i>Sorghum bicolor</i> (rice) Genome data: <i>S. bicolor</i> strain/cv. BTx623
Search	SorghumCyc
Browse	Pathways Enzyme function Compounds Genes
Database Summary	View
Cellular Overview	View (It may take 1-2 min to generate this view)
Pathway Tools Omics Viewer	Upload the data sets on gene expression, metabolomics, proteomics experiments to overlay and overview the profile in realtime. (It may take more than 3-4 min to generate this view)
Get SorghumCyc	Download a free copy of the SorghumCyc database in BioCyc format for your local use. In order to run a local copy of SorghumCyc you need to get a licensed copy of the Pathway Tools developed by the SRI International.
Developed and curated by	Gramene database and the Sorghum Biomass/Feedstock project
Modifications	None available.

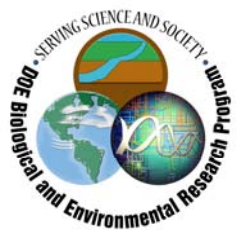
<http://genomicsgtl.energy.gov/research/DOEUSDA/index.shtml>



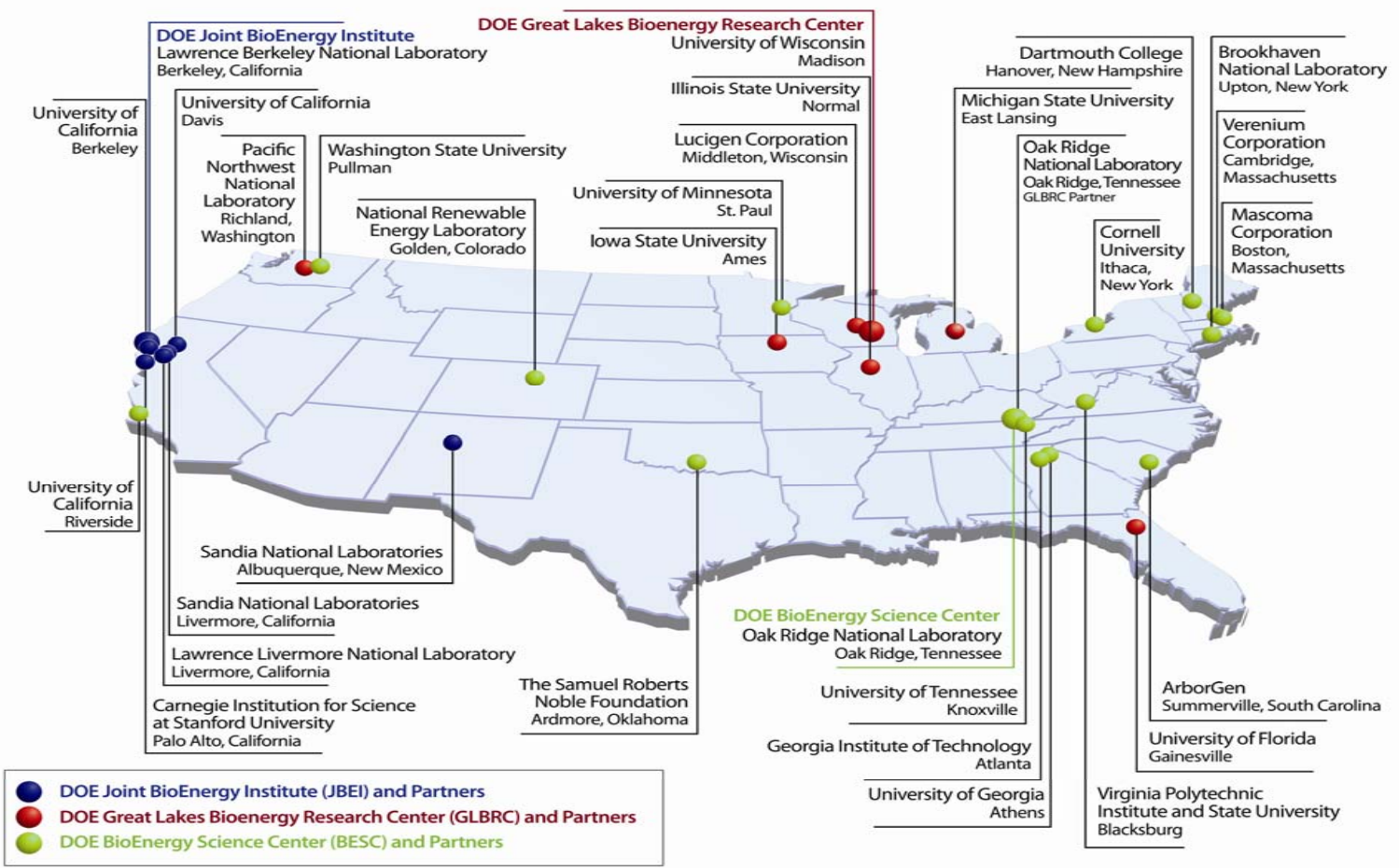


DOE Bioenergy Research Centers Integration and Coordination





DOE Bioenergy Research Centers: Multi-Institutional Partnerships





DOE Bioenergy Research Centers Priorities for Biofuels



- Concerns about impact of corn ethanol on **food supply and prices** and **lifecycle greenhouse gas emissions** makes development of **cellulosic biofuels** from **inedible feedstocks** more urgent
- Close attention to and research on **sustainability** will be essential to gain the benefits of next-generation cellulosic biofuels and to winning public acceptance
- The possibility of moving **beyond ethanol** and producing **hydrocarbon fuels** (green gasoline, diesel, and even jet fuel) from plant lignocellulose looks more promising
- The fundamental research pursued at the BRCs will have implications and benefits that extend well beyond the biofuels area





Thank you for your attention!

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