Genomics: GTL Research and Bioenergy Research Centers

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Biomass R&D Technical Advisory Committee Meeting

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Advanced Scientific Computing Research (ASCR)
Basic Energy Sciences (BES)
Biological & Environmental Research (BER)
Fusion Energy Sciences (FES)
High Energy Physics (HEP)
Nuclear Physics (NP)
We can find biotechnology solutions using the natural diversity of microbes and microbial communities.

Thalassiosira pseudonana

Microbulbifer 2-40

Methanococcus jannaschii

Ocean carbon pumping

Biomass conversion

Methane production

Rhodopseudomonas palustris

Deinococcus radiodurans

Hydrogen production / Carbon sequestration

Radiation resistance - bioremediation
Genomics: GTL

A systems biology focused program supporting fundamental research on plants, microbes, and biological communities.

Mission Science Goals

- Develop biological solutions for intractable environmental problems
- Understand relationships between climate change and earth’s microbial systems
- **Support development of biofuels as a major secure energy source**

http://genomicsgtl.energy.gov
Genomics: GTL – A Systems Biology Research Program

From Molecules to Cells to Ecosystems

Subcellular

Identification, subcellular location, and dynamics of molecular machines

Cellular

Regulation of gene expression in individual cells

Ecosystems

Who is expressing what, when, where, and under what conditions? How do they work together?
In 10-15 years we would like to be able to start with a microbe or microbial community of interest and in a matter of days or weeks:

- Generate an annotated DNA sequence
- Produce proteins and molecular tags for most/all proteins
- Identify the majority of multi protein complexes
- Generate a working regulatory network model
- Identify the biochemical capabilities
- Design reengineering or control strategies in silico
A joint SC / EERE workshop
Steps in cellulosic ethanol production

From: Breaking the Biological Barriers to Cellulosic Ethanol
Science can improve the process

From: Breaking the Biological Barriers to Cellulosic Ethanol
Funding: $375 million to be provided over five years to establish and operate three new Bioenergy Research Centers (under review)

Goals: transformational discoveries in basic science to make production of cellulosic ethanol, sunlight-to-fuels, and other biofuels truly cost-effective and economically viable

Method: advanced systems biology research on microbes and plants - to learn to exploit nature's own conversion methods, plus develop a new generation of optimized bioenergy crops

- Understand metabolic pathways in microbial bioconversion processes
- Analyze plant cell wall structure and assembly
- Fine-tune microorganisms and plants to each other
- Pursue both microbial and bio-mimetic conversion methods
• DOE user facility for mission relevant genome sequencing

• 154 finished Prokaryote genomes, 25 finished Eukaryote genomes (many in progress):
  – Poplar, switchgrass, soybean, brachypodium, white rot fungus, termite hindgut microbes

• 3.6 billion bases per month

http://www.jgi.doe.gov
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

Improved cellulose & lignin degradation
- Termite hindgut microbiota
- White Rot Fungus
- Clostridium thermocellum
- Saccharophagus degradans
- Acidothermus cellulolyticus

Saccharification → Sugars → Fermentation
New Cellulase Genes from Termite Gut

15 Endoglucanases

12 Exoglucanases

22 β-glucosidase

Cellulose

Celllobiose

Glc

Glc

Glc-1-P

H₂O

P
Natural forms of cellulase machines are too inefficient for commercial ethanol production.

Fundamental knowledge of plant and microbial processes gained in GTL can be applied to develop more efficient methods.

Research objectives include: altering cellulose structure, identifying new sources of cellulases, understanding cellulosome structure and function, structural studies, directed evolution studies, enzyme mixture studies.
90-day-old *Populus* cuttings

**Enhanced radial growth of IAA16.3 transgenic trees**

- **transgenic**
- **control**

<table>
<thead>
<tr>
<th>Stem cross sectional area (cm)</th>
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<tr>
<td>transgenic: 7.1</td>
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<td>control: 4.4</td>
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Plant Feedstock Genomics for Bioenergy

- DOE/USDA Joint Research Program

- Supports research on plants for improvement of:
  - Biomass Characteristics
  - Biomass Yield
  - Degradability of Lignocellulose

- Need for broader USDA role, e.g., agronomics

http://genomicsgtl.energy.gov/research/DOEUSDA/index.shtml
Other FY07 Genomics: GTL Solicitations

- New Analytical and Imaging Technologies for Lignocellulosic Material Degradation, and for Multiplexed Screening for Plant Phenotypes

- Quantitative Microbial Biochemistry and Metabolic Engineering for Biological Hydrogen Production

- New Genomic Strategies and Technologies for Studying Complex Microbial Communities and Validating Genomic Annotations

- Ethical, Legal, and Societal Implications (ELSI) of Research on Alternative Bioenergy Technologies, Synthetic Genomics, or Nanotechnologies
EERE is a principal customer

- Identify and exploit opportunities for coordination and collaboration
- Help inform research and funding decisions
- Overcome traditional barriers between fundamental and applied research