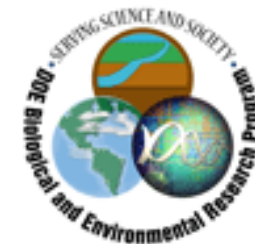




Office of Science
U.S. Department of Energy



Genomics: GTL Research and Bioenergy Research Centers

May 16, 2007

Biomass R&D Technical Advisory Committee Meeting

David Thomassen, Ph.D.

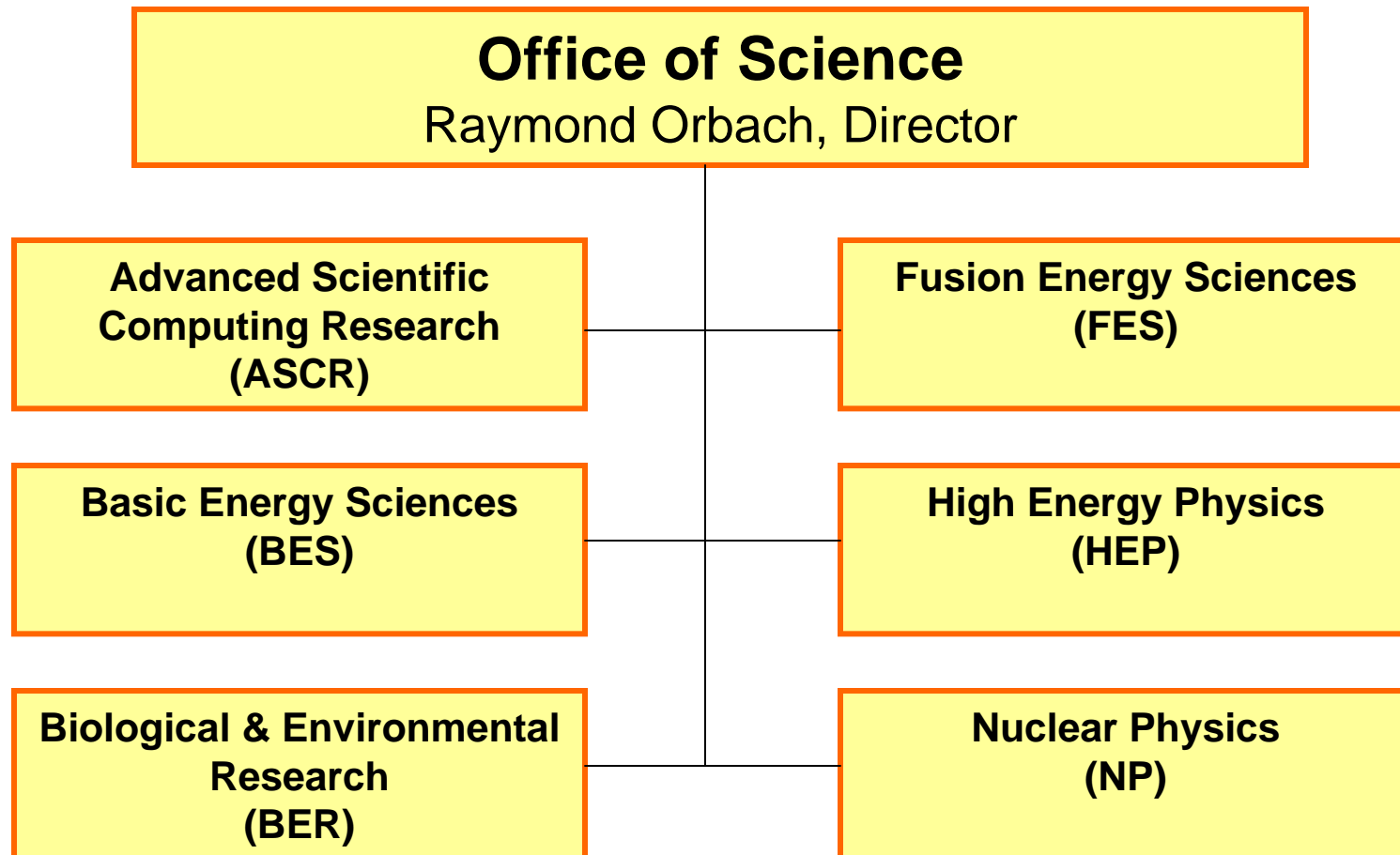
Chief Scientist

Office of Biological and Environmental Research

DOE Office of Science



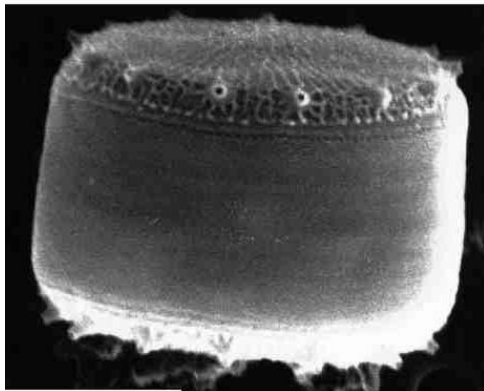
Office of Science





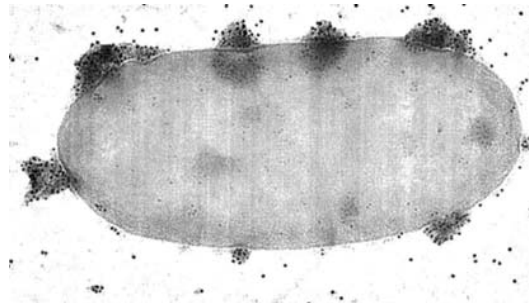
We can find biotechnology solutions using the natural diversity of microbes and microbial communities

Thalassiosira pseudonana



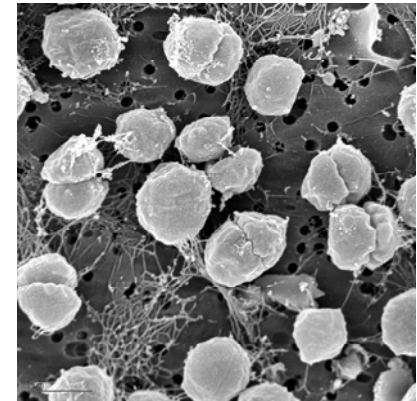
Ocean carbon pumping

Microbulbifer 2-40



Biomass conversion

Methanococcus jannaschii



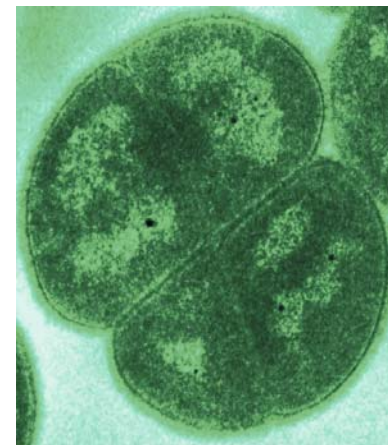
Methane production

Rhodospseudomonas palustris



**Hydrogen production /
Carbon sequestration**

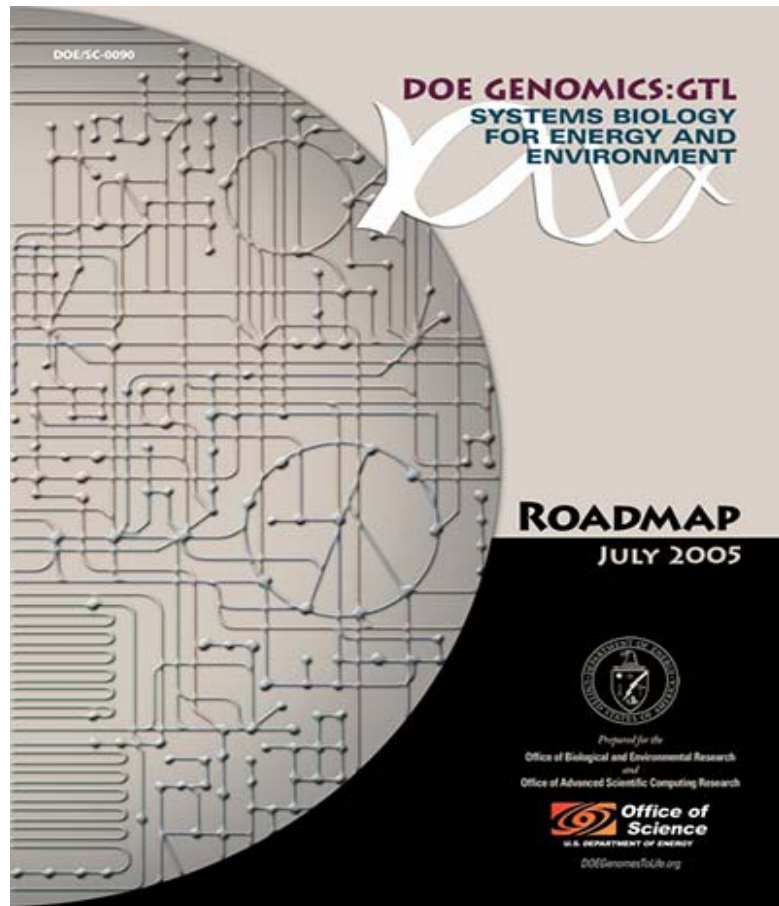
Deinococcus radiodurans



**Radiation resistance -
bioremediation**



Genomics:GTL



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

Mission Science Goals

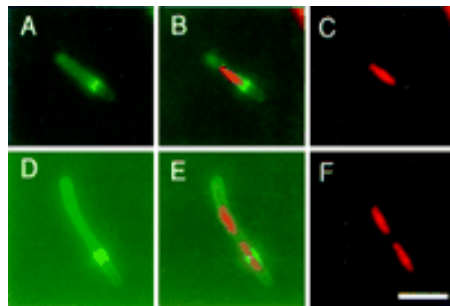
- Develop biological solutions for intractable environmental problems
- Understand relationships between climate change and earth's microbial systems
- Support development of biofuels as a major secure energy source



Genomics:GTL – A Systems Biology Research Program

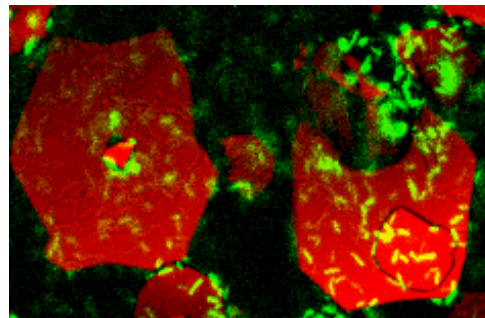
From Molecules to Cells to Ecosystems

Subcellular



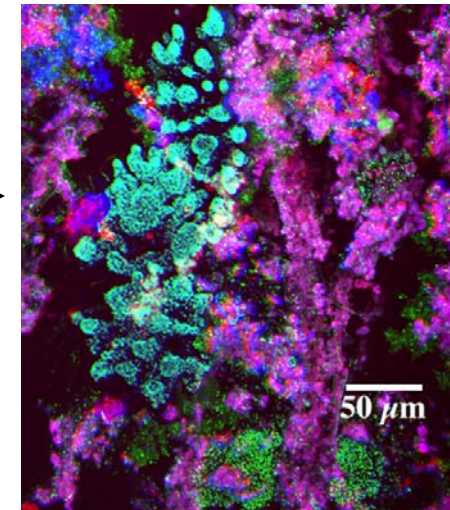
Identification, subcellular location, and dynamics of molecular machines

Cellular



Regulation of gene expression in individual cells

Ecosystems



Who is expressing what, when, where, and under what conditions? How do they work together?



Genomics: GTL – A Vision of Systems Biology Research

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:**

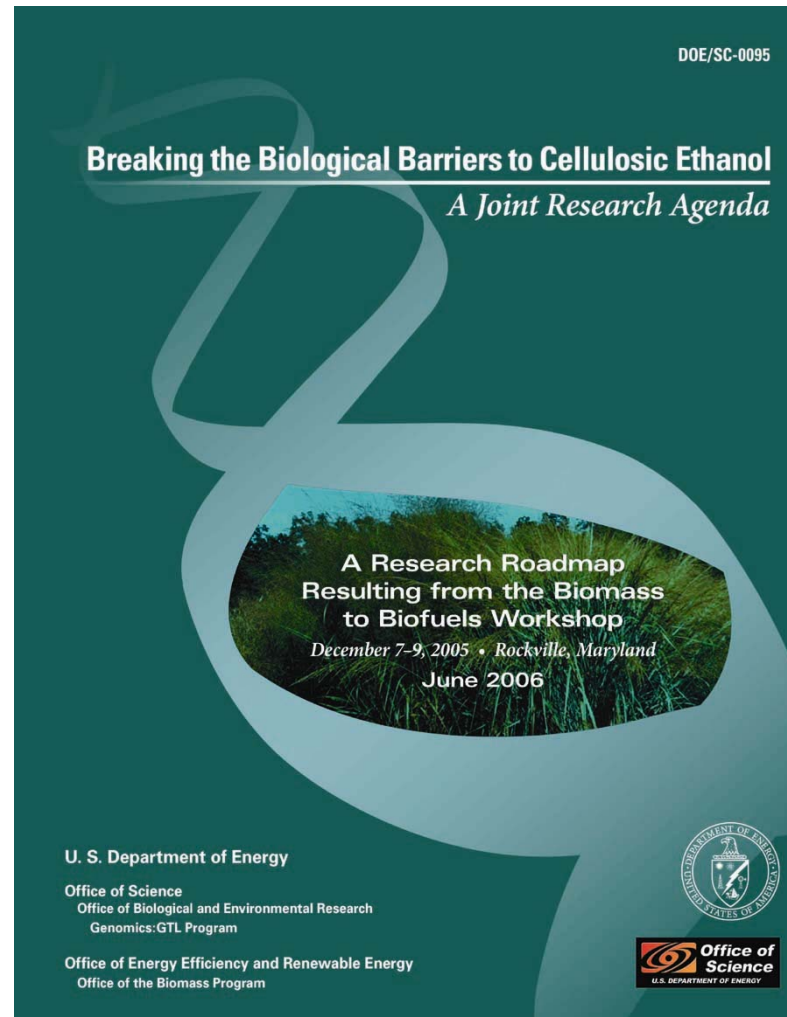
- **Generate an annotated DNA sequence**
- **Produce proteins and molecular tags for most/all proteins**
- **Identify the majority of multi protein complexes**
- **Generate a working regulatory network model**
- **Identify the biochemical capabilities**
- **Design reengineering or control strategies in silico**

U.S. Department of Energy



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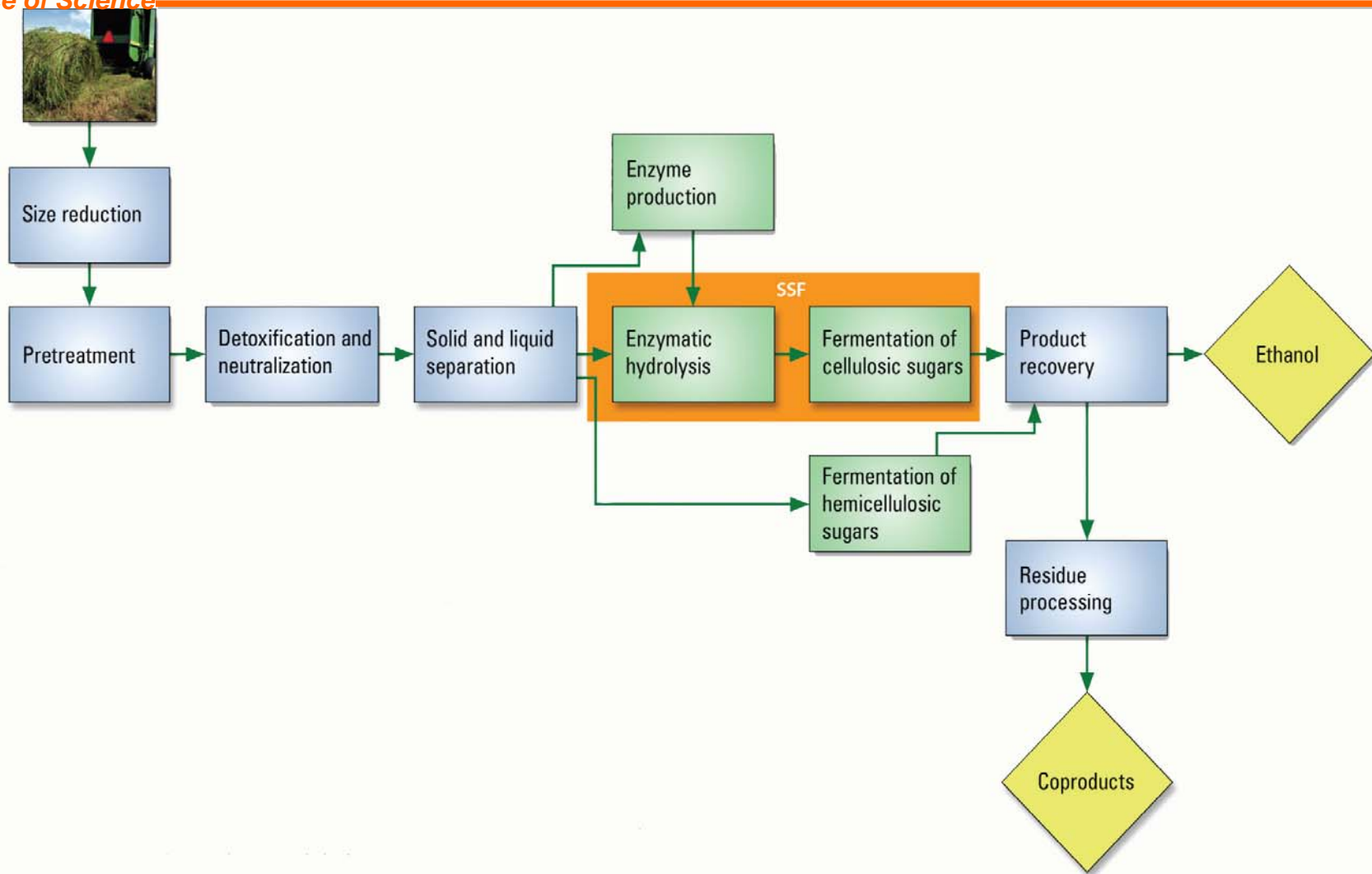
A Path Forward for Energy from Biomass



A joint SC / EERE workshop



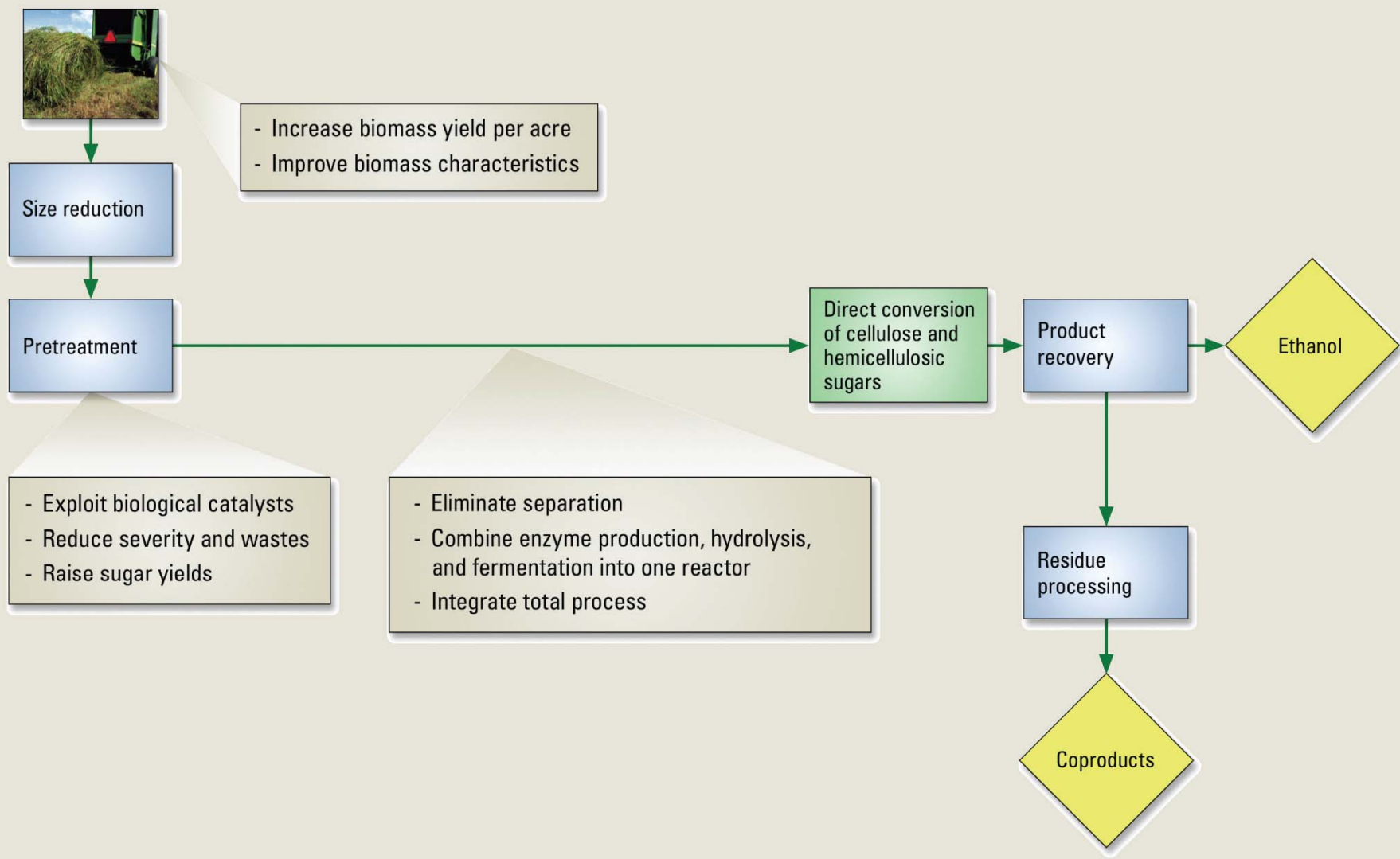
Steps in cellulosic ethanol production



From: Breaking the Biological Barriers to Cellulosic Ethanol



Science can improve the process



From: Breaking the Biological Barriers to Cellulosic Ethanol



GTL Bioenergy Research Centers

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 Joint Genome Institute

- 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



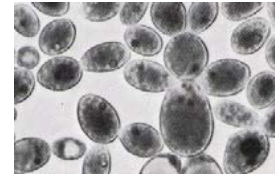
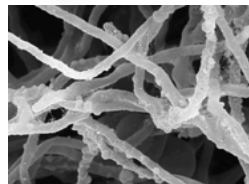
Saccharification

Sugars

Fermentation

Improved cellulose & lignin degradation

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



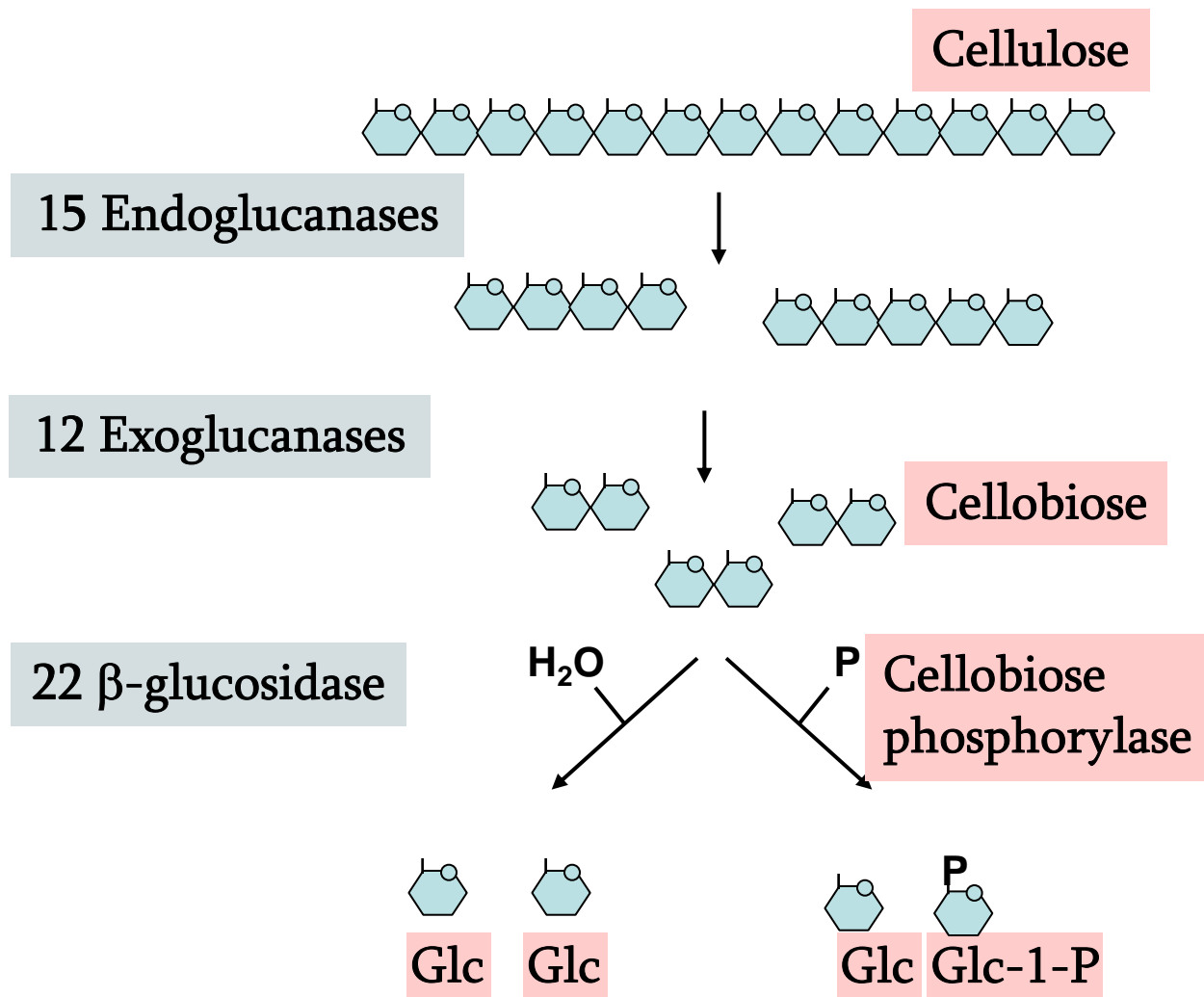
- Saccharomyces cerevisiae
- Zymomonas mobilis
- Thermoanaerobacter ethanolicus
- Pichia stipitis

Ethanol producing organisms



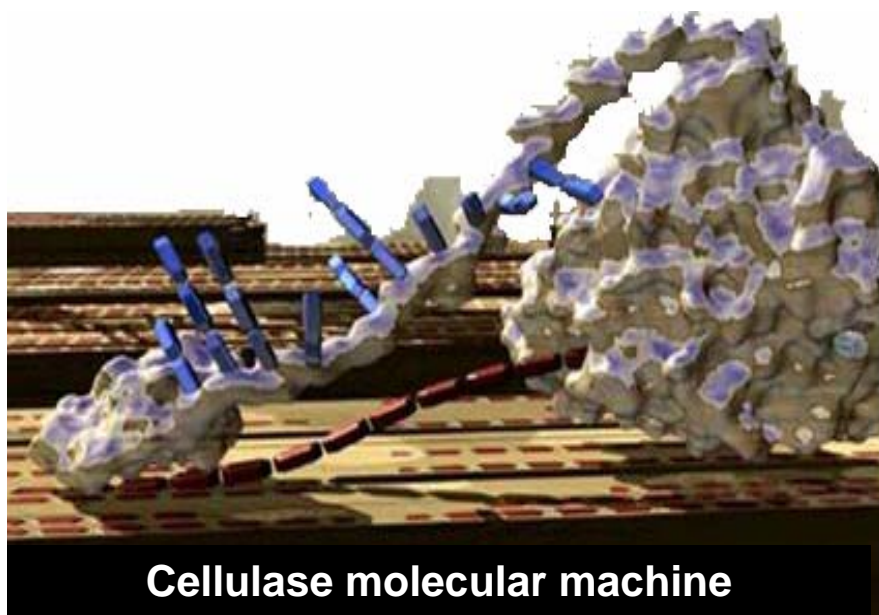


New Cellulase Genes from Termite Gut





Understanding Molecular Machines & Putting Them to Work



Cellulase molecular machine

- 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

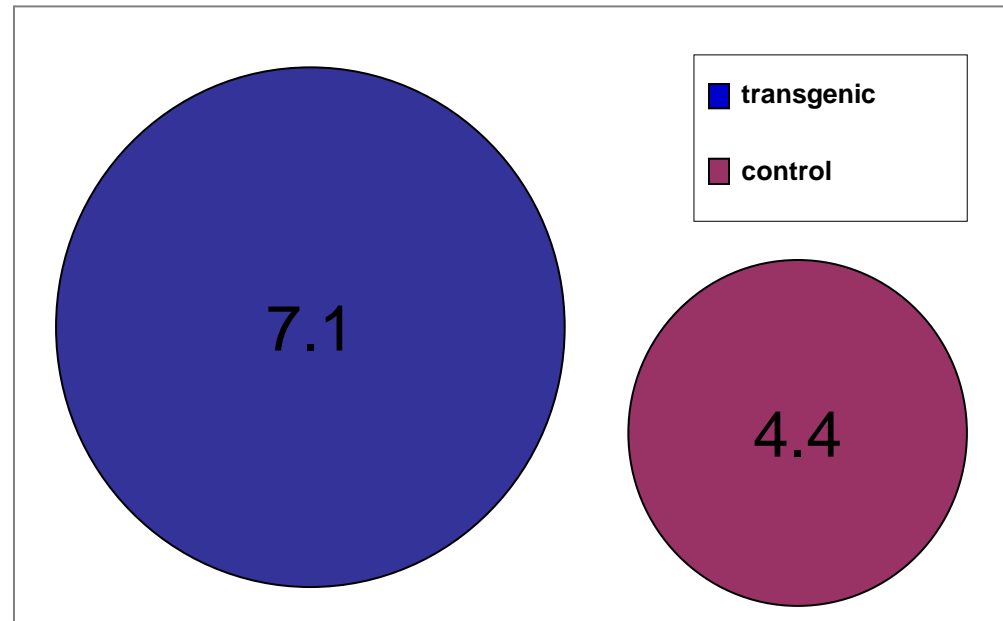


Auxin Regulation of Poplar Shape

90-day-old *Populus* cuttings



Enhanced radial growth of IAA16.3 transgenic trees



stem cross sectional area (cm)



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>



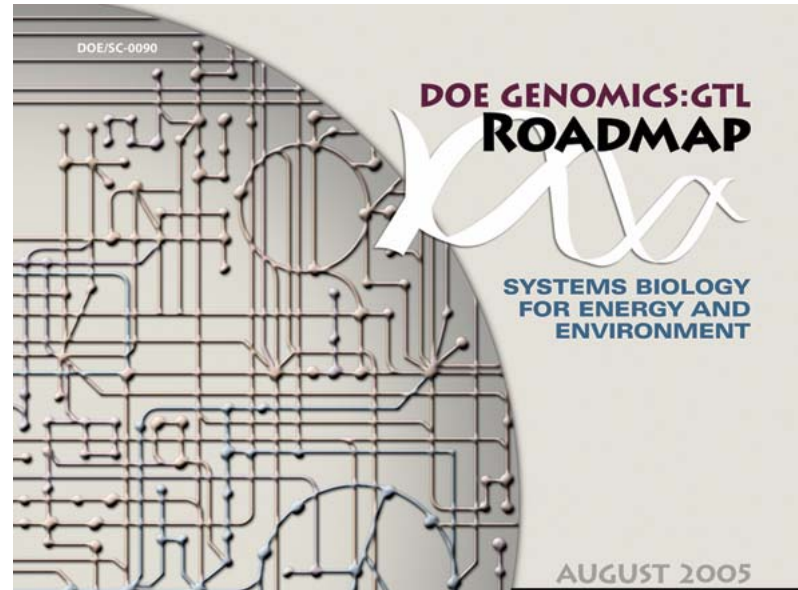
Other FY07 Genomics:GTL Solicitations

- **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**



<http://genomicsgtl.energy.gov/>

