Presentation to the Hydrogen and Fuel Cell Technical Advisory Committee Nov. 4th, 2009

Biological Hydrogen Production: Fundamental Research on Systems Biology

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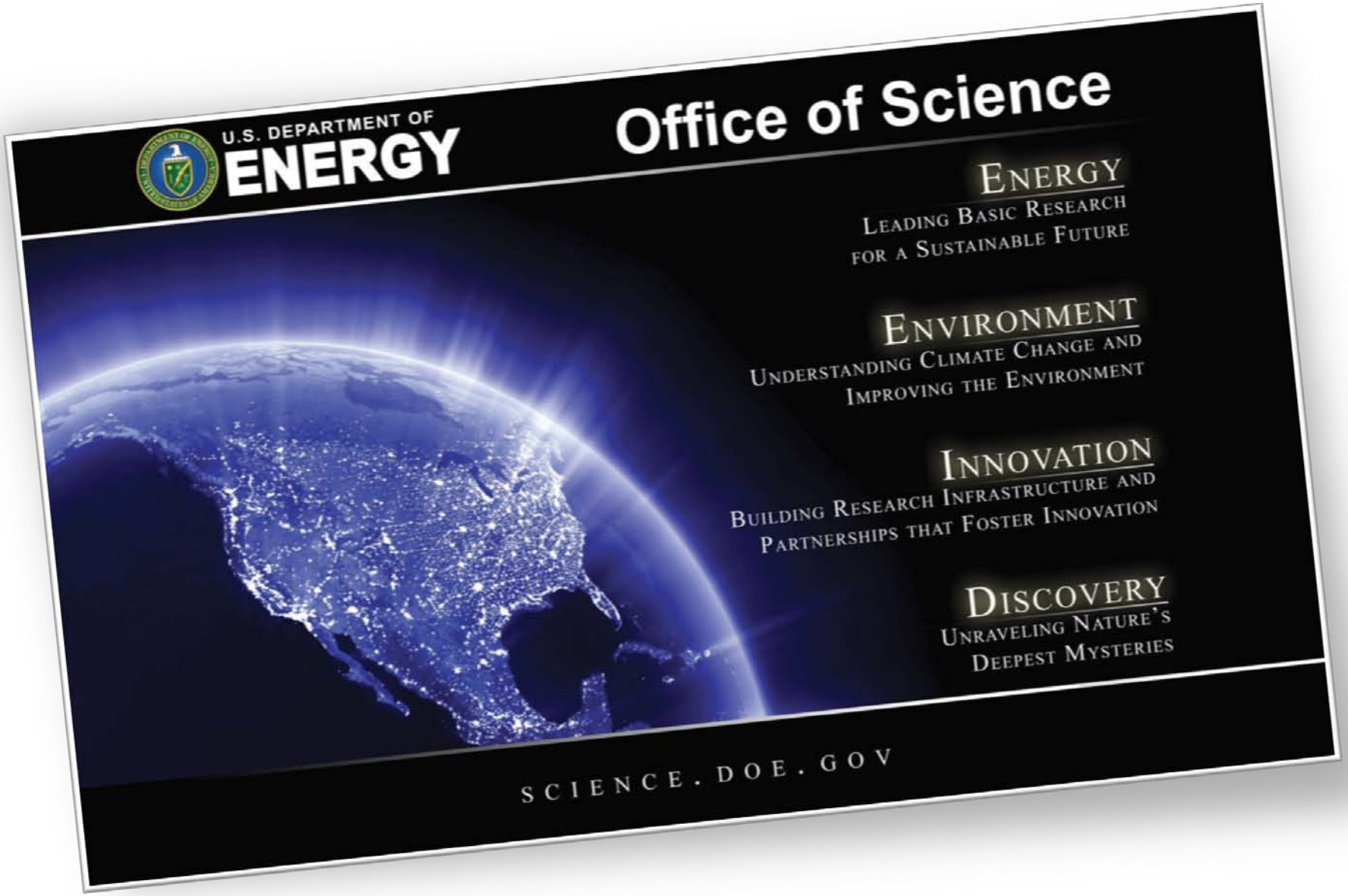
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ENERGY
Office of Science
ENERGY
LEADING BASIC RESEARCH
FOR A SUSTAINABLE FUTURE
ENVIRONMENT
UNDERSTANDING CLIMATE CHANGE AND
IMPROVING THE ENVIRONMENT
INNOVATION
BUILDING RESEARCH INFRASTRUCTURE AND
PARTNERSHIPS THAT FOSTER INNOVATION
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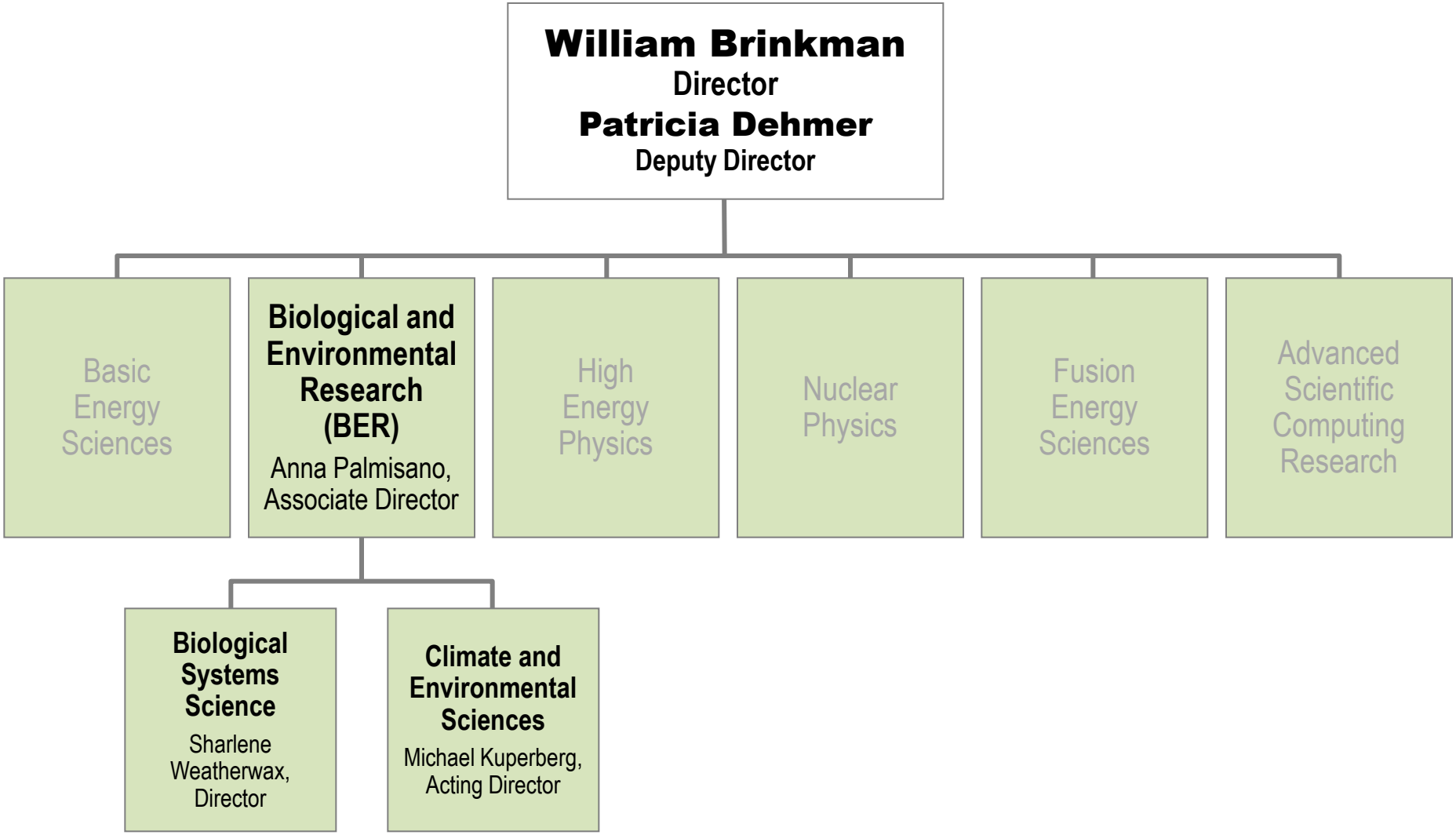


Biological and Environmental Research Mission

- To understand complex biological, climatic, and environmental systems across spatial and temporal scales.
- BER provides the foundational science to:
  - Support the development of biofuels as major, secure, and sustainable national energy resources
  - Understand potential effects of greenhouse gas emissions on Earth's climate and biosphere and the implications of these emissions for our energy future
  - Predict the fate and transport of contaminants in the subsurface environment at DOE sites
  - Develop new tools to explore the interface of biological & physical sciences

Biological and Environmental Research

Budget

Appropriations		FY09	FY10
Research	Biological Systems	$173M	$166M
	Bioenergy Research Centers	$75M	$75M
	Climate Change Research	$132M	$134M
	Subsurface Biogeochemical Research	$49M	$50M
	Total	**$429M**	**$425M**
Facilities: Scientific User Facility Operations	Joint Genome Institute (JGI)	$65M	$69M
	Atmospheric Radiation Measurement (ARM)	$40M	$42M
	Environmental Molecular Science Laboratory (EMSL)	$49M	$52M
	Total	**$154M**	**$163M**
Other	(e.g., Small Business Innovation Research)	$17M	$16M
	Total BER	**$600M**	**$604M**

Biological and Environmental Research Divisions

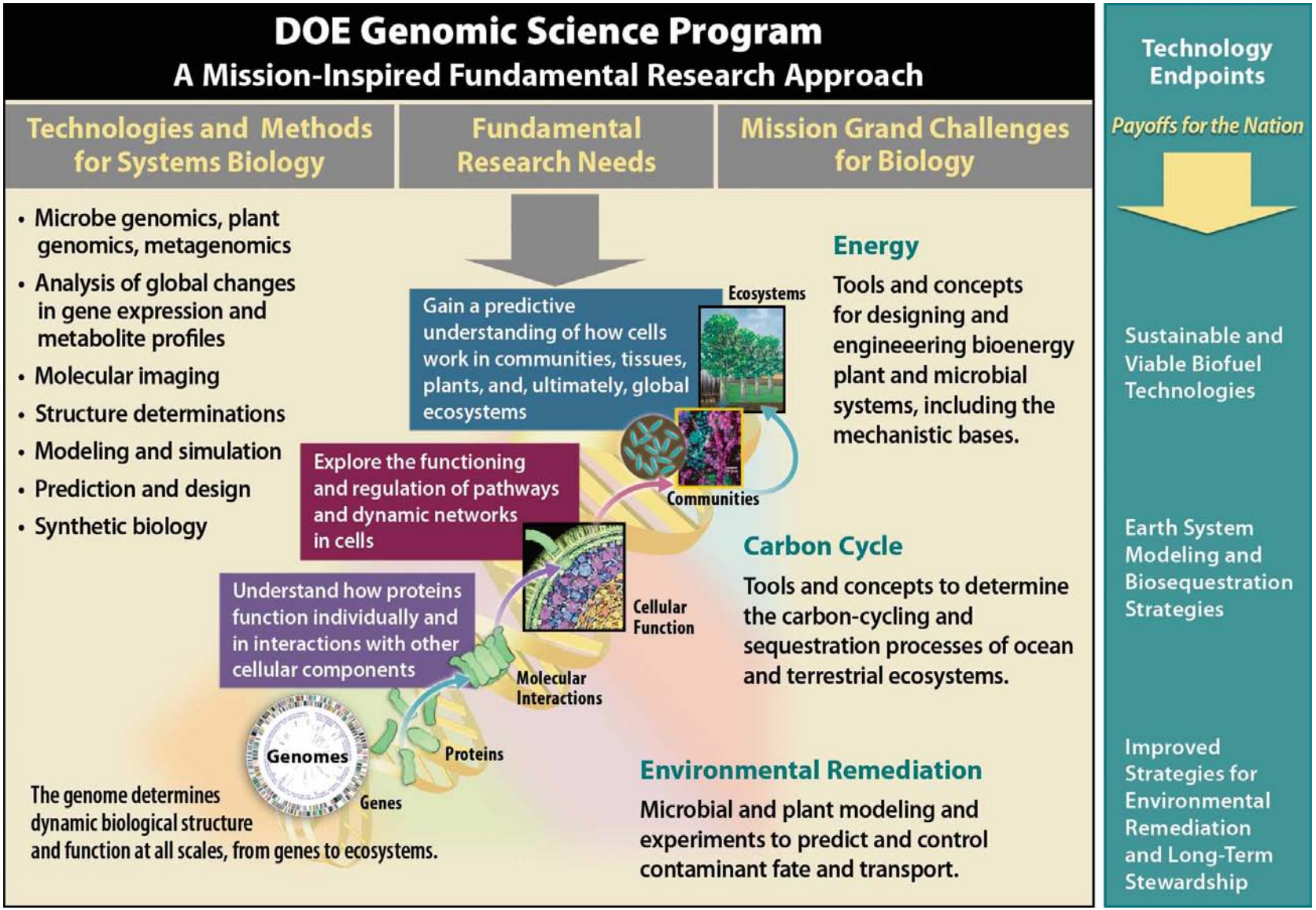
Biological Systems Science Division

- Genomic Sciences Program
- Bioenergy Research Centers
- DOE Joint Genome Institute
- Low Dose Radiation
- Radiochemistry, Imaging, and Instrumentation
- Structural Biology

Climate and Environmental Sciences Division

- Climate Change Research
- ARM Climate Research Facility
- Subsurface Biogeochemical Research
- Environmental Molecular Sciences Laboratory

Genomic Sciences Program



DOE Scientific User Facility

DOE Joint Genome Institute

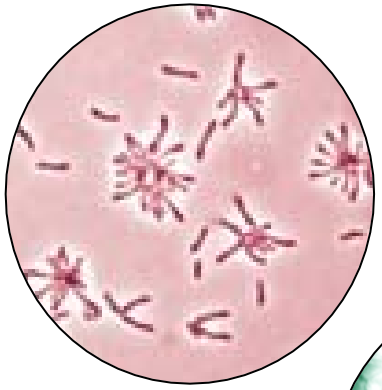
- Focus: Genomes and metagenomes of microbes, microbial communities, and plants vital to DOE missions
  - Provide state-of-the-art capabilities for sequencing and analysis
  - Maintain expert staff in a range of computing and biological research disciplines
  - Host workshops and annotation jamborees

High-throughput sequencing facility at DOE JGI in Walnut Creek, California

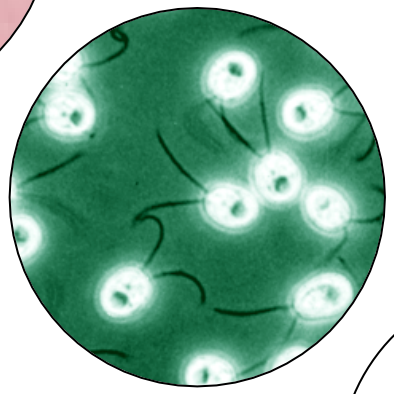
Sequencing more than 1 tera base pairs of DNA per year or 333 human genome equivalents!

DOE Joint Genome Institute: Biohydrogen Relevant Sequencing

JGI has provided sequencing of whole genomes, expressed sequence tagged (EST) libraries, and metagenomes of:



Hydrogen-producing bacteria

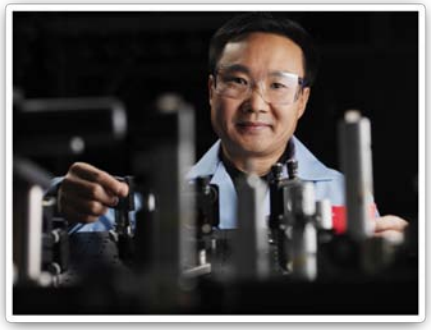


Hydrogen-producing algae

Intact microbial communities

DOE Scientific User Facility
Environmental Molecular Sciences Laboratory

- EMSL science themes:
  - Biological interactions and dynamics
  - Geochemistry/biogeochemistry and subsurface science
  - Science of interfacial phenomena
- Unparalleled capabilities:
  - Integrated experimental and supercomputing capabilities enable users to study molecular-level processes underpinning energy and environmental challenges
  - 60+ leading-edge capabilities and expert staff are available to university, DOE laboratory, and industry scientists



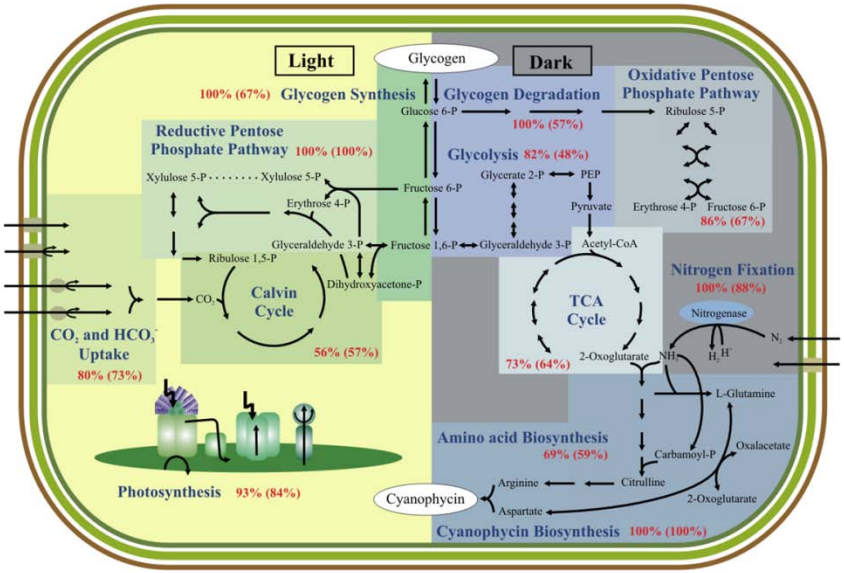
EMSL

BER Research: Systems Biology of Hydrogen Production

Objective: Provide integrative, systems-level understanding of hydrogen production by photosynthetic and fermentative microbes

- Identification of novel genes, enzymes, and biochemical pathways relevant to hydrogen metabolism
- Understanding metabolic and regulatory networks involved in biological hydrogen production by microbes or microbial communities
- Development of genetic tools and research capabilities for a broader range of hydrogen-producing model organisms
- Enable directed metabolic engineering approaches for enhanced hydrogen production

Tracking Temporal Integration of Metabolic Cycles in Cyanobacteria



Objective:

- Study regulation of carbon, nitrogen, and hydrogen metabolism in *Cyanothece,* a genus of photosynthetic marine bacteria

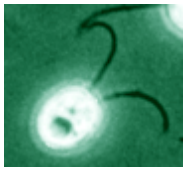
Approach:

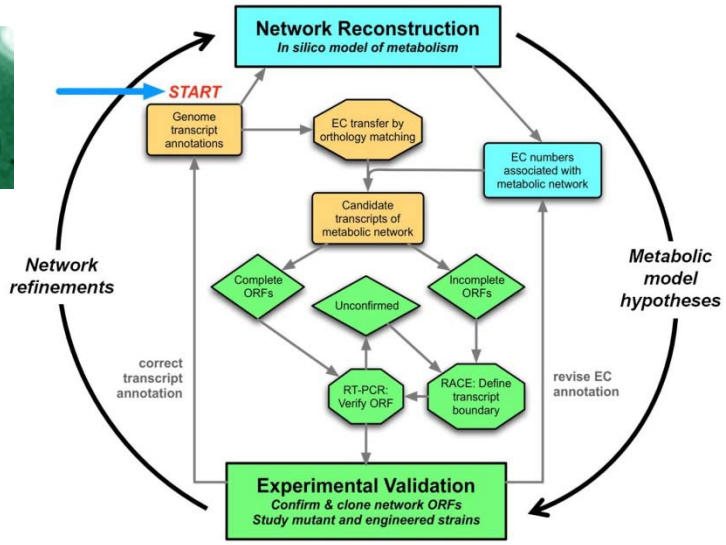
- Compare hydrogen production among strains
- Analyze expression and regulation of genes during hydrogen synthesis
- Make targeted mutations to genes involved in hydrogen production

Outcomes:

- Understand regulation of hydrogen production
- Development of new genetic tools to advance *Cyanothece* as a model organism for hydrogen production

Metabolic Network Analysis and Annotation of Gene Function in Algae





Objective:

- Develop a new approach to build metabolic network models and study gene function in the alga *Chlamydomonas reinhardtii*

Approach:

1. Computational prediction of gene function
2. Construct metabolic network model
3. Verify gene expression

Outcomes:

- Enables new metabolic engineering approaches for enhancing algal hydrogen production
- Provides a new systems-based method applicable to any organism with a sequenced genome.

Manichaikul et al. 2009. Nature Methods. 6:589-94

Hydrogen Production & Consumption In Complex Microbial Communities

Objective:

- Examine conversion of woody plant material to hydrogen by the symbiotic microbial community of wood-feeding beetles

Approach:

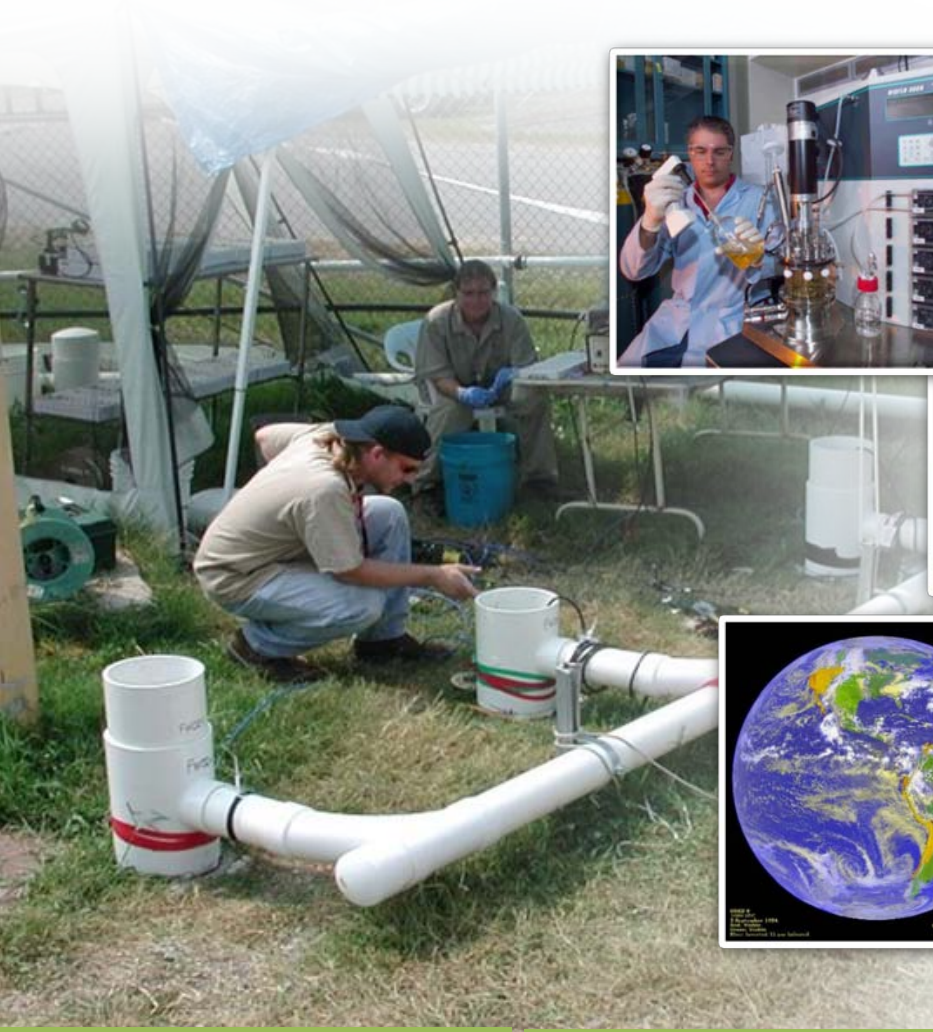
- Identify resident microbes by metagenome sequencing
- Characterize chemical conditions in gut compartments
- Determine which microbes are involved in hydrogen production

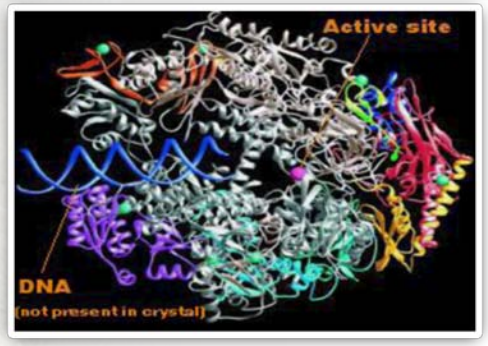
Outcomes:

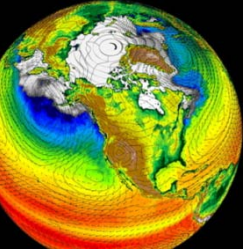
- Understand highly efficient conversion of biomass, production of hydrogen, and capture of energy by symbiotic system
- Identify new organisms, enzymes, and biochemical pathways for hydrogen production

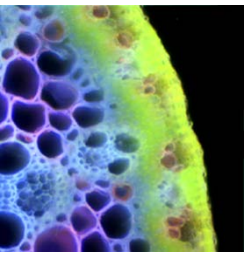
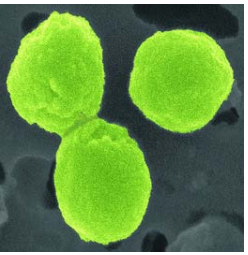
Biological and Environmental Research

Complex systems science to meet DOE mission needs in bioenergy, climate, and the environment







Thank you!

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