

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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ENERGY
LEADING BASIC RESEARCH
FOR A SUSTAINABLE FUTURE

ENVIRONMENT
UNDERSTANDING CLIMATE CHANGE AND
IMPROVING THE ENVIRONMENT

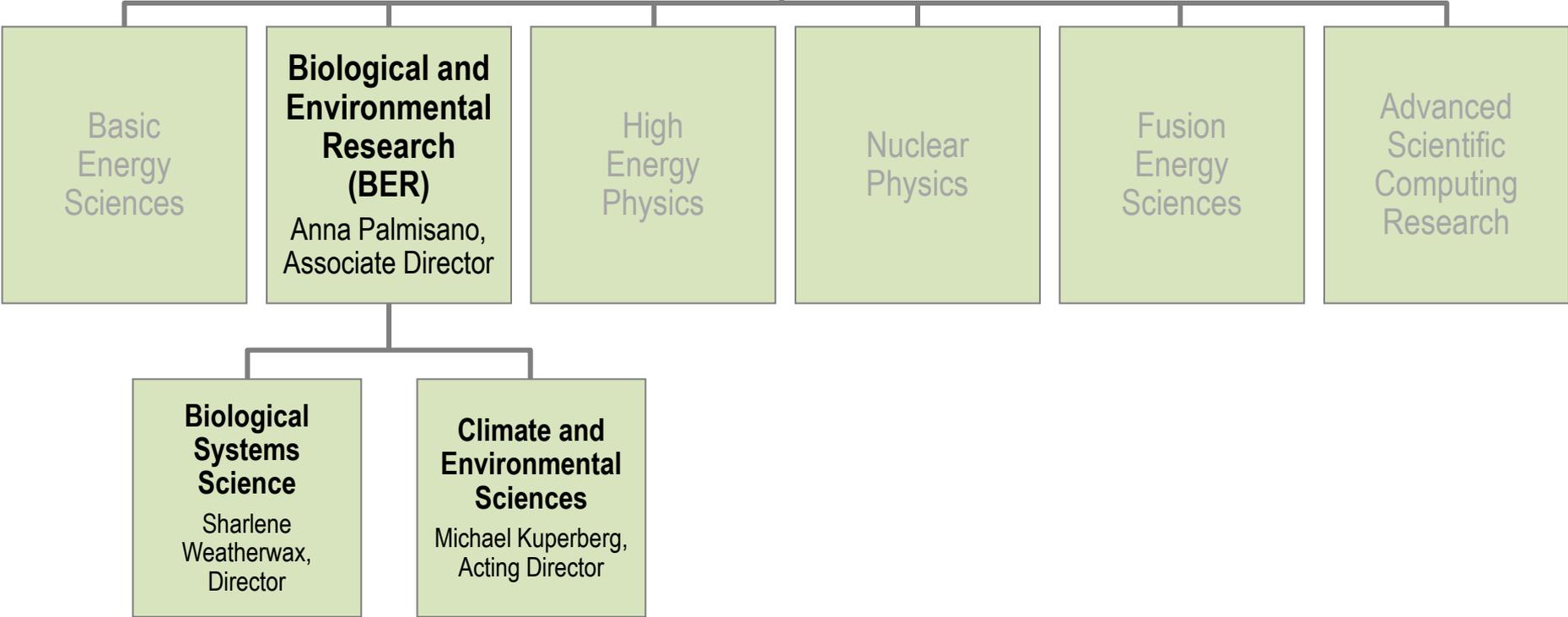
INNOVATION
BUILDING RESEARCH INFRASTRUCTURE AND
PARTNERSHIPS THAT FOSTER INNOVATION

DISCOVERY
UNRAVELING NATURE'S
DEEPEST MYSTERIES

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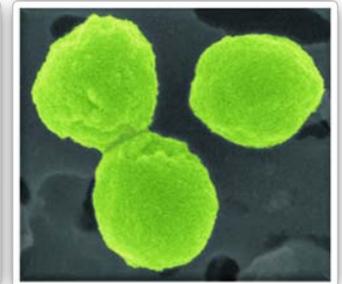
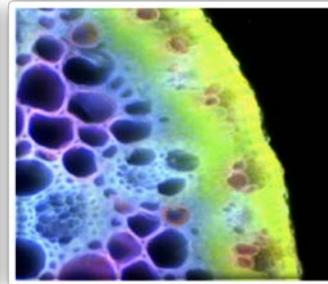
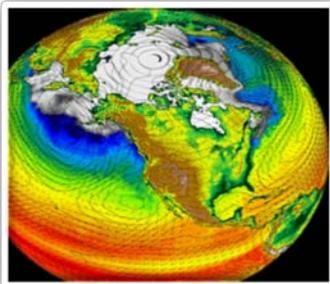
Department of Energy Office of Science

William Brinkman
Director
Patricia Dehmer
Deputy Director



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

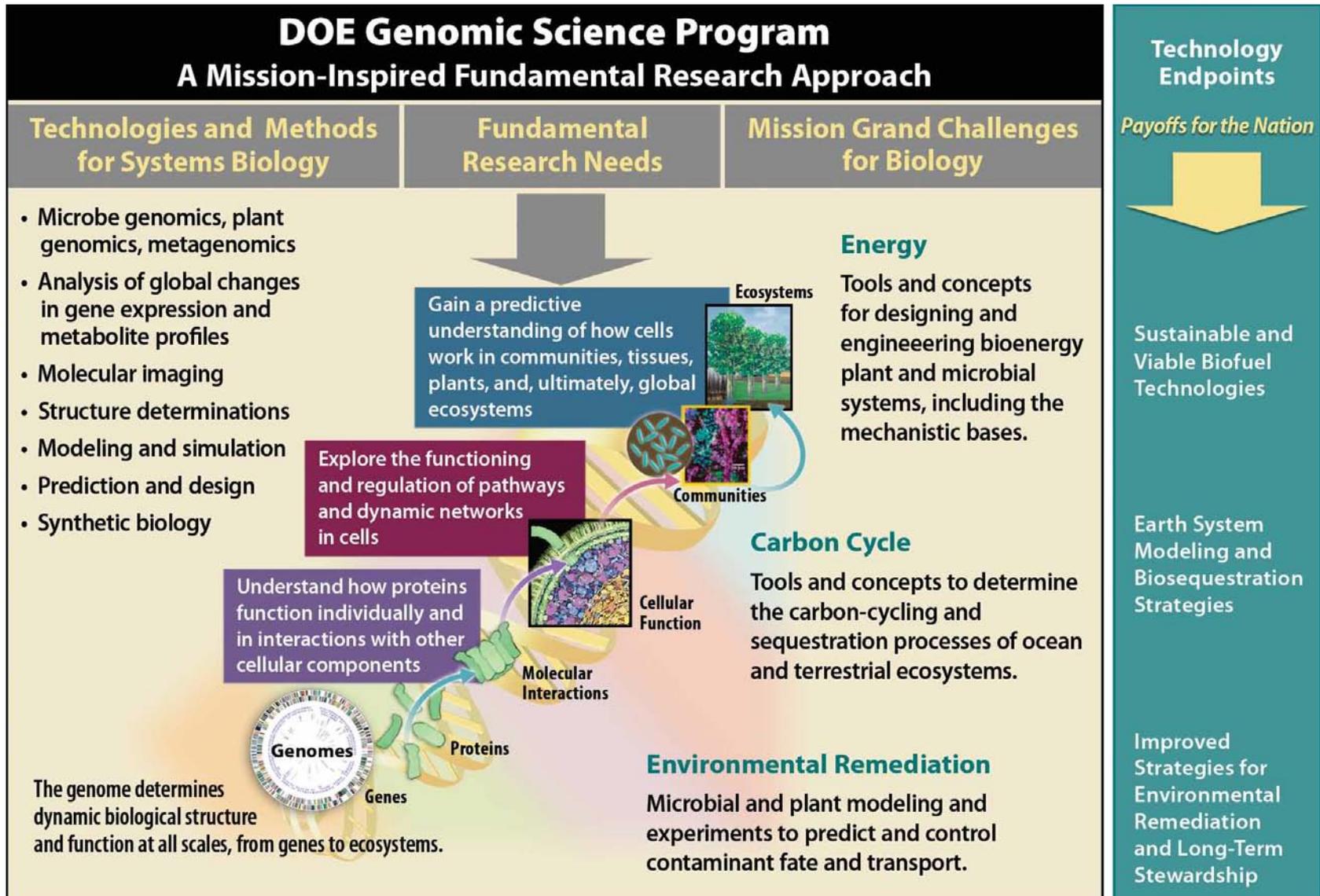
Biological Systems Science Division

- 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

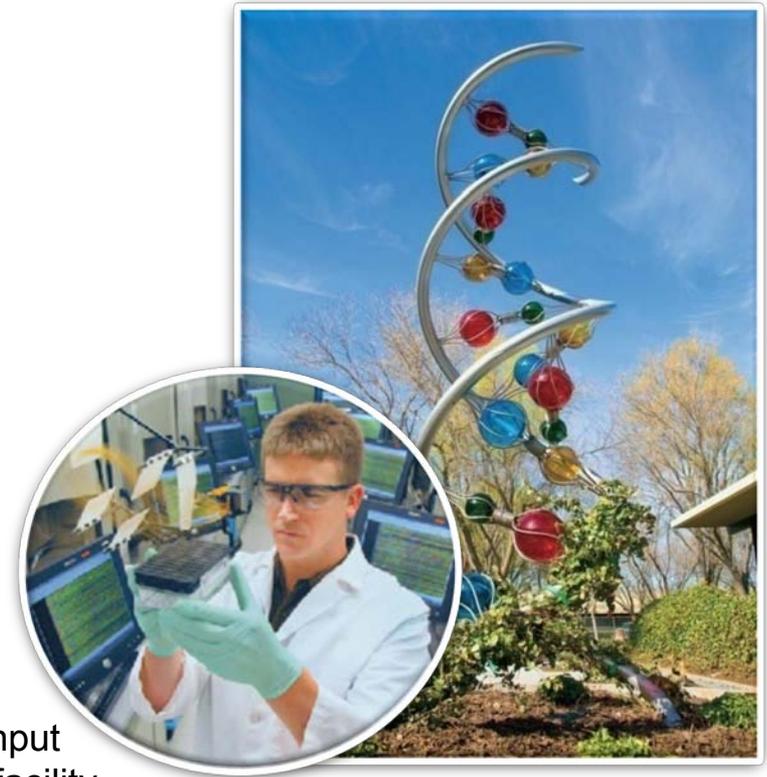
Genomic Sciences Program



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



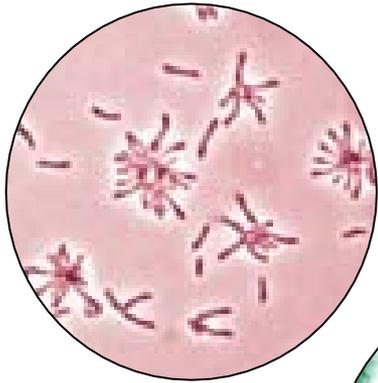
High-throughput sequencing facility at DOE JGI in Walnut Creek, California

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

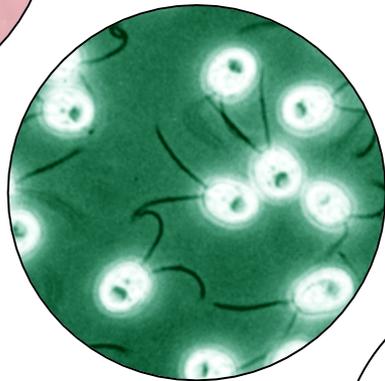
DOE Joint Genome Institute: Biohydrogen Relevant Sequencing



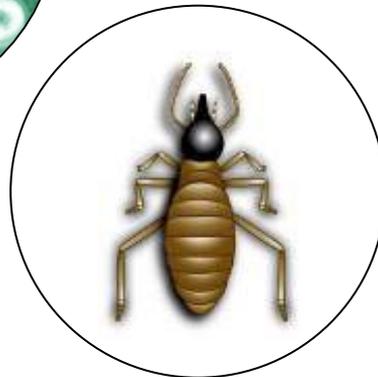
JGI has provided sequencing of whole genomes, expressed sequence tagged (EST) libraries, and metagenomes of:



Hydrogen-producing bacteria



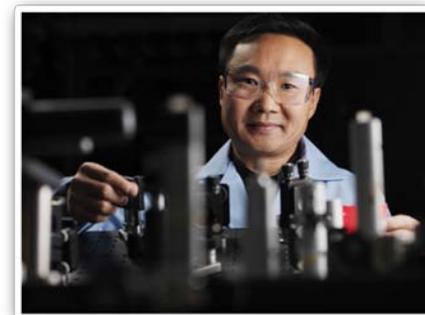
Hydrogen-producing algae



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



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

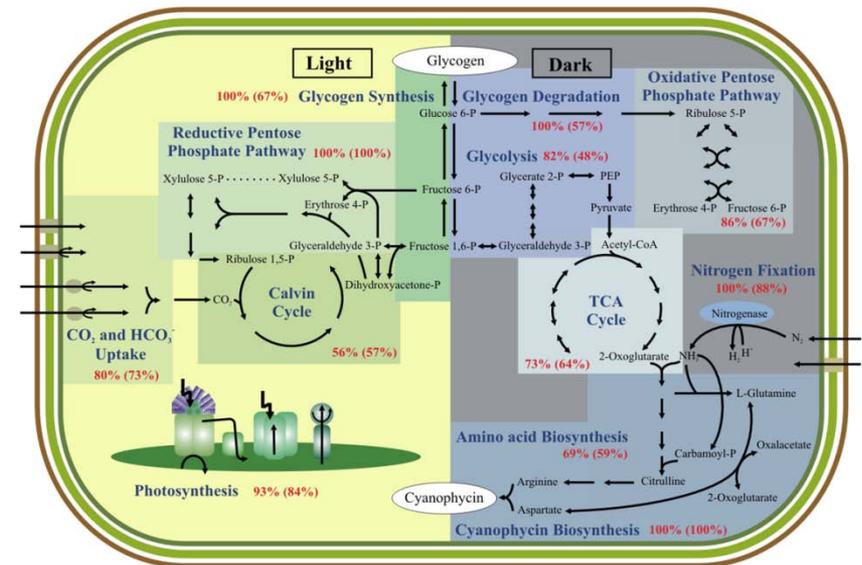
Tracking Temporal Integration of Metabolic Cycles in Cyanobacteria

Objective:

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

Approach:

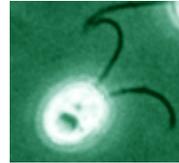
- Compare hydrogen production among strains
- Analyze expression and regulation of genes during hydrogen synthesis
- Make targeted mutations to genes involved in hydrogen production



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

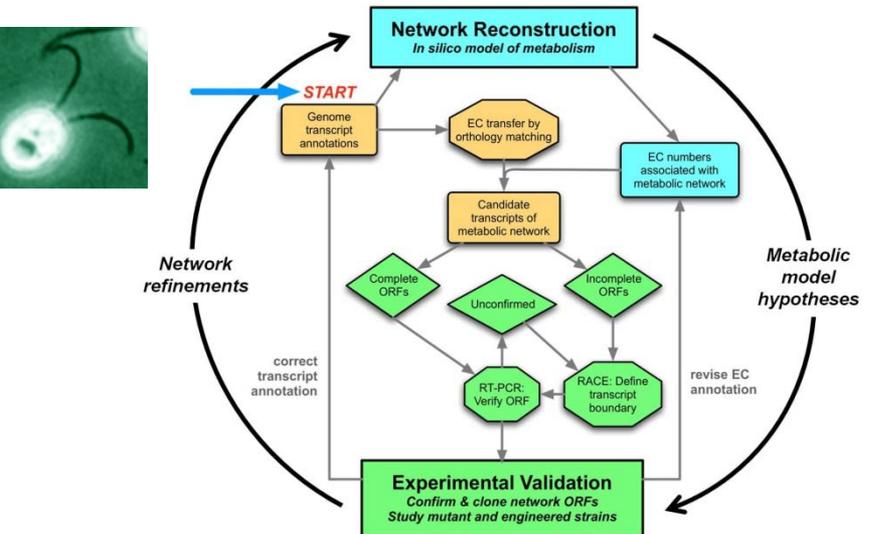


Objective:

- 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.

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:

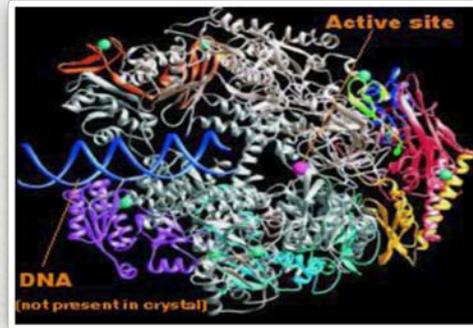
- Identify resident microbes by metagenome sequencing
- Characterize chemical conditions in gut compartments
- Determine which microbes are involved in hydrogen production

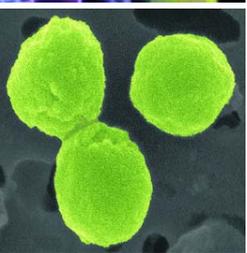
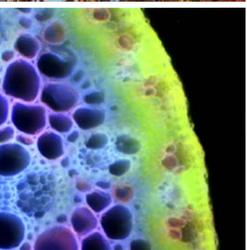
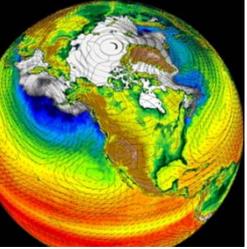
Outcomes:

- 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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