Office of Biological and Environmental Research

Biological Systems Science Division Strategic Plan

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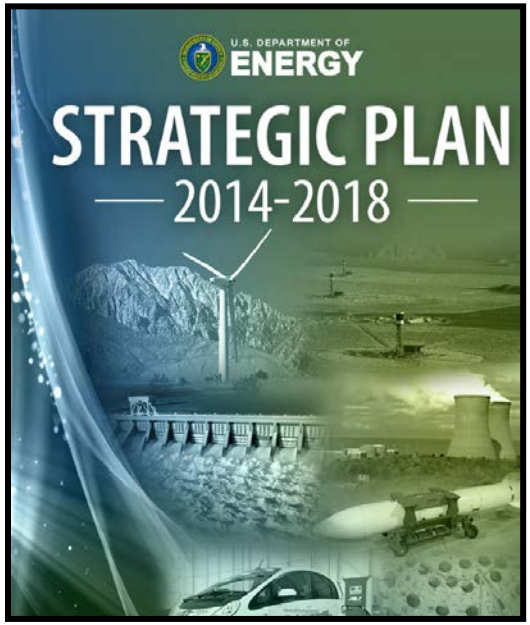
October 29, 2015

Biological and Environmental Research Mission Drivers

Provide the foundational science to:

- Support the development of biofuels as major, secure, and sustainable national energy resource
- Understand the potential effects of energy-related greenhouse gas emissions on Earth's climate and biosphere, and feedbacks to future energy systems.
- Predict and control the cycling and mobility of materials in the subsurface and across key surface-subsurface interfaces in the environment
- Develop new tools to explore the interface of biology with the physical sciences

DOE Strategic Plan

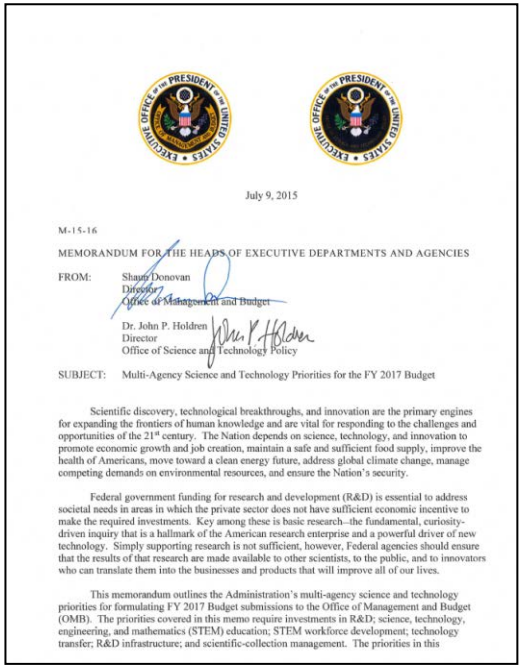


DOE Mission

Enhance U.S. security and economic growth through transformative science, technology innovation, and market solutions to meet our energy, nuclear security, and environmental challenges

DOE Strategic Goal 1.

Advance foundational science, innovate energy technologies, and inform data driven policies that enhance U.S. economic growth and job creation, energy security, and environmental quality, with emphasis on implementation of the President's Climate Action Plan to mitigate the risks of and enhance resilience against climate change



July 9, 2015

M-15-16

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Shaun Donovan
Director
Office of Management and Budget

Dr. John P. Holdren
Director
Office of Science and Technology Policy

SUBJECT: Multi-Agency Science and Technology Priorities for the FY 2017 Budget

Scientific discovery, technological breakthroughs, and innovation are the primary engines for expanding the frontiers of human knowledge and are vital for responding to the challenges and opportunities of the 21st century. The Nation depends on science, technology, and innovation to promote economic growth and job creation, maintain a safe and sufficient food supply, improve the health of Americans, move toward a clean energy future, address global climate change, manage competing demands on environmental resources, and ensure the Nation's security.

Federal government funding for research and development (R&D) is essential to address societal needs in areas in which the private sector does not have sufficient economic incentive to make the required investments. Key among these is basic research--the fundamental, curiosity-driven inquiry that is a hallmark of the American research enterprise and a powerful driver of new technology. Simply supporting research is not sufficient, however, Federal agencies should ensure that the results of that research are made available to other scientists, to the public, and to innovators who can translate them into the businesses and products that will improve all of our lives.

This memorandum outlines the Administration's multi-agency science and technology priorities for formulating FY 2017 Budget submissions to the Office of Management and Budget (OMB). The priorities covered in this memo require investments in R&D; science, technology, engineering, and mathematics (STEM) education; STEM workforce development; technology transfer; R&D infrastructure; and scientific-collection management. The priorities in this

Administration's Priorities **(applicable to BSSD)**

- *Clean Energy*
- *Innovation in Life Sciences, Biology and Neuroscience*

Biological Systems Science

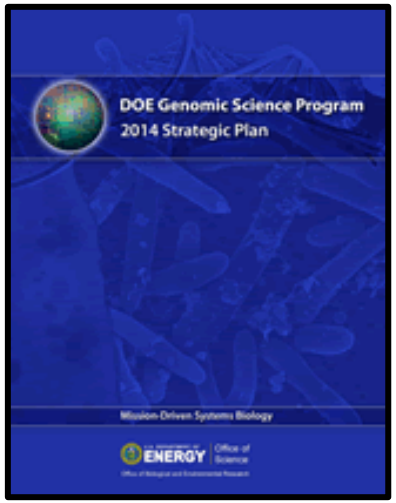
Foundational Genomic Research Supporting DOE's Energy and Environmental Missions

Overarching Goal

Provide the necessary fundamental science to understand, predict, manipulate and design biological processes that underpin innovations for bioenergy and bioproduct production and enhance the understanding of natural environmental processes relevant to DOE.

- *Provide a basic understanding of plant and microbial biology to underpin the production of biofuels and bioproducts from sustainable plant biomass resources.*
- *Develop the fundamental understanding of genome biology needed to design, modify and optimize plants, microbes and biomes for beneficial purposes.*
- *Gain a predictive understanding of biological processes controlling the flux of materials (carbon, nutrients, and contaminants) in the environment and how these processes impact ecosystem function.*
- *Develop the enabling computational, visualization and characterization capabilities to integrate genomic data with functional information on biological processes.*
- *Broaden the integrative capabilities within and among DOE user facilities to foster a more interdisciplinary approach to BER-relevant science and aid interpretation of plant, microbe and microbial community biology.*

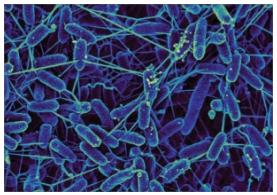
Planning Inputs



Science directions informed by input from the scientific community via workshops, planning documents and NAS studies.

Biological Systems Science

Biological Systems Science supports a diverse portfolio of fundamental research and technology development to achieve a predictive systems-level understanding of complex biological systems.



DOE Bioenergy Research Centers
Plant Feedstocks Research
Sustainability Research
Biosystems Design
Computational Biology
Bioimaging Technology Development
Joint Genome Institute
Structural Biology Infrastructure

BESC BioEnergy Science Center

jbei Joint BioEnergy Institute

GREAT LAKES BIOENERGY RESEARCH CENTER

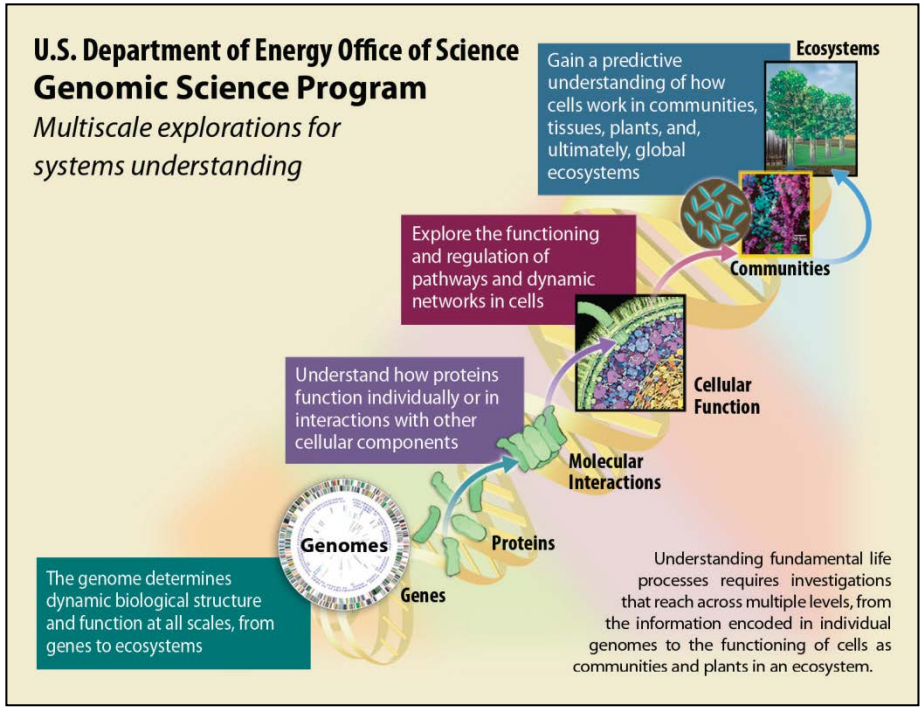
KBase PREDICTIVE BIOLOGY
DOE Systems Biology Knowledgebase

JGI JOINT GENOME INSTITUTE
A DOE OFFICE OF SCIENCE USER FACILITY

Systems Biology Understanding for DOE's Bioenergy and Environmental Missions

Challenges

- *Broad subject area: Plants and microbes*
- *Complex bioenergy and environmental systems*
- *Enormous, diverse datasets: genomic/omics/experimental data*
- *Need for Integrative analyses*
- *Need for understanding across scales: systems biology*



Structure the portfolio to accelerate the understanding of Biology for DOE missions in bioenergy and the environment

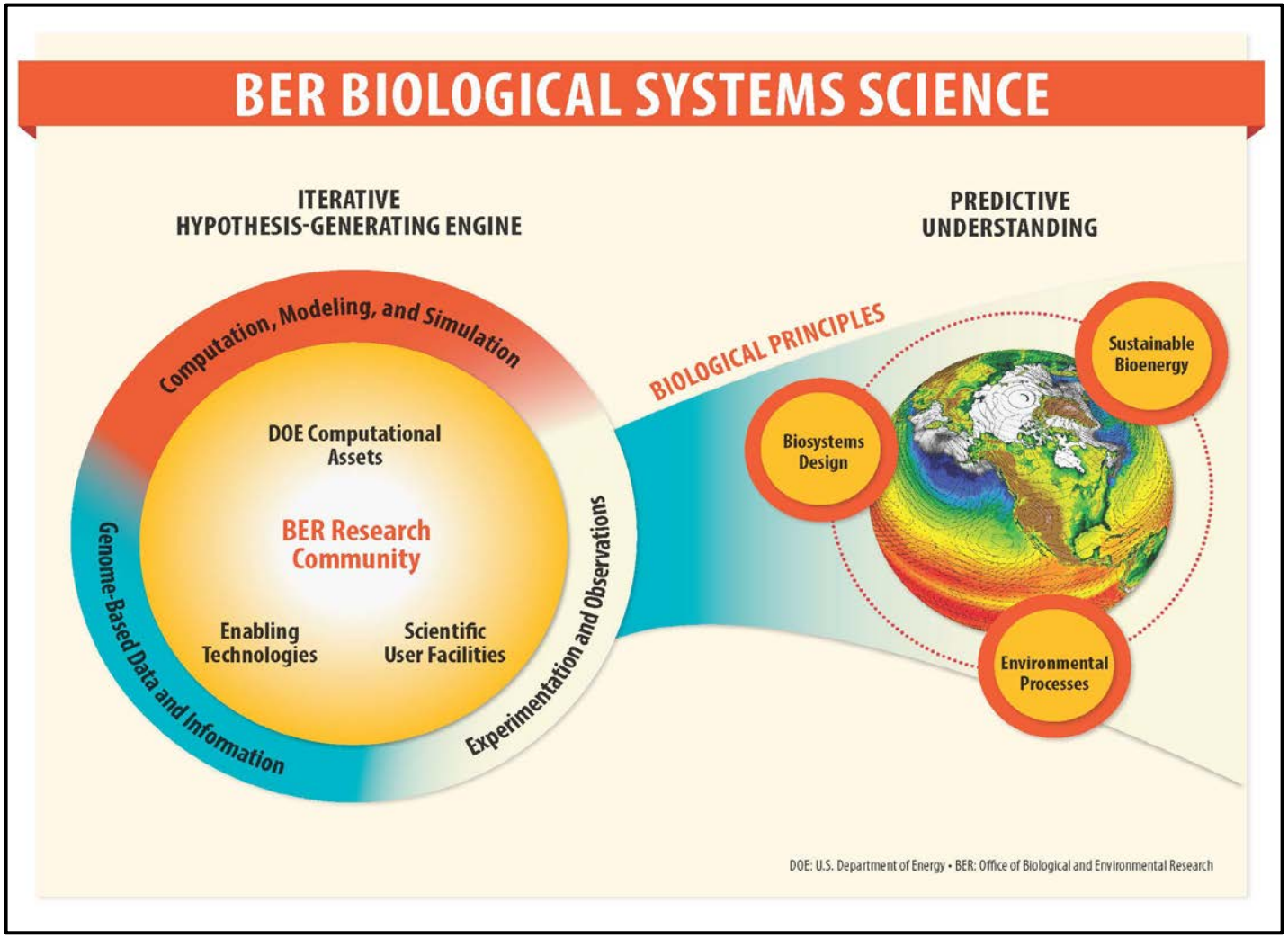
Support Interdisciplinary Research: *The current DOE mission-relevant challenges in bioenergy and environmental research are complex in nature and require an interdisciplinary research approach.*

Develop Enabling Technology: *New measurement and imaging technologies are needed that can evaluate whole biological systems.*

Leverage High Performance Computation Systems to Facilitate Analysis and Collaboration: *Common cyberinfrastructure platforms operating on HPC systems in the cloud offer the potential to organize large scale, complex genomic data into experimentally tractable formats quickly and easily for use by whole communities of researchers.*

Integrate Unique Capabilities across User Facilities: *BSSD will continue to support development of unique instrumentation at the BER user facilities but will also look to combining those capabilities across DOE facilities to offer users unique combinations of capabilities for interdisciplinary research.*

Biological Systems Science



Bioenergy Research: Bioenergy/Bioproducts

Goal: Provide a basic understanding of plant and microbial biology to underpin the production of biofuels and bioproducts from sustainable plant biomass resources.

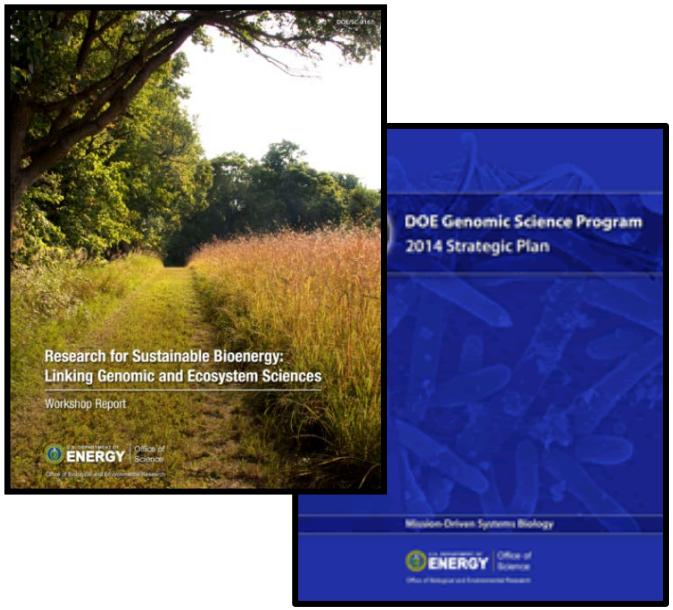
Sub-Goal: Provide the basic science to enable a sustainable and commercially viable lignocellulosic biomass-derived advanced biofuels and bioproducts industry.

- Develop the basic understanding of plant biology needed to produce dedicated, sustainable feedstocks with beneficial traits for bioenergy production.
- Create new methods to cost effectively deconstruct biomass.
- Explore a range of new microbial-based methods to convert plant biomass-derived components to next generation biofuels and related bioproducts.

Bioenergy Research: Sustainability Research

Sub-Goal: Develop new approaches to bioenergy agriculture that cost-effectively provides high yields of biomass on marginal lands requiring few or no inputs with plants highly adaptable to changing environmental conditions and having minimal to no impacts on the ecosystem.

- Gain a fundamental understanding of plant-microbe interactions
- Link mechanistic understanding of plant-microbe interactions to biogeochemical processes in soils
- Developing process-based, multiscale models of plant performance under changing environments.



Biosystems Design

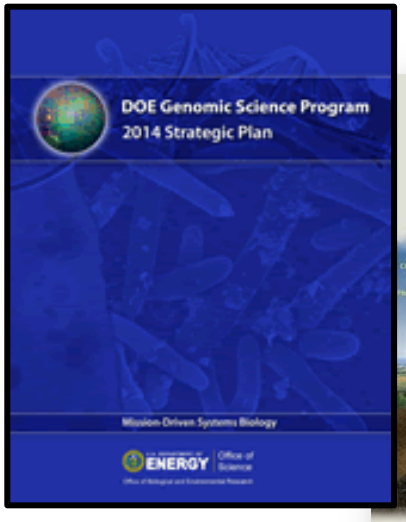
Goal: Develop the fundamental understanding of genome biology needed to design, modify and optimize plants, microbes and biomes for beneficial purposes.

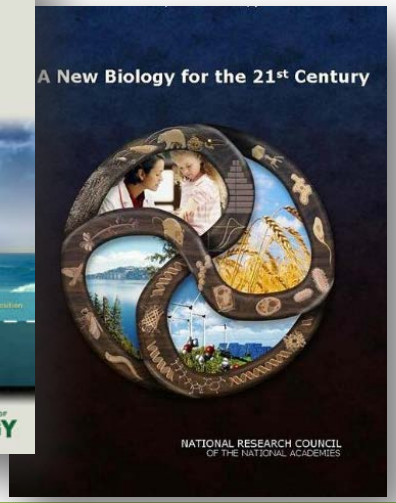
- Better understanding of underlying principles needed to engineer new traits into plants and microorganisms
- Improved computational and experimental tools for biosystems design
- Diversified range of model microbes and plants
- Biocontainment mechanisms permitting incorporation of multiple redundant safeguards at each step of the design process.

Environmental Research

Goal: Gain a predictive understanding of biological processes controlling the flux of materials (carbon, nutrients, and contaminants) in the environment and how these processes impact ecosystem function.

- Systems biology studies on microbes, microbial consortia, and microbe-plant interactions involved in large-scale terrestrial carbon cycling processes.
- Determination of the role of microbial communities as key contributors in major biogeochemical cycles (e.g., carbon, nitrogen, sulfur, and phosphorus).
- Scale understanding of biological processes from individual organisms to complex communities operating at ecosystem scales.



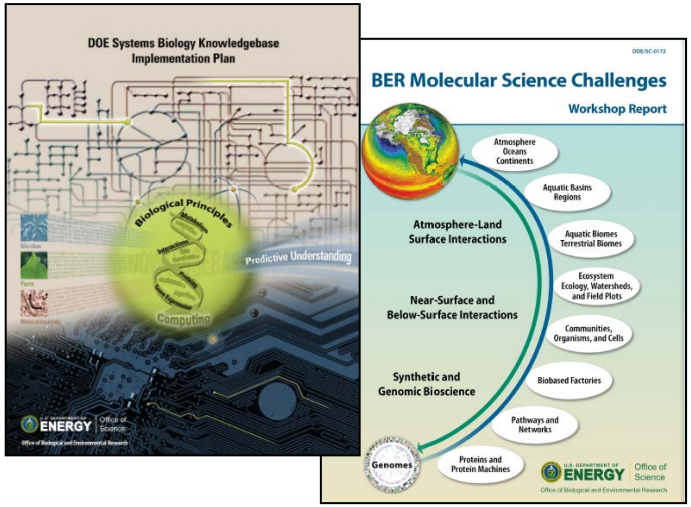


Enabling Technologies

Goal: Develop the enabling computational, visualization and characterization capabilities to integrate genomic information with functional information on biological processes.

High Performance Computational Platforms for Systems Biology Research

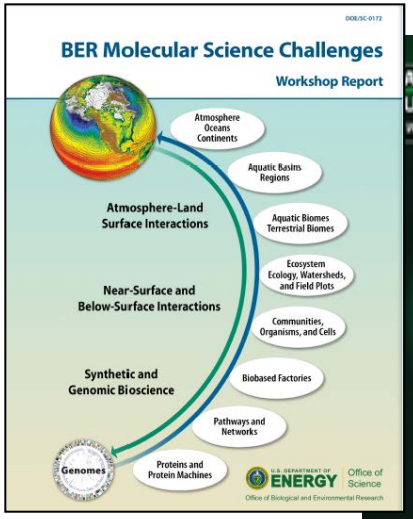
- Leverage open access cloud-based cyberinfrastructure platforms operating on high-performance computers to enable the performance of complex and diverse integrated genomic-based analyses among researchers.
- Develop tools to simplify the analysis of complex, large scale “omic” data and assemble the results in an experimental tractable format.
- Capabilities to reproducibly share large-scale “omics” analyses with other researchers.
- Assembling models of single and multicellular organisms and communities to gain a predictive understanding of the plant and microbial community function.



Enabling Technologies Cont'd

Molecular Scale Science and Bioimaging Technology for Systems Biology

- Combine structural information on biomolecules with computation and/or bioinformatics to infer function and improve genome annotation or design new functions.
- Visualize the spatial and temporal dynamics of expressed biomolecules within living plant or microbial cells or within microbial communities.
- Use visualization techniques to validate predictions/simulations of cellular dynamics.
- Develop multifunctional, bioimaging technology capabilities and scientific infrastructure for measuring, analyzing and modeling whole cell and multicellular biological systems.
- Develop *in situ*, dynamic, and nondestructive approaches to multifunctional imaging, quantitative flux measurements, and multiscale integrative analysis of biological systems.

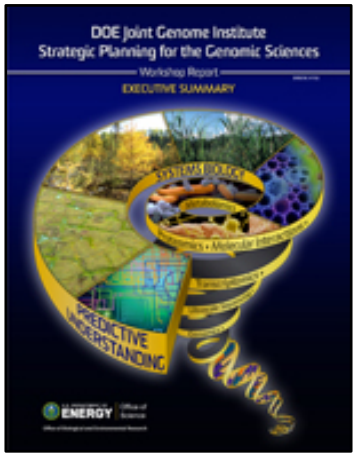


User Facility Capabilities and Integration

Goal: Broaden the integrative capabilities within and among DOE user facilities to foster a more interdisciplinary approach to BER-relevant science and aid interpretation of plant, microbe and microbial community biology.

Genome Sequence Production and Interpretation (DOE Joint Genome Institute)

- Continued leadership in genome sequencing technologies.
- Development of large-scale DNA synthesis and genomic manipulation capabilities.
- New analysis techniques to compare genomic data to improve structural and functional genomic annotations.
- Development of new high throughput phenotyping technologies to support genomic functional annotation with experimental data.
- Incorporation of high performance computing into genome analysis capabilities.
- Collaborations and joint user access activities with other DOE user facilities with complementary capabilities for interpreting gene and genome function.



Research Coordination

Bioenergy Research
U.S. Department of Agriculture
DOE Advanced Research Projects Agency – Energy (ARPA-E)
DOE- Office of Energy Efficiency and Renewable Energy (EERE)
BER – Climate and Environmental Sciences Division

Biosystems Design
National Science Foundation (NSF)
DoD – Defense Advanced Research Projects Agency (DARPA)

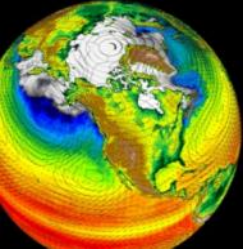
Environmental Research
BER- Climate and Environmental Science Division

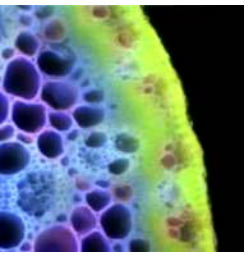
Computational Capabilities
DOE – Office of Advanced Scientific Computing Research (ASCR)
BER – Climate and Environmental Sciences Division

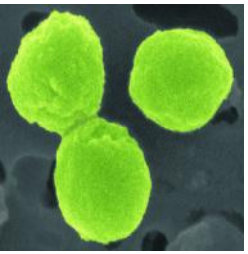
Molecular Scale Science and Bioimaging Technology
NIH- Structural biology and Biomedical Technology
DOE National Scientific User Facilities

User Facility Integration
DOE National Scientific User Facilities
NIH – Structural Biology Capabilities

In addition to coordinating under the umbrella of the National Science & Technology Council (NSTC)







Systems science to meet DOE mission needs in bioenergy and the environment.

http://science.energy.gov/ber/

Thank you!

http://genomicscience.energy.gov/index.shtml