Research Activity: **Energy Biosciences Research**

Division: Chemical Sciences, Geosciences, and Biosciences
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Portfolio Description:

The Energy Biosciences program supports fundamental research in the plant and microbial sciences. The mission of the program is to create a science base to inspire future energy-related biotechnologies. This includes:

- Mechanistic studies on solar energy capture by plants and microbes through photosynthesis;
- Research on the mechanisms and regulation of carbon fixation and carbon/energy storage;
- Examination of metabolic pathways for biological synthesis, degradation and molecular interconversions;
- Experimental activities focused on the regulation of plant growth and development;
- Studies on novel biosystems and their potential for material synthesis and catalysis; and
- Coordinate and collaborate with other DOE and federal funding programs to assure rapid scientific advances related to energy-related biotechnologies.

Unique Aspects:

The Energy Biosciences program is the sole federal program devoted to the fundamental science underlying the use of biological systems to produce and conserve energy.

- Prime provider of funding for molecular research on plants without a focus on traditional crops and agricultural bioprocesses.
- Major supporter of research on microbial systems that have broader emphases than model systems currently used in the biomedical community.
- Energy Biosciences occupies an unusual niche within DOE at the interface between the life sciences and physical sciences that can promote multi- and cross-disciplinary research activities to study biological systems.

Relationship to Others:

The program strives to support fundamental research that may influence the directions of the biotechnology-related programs in the Office of Energy Efficiency and Renewable Energy (including Transportation Technologies, Industrial Technologies, and Power Technologies); Office of Fossil Energy; and the Office of Environmental Management. The program collaborates and coordinates its activities with NSF, USDA and NIH in areas of mutual interest where there are multiple benefits.

Significant Accomplishments:

The program has had a significant impact on the scientific disciplines supported. Among the longer term accomplishments are determining the biosynthetic pathway for biological methane production from CO_2 and molecular hydrogen; the elucidation of the biochemistry and genetic regulation of plant lipid synthesis; determining the carbohydrate chemistry and structure of plant cell walls; and providing a central role in developing *Arabidopsis thaliana* as a model plant experimental system. Scientists supported by the program have received numerous awards and prizes including the 1997 Nobel Prize to Dr. Paul Boyer for his work on ATP, the energy currency of living systems.

Mission Relevance:

The program focuses on plants and microbes as biological systems that capture solar energy through photosynthesis, store photosynthetically-fixed carbon into a variety of organic compounds including potential as fuels and chemical feedstocks, or can convert plant-derived or industrial waste materials into useful chemicals and fuels. The program strives for mechanistic understanding that will provide potential technical options to use whole plants and microbes or their components in energy-related processes. New commercial activities in ethanol production, pulp and paper

manufacturing, and *in planta* production of oils are examples of technical options built on the foundations laid by the Energy Biosciences program.

A goal of the Department of Energy by the year 2050 is to dramatically increase the utilization of bioenergy resources. Renewable resources (agricultural, industrial and forestry wastes and specialty energy crops and trees) currently supply three percent of the nation's total current energy consumption. A major increase in bioenergy production is an extremely ambitious goal with anticipated societal benefits of enhanced national energy security, improved environmental protection involving carbon neutral processes, improved rural economic growth, and long-term sustainable global development. There is considerable bipartisan support for expanded use of sustainable and renewable energy resources and it is likely to remain a focal point of the Department's activities in the future. A major role of the Energy Biosciences program is to provide the fundamental knowledge base for achieving these goals.

Scientific Challenges:

Traditionally, mechanistic biology has been summarized and catalogued in relatively simple linear models. Analysis of both spatial and time-dependent dynamics and its subsequent integration in a coherent fashion represents a significant challenge, but also new opportunities. Another enormous scientific challenge facing all biology is to assimilate the vast amounts of genomic-sequence data and associate them with specific biochemical, physiological and developmental processes. Studies specific to energy-related organisms and processes must be rationally integrated with the broader biological efforts. Whole genome analysis of plants and microbes may reveal unknown genetic capacity with relevance to energy-related processes and potential biotechnological applications and thus represents another important challenge. The vast majority of metabolic studies have focused on hydrocarbons and the major nutrient elements nitrogen, sulfur and phosphorous. There are other elements that are metabolized extensively by microbes. Microbial mineral respiration offers unique challenges on the interface of several traditional disciplines.

Funding Summary:

Dollars in Thousands

FY 2000	FY 2001	FY 2002
$29,850	$31,853	$31,559

Performer	Funding Percentage
DOE Laboratories	7.0%
Universities	83.0%
Other	10.0%

The program is providing support for 270 specific activities in FY2001.

- 7 percent of the research funds allocated go to the National Laboratories and 93% of the funds are provided to academia and other non-profit institutions.
- The research programs cooperate with many private companies; however, the only direct financial support provided to the industrial sector is through the SBIR/STTR program.
- The program provides substantial funding for two dedicated institutes, the Michigan State University/ Department of Energy Plant Research Laboratory and the Complex Carbohydrate Research Center at the University of Georgia.

Projected Evolution:

The plant sciences research supported at DOE has evolved considerably from the late nineteen forties where the emphases were on radiation damage and breeding to demonstrate the peaceful use of the atom. Today, knowledge of the complete sequence of *Arabidopsis* is expected to elicit a number of new research approaches. The traditional

strengths of the program in bioenergetics and biochemistry will likely be greatly influenced by the results of these analyses as new strategies to study and manipulate molecular structures and processes are developed.

The core program activities in the microbial sciences have evolved since inception as scientific opportunities and technical needs change. Currently, the large-scale genome projects in microbiology are providing new ways of easily and quickly identifying appropriate genetic material. Gene identification is critical if one wants to alter the protein produced in order to study the role of the protein in the microbe or to mechanistically study enzyme function. The physical organization of the microbial genome is also providing information about the number and types of genes involved in a particular biochemical and physiological process. This information can provide insights to develop hypotheses on protein processing and assembly, pathway delineation and process regulation. The research supported during the next five years is expected to reflect these new opportunities.

Research activities at the interface between biology and the physical sciences, earth sciences and engineering will continue to be explored based on the philosophy that the best interdisciplinary studies are true partnerships where all participating communities benefit.

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