Research Activity: **Energy Biosciences Research**
Division: Chemical Sciences, Geosciences, and Biosciences
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Portfolio Description:

This activity supports fundamental research required to understand and use biological energy, and to adapt strategies used by plants and microorganisms to capture, store, and mobilize energy. The program relies upon biochemical, physiological, and genetic methods to investigate and manipulate organisms and their biological processes. Emphasis is given to areas where these biological sciences intersect with energy-relevant chemical sciences; these include: (1) Mechanistic, molecular and biophysical studies on photosynthetic energy capture by plants and microbes. This entails research on light harvesting, exciton transfer, charge separation, transfer of reductant to carbon dioxide and initial reactions of carbon fixation and carbon storage. (2) Regulation of plant growth and development. Projects supported in this area focus on mechanisms that generate differentiated cells and cell-type determinations that are central to changing the properties and/or relative amounts of plant tissues for future use. (3) Understanding and manipulating plant biochemistry to increase levels of desirable components. This thrust investigates plant components with state-of-the-art biophysical, biochemical and chemical approaches, as well as ways in which plants generate and assemble components using the tools of biochemistry, physiology, and structural biology. (4) Metabolic pathways. Projects in this area examine biological syntheses and molecular interconversions with emphasis on novel systems for material production and chemical catalysis. (5) *In-situ* imaging of biological energy-tranduction systems. This research provides fundamental structural, chemical and biophysical knowledge required to improve natural light-harvesting and energy transformation systems, as well as for the design of biomimetic solar conversion systems. (6) Non-covalent biological interactions. Projects focus on mechanisms that govern self-assembly of biological components into complex systems, as well as studies that allow for their self repair. (7) Partitioning in plants and microbes. Priority is placed on projects that will allow for intelligent design of bioseparations and bioinspired separation technology.

Unique Aspects:

The Energy Biosciences program is the sole federal program devoted to fundamental science that underlies the use of biological systems to produce and conserve energy. It occupies an essential niche within the Department of Energy (DOE) at the interface between the life sciences and physical sciences and, thereby, promotes multi- and cross-disciplinary research activities. The program will generate a science base to inspire future energy-related biotechnologies and technologies that mimic biological systems.

Relationship to Other Programs:

The research effort interfaces with several activities within BES, including Photochemistry and Radiation Research in the area of biomimetic photosynthetic systems and Catalysis and Chemical Transformations in the area of biocatalysis. The program also supports basic research that may influence the directions of biotechnology-related programs in the DOE Office of Biological and Environmental Research, the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy, and the Office of Environmental Management. The program collaborates and coordinates its activities with the National Science Foundation, U. S. Department of Agriculture, and National Institutes of Health in areas of mutual interest where there are multiple benefits.

Significant Accomplishments:

The program has a rich history of scientific impact. Among longer term accomplishments are the determination of the biosynthetic pathway for 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:

Enhanced understanding regarding how plants and microbes as biological systems capture solar energy through photosynthesis, biochemically transduce it, and store photosynthetically-fixed carbon into a variety of organic compounds is essential for future energy independence. The program strives for mechanistic knowledge that will provide potential technical options to use whole plants and microbes, their components, or biomimetic systems 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.

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. This is relevant to much needed molecular and biophysical studies on real-time control of photosynthesis, particularly mechanisms of light harvesting and energy transduction in microbes and chloroplasts as well as maintenance of the biological integrity of these systems. Understanding biological interactions that occur on the nanoscale is an immense challenge as well, but, when coupled to advances in molecular biology, it offers considerable dividend. An 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 their life processes must be rationally integrated with the broader, interdisciplinary efforts, such as with the chemical and physical sciences.

Funding Summary:

Dollars in Thousands

	FY 2005	FY 2006	FY 2007 Request
Molecular Mechanisms	13,640	12,411	18,188
Metabolic Regulation of Energy Production	19,427	17,554	17,601
Energy Biosciences Research (Total)	33,067	29,965	35,789

Performer	Funding Percentage
DOE Laboratories	9 %
Universities	90 %
Other	1 %

Funding numbers do not include awards for conferences or training activities.

Projected Evolution:

Plant sciences research supported at DOE has evolved considerably from the late 1940s, when the emphasis was on radiation damage and breeding to demonstrate the peaceful use of the atom. Recent advances in sequencing plant genomes provide new opportunities to leverage the traditional strengths of the program in genomics and biochemistry with powerful capabilities in imaging and computation. For example, this will allow for an unprecedented biophysical understanding of photosynthesis at the nanoscale. Similarly, molecular and biochemical studies on microbes with novel metabolic capabilities, tolerance of extreme conditions, and/or efficient catalytic mechanisms will allow for efficient energy and chemical conversion strategies. Through an integrated approach, efficient future conversions can likely be accomplished by a plant in conjunction with a microorganism (the coupling of green and white biotechnology).

A unique aspect of biological systems is their ability to self-assemble and self-repair. These capabilities occur via complex, poorly understood processes, and much work is needed before application to synthetic or semi-synthetic energy systems may be realized; however, the potential in this area of prospective study is immense. Future impact is also envisioned through increased research in natural photosynthesis to serve as a basis for biomimetic solar conversion systems, amplified use of experimental and computational tools from the physical sciences (ultrafast laser spectroscopy, current and future x-ray light sources, quantum chemistry) to probe biological energy transduction systems, and enhanced efforts in molecular biology and biochemistry that are relevant to improved chemical processes.