

Biosystems Design

Report from the July 2011 Workshop

Convened by
U.S. Department of Energy
Office of Science
Office of Biological and Environmental Research



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Executive Summary

Growing energy demand cannot be met by nonrenewable fossil fuels, and consequently, alternative energy sources are intensively being pursued. Cellulose, a very stable carbohydrate that makes up plant cell walls, is a potential source of renewable fuels. Transforming cellulose into liquid fuels, however, requires substantial chemical and biological processing, first to extract the sugars that comprise the cellulose and then convert those sugars into fuels. These requirements pose major hurdles to sustainable biofuels production, but overcoming them may be possible by engineering new plants that facilitate the extraction and conversion of their cell walls into liquid fuels. Similarly, newly designed microbes capable of metabolizing plant cell wall components can simplify biomass processing for fuel conversion. Other microorganisms such as microalgae and cyanobacteria can be redesigned to incorporate new functionalities. For example, these photosynthetic organisms, which capture light and convert it into chemical energy, can be re-engineered to produce biofuels, including biodiesel, directly from sunlight.

Technological advances enabling the design of new biological systems are already moving biofuels closer to becoming a viable, alternative renewable energy resource. Further advances are necessary for developing useful bioenergy crops that not only allow facile conversion of biomass into biofuels, but also do not compete with food crops for arable land. In other words, crops must be rationally redesigned to produce high biomass yields on marginal agricultural lands and under changing weather conditions.

To explore the current state-of-the-art in the field of biosystems design, discuss new biodesign technologies and approaches, and identify key scientific challenges and knowledge gaps, the Department of Energy's Office of Biological and Environmental Research organized the Biosystems Design Workshop in July 2011 in Bethesda, Maryland. The workshop's goal was to bring together scientific leaders in microbiology, plant biology, metabolic engineering, systems biology, bioinformatics, computational modeling, and other relevant disciplines to examine fundamental aspects of biosystems design from molecules to organisms to communities. The focus was on the fundamental biological principles that must be harnessed to make biological design possible as well as the tools and computer-aided testbeds needed to design, prototype, and functionally validate multiscale natural and hybrid biological systems.

Building on the outcomes of the genomic revolution that altered the course of biological research in the last decades, biosystems design research will identify modular components that can be modified, enhanced, and exchanged among different organisms, enabling the manipulation of biological systems. With the help of computational modeling, de novo design of new organisms with novel capabilities for defined purposes will be possible. These new biological systems and modules will not only generate new, useful functions but also provide powerful tools to further our understanding of the fundamental principles that rule biology.

The time is ripe for bold new research approaches that harness biology's potential. These approaches include designing new biosystems to address critical needs, such as sustainable production of advanced liquid biofuels, while contributing to carbon sequestration and reduction of greenhouse gas emissions and improving nutrient and water-use efficiency of bioenergy crops. The field of biosystems design will enable living organisms to be manipulated and tailored in unprecedented ways, paving the way for a bioeconomy that can meet our energy needs while minimizing impacts on the environment.

