NSF Biofuels Activities

BRDI TAC Meeting

December 3, 2008

John Regalbuto
Director
Catalysis and Biocatalysis Program
Directorate for Engineering

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Outline

- Intro to NSF
- Types of Biofuels-related grants
  - Sustainability
  - EHS
  - Conversion
  - Societal Impacts and Education
- Recent Developments at NSF in Biofuels
  - NSF Participation in the Board
  - Emerging Frontiers in Research and Innovation topic
  - Engineering Research Center
- Summary

United States Government

Office of Management and Budget

Science Advisor
Office of Science and Technology Policy

Other boards, councils, etc.

Major Departments

Agriculture

Health and Human Services

Interior

Homeland Security

Transportation

Defense

Energy

Commerce

Independent Agencies

National Aeronautic and Space Administration

Environmental Protection Agency

Smithsonian Institution

Nuclear Regulatory Commission

Other agencies

NSF in the Federal Context

DOE is entrusted to contribute to the welfare of the nation by providing the scientific foundation, technology, policy and institutional leadership necessary to achieve efficiency in energy use, diversity in energy sources, a more productive and competitive economy, improved environmental quality, and a secure national defense.

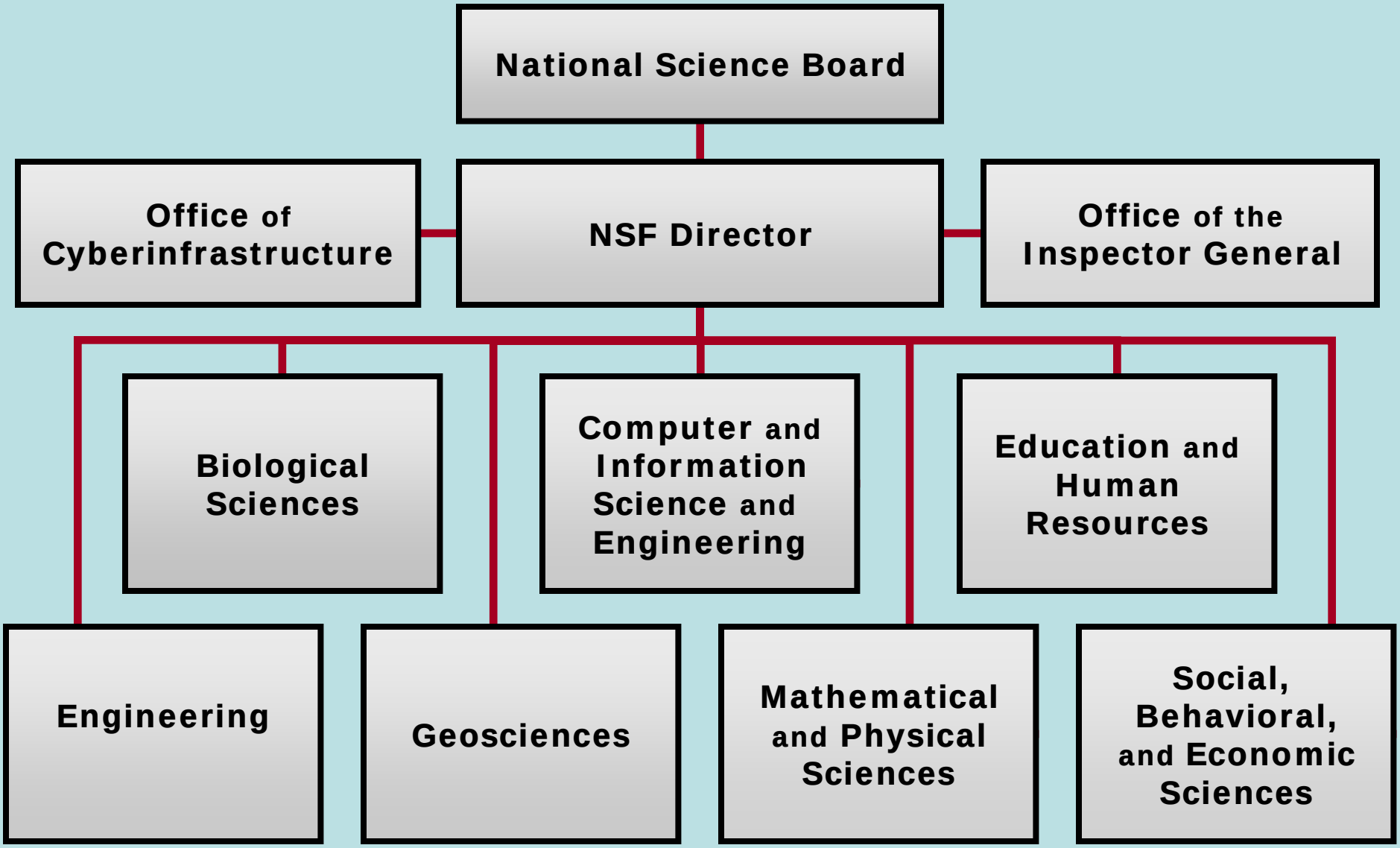
DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.

Translated:
- milestones
- stage gates

NSF:
To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

Translated:
- "Do I really have to submit a final report?"

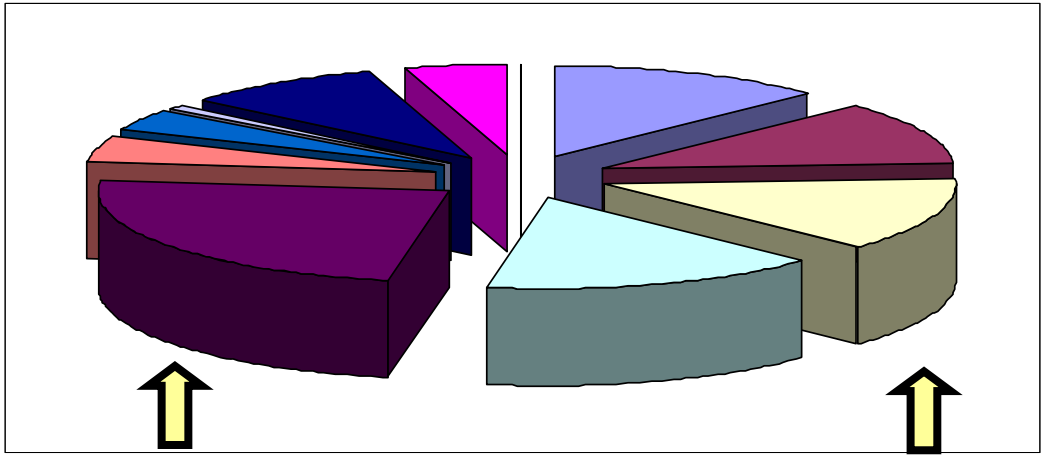
National Science Foundation



NSF Budget by Research Directorate

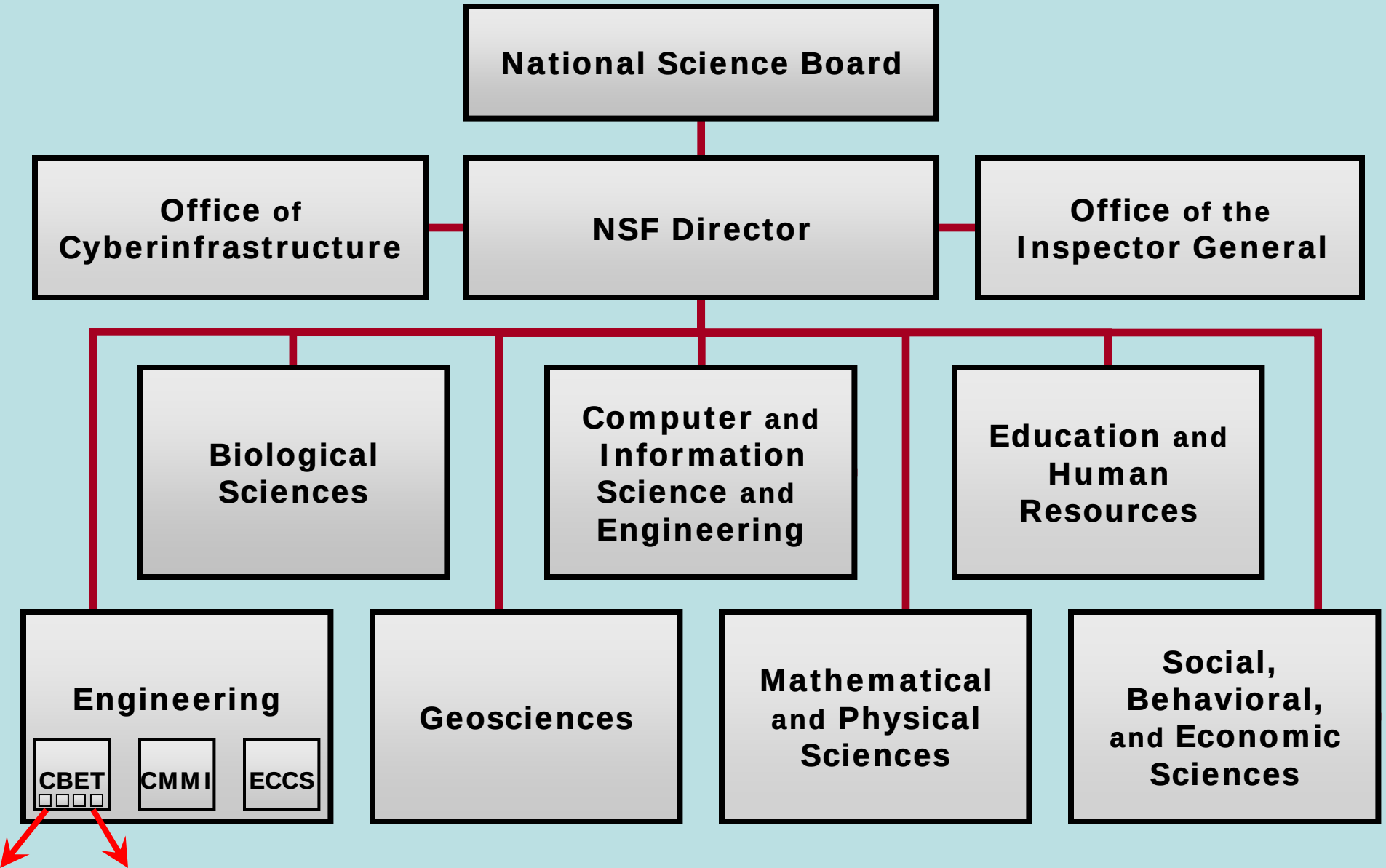
Dollars in Millions

Directorate	FY 2007 Actual
BIO	$608.54
CISE	526.68
ENG *(less SBIR/STTR)*	521.33
SBIR/STTR	108.67
GEO	745.85
MPS	1,150.73
SBE	214.54
OCI	182.42
OISE	40.36
OPP	438.43
IA	219.45
U.S. Arctic Research Commission	1.45
Research & Related Activities	$4,758.44

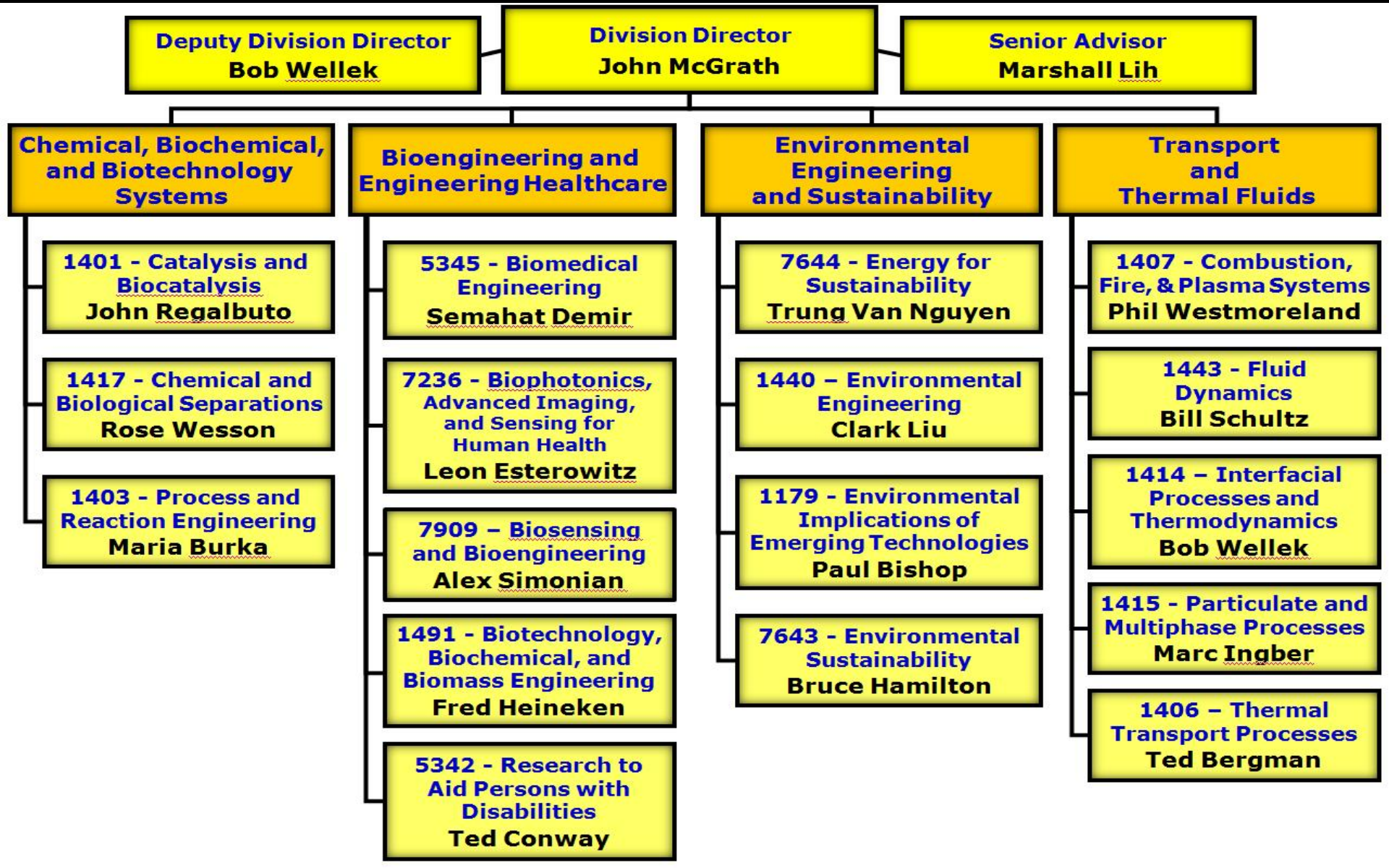


MPS: 24% **ENG: 13%**

National Science Foundation



National Science Foundation



Directorate for Biology

- Much fundamental plant research (feedstock production, sustainability)

- iPlant Collaborative
  - Includes education and societal impact efforts

Plant Genome Research Program

Summary - Supports research on plant genomics and on accelerating the analysis of fundamental biological processes in plants. Focuses on plants of economic importance and plant processes of potential economic value.

Example award: 0501720 "Genes Required to Make a Soybean Seed" (Robert Goldberg, UCLA, $11.9 million).

Maize Genome Sequencing Project:
An NSF/DOE/USDA Joint Program

Summary - **Large-scale sequencing of the maize genome is being supported.**

Funding – **Approximately $30 million over 3 years is being invested. No longer receiving proposals.**

ABOUT IPC
- Project Overview
- Cyberinfrastructure
- Education, Outreach and Training
- Social Science
- Collaboration
- Board of Directors
- Principal Project Personnel
- Director's Log
- Your Privacy
- Email iPC Webmaster

Project Overview

The Plant Science Cyberinfrastructure Collaborative (PSCIC) program is intended by NSF to create a new type of organization – a cyberinfrastructure collaborative for the plant sciences - that would enable new conceptual advances through integrative, computational thinking. To achieve this, we have developed the "iPlant Collaborative" (iPC). The iPC will be fluid and dynamic, utilizing new computer, computational science and cyberinfrastructure solutions to address an evolving array of grand challenges in the plant sciences. It will be community-driven, involving plant biologists, computer and information scientists and engineers, as well as experts from other disciplines, all working in integrated teams. The iPC brings together strengths in plant biology, bioinformatics, computer science and high throughput computing as well as innovative approaches to education, outreach, and the study of social networks.

Several key principles guided our development of the iPC. Specifically, the iPC:

- is a cyberinfrastructure collaborative rather than purely a cyberinfrastructure,
- will enable multi-disciplinary teams to address grand challenges in plant science,
- will be an entity that is by, for and of the community,
- will train the next generation in computational thinking, and
- is designed to be able to reinvent itself as needs and technologies change.

"… a cyberinfrastructure collaborative for the plant sciences…"

The driving force behind the iPC is the nature of the grand challenges of the plant sciences, and all facets of the Collaborative are organized around those selected questions. The act of selecting these questions will be community-driven, and to facilitate that, we will host a series of workshops, each focused on a specific area of plant biology, but with participants cutting across the spectrum of the computational and biological sciences. The goal of each workshop will be to identify the "grand challenge" questions in that field, as well as the necessary strategies and approaches that will be needed to solve the question(s). Self-forming Grand Challenge Teams from the community (chosen by a community-representative Board of Directors) will then work with iPC personnel to develop 'Discovery Environments' (DEs), each of which will be a cyberinfrastructure within which the GC team (and the community) will address and solve the grand challenge (and related problems of interest). It is anticipated that DEs designed for different grand challenges will overlap and coalesce into a comprehensive cyberinfrastructure for the whole of the plant sciences. To achieve this coalescence, it will be necessary to simultaneously address 2-4 grand challenges covering a broad range of plant biology, from the molecular, cellular and developmental to the organismic, ecological, and evolutionary

NSF Funding:
$50 million

iPlant Conferences

The following is a list of conferences that have already taken place. You may still view the details of each conference, as well as any available archived footage.

- Climate Change *Sep 30–Oct 3, 2008*
- Mechanistic Basis of Plant Adaptation *Sep 30–Oct 3, 2008*
- Mechanistic Models *Nov 7–Nov 10, 2008*
- Assembling the Tree of Life to Enable the Plant Sciences *Nov 19–Nov 23, 2008*

Acknowledgements: The iPlant Collaborative is funded by a grant from the National Science Foundation Plant Cyberinfrastructure Program (#EF-0735191).

Long Term Ecological Research (LTER)

NSF Award LTER-0080382 (University of Minnesota)
$4,561,563

***Science* 314 :1598-1600 (2006)**

"Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass"

David Tilman, Jason Hill, Clarence Lehman

MUSES Program

(Materials Use: Science, Engineering, and Society)

Summary - MUSES funds research on understanding the supply, treatment, use, and reuse of resources provided by natural systems as well as the environmental effects of introducing alternative materials or new processes.

Funding – Total program about $4 to $6 million per year (ran for 5 years).

MUSES Program

MUSES called for interdisciplinary proposals that covered both:

Technological issues such as environmentally benign process redesign and manufacturing, and

Behavioral factors such as economic and other social forces that affect consumption and adoption of new technologies and materials.

An international workshop on

Assessing the Sustainability of Bio-based Products

Thursday – Friday, 26-27 June 2003
University of Oklahoma
Norman, Oklahoma

Supported by:

The National Science Foundation

Organized by:

The University of Oklahoma

Coordinated by National Conference Logistics Center
The University of Oklahoma
College of Continuing Education

MUSES: EXAMPLE GRANT #1

Award #0424700

"Biocomplexity in the Bioeconomy: the Natural and Industrial Ecology of Biobased Products"

$1.85 million over 5 years

PI = Rob Anex (Iowa State University, Engineering)

Co-PI = Lee Lynd (Dartmouth, Engineering)

Co-PI = Thomas Richard (Penn State, Engineering)

Co-PI = Clare Hinrichs (Penn State, Sociology)

Co-PI = Suzie Greenhalgh (World Resources Institute, Economics)

MUSES: EXAMPLE GRANT #2

Award #0524872

"Renewable Energy from Forest Resources: An Investigation into the Viability of Large-Scale Production of Sustainable Transportation Fuels from Lignocellulosic Biomass"

$1.7 million over 5 years

PI = Ann Maclean (Michigan Tech. Univ, Forest Resources)

Co-PI = David Flaspohler (MTU, Forest Resources)

Co-PI = David Shonnard (MTU, Chemical Engineering)

Co-PI = Kathleen Halvorsen (MTU, Social Sciences)

Co-PI = Barry Solomon (MTU, Social Sciences)

MUSES: EXAMPLE GRANT #3

Award #0628084

"Materials Use, Infrastructural Change, and Environmental Impacts for Alternative Fuels and Vehicles"

$1.5 million over 5 years

PI = Lester Lave (Carnegie-Mellon Univ., Economics)

Co-PI = Chris Hendrickson (CMU, Civil & Environmental Engineering)

Co-PI = H. Scott Matthews (CMU, Civil & Environmental Engineering)

Co-PI = Michael Griffin (CMU, Green Design Initiative)

Co-PI = Jeremy Michalek (CMU, Mechanical Engineering)

Metabolic Engineering

- **Explicitly cited as an area for research support in the Biomass Research and Development Act of 2000 (renewed in the Energy Policy Act of 2005).**
- **Sec. 307. Biomass Research and Development Initiative:**

(d) Uses of Grants, Contracts, and Assistance

(2) research on technologies

(A) *metabolic engineering* of biological systems...to produce novel products, especially commodity products, or to increase product selectivity and tolerance, with a research priority for the development of biobased industrial products that can compete in cost and performance with fossil-based products.

Interagency Opportunities in Metabolic Engineering

Program Solicitation
NSF 05-502
Replaces Document nsf03516

National Science Foundation
Directorate for Engineering
Division of Bioengineering and Environmental Systems
Directorate for Biological Sciences
Division of Integrative Organismal Biology
Division of Molecular and Cellular Biosciences
Directorate for Mathematical and Physical Sciences
Division of Chemistry

U.S. Dept. of Energy

Department of Defense

Department of Commerce

Metabolic Engineering

Example grant: 0418157 “Genomic Approaches to Metabolic Engineering of Solventogenic Clostridia”

Terry Papoutsakis, Northwestern University

~$600K over 3 years

(Think: butanol as a biofuel)

IGERT

IGERT = Integrative Graduate Education and Research Traineeships

- Each grant about $2.5 - $3 million over 5 years
- For each grant, most of the funds go to support a “cohort” of about 15 graduate students at an IGERT site
- Emphasizes interdisciplinary research and education
- About 150 IGERT sites across the country

IGERT: EXAMPLE GRANT #1

Award #0549399

"Sustainable Energy from Solar Hydrogen"

(hydrogen generated from sustainable solar-derived energy such as photovoltaics or biomass)

About $2.5 million over 5 years

Christiana Honsberg

University of Delaware

EHR: EXAMPLE GRANT

Award #06033308

"Biotechnology Curriculum Development and Dissemination"

$737,000 over 3 years

R. Klepper

University of Iowa

EPSCoR

(Experimental Program to Stimulate Competitive Research)

Example grant: **0554545** "Investing in Maine Research Infrastructure: Sustainable Forest Bioproducts"

-$6.9 million from NSF EPSCoR over 3 years, plus $3.45 million from the state of Maine.

- Lead institution is the University of Maine, partnered with other educational, public, provate, and non-profit institutions.

-Includes wood chips to biofuels and bioproducts.

ENG IIP's SBIR/STTR Program

Summary **- Supports research at small businesses. From ENG/NSF, over $100 million per year.**

Example grant : **0522310**

"SBIR Phase II: Designer Cellulases for Biomass Conversion"

PI = William Coleman, Kairos Scientific, Inc. $500,000 over 2 years).

NSF Program Contact **–** Kesh Narayanan

Biochemical and Biomass Engineering, and Biotechnology

Example grant: 0328187

"Functional and Structural Analysis of Algal Hydrogenase Combinatorial Mutants"

Dianne Ahmann

Colorado School of Mines (Golden, CO)

$246,020 over 3 years

Biochemical and Biomass Engineering, and Biotechnology (continued)

Example *CAREER* grant: **0645188**

"Understanding and Harnessing the Fermentative Metabolism of Glycerol in E. coli: A New Path to Biofuels and Biochemicals"

Ramon Gonzalez, Rice Univ.

$400,000 over 5 years

Catalysis and Biocatalysis

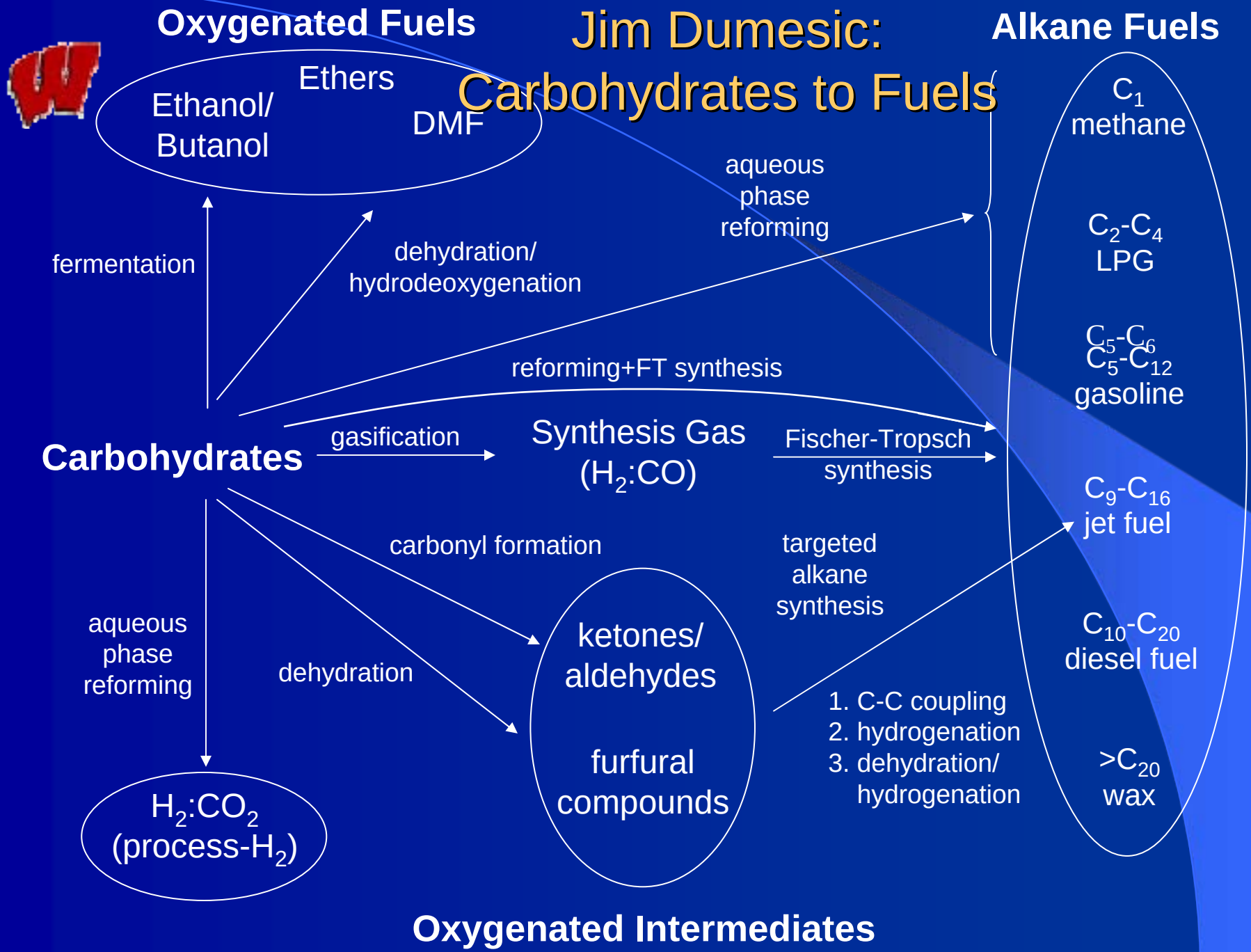
Summary - **This program primarily supports fundamental and applied research, including, but not limited to, sustainability and green chemistry and utilization of biorenewable resources.**

Example grant: **0456693 "Selective Production of Large Water Soluble Organics from Biomass" (James Dumesic, U. of Wisc.-Madison, $296,695 over 3 years.**

Funding **– Approximately $6 million per year for all subjects.**

Program contact – **John Regalbuto**

Jim Dumesic: Carbohydrates to Fuels



Virent Energy Systems Overview

- Founded in 2002 by Dr. Randy Cortright and Professor Jim Dumesic from the Department of Chemical Engineering of the University of Wisconsin

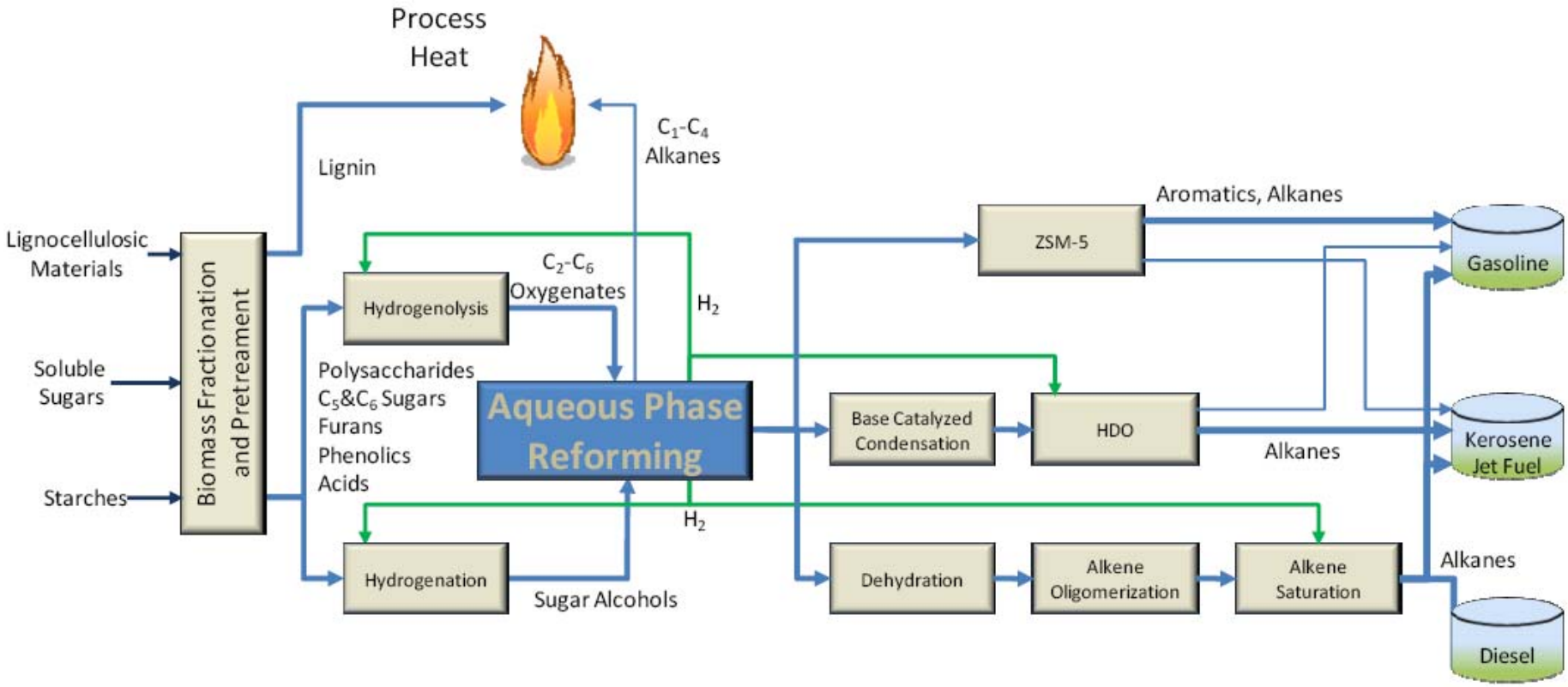
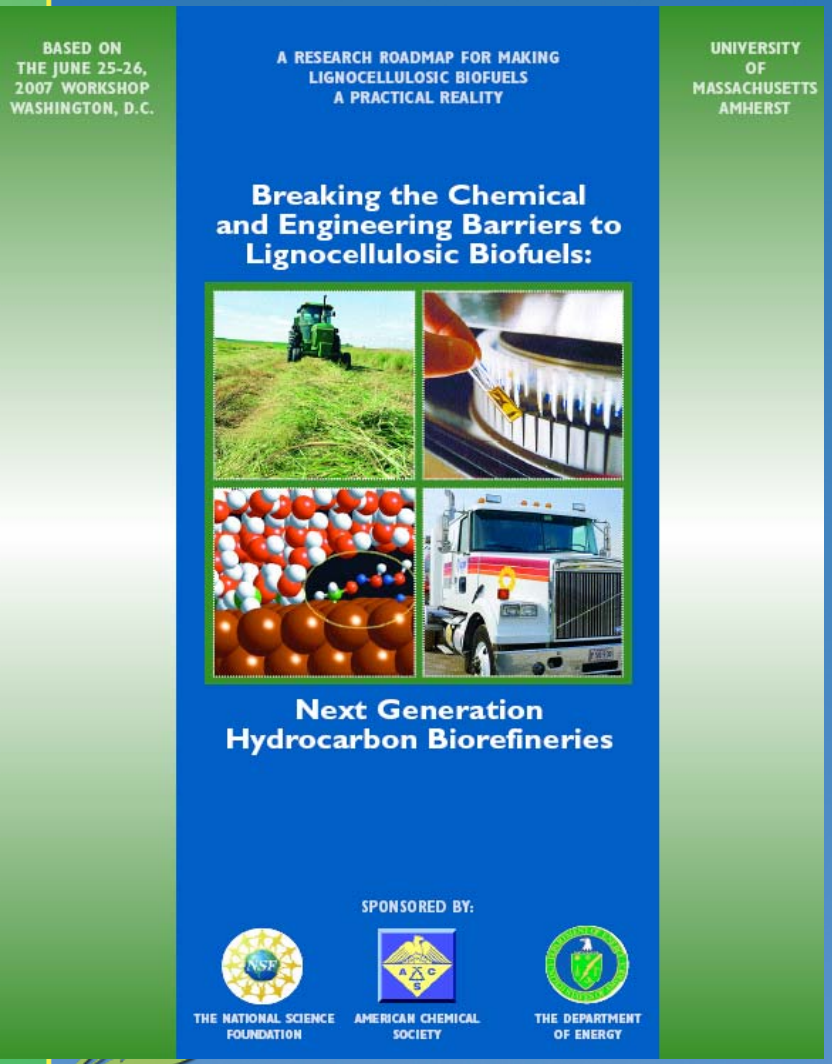


Figure 1. Virent's BioForming® process to produce conventional liquid transportation fuels from biomass feedstocks. APR enables the process to partially defunctionalize carbohydrate feedstocks for further catalytic upgrading.

Roadmap for Hydrocarbon Production

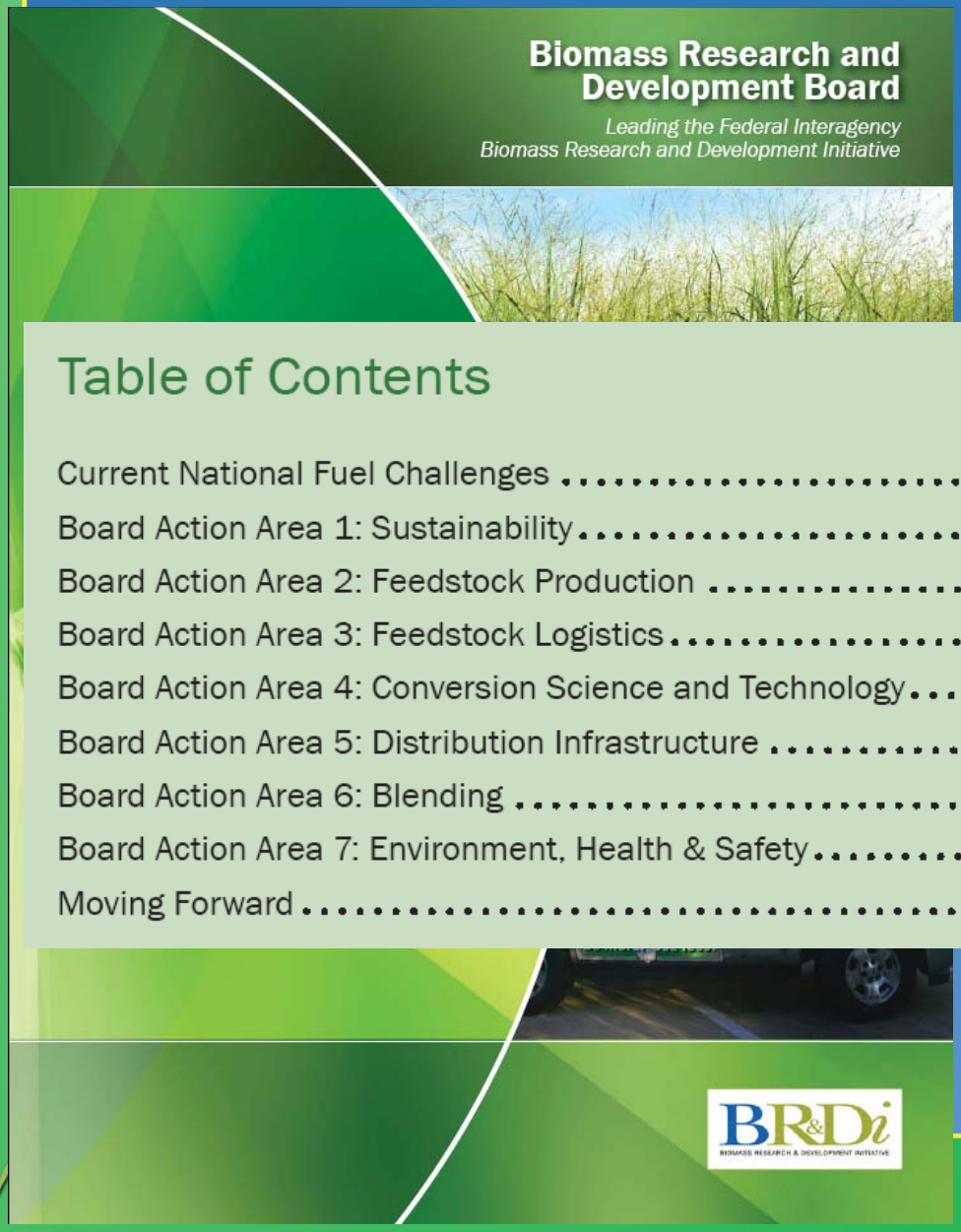


- 2007 NSF/ENG and DOE/EERE Cosponsored Workshop in June, 2007
- Final Report Released April 1, 2008
  - www.ecs.umass.edu/biofuels/roadmap.htm
- Input for Interagency Working Group on Biomass Conversion

NSF Involvement Timeline

- C2B workshop (NSF/DOE), summer 2007
- Dr. Bement suggests BCIWG, fall 2007
  - NSF involvement in most WGs
- Congressional R&D Caucus, Oct. 4, 2007
  - "Green Gasoline: An Alternative Alternate Fuel"
- NAP rewritten to include lignocellulosic hydrocarbon biofuels, winter 2008
- BCIWG completes Federal Research Inventory, May 2008
- Congressional Briefing, Sept. 24, 2008
  - "Green Gasoline: A Renewable Petroleum Alternative from Plants"
- BCIWG to complete 10 Year R&D Plan, Dec. 2008
- HyBi EFRI at NSF/ENG, FY 2009
- Programs at other agencies

NSF Involvement in Biofuels



NSF ENG Program Directors WG members:

→B. Hamilton, A. Russell (BIO)
→B. Hamilton
→B. Schultz
→J. Regalbuto (Chair)

→P. Bishop

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Biofuels 101: Routes to Biofuels

John R. Regalbuto
Catalysis and Biocatalysis Program
National Science Foundation

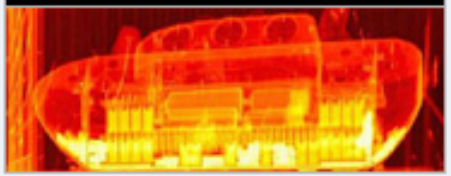
Congressional Briefing
Sept. 24, 2008

A Renewable Petroleum Alternative from Plants



NSF

Emerging Frontiers in Research and Innovation (EFRI)



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ENG Organizations

Chemical, Bioengineering, Environmental, and Transport Systems (CBET)

Civil, Mechanical and Manufacturing Innovation (CMMI)

Electrical, Communications and Cyber Systems (ECCS)

EMERGING FRONTIERS IN RESEARCH AND INNOVATION 2009 (EFRI-2009)

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PROGRAM GUIDELINES

Solicitation 08-599

DUE DATES

Preliminary Proposal Deadline Date : December 2, 2008

Full Proposal Deadline Date : April 30, 2009

ENG EEC's ERC Program

Summary -The goal is to create a culture of innovation in engineering research and education that links scientific discovery to technological innovation through transformational engineered systems research in order to advance technology and produce engineering graduates who will be creative innovators in a global economy.

Example grant in ERE area: 0813570

"ERC for Biorenewable Chemicals"

PI = Brent Shanks, ISU

Potentially $30-40 million over 10 years

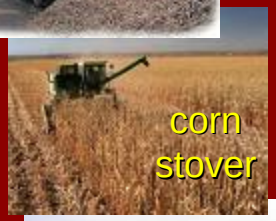
NSF Program Leader – Lynn Preston

Summary

- Many longstanding programs with fundamental research relative to biofuels
  - Plant Genomics, Metabolic Engineering (interagency)
  - MUSES: science and society
  - IGERT, EHR: education
- Unquotable budget estimates:
- Recent Developments at NSF in Biofuels
  - Active NSF Participation in the BRDI Board
  - Emerging Frontiers in Research and Innovation topic
    - Hydrocarbons from Biomass (HyBi)
  - Engineering Research Center
    - Center for BioRenewable Chemicals (CBiRC)
  - Helping to push the “green gasoline” paradigm

Biofuel Production Alternatives

lignocellulose



gasification to “syngas” ($CO + H_2$)

pyrolysis, fast or slow

gases

bio-oil

dissolution

liquid phase processing

Fisher-Tropsch

methanol

Jet Fuel

Diesel

Gasoline

Sugar/Starch

starch

saccharification

lignin → Heat/Power

sugar

fermentation

Ethanol

butanol

Lipids

hydrotreating

transesterfication → Biodiesel

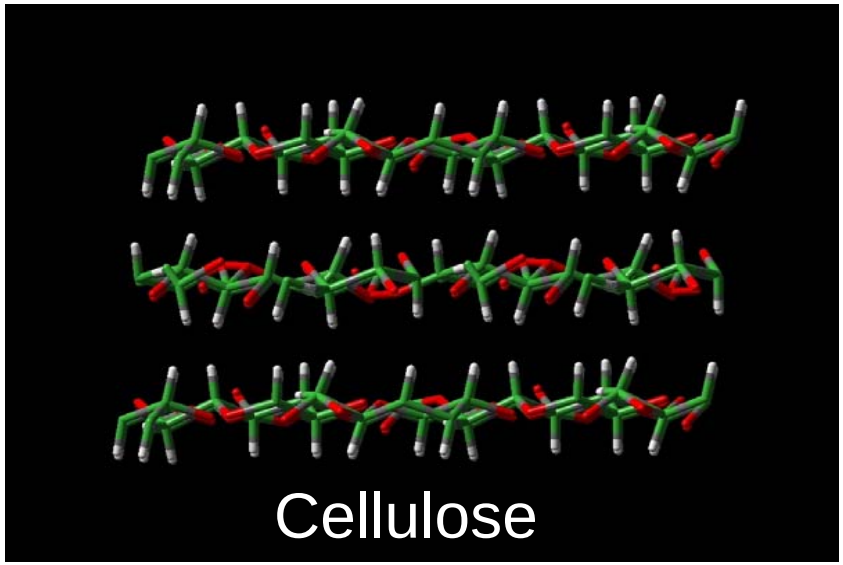
thermal routes

catalytic routes

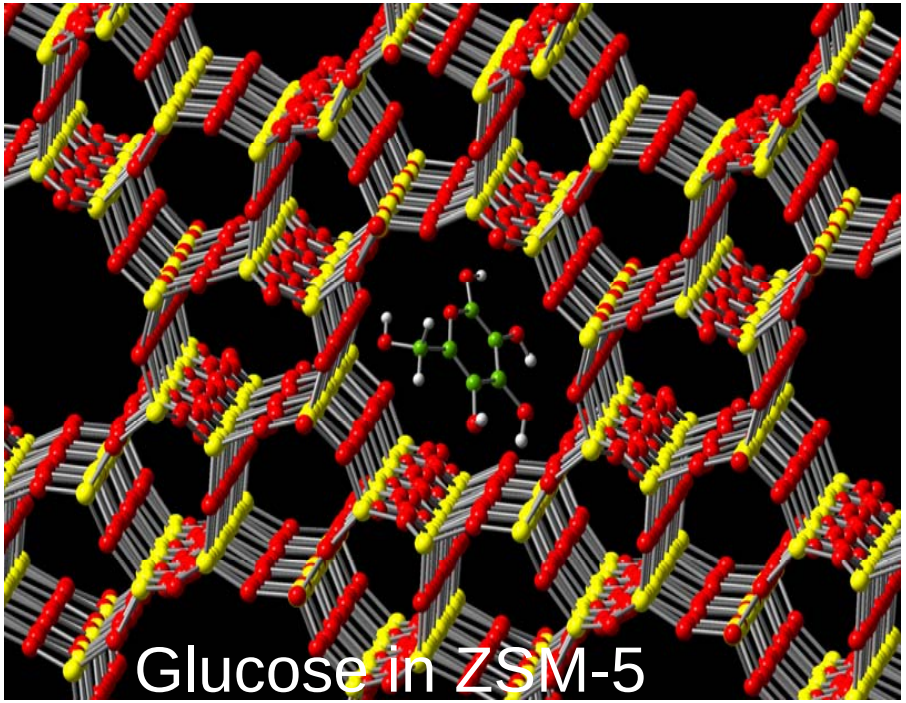
biological routes

synthetic biology

Gasoline from Cellulose by Catalytic Fast Pyrolysis in a Single Reactor



Pyrolysis to Sugars, Adsorption into catalyst



Catalytic Conversion

Gasoline, CO_2, Water