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ADVANCING NEXT-GENERATION BIOFUELS

BLAKE SIMMONS, VP, DECONSTRUCTION DIVISION

BIOMASS 2010 CONFERENCE

U.S. DEPARTMENT OF ENERGY | Office of Science

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JBEI AT A GLANCE

Unified Research & Operations

- $134M, 5-year DOE OBER program
- Highly focused research agenda
- Single operation and facility

Six Partners

- Three DOE National Laboratories
- Two Universities
- One Foundation

Berkeley Lab · Sandia National Laboratories · Lawrence Livermore National Laboratory · UC Davis University of California · Carnegie Institution for Science

Four Science Divisions

- Feedstocks
- Deconstruction
- Fuels Synthesis
- Cross-cutting Technologies

Industry Partnership Program

- Underpin growth of biofuels industry
- Ensure technology transfer to the developing biofuels industry

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JBEI'S PHILOSOPHY: PARTNERS CO-LOCATED AT A SINGLE LOCATION

Berkeley Lab

Carnegie Institution for Science

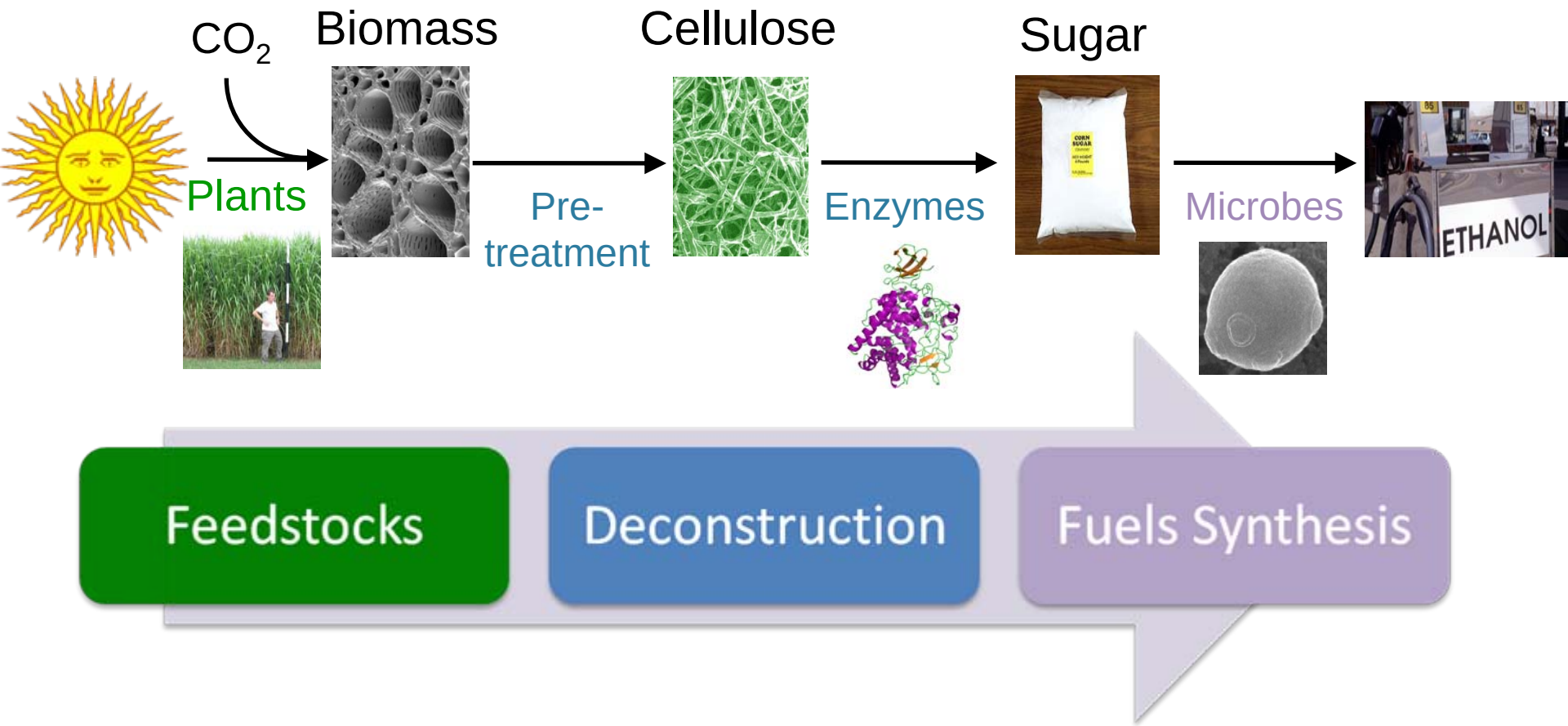
Sandia National Laboratories

The University of California Berkeley 1868

Lawrence Livermore National Laboratory

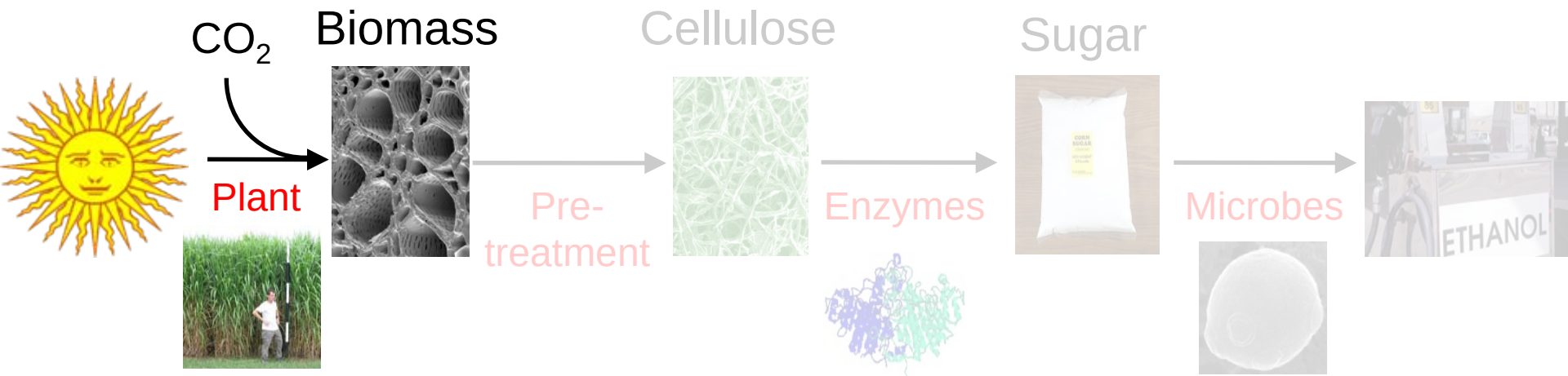
UC Davis
University of California

JBEI'S INTEGRATED APPROACH TO BIOFUELS RESEARCH



THREE SCIENTIFIC DIVISIONS AND SUPPORTING TECHNOLOG

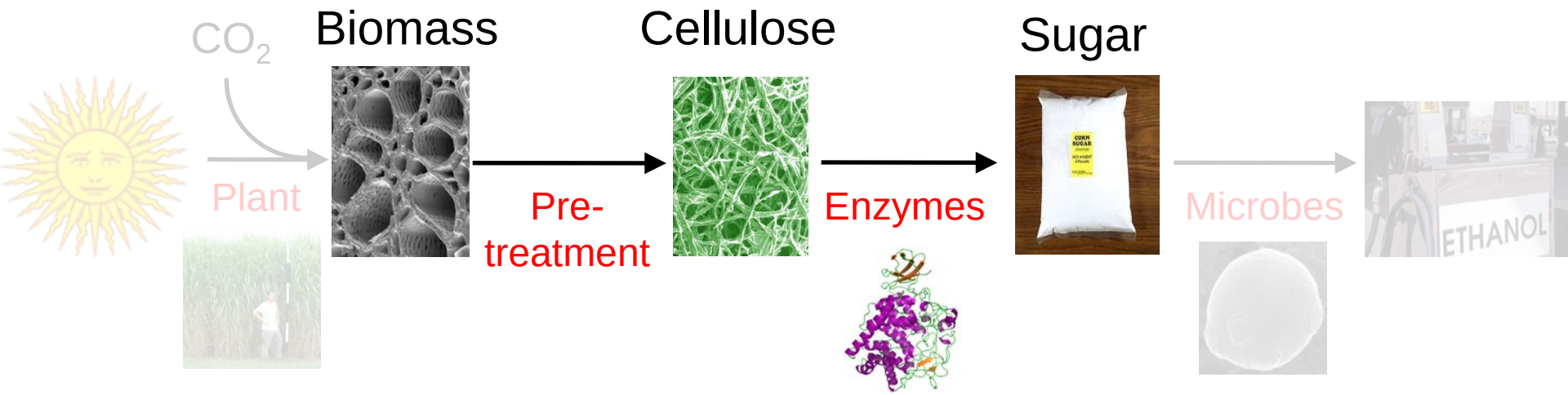
CHALLENGES IN CONVERTING LIGNOCELLULOSIC BIOMASS TO FUELS



Feedstock Challenges

- **Cellulose and hemicellulose are occluded by lignin**
- **Lignin is recalcitrant to depolymerization**
- **Acetate and ferulate are inhibitory to fermentation of lignocellulose-derived monosaccharides**

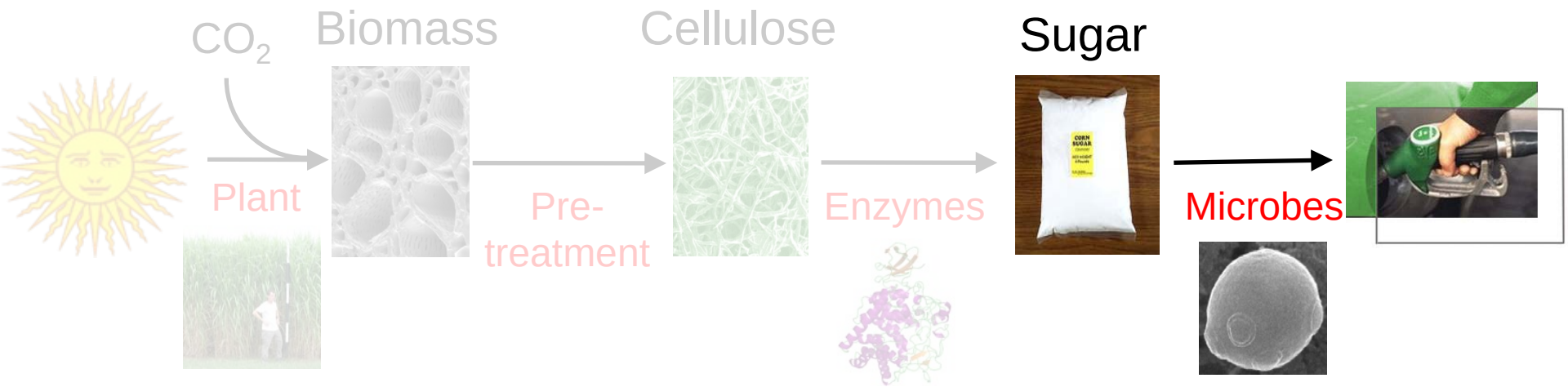
CHALLENGES IN CONVERTING LIGNOCELLULOSIC BIOMASS TO FUELS



Deconstruction Challenges

- **Pretreatment methods release or form products that are inhibitory to fermentation**
- **Cellulases and hemicellulases have limited pH and temperature ranges, and represent significant cost in deconstruction**
- **Limited methods to depolymerize & upgrade value of lignin**

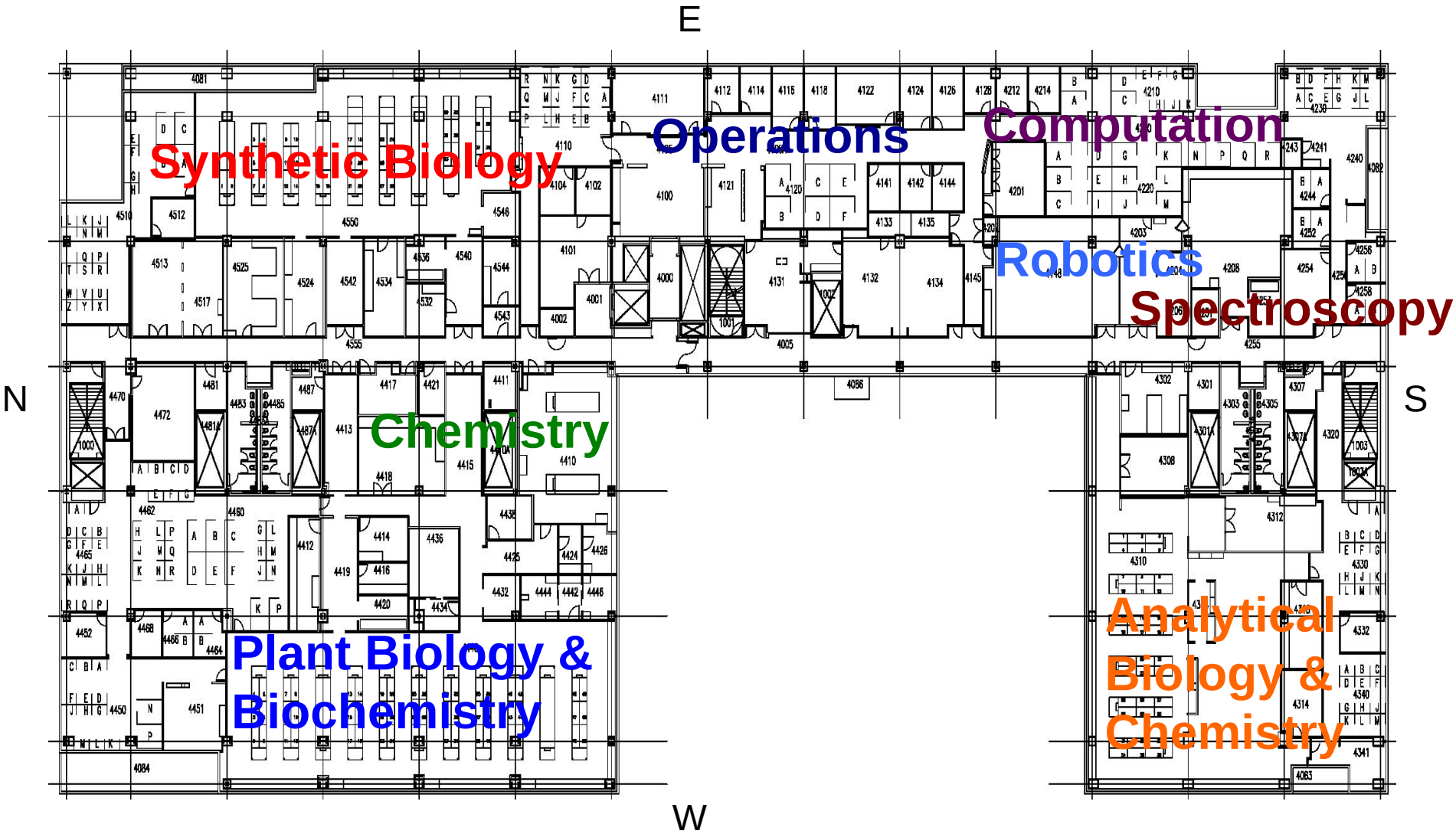
CHALLENGES IN CONVERTING LIGNOCELLULOSIC BIOMASS TO FUELS



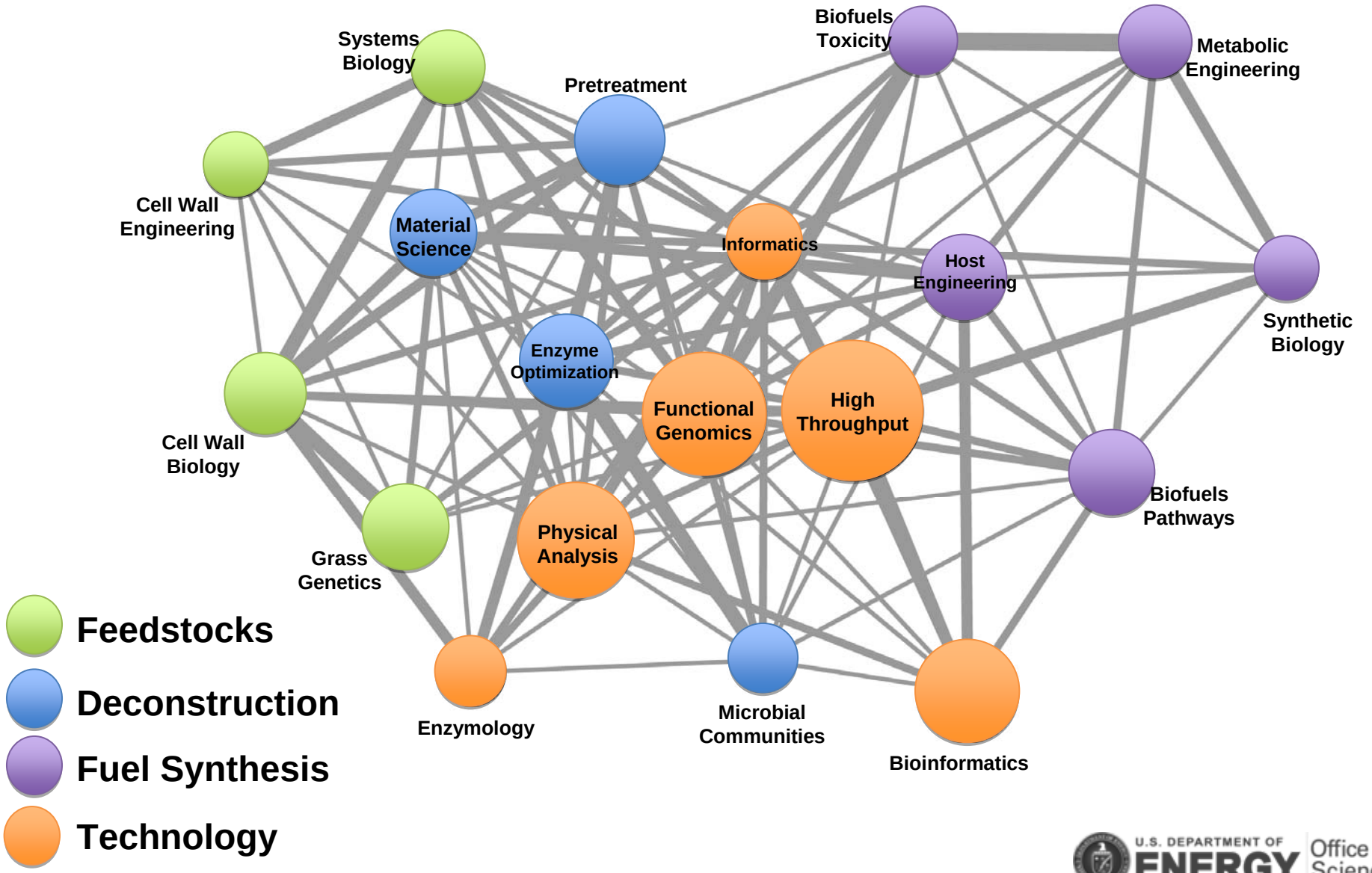
Fuel Synthesis Challenges

- **Advanced biofuels are needed for diesel and jet engines**
- **Many fuel-producing organisms can only incompletely metabolize C_5 (xylose, arabinose) sugars**
- **Inhibitors (e.g., acetate) released from biomass pretreatment can limit fuels production**

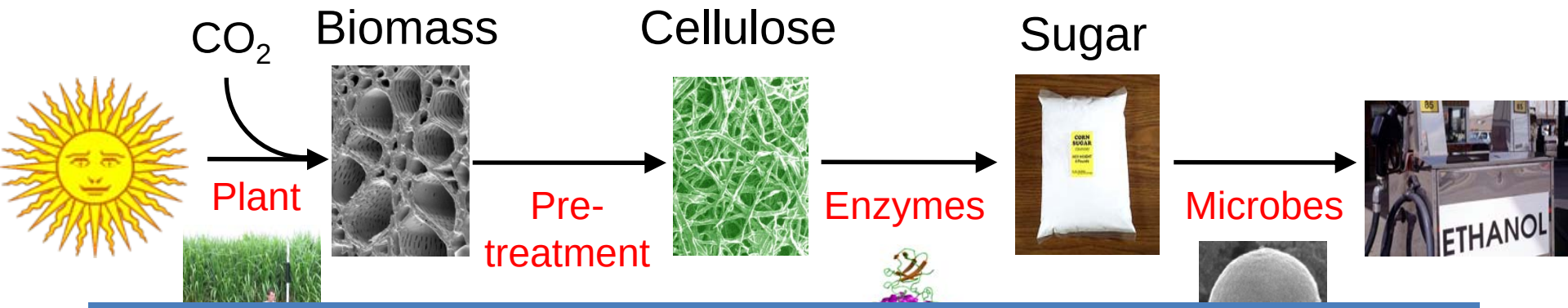
LABORATORIES DESIGNED FOR OPTIMAL FUNCTION AND INTEGRATION – NO JBEI DIVISIONAL OWNERSHIP OF SPACE

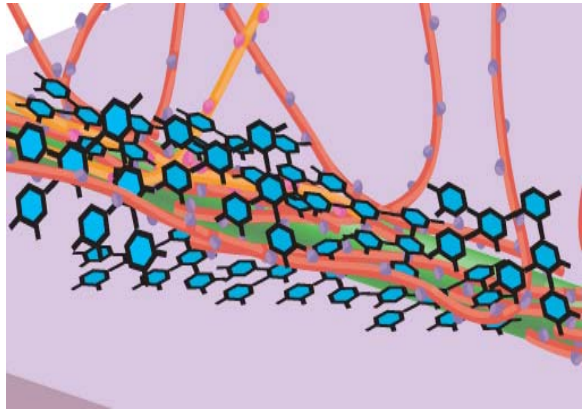


JBEI PROJECT INTERACTIONS: YEAR 2

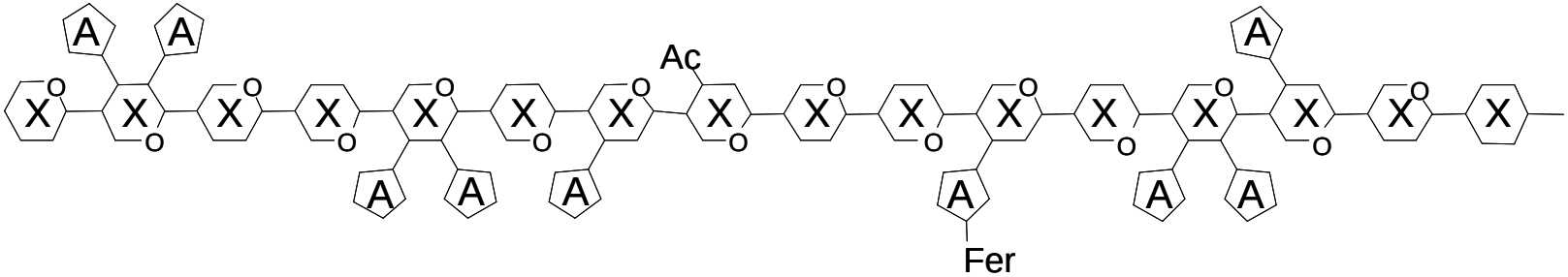


EXAMPLE: FERMENTATION INHIBITORS FROM BIOMASS DECONSTRUCTION

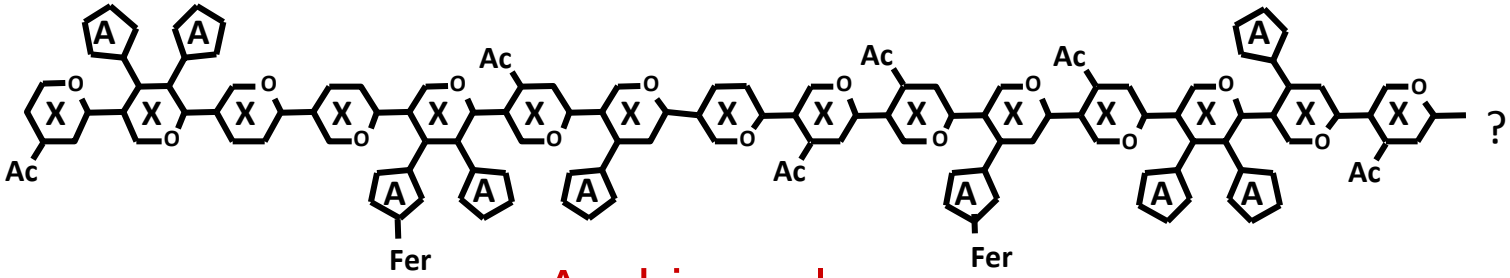




Feedstocks determines enzymes involved in hemicellulose functionalization



MOST ABUNDANT NON-CELLULOSE COMPONENT: XYLAN



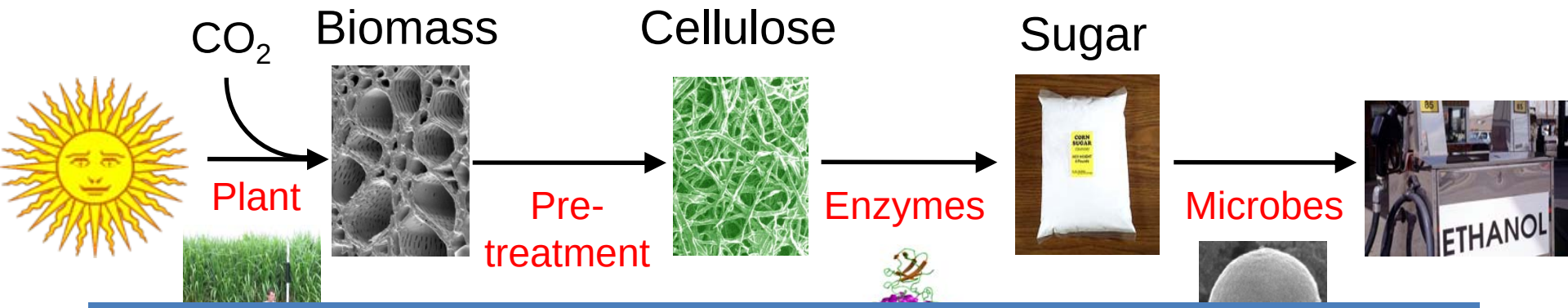
Arabinoxylan

Xylan is the major non-cellulosic polysaccharide in biomass and poses several challenges for biofuel production

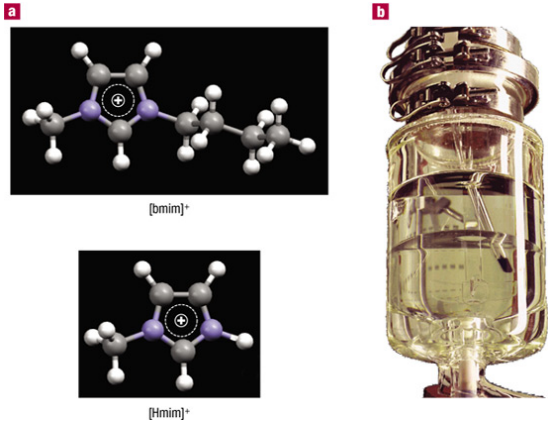
None of the biosynthetic enzymes have been unambiguously identified

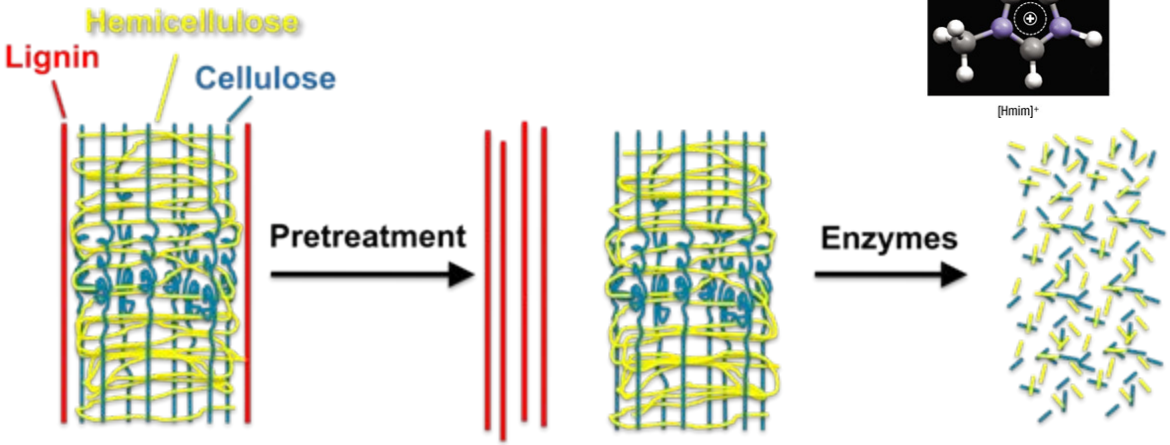
JBEI is investigating putative acetyl- and feruloyl-transferases as well as glycosyltransferases likely to be involved in xylan biosynthesis

EXAMPLE: FERMENTATION INHIBITORS FROM BIOMASS DECONSTRUCTION

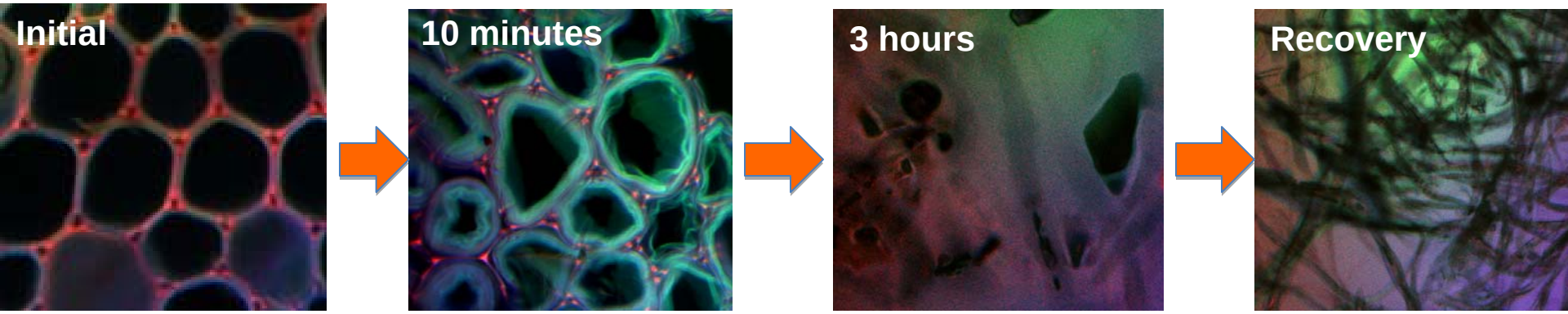


Deconstruction develops gentler pretreatment conditions that reduce production of inhibitors

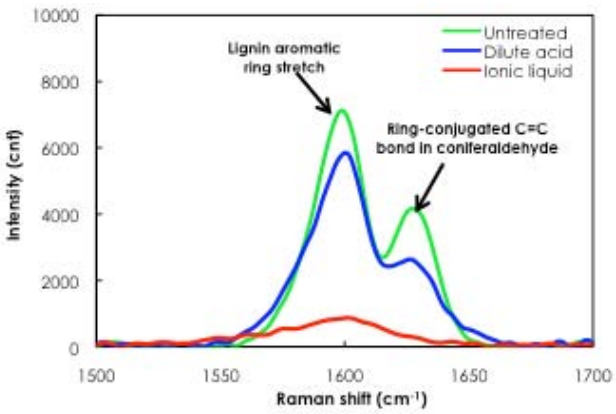




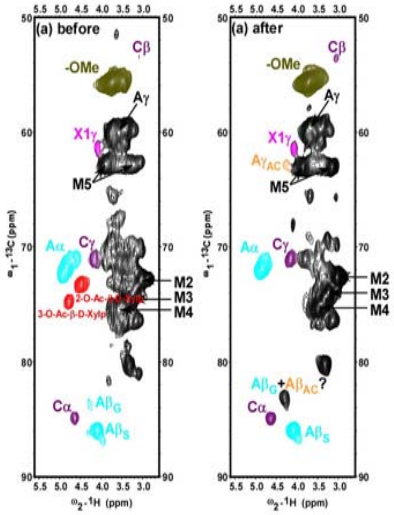
UNDERSTANDING IONIC LIQUID PRETREATMENT



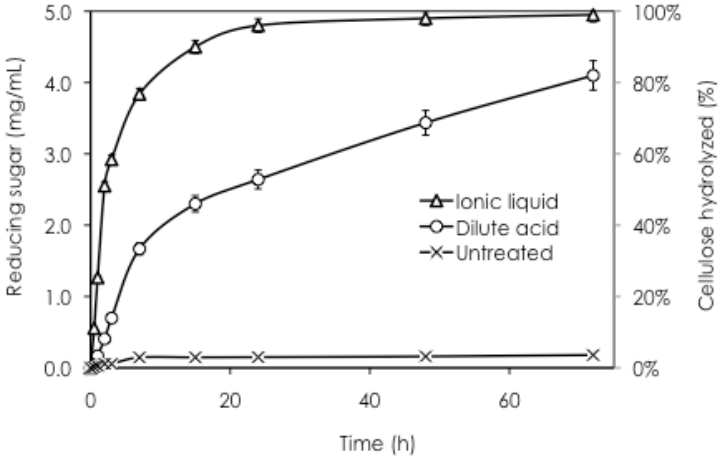
Singh, S.; Simmons, B.A.; Vogel, K.P. Visualization of biomass solubilization and cellulose regeneration during ionic liquid pretreatment of switchgrass, Biotechnology and Bioengineering (2009) 104(1), 68-75 – Featured Cover Article



Raman Profile Tracking



2D NMR



Comparison of Enzymatic Hydrolysis

DEVELOPING IONIC LIQUID PRETREATMENT PROCESS TECHNOLOGY

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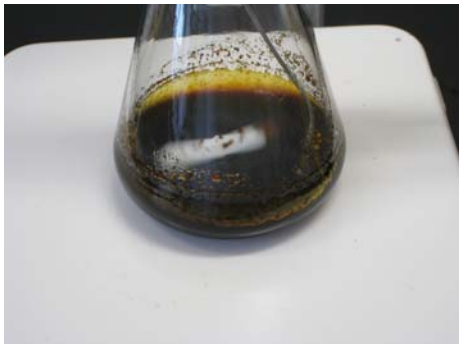
Emim Ac Biomass

Mix

Heat
Stir



Heat
Time

Solubilized biomass

Anti
Solvent

Top: traditional anti-solvent
- Forms gel
- Solid/liquid separation difficult

Bottom: novel anti-solvent (JBEI IP)
- No gel
- Filters easily

Filter
Dry

Recovered product:
- High surface area
- Amorphous cellulose
- Decreased lignin

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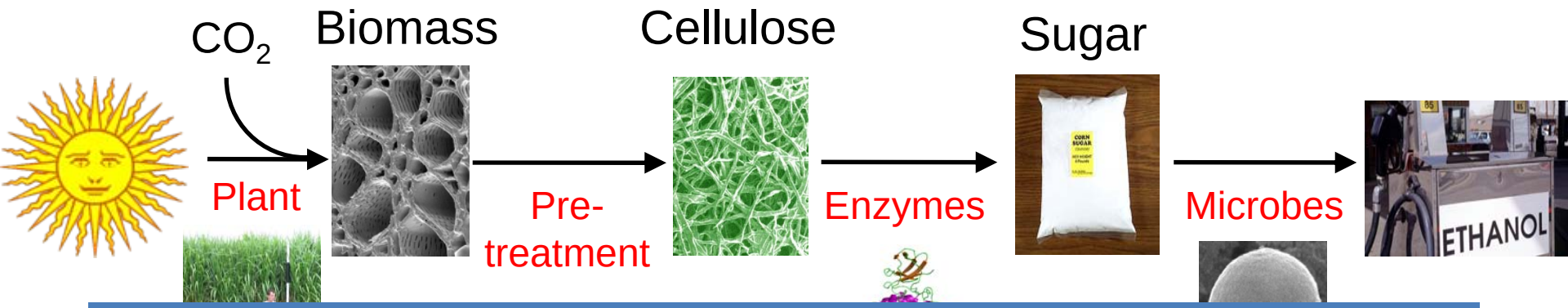
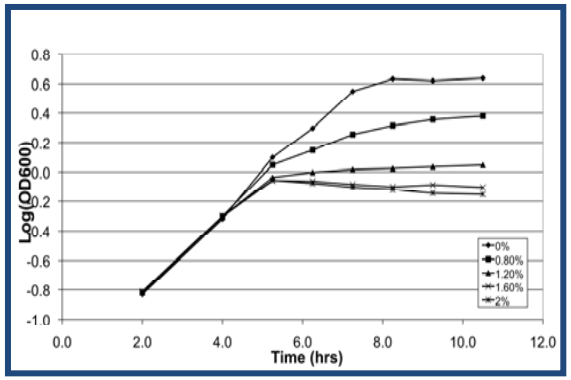
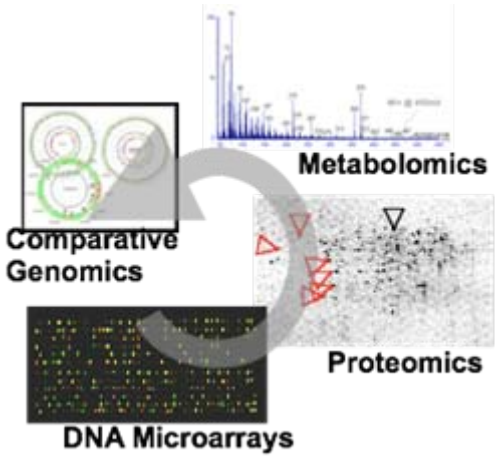
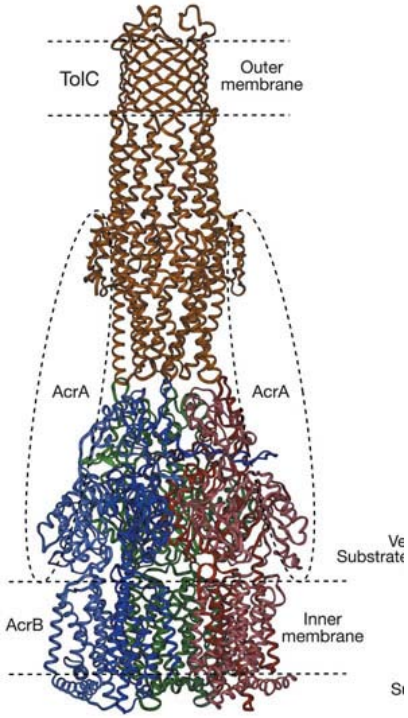
EXAMPLE: FERMENTATION INHIBITORS FROM BIOMASS DECONSTRUCTION



Fuels Synthesis and Technologies determine stress response of fuels-producing microbes to inhibitors using functional genomics

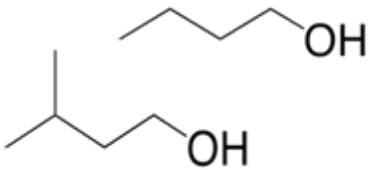


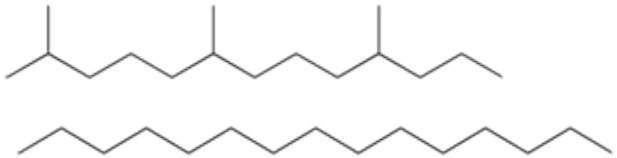




INITIAL JBEI BIOFUEL TARGETS

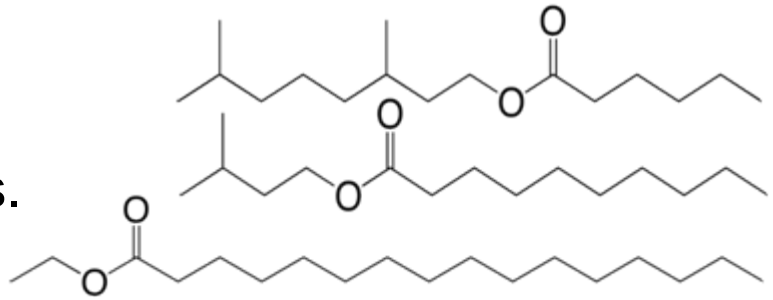
Alcohols
- Low miscibility with water
- High octane
- Appropriate vapor pressure

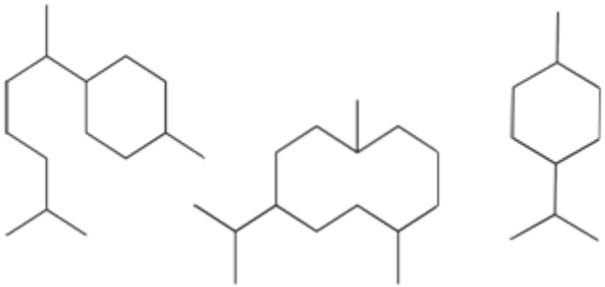




Alkanes
- Diesel (or gasoline) replacements
- Appropriate cetane (or octane) numbers

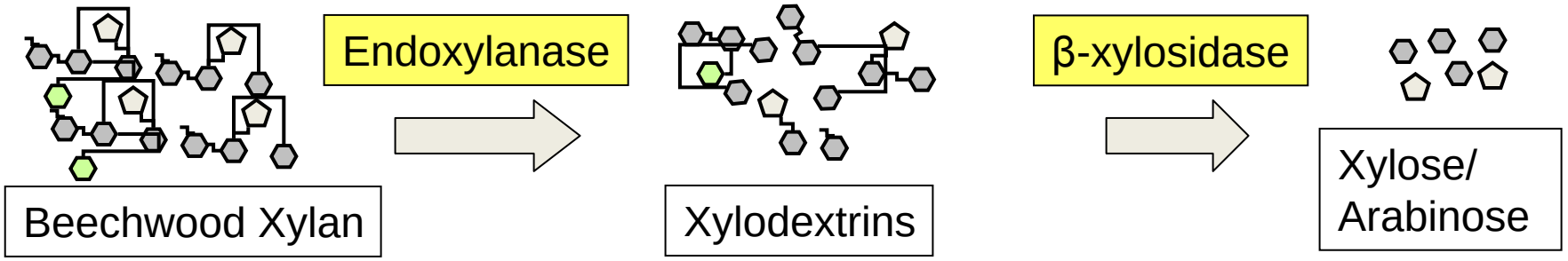
Esters
- Diesel replacements
- Appropriate cetane nos.

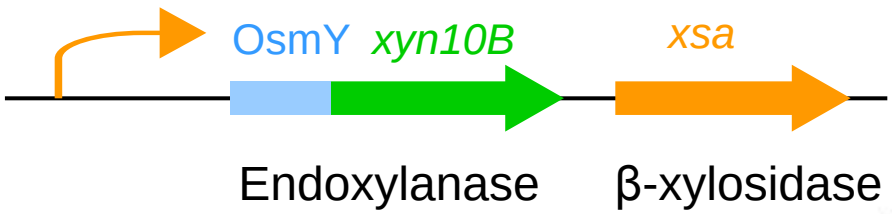




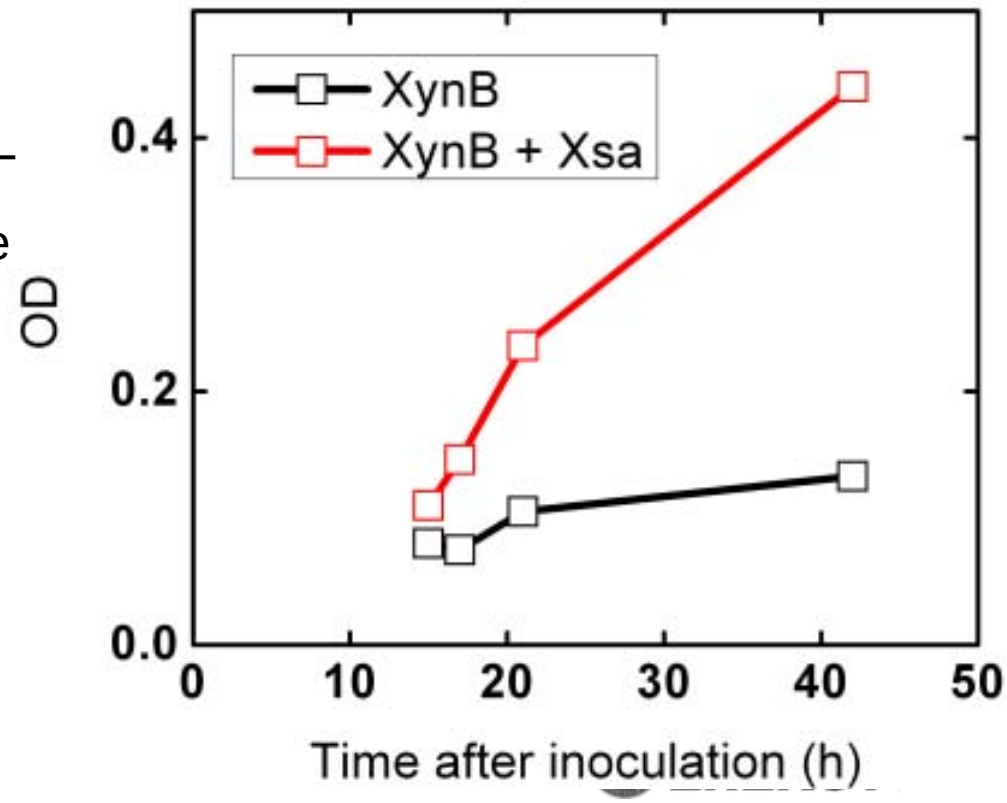
Cyclic alkanes/alkenes
- Jet fuel replacements
- Low freezing point

XYLAN DIGESTION AND UTILIZATION



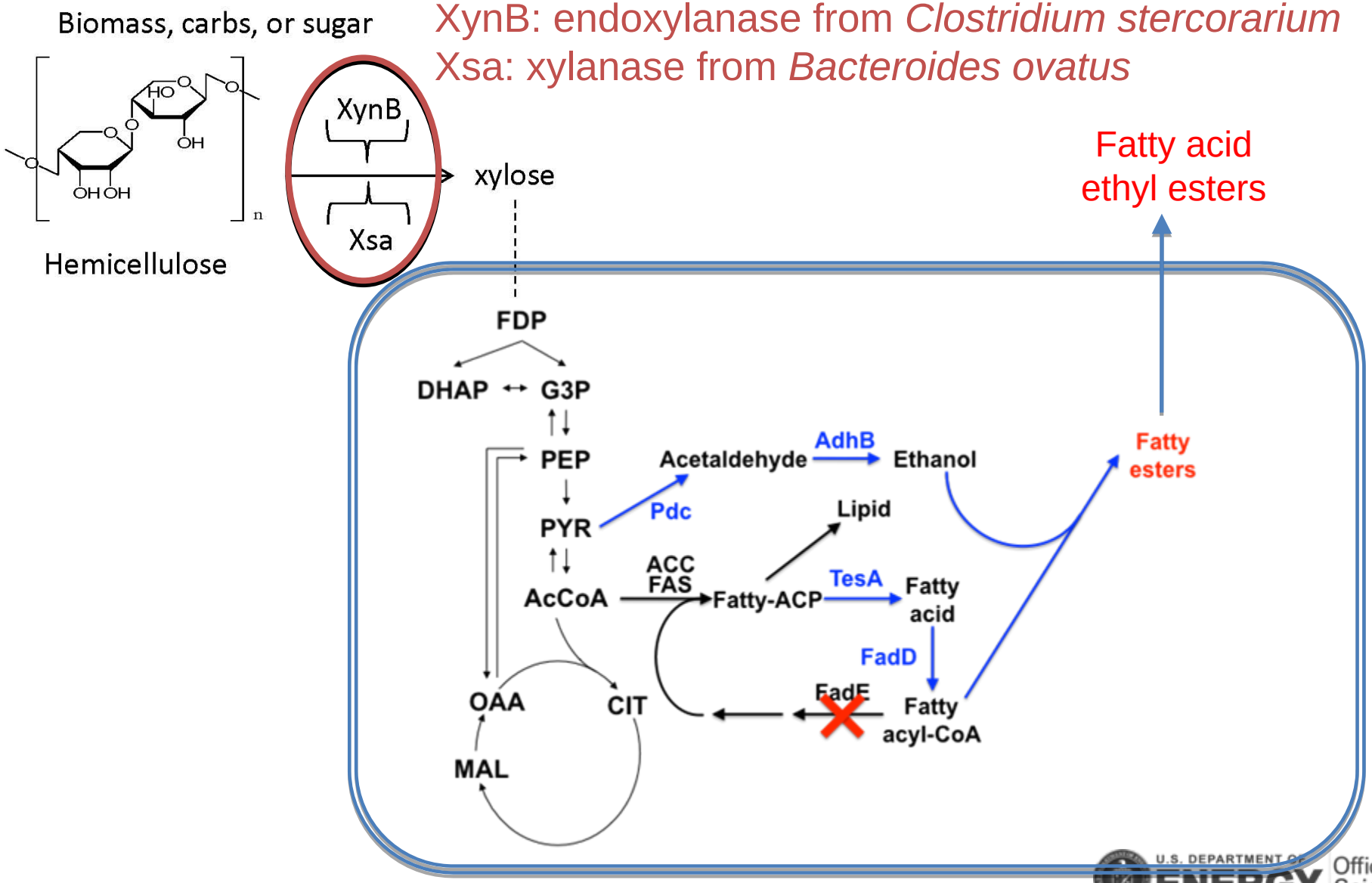


M9 minimal medium with 0.2% ionic liquid-extracted switchgrass

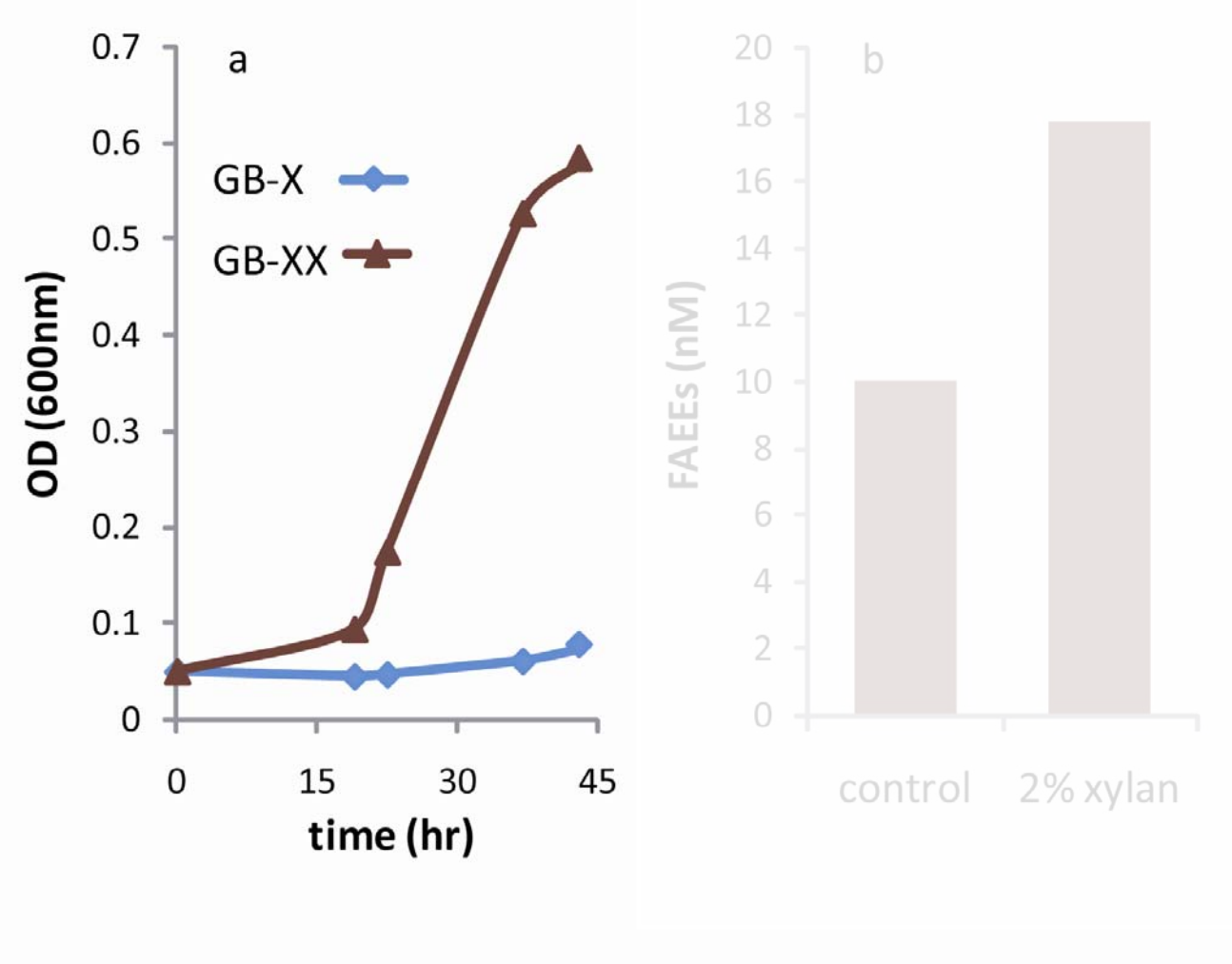


CONSOLIDATED BIOPROCESSING MICROBE

XynB: endoxylanase from *Clostridium stercorarium*
Xsa: xylanase from *Bacteroides ovatus*

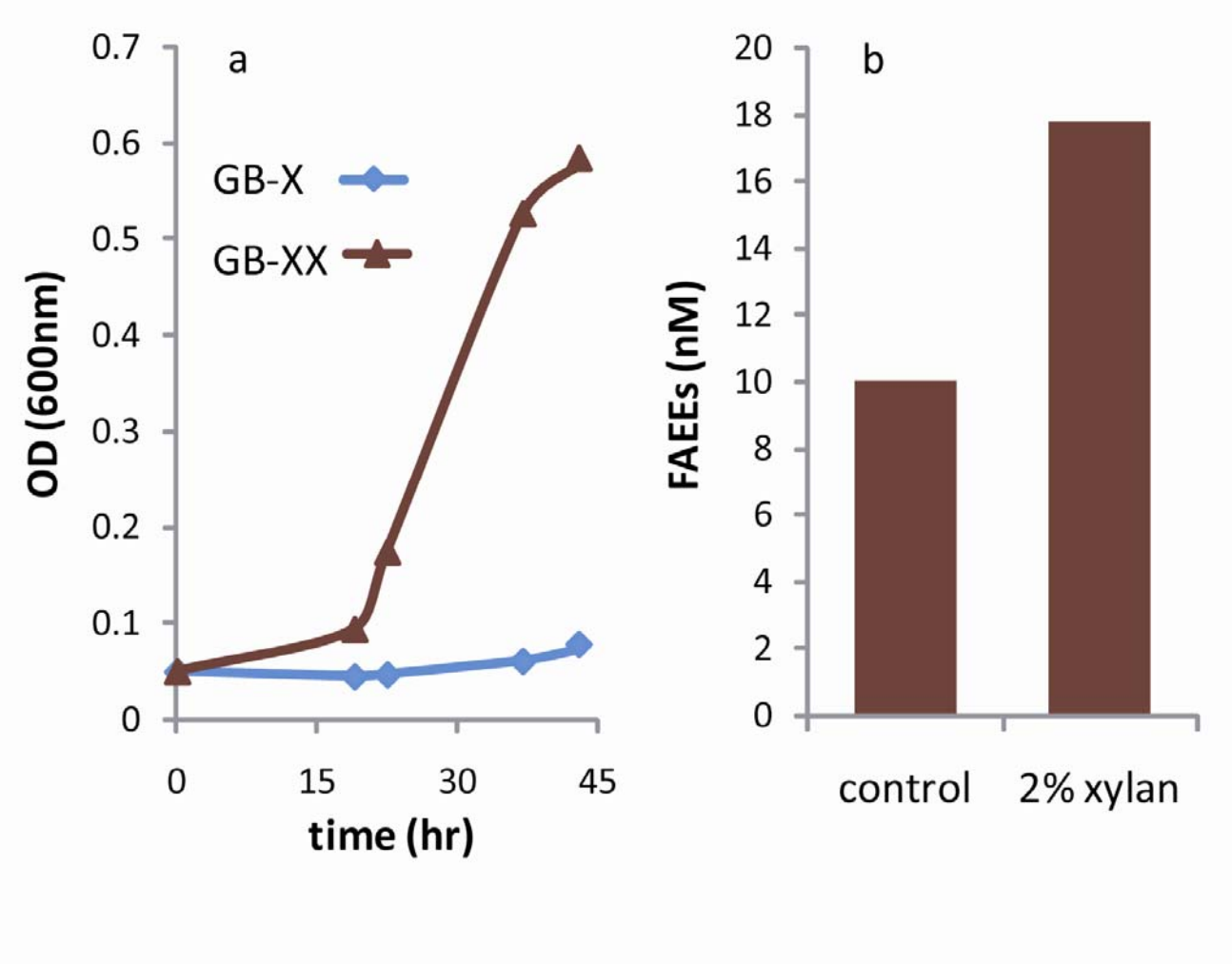


TOWARDS CONSOLIDATED BIOPROCESSING FOR BIODIESEL PRODUCTION



w/ G Bokinsky

TOWARDS CONSOLIDATED BIOPROCESSING FOR BIODIESEL PRODUCTION



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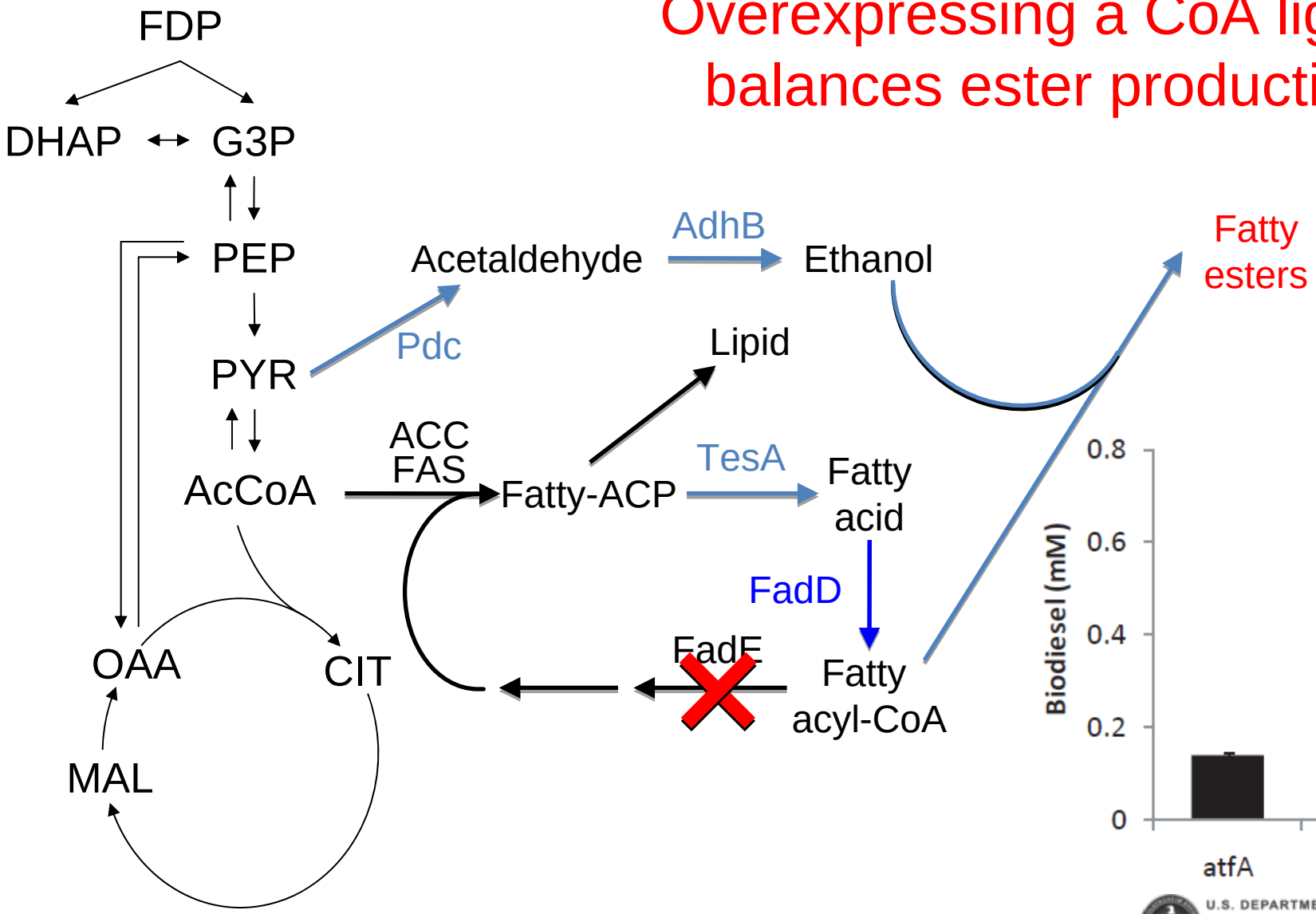
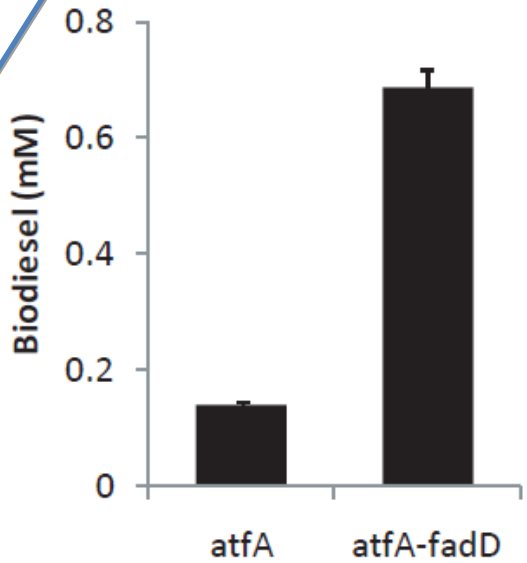
MAKING BIODIESEL: PUTTING IT TOGETHER

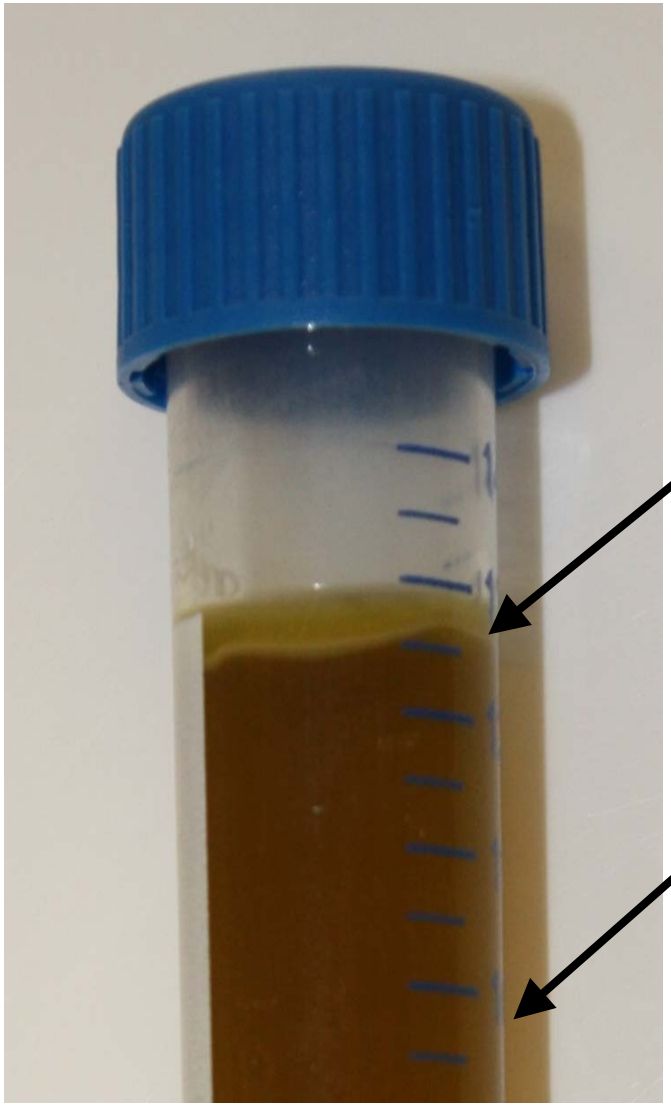
Overexpressing a CoA ligase balances ester production





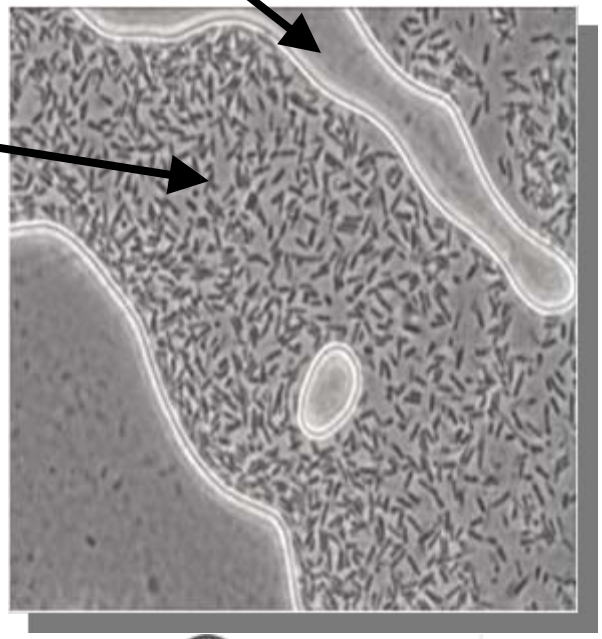
Steen et al. 2010. *Nature* 463:559-562

ADVANCED BIOFUELS PHASE-SEPARATE



Biodiesel

Cells and media



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JBEI ACCOMPLISHMENTS

- 77 Publications
- 218 Presentations
- 43 Technical Disclosures
- 18 Patent Applications; 2 Software Copyrights Registered
- Hosted 8 Visiting International Researchers (Chile, Brazil, Sweden, Australia, New Zealand)
- 34 Student Interns (21) and Graduate Students (13)
- Hosted two high school student summer outreach programs
- Participated in Cleantech to Market Program at Haas School of Business 2008-2010

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ACKNOWLEDGEMENTS

JBEI Winter Retreat, February 2010

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