Biomanufacturing for a Sustainable Future

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Joint BioEnergy Institute

Seven Partners

One Location

- Funded by DOE
- Started in 2007
- Renewed in 2012
- $25M/year
JBEI’s Mission: Basic Science to Convert Cellulosic Biomass to Drop-in Fuels

CO₂ → Hay → Factory → Fuel

- Cellulose
- Hemicellulose
- Sugars
- Lignin
- Enzymes
- Microbes
Engineering cell wall deposition in fibers

Challenges

• High-density biomass would reduce transport costs and increase fuel yields

• More sugar but less lignin is preferable
Can we fill the fibers up with cellulose?
Genetic changes direct cellulose to fibers

Wild type

Engineered

Cellulose  Hemicellulose  Lignin

Cellulose  Hemicellulose  Lignin

Fiber  Vessel

Fiber  Vessel

Cellulose  Hemicellulose  Lignin

Cellulose  Hemicellulose  Lignin
Engineered plants contain approximately twice the sugar as the native plants.

### Native Plant

### Engineered Plant

**Dilute-alkaline pretreatment**

**Increased sugars**

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Some key challenges in converting lignocellulosic biomass to fuels

Challenges

- We need better pretreatment processes that yield cleaner cellulose/hemicellulose
Ionic liquids for pretreatment

Pretreatment

 Ionic liquids

Mix
Heat
Stir

Biomass

Add
Anti-solvent
Biological ionic (Bionic) liquids from lignin

Pretreatment

Cellulose

Hemicellulose

Lignin

Convert to ionic liquids

Bionic Liquids

Cations

R = H, CH₂OH
R' = H, OH, OCH₃

Anions

HO⁻, HO⁻, OSO₃⁻, CO₂⁻, etc.
Some key challenges in converting lignocellulosic biomass to fuels

Challenges
• We need fuels for all types of engines
Advanced biofuels from biomass

- sugars
- \( \alpha \)-pinene
- bisabolane
- Fatty acid ethyl ester
Phase separation allows simple purification of fuel
JBEI’s advancements were made possible, in part, through the development of technologies.
Major issues of our time

Biology will be part of the solution to all of these challenges

Engineered plants with improved photo-synthetic efficiency to increase productivity

Engineered plants and microbiomes for improved nutrient uptake and reduced fertilizer application

Fuels and chemicals sustainably produced from biomass

Biosynthesis of new classes of natural products as antibiotics
Can the tools developed with JBEI funding improve biological engineering generally.

Biology is engineered iteratively because we know so little about it.

A single turn of this cycle can take months.

We need to turn the crank faster and in higher throughput.
Hosts and tools are not shared

Engineering E. coli to produce 1,3-PDO

Engineering yeast to produce Artemisinin

Engineering process X to produce Product 3

Time for commercialization
Development costs limit startups
A professional biological foundry

1. **Design**
   - Host
   - Pathway
   - Expression
   - Build

2. **Build**
   - Liquid handling
   - QA/QC
   - Transformation

3. **Integration**
   - Machine learning
   - Integration

4. **Learn**
   - Mass spec.
   - Sample prep.

5. **Test**
   - Target achieved

- **Selected Target**
- **Targets**
- **Molecule**
- **Circuit**
- **Cellular function**

**Key Components**
- Sample preparation
- Mass spectrometry
- Machine learning
- Liquid handling
- Quality assurance and quality control
- Transformation equipment
- Design and build processes
- Target achievement
Potential improvements in commercialization time with a professional foundry

- Polyester monomers
- Terpene-based co-polymers
- Phenylpropanoid pathways

Time for commercialization
Profession biological foundry would increase the chance of successful startups.
Biomanufacturing vision

The **FutureBio Institute** will be the worldwide leading institute for the development of *sustainable* biomanufacturing.
FutureBio Institute Programs

• Advanced Bioengineering Center (ABC)
  – Develops biological components, software, and hardware to improve the DBTL cycle

• FutureBio Foundry (FBF)
  – Uses biological components, software, and hardware to successfully build biological systems for many purposes

• Open Collaboration Facility (OCF)
  – Enables companies, government agencies, academics to use FBF and the latest tools created by ABC to solve important problems
FutureBio Foundry

- **Design**
- **Build**
- **Integration**
- **Learn**
- **Test**

**Selected Target**

- **Molecule**
- **Pathway**
- **Host**
- **Expression**
- **Build**
- **Liquid handling**
- **QA/QC**
- **Transformation**
- **Sample prep.**
- **Machine learning**
- **Mass spec.**

**Targets**

- **Cellular function**
- **Circuit**
- **FutureBio INSTITUTE**
- **FutureBio Foundry**
How the components fit together
FBI Target: Advanced Materials

• Proteins that serve as templates for inorganic and bio-inorganic composite materials

• Low cost, high MW conductive polymers for nanoelectronics and flexible electronics

• Structured, responsive nanoporous membranes with active transporters for pollutants and desalination
FBI Target: Safe, Effective Engineered Microbial Communities

- Development of “safe” soil and symbiotic bacteria for support of particular plant processes.

- Development of safe rumen platform microbes for nutrient and methane mediation.

- Demonstrated contained, persistent microbes improving plant growth and nutrient utilization in ruminant-stomach-like environments.
FBI Target: Rapid Production of Efficacious Antimicrobials

- Explore biosynthetic diversity for new antimicrobial scaffolds and tailoring enzymes
- Develop a robust capability to identify, design, and construct microbial metabolic pathways that will produce many thousands of antimicrobial variants
- Produce a vast library of antimicrobials
- Scalable and reliable antimicrobial biomanufacturing processes
Thank you