U.S. Department of Energy

From BIOMASS to CELLULOSIC ETHANOL: Genomics for Alternative Fuels

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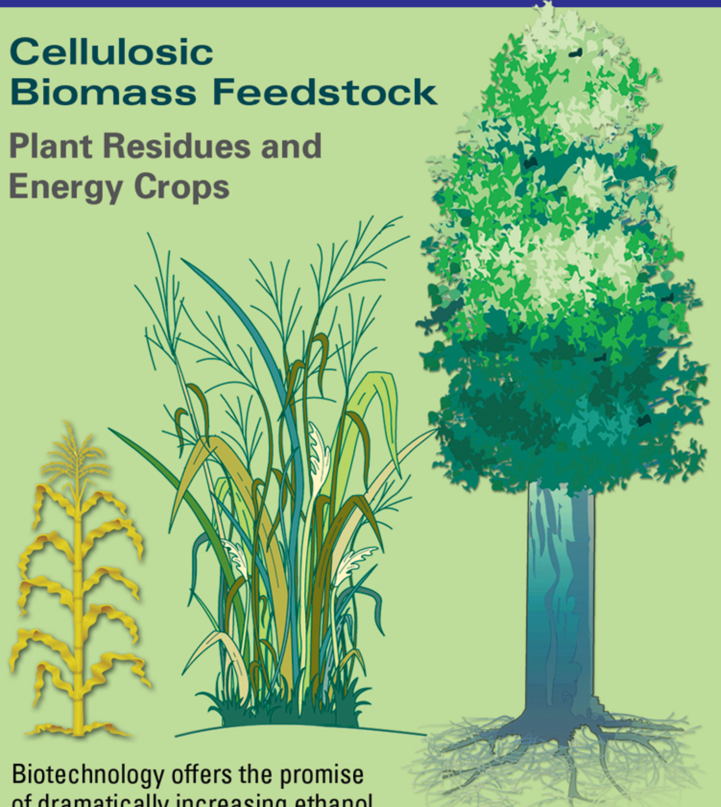
Office of Science
U.S. Department of Energy

Cellulosic Biomass Feedstock

Plant Residues and Energy Crops



Biotechnology offers the promise of dramatically increasing ethanol production using cellulose, the most abundant biological material on earth, and other polysaccharides (hemicellulose) located in plant cell walls (see details on reverse). Residue including postharvest corn plants (stover) and timber residues could be used, as well as such specialized high-biomass "energy" crops as domesticated poplar trees and switchgrass.

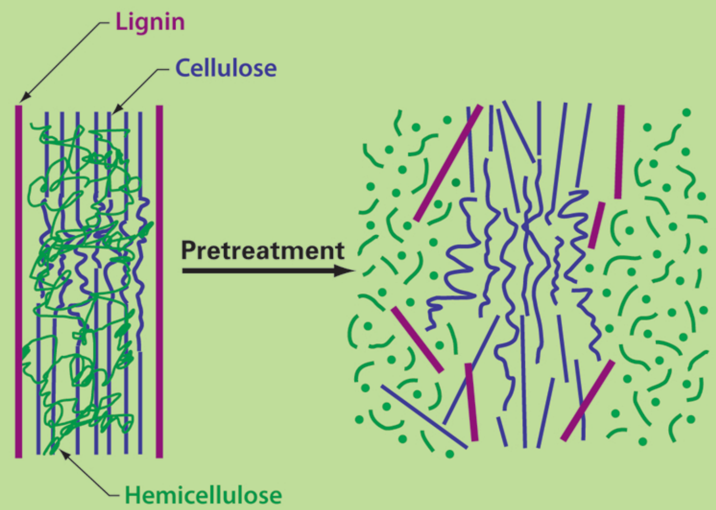
Biochemical conversion of cellulosic biomass to ethanol for transportation fuel currently involves three basic steps:

- **Pretreatments to increase the accessibility of cellulose to enzymes and solubilize hemicellulose sugars**
- **Hydrolysis with special enzyme preparations to break down cellulose to sugars**
- **Fermentation to ethanol**

Making cellulosic biomass conversion to ethanol more economical and practical will require a science base for molecular redesign of numerous enzymes, biochemical pathways, and full cellular systems.

Pretreatment

Goal: Make cellulose more accessible to enzymatic breakdown (hydrolysis) and solubilize hemicellulose sugars



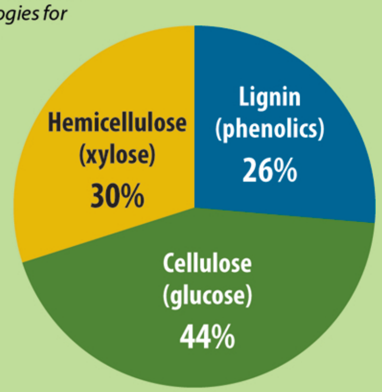
Plant cell wall

In plant cell walls (see reverse), cellulose exists within a matrix of other polymers, primarily hemicellulose and lignin. Pretreatment of biomass with heat, enzymes, or acids removes these polymers from the cellulose core before hydrolysis.

Pretreatment, one of the more expensive processing steps, has great potential for improvement through R&D.

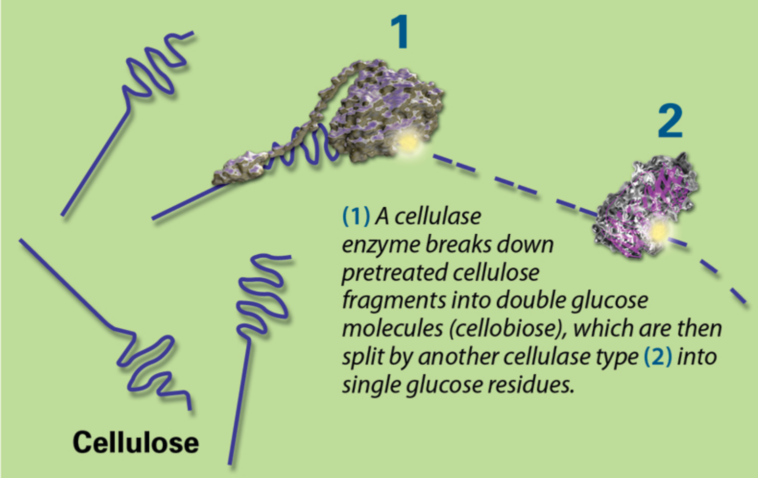
[Figure adapted from N. Mosier et al. 2005. "Features of Promising Technologies for Pretreatment of Lignocellulosic Biomass," Bioresource Technology ***96****(3), 673–86.]*

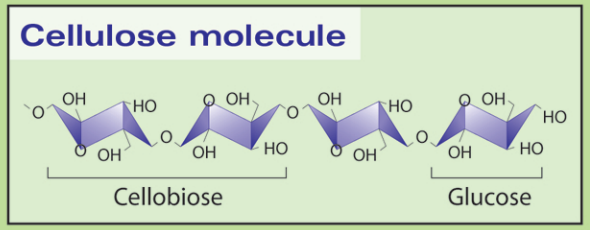
Composition of Biomass (lignocellulose)



Hydrolysis

Goal: Break down cellulose into its component sugars using enzyme preparations



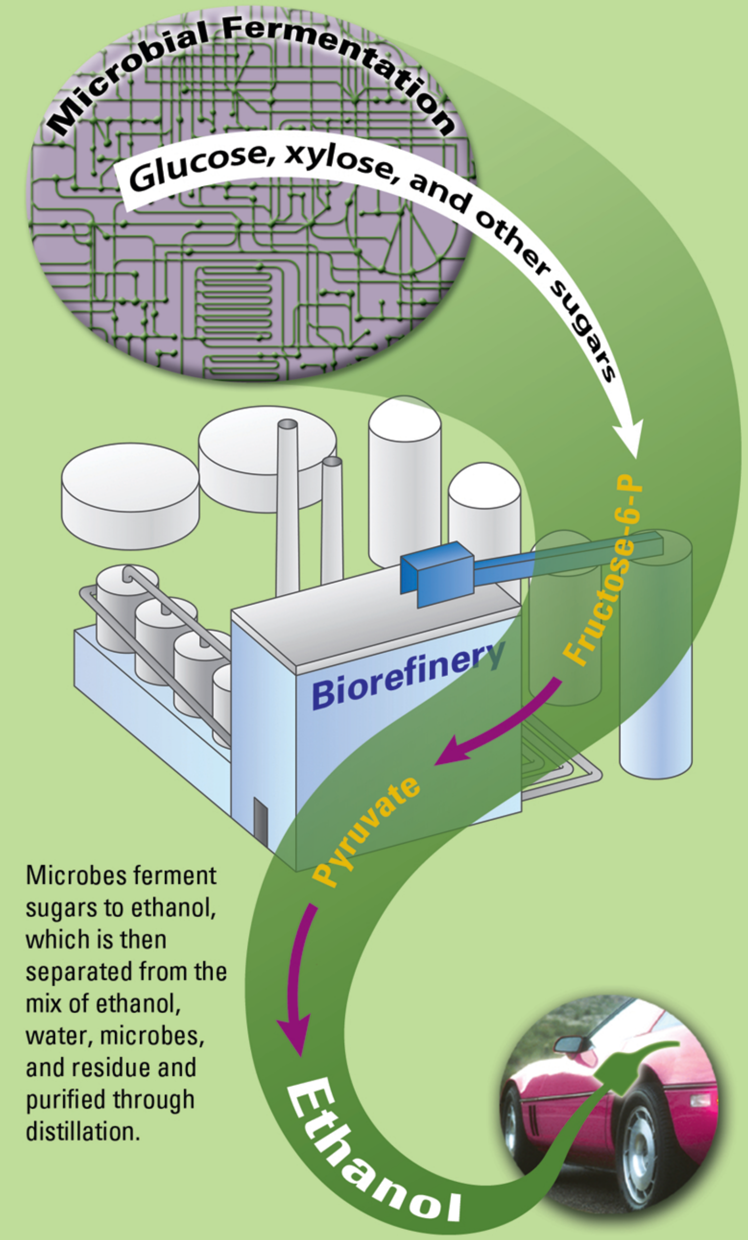


Cellulose is made up of double glucose molecules (cellobiose).

Enzymes such as cellulases synthesized by fungi and bacteria work together to degrade cellulose and other structural polysaccharides in biomass. Optimizing these complex systems will require a more detailed understanding of their regulation and activity.

Fermentation to Ethanol

Goal: Convert sugars to ethanol using microbes



Microbes ferment sugars to ethanol, which is then separated from the mix of ethanol, water, microbes, and residue and purified through distillation.

DOE GTL program contributions needed to

- Control cell-wall composition for energy production
- Develop appropriate model systems for energy crops
- Improve quantity and quality of perennial herbaceous and woody biomass crops
- Domesticate energy crops for stress tolerance
- Develop sustainable management practices

DOE GTL program contributions needed to

- Optimize and exploit biological catalysts
- Reduce thermochemical treatments and waste
- Increase simple sugar yields and concentration

All recommendations for contributions from the DOE Office of Science's (SC) Genomics:GTL program (formerly Genomes to Life) originate from a December 2005 workshop sponsored by SC and the DOE Office of Energy Efficiency and Renewable Energy. The workshop report and this flyer are available at *www.genomicsgtl.energy.gov/biofuels/*.

DOE GTL program contributions needed to

- Increase specific activities
- Increase thermal tolerance
- Reduce product inhibition
- Broaden substrate range

Consolidate Processing Steps

Integrate hydrolysis and fermentation steps into a single microbe or mixed stable culture that

- Produces hydrolytic enzymes
- Ferments sugars to ethanol
- Is process tolerant
- Has stable integrated traits

DOE GTL program contributions needed to

- Eliminate solid-liquid separation step
- Coferment 5- and 6-carbon sugars from biomass feedstocks
- Increase process tolerance and resistance to inhibitors
- Return minerals to soils

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