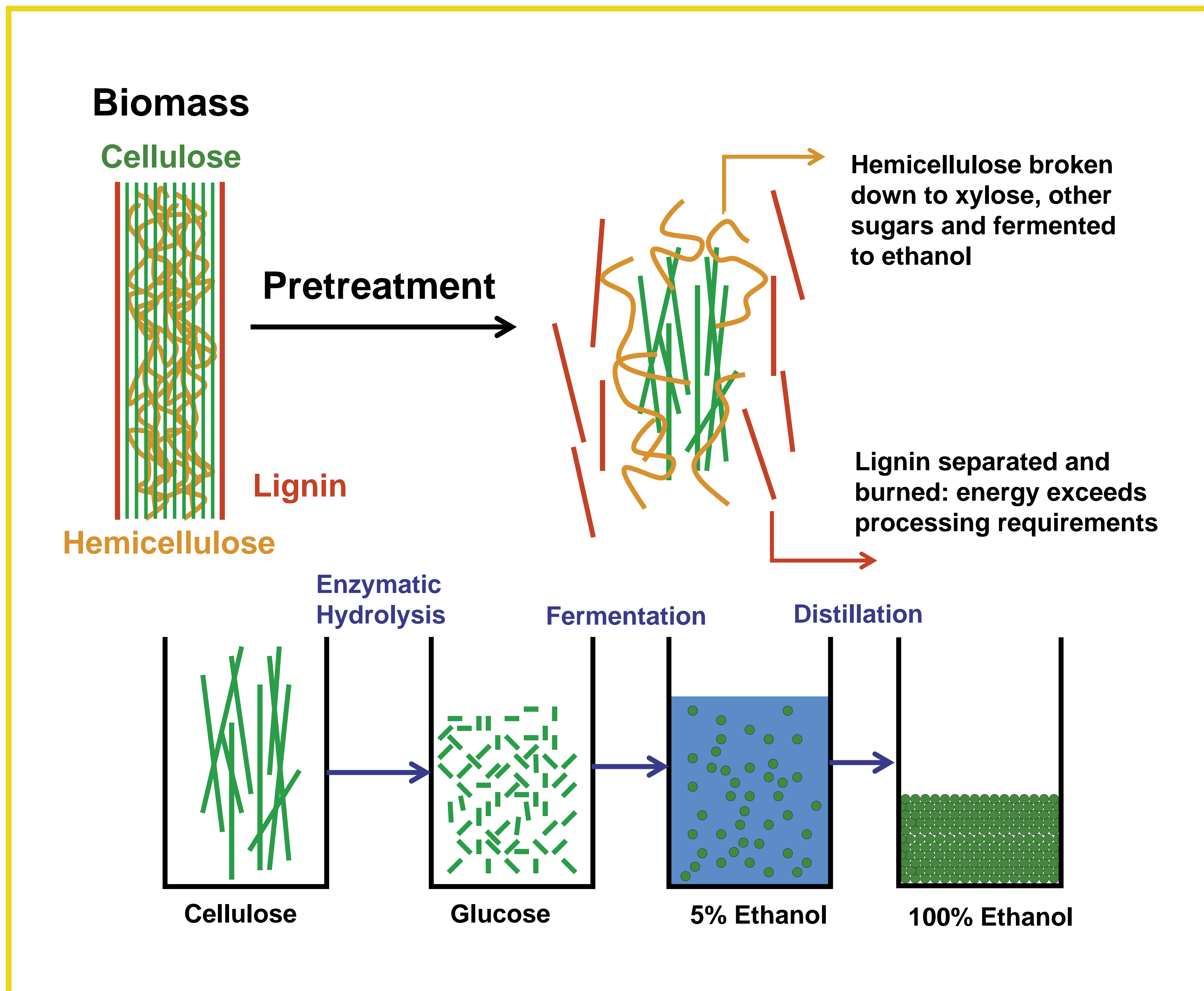


# From Biomass to Ethanol

## Breaking it Down

**B**iomass and  
**D**ioproducts  
Initiative



### Feedstock harvest, transportation and storage

Perennial grasses, agricultural residues and wood chips can all be used to produce ethanol. The low bulk density of biomass leads to many challenges including finding economical means for transportation and storage.

### Pretreatment

A pretreatment process is needed prior to hydrolysis to open the biomass structure and allow cellulase enzymes better access to the cellulose. Some separation and hydrolysis of hemicellulose also may occur during pretreatment. Pretreatment is a critical processing step and projected to be 33% of total processing costs.

### Enzymatic hydrolysis

Several types of microbial cellulase enzymes, including endoglucanases, exoglucanases and  $\beta$ -glucosidases, are used to break down the cellulose to fermentable glucose molecules. Enzyme development is often considered the bottleneck in the cellulosic ethanol process but considerable gains have reduced cellulase prices to less than 15¢ per gallon of ethanol.

### Fermentation

Fermentation typically is done in conjunction with hydrolysis in a simultaneous saccharification and fermentation process using yeast or bacteria. One particular challenge is developing an organism that will efficiently ferment sugars from both the cellulose and hemicellulose components.

### Distillation

As in corn ethanol production, distillation is needed to separate the ethanol from the water following fermentation. Where ethanol concentrations for corn ethanol are typically 12-13%, cellulosic fermentations yield 5-6% ethanol, requiring higher distillation energy inputs.

### Lignin utilization

Lignin is the nonfermentable glue holding biomass together and is the primary coproduct of cellulosic ethanol production. The energy value of lignin typically exceeds that needed for distillation and other process energy needs. Excess energy can be used to produce electricity to sell on the grid. Other uses for lignin that potentially could have much higher values than energy production are being explored.

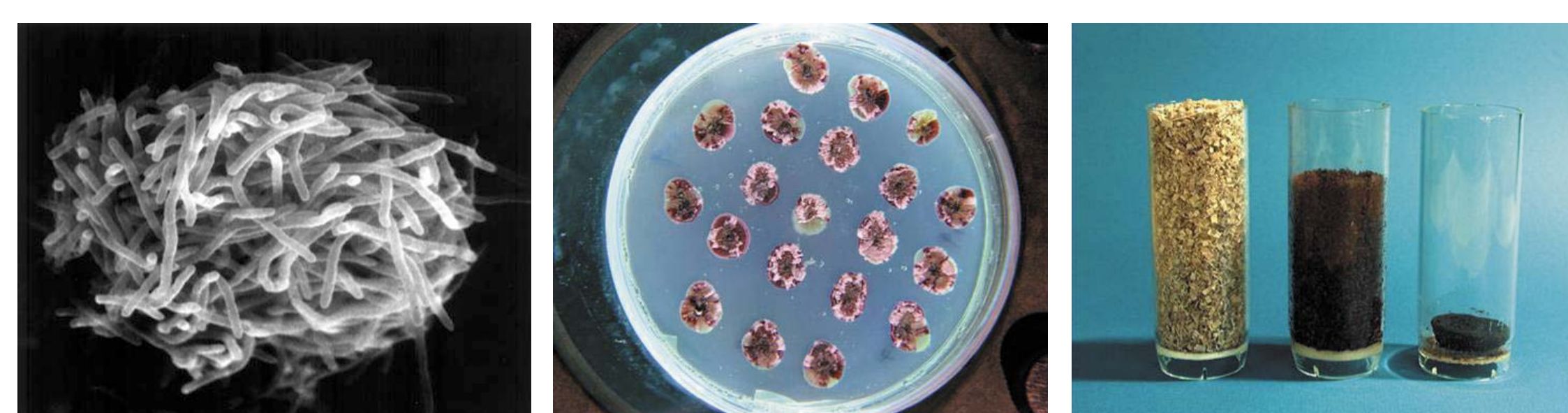
Pretreatment reactor



Biomass feedstock



Enzymatic hydrolysis



Fermentation

