

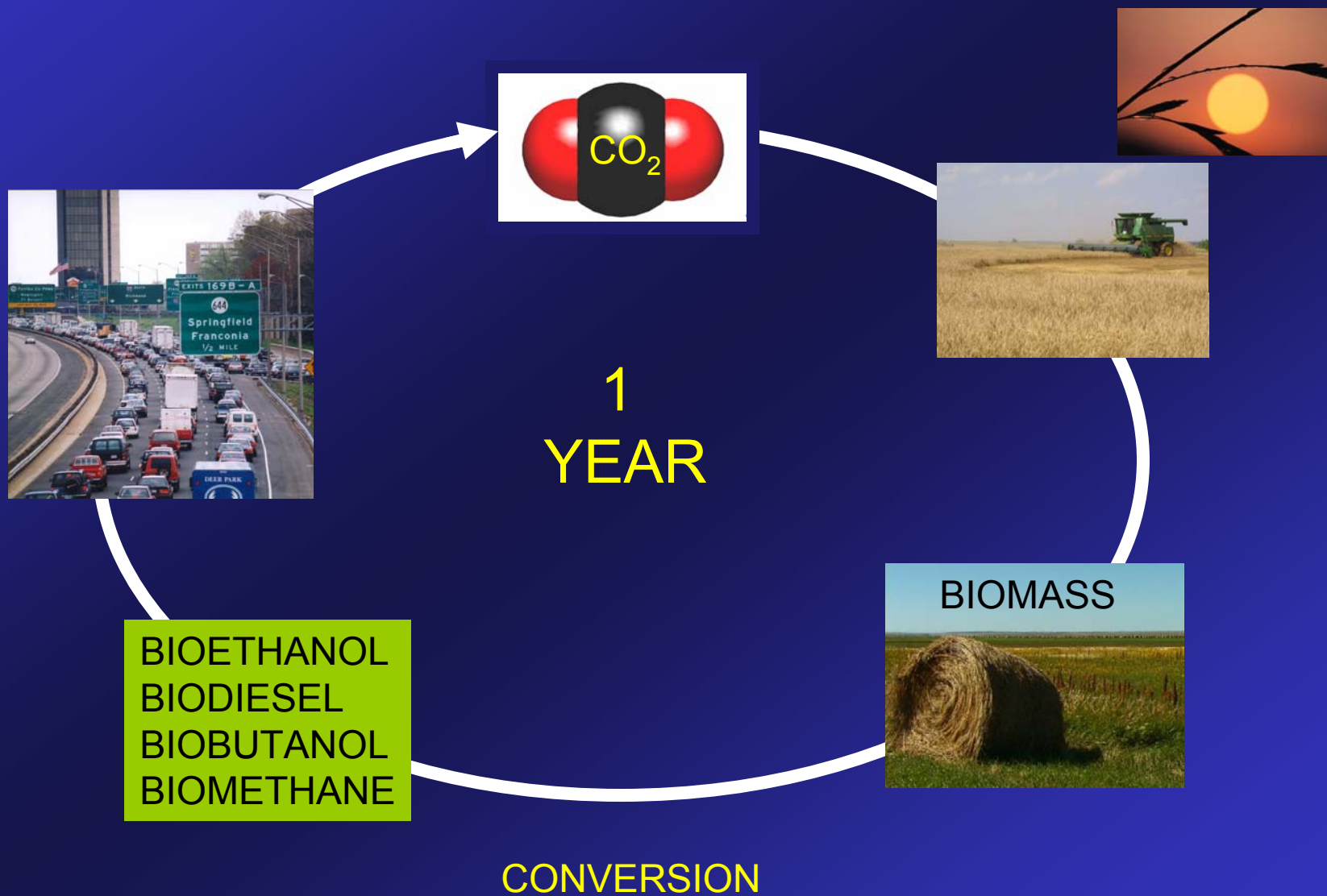
BIOMASS TO FUEL: PROBLEMS AND SOLUTIONS



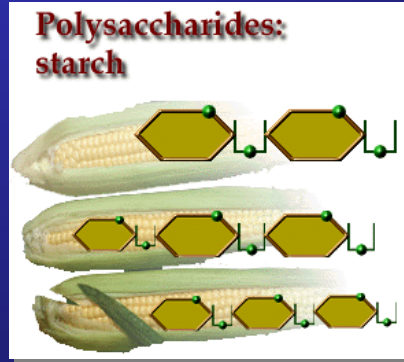
Dr. Steve Hutcheson, PhD
Dept. Cell Biology and Molecular Genetics



BIOFUEL CARBON CYCLE



CORN-BASED ETHANOL

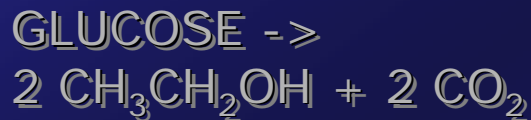


α 1,4 glucose +
 α 1,6 branches

Grain milled to release corn starch

Enzymes

Glucose



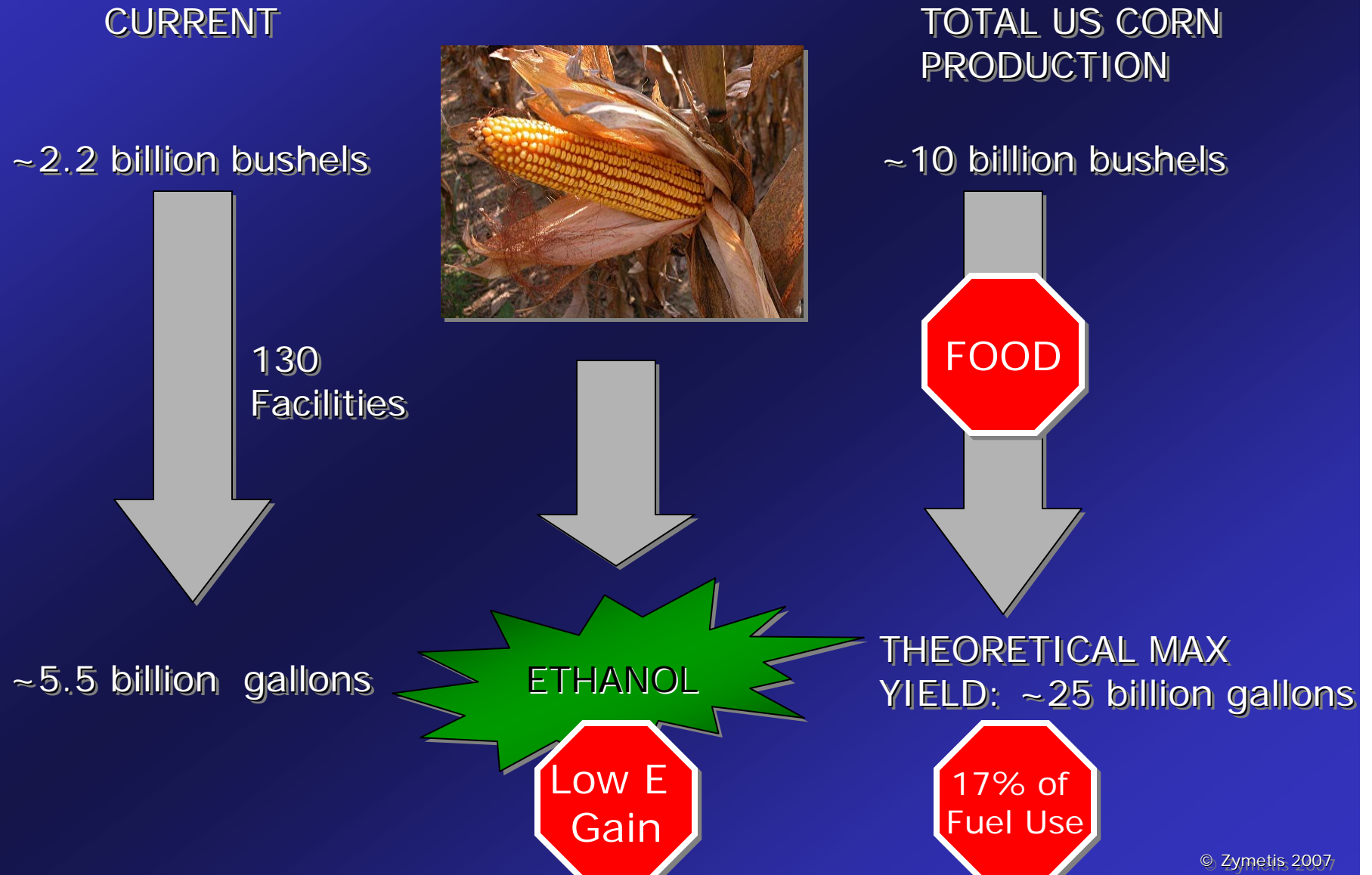
Fermentation

Distillation

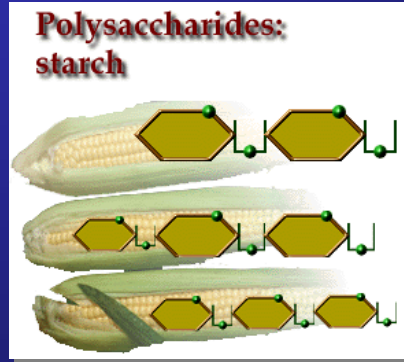
Yield: 89 gallons/ton
375 gal/acre

BIOETHANOL

ETHANOL PRODUCTION IN THE USA



ETHANOL FROM GRAIN IS WASTEFUL



α 1,4 glucose +
 α 1,6 branches

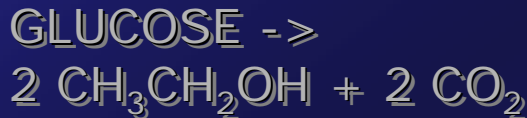
>80% biomass



Grain milled to release corn starch

Enzymes

Glucose



Fermentation

Yield: 89 gallons/ton
Production cost: \$~1.20/gallon

Distillation



POTENTIAL CELLULOSIC ETHANOL PRODUCTION

Wheat straw



100-150 gal/acre

Corn stover



300 gal/acre

Switchgrass



800 gal/acre

Forestry byproducts



1000 gal/acre

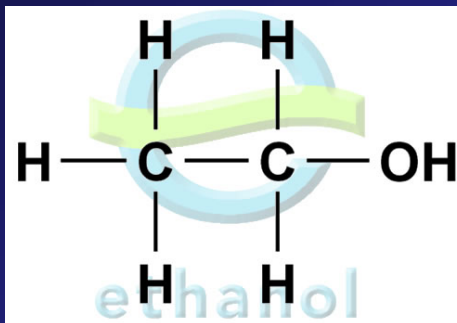
Estimated >75 billion
gallons/year renewable
resource

BIOMASS CONVERSION METHODS

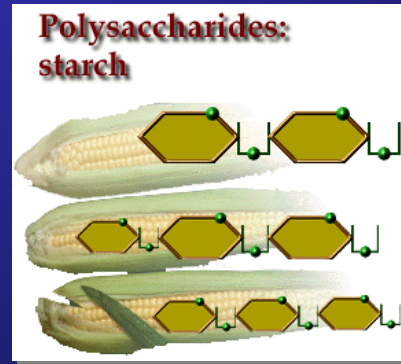


ENZYME-
MEDIATED

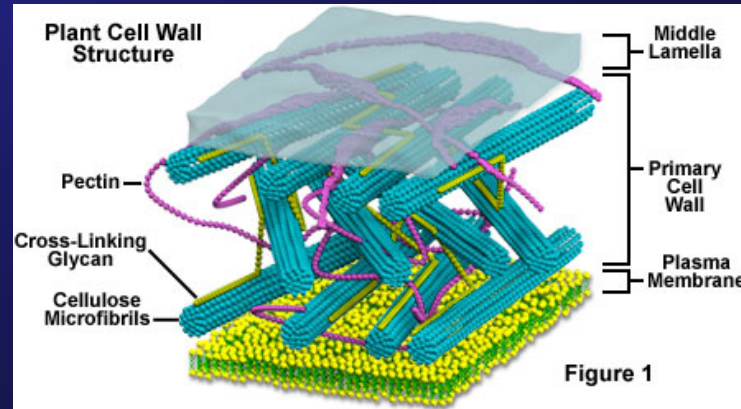
GASIFICATION



CORN IS
CHEMICALLY
SIMPLE

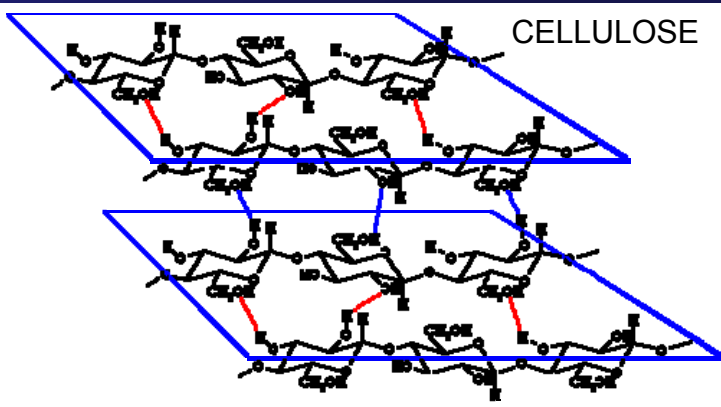


□ □ STARCH
 α 1,4 glucose +
 α 1,6 branches

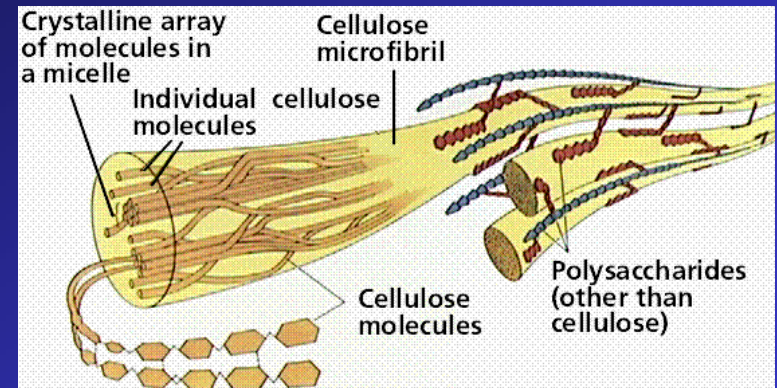


BIOMASS IS
CHEMICALLY
COMPLEX

<http://micro.magnet.fsu.edu/cells/plants/images/>

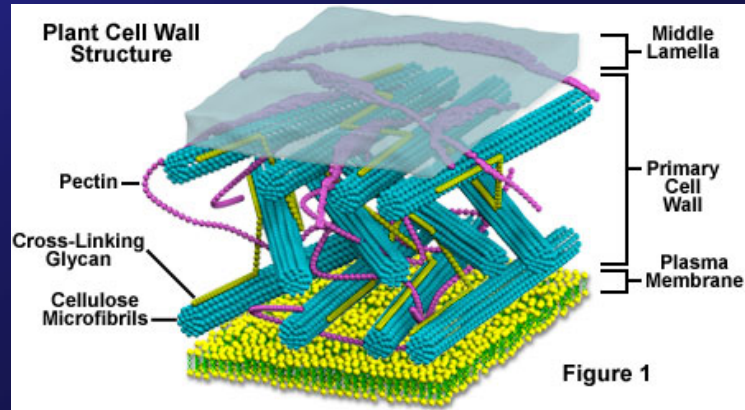
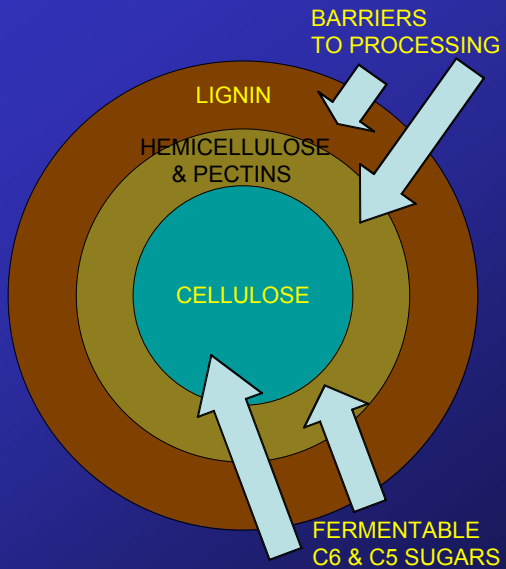


β 1,4 glucose

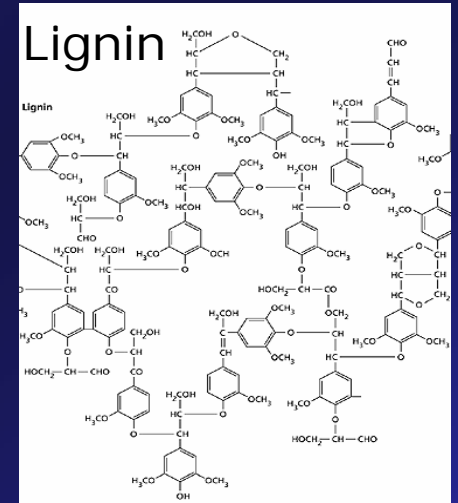


<http://www.emc.maricopa.edu/faculty/farabee/BIOBK/cellulose.gif>

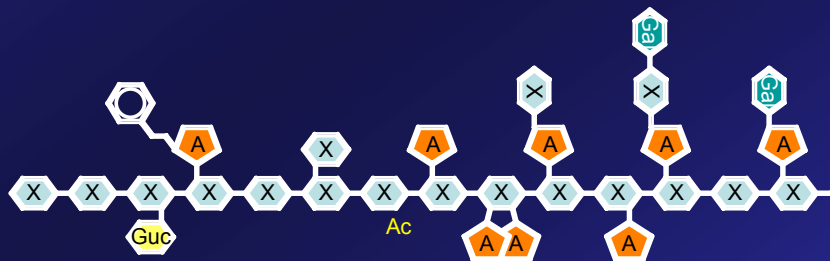
CELL WALL POLYSACCHARIDES



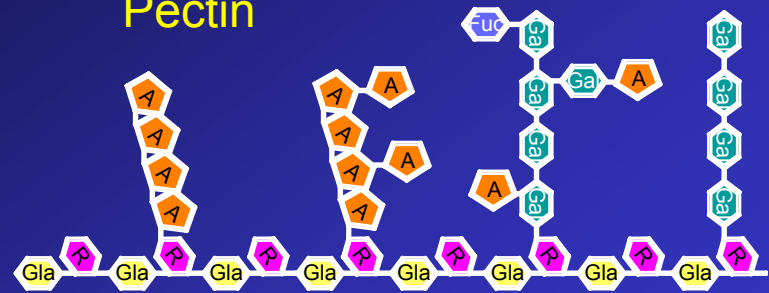
<http://micro.magnet.fsu.edu/cells/plants/images/>



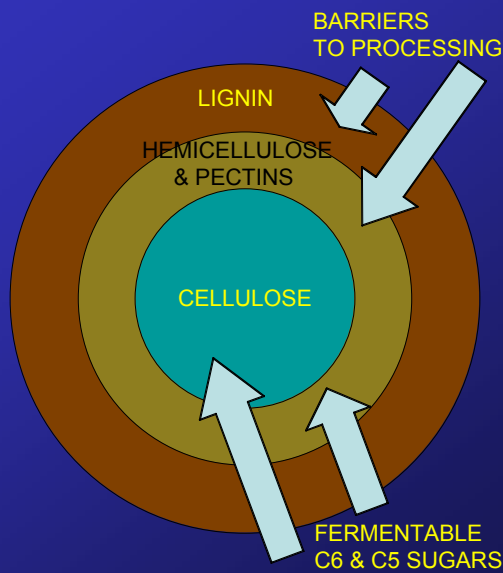
Hemicellulose



Pectin



ENZYMIC BIOETHANOL PRODUCTION



Milling
Lignin & hemicellulose extraction (hot H₂SO₄)
Steam explosion

Pretreatment

Processed Material

C5 sugars

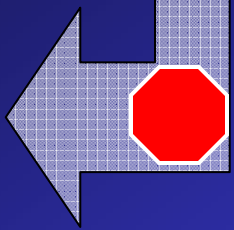
Lignin (Fuel)

Enzymes

C6 Sugars

Fermentation

Distillation



SIEVE

BIOETHANOL



ETHANOL PRODUCTION

\$1.50



9 kg

\$0.60



11 kg

\$0.44



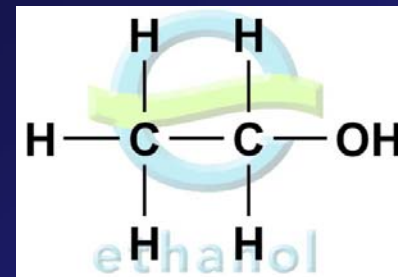
10 kg

>34 moles



6 C sugars

68 moles



\$2.50

One gallon

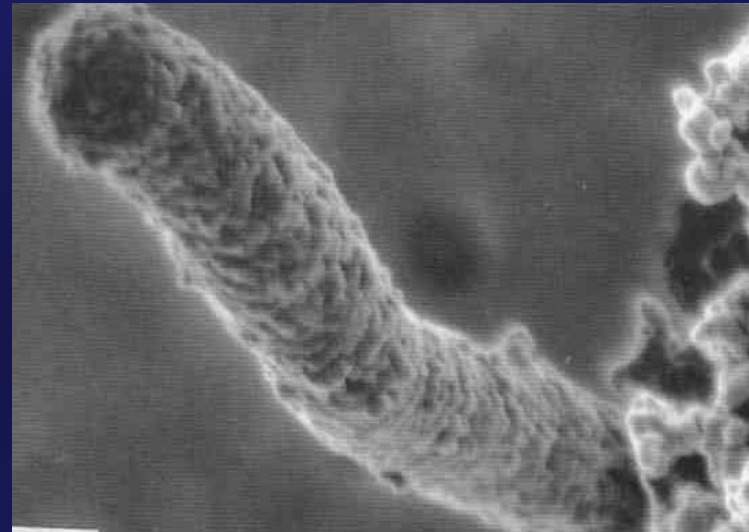
**TARGET
ENZYME < \$0.25
COST**

ECONOMICAL SOURCES OF ENZYMES?

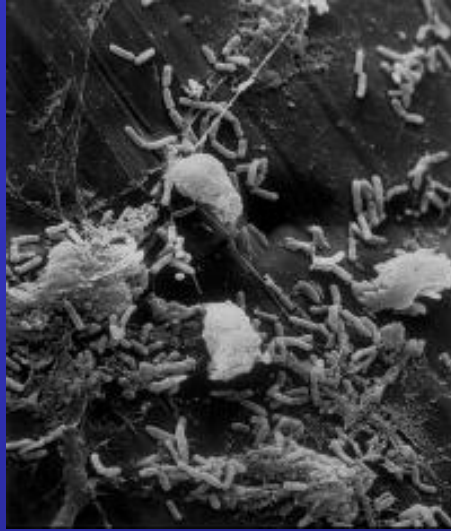
SOURCES OF CELLULOLYTIC ORGANISMS



Saccharophagus degradans 2-40



- Isolated from decaying marsh grass
- Gamma-proteobacterium
(*Pseudoalteromonas* group)
- Aerobic, marine bacterium
- Unusual degradative abilities



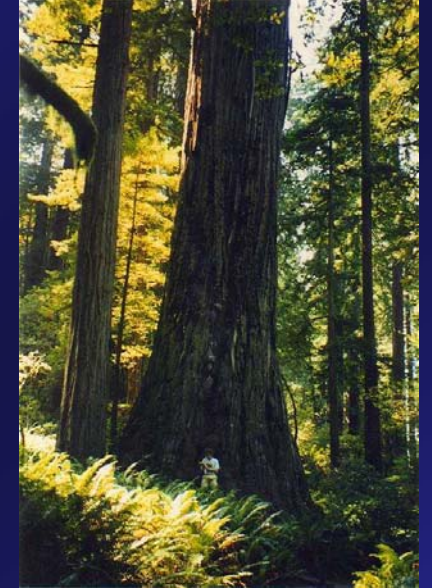
Biofilm Components

Alginate



Higher Plant Polysaccharides

Cellulose Xylan
Pectin Starch



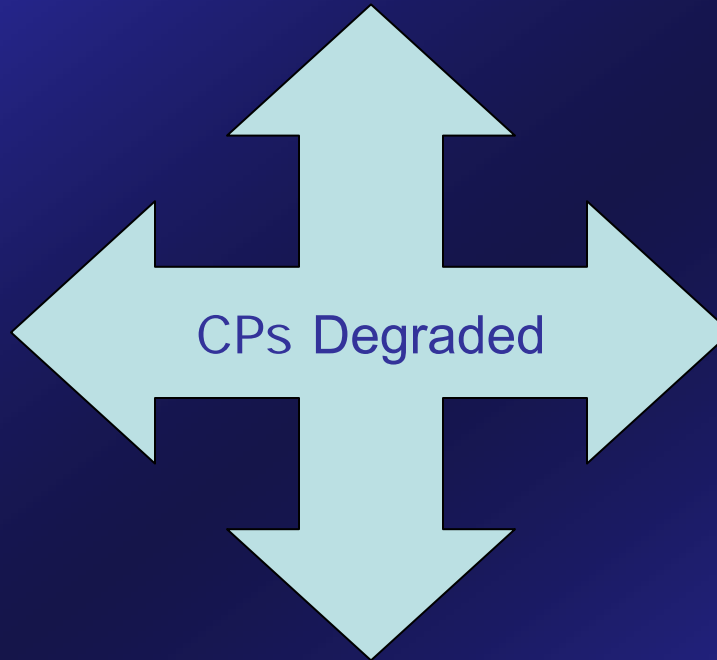
Exoskeleton and Fungal Components

Chitin

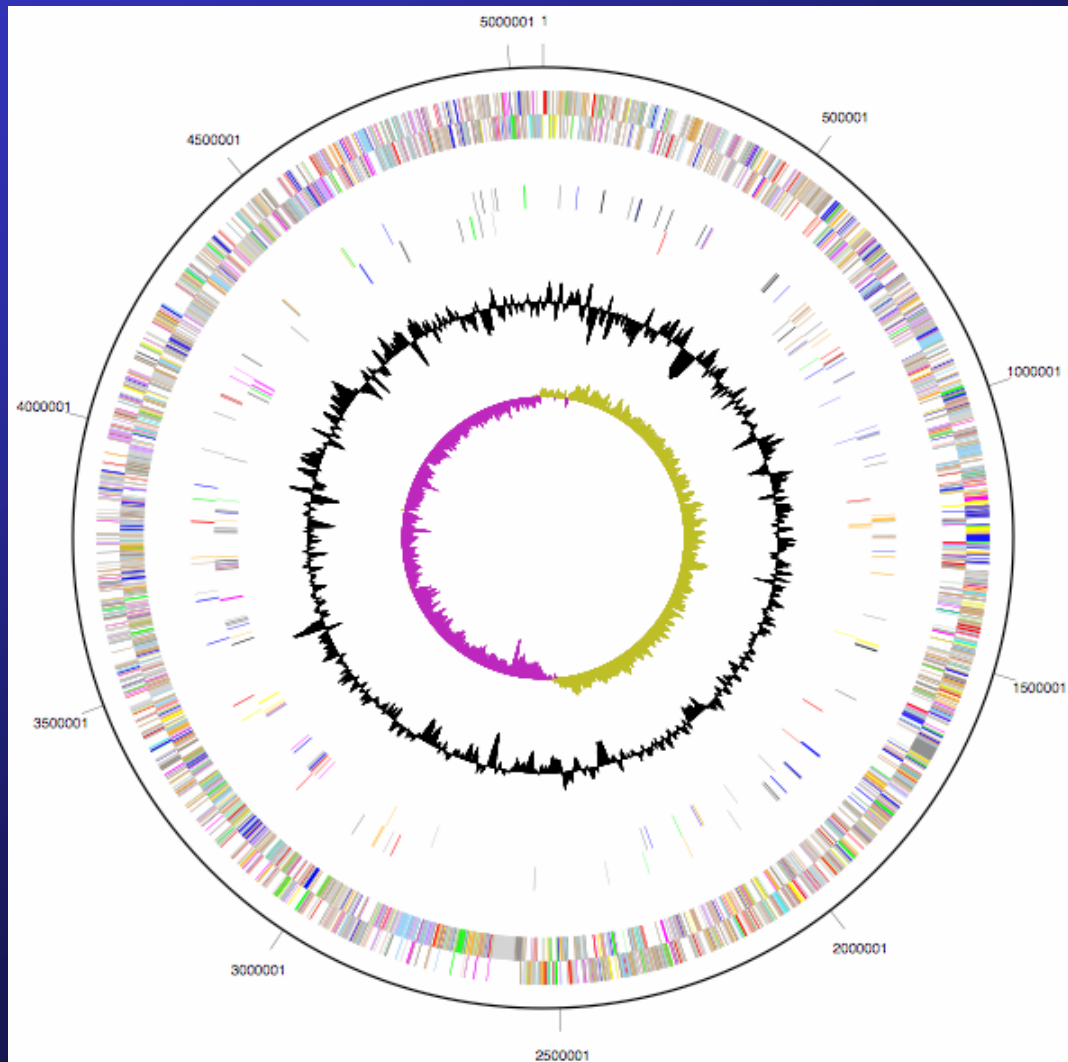


Algal Polysaccharides

Agar Pullulan
Laminarin Fucoidan



GENOMICS



- 5.06 MB chromosome
- 4009 gene models
- 128 genes with GH domains
33 genes with PL domains
- Accessory genes

A conservative estimate:
~10% of the genome is
dedicated to polysaccharide
depolymerization, transport,
and metabolism

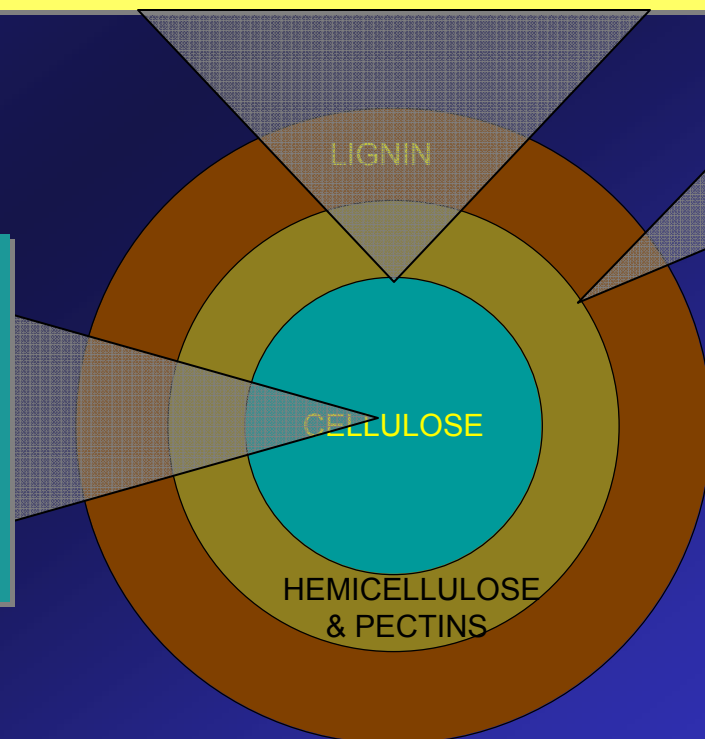
Courtesy of L. Hauser, F. Larimer, and P. Richardson

CELL WALL PROCESSING ENZYMES PREDICTED FROM THE GENOME SEQUENCE

- Xylanases (7)
- Xylosidases (8)
- Arabinofuranosidases (11)
- Acetylxyylan esterases (2)
- Mannases (5)
- Pectate lyases (14)
- Pectin methyl esterases(2)
- Arabinases (10)
- Galactosidases (2)
- Glucuronidases (2)

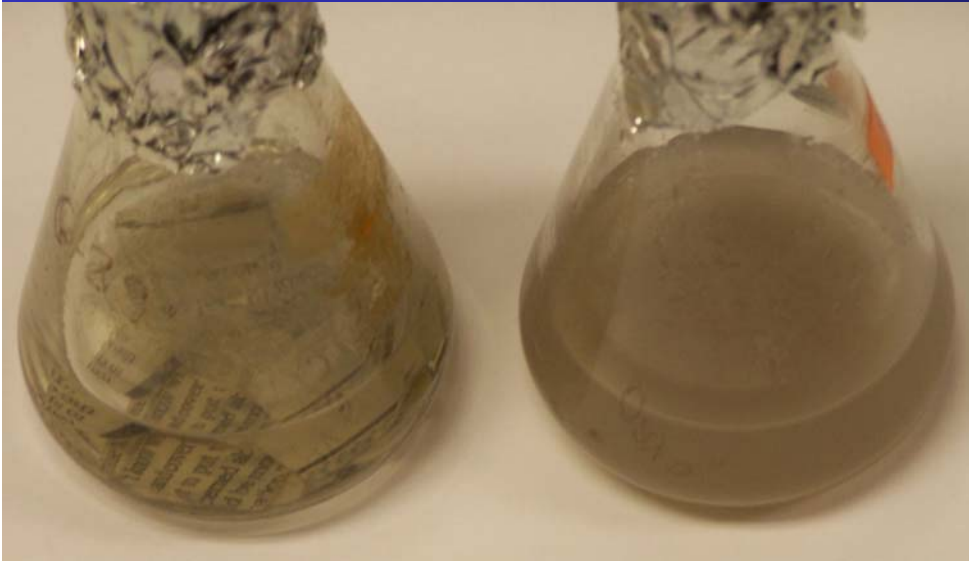
- Endoglucanases (12)
- Cellobiohydrolase (1)
- Cellodextrinases (2)
- Glucanases (3)
- CBM proteins (>10)

Ligninases (3-5)



**ONE
STOP
SHOP!!!**

DIGESTION OF PLANT MATERIAL DURING CULTURE WITH *S. DEGRADANS*



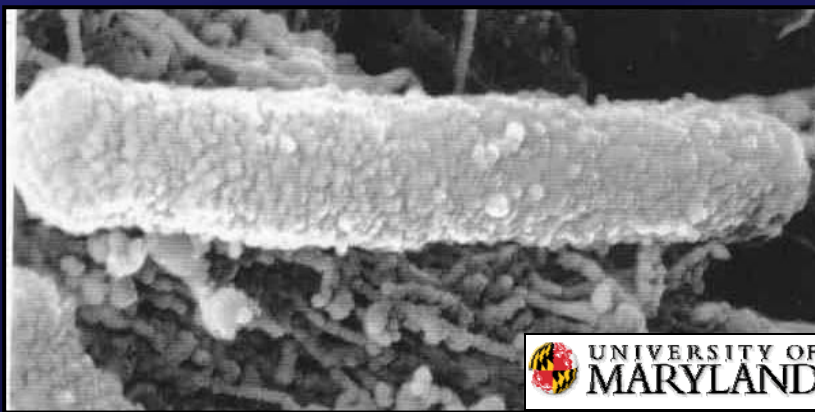
NEWSPRINT

CORN LEAVES





ENZYMES FOR FUELS



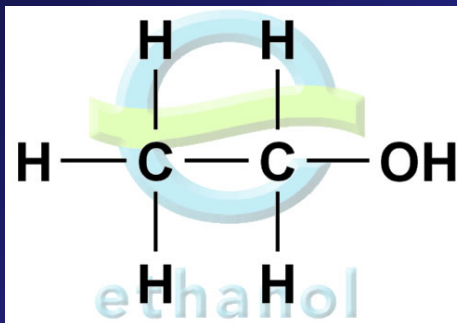
(Zy - met - is)

BIOMASS CONVERSION METHODS

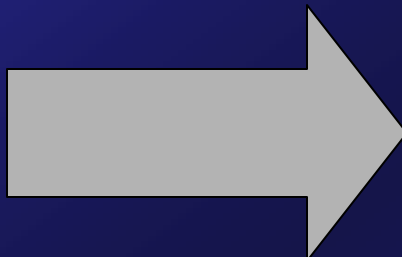


ENZYME-
MEDIATED

GASIFICATION



SYNTHETIC "BIOETHANOL"



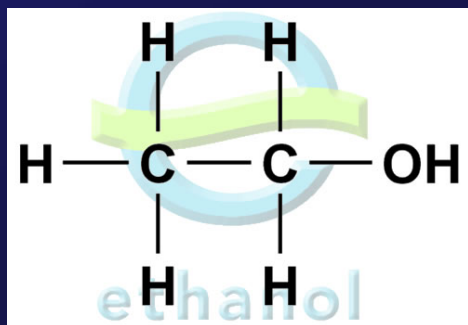
HIGH
TEMP
GASIFIER

(1800 F)

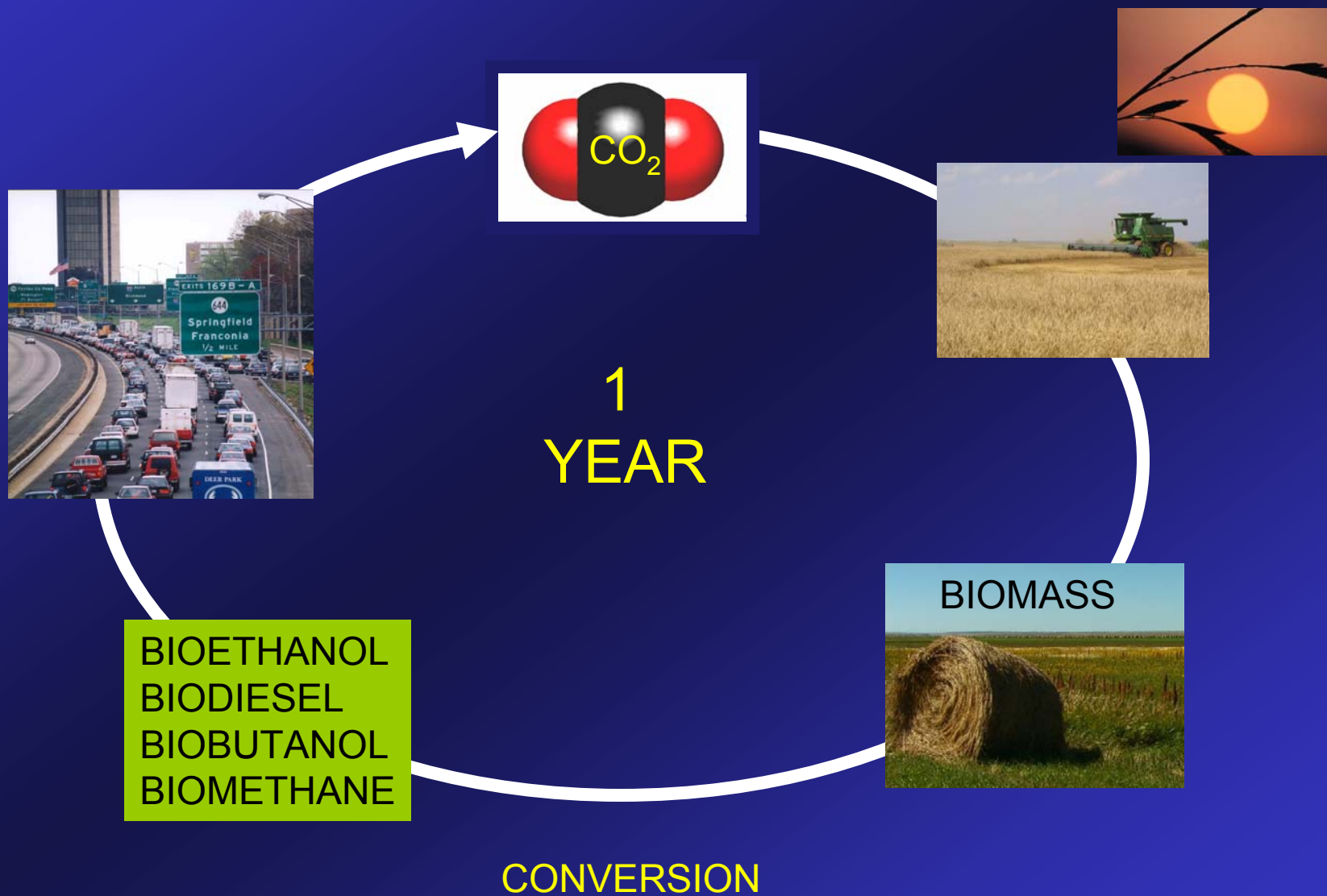


SYNGAS

CATALYTIC
CONVERSION

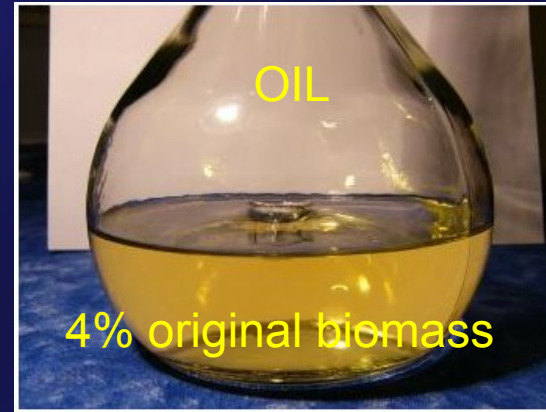
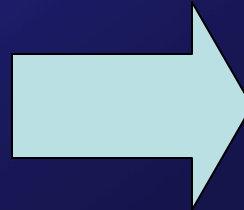


BIOFUEL CARBON CYCLE

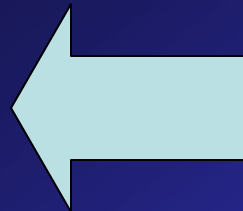


BIODIESEL

OIL SEED



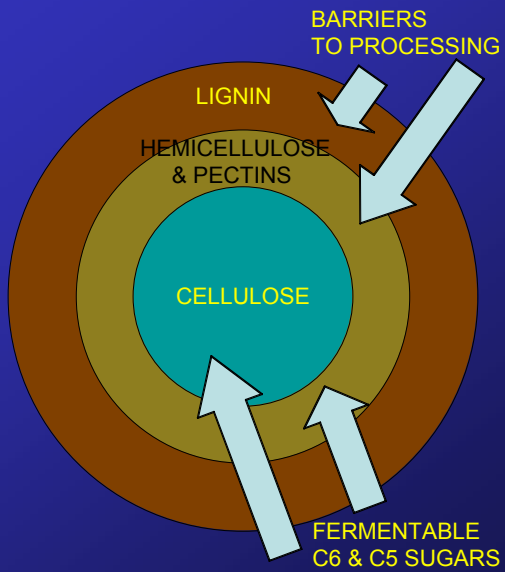
Lye
Methanol



POTENTIAL BIODIESEL YIELDS

Crop	Yield		Land area 50% need
	Gal / acre	Total (billion gal)	
Soybean	48	5	2.5 million sq mi
Peanuts	113	0.18	1 million sq mi
Oil palm	635		190,000 sq mi
Algae	7000		16,700 sq mi

BIOBUTANOL PRODUCTION



Pretreatment

Milling
Lignin & hemicellulose
extraction (hot H_2SO_4)
Steam explosion

Processed Material

Enzymes

C6 Sugars

Fermentation

Distillation

C5 sugars

Lignin
(Fuel)

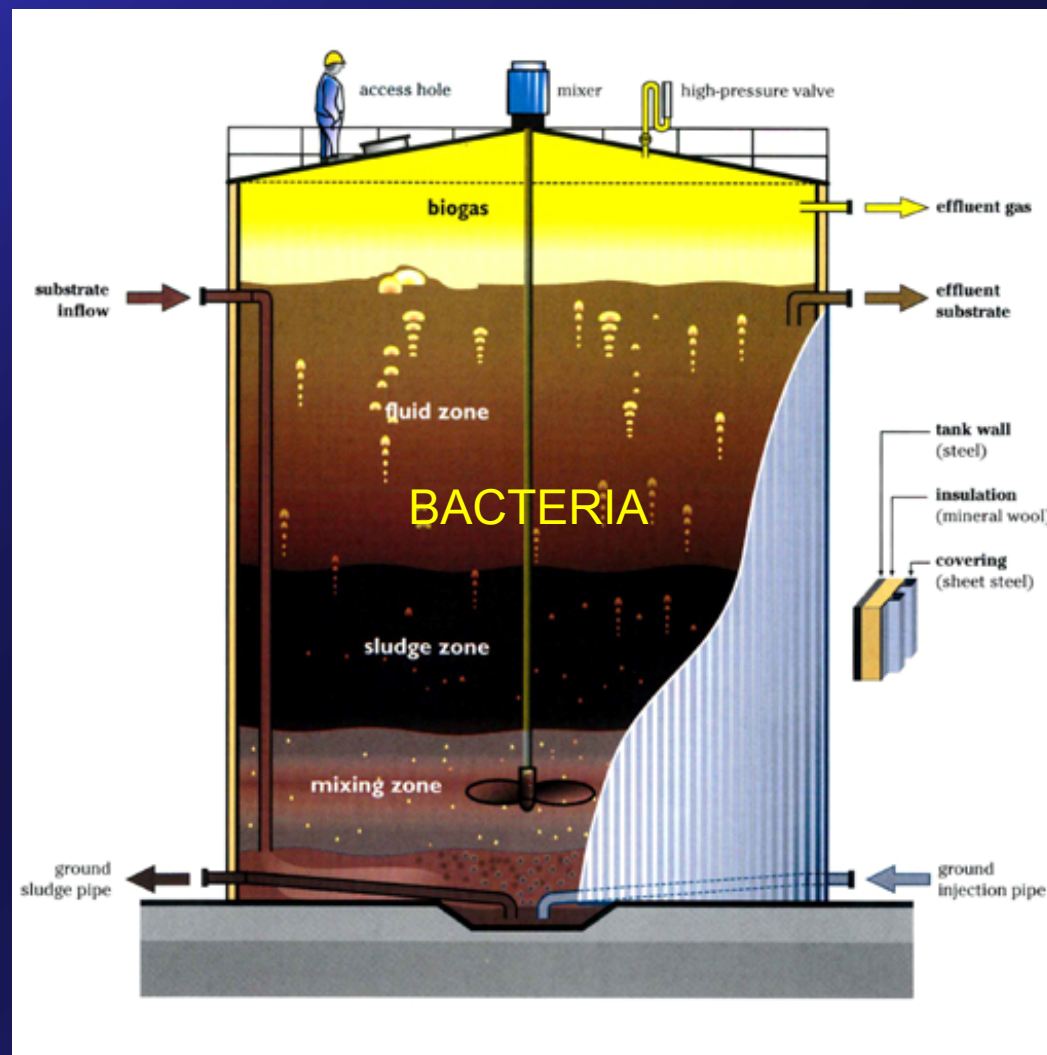
butanol



SIEVE

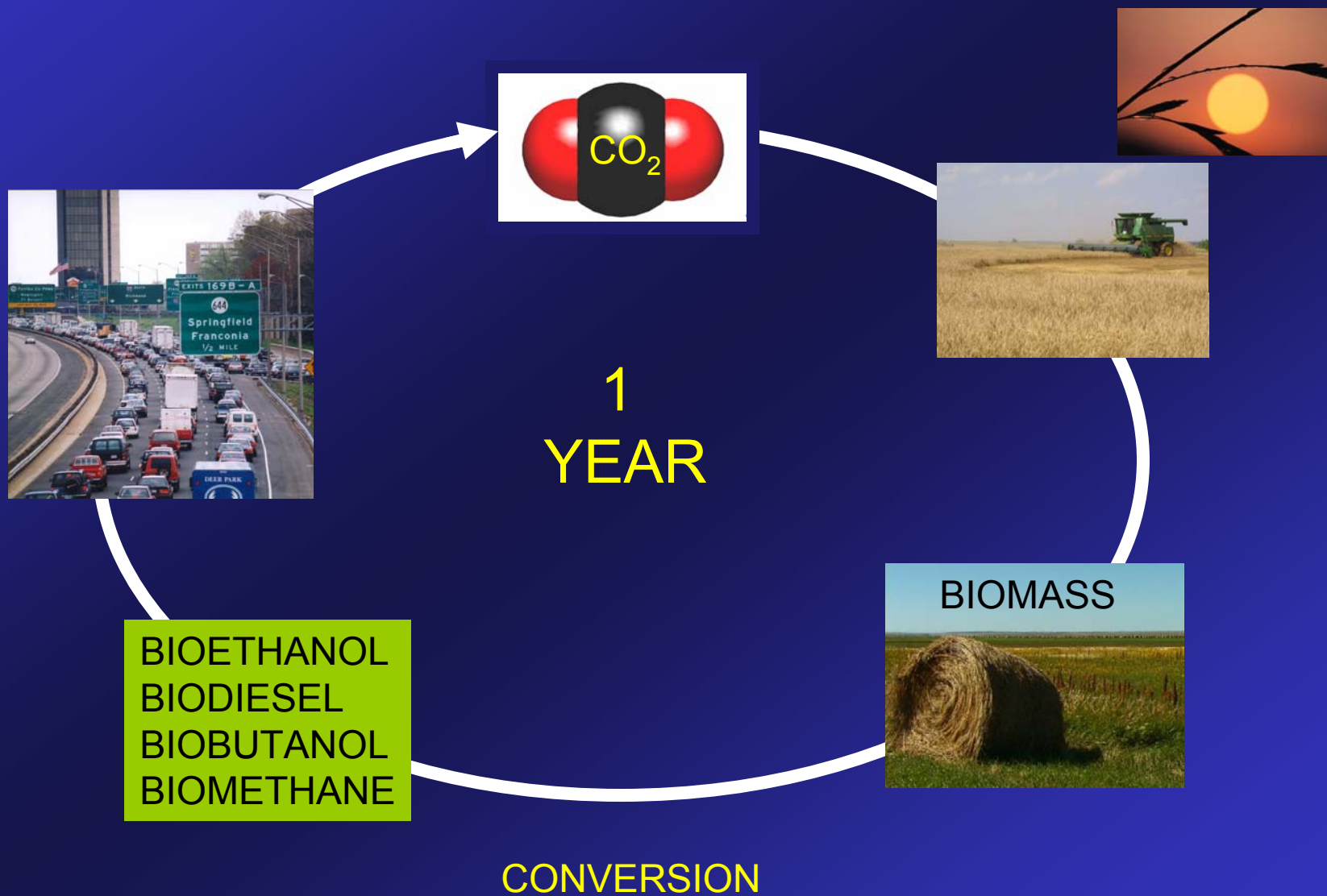
ANAEROBIC DIGESTORS

BIOMASS



METHANE

BIOFUEL CARBON CYCLE



ACKNOWLEDGEMENTS

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