

Genetic Engineering of Cellulose Accumulation

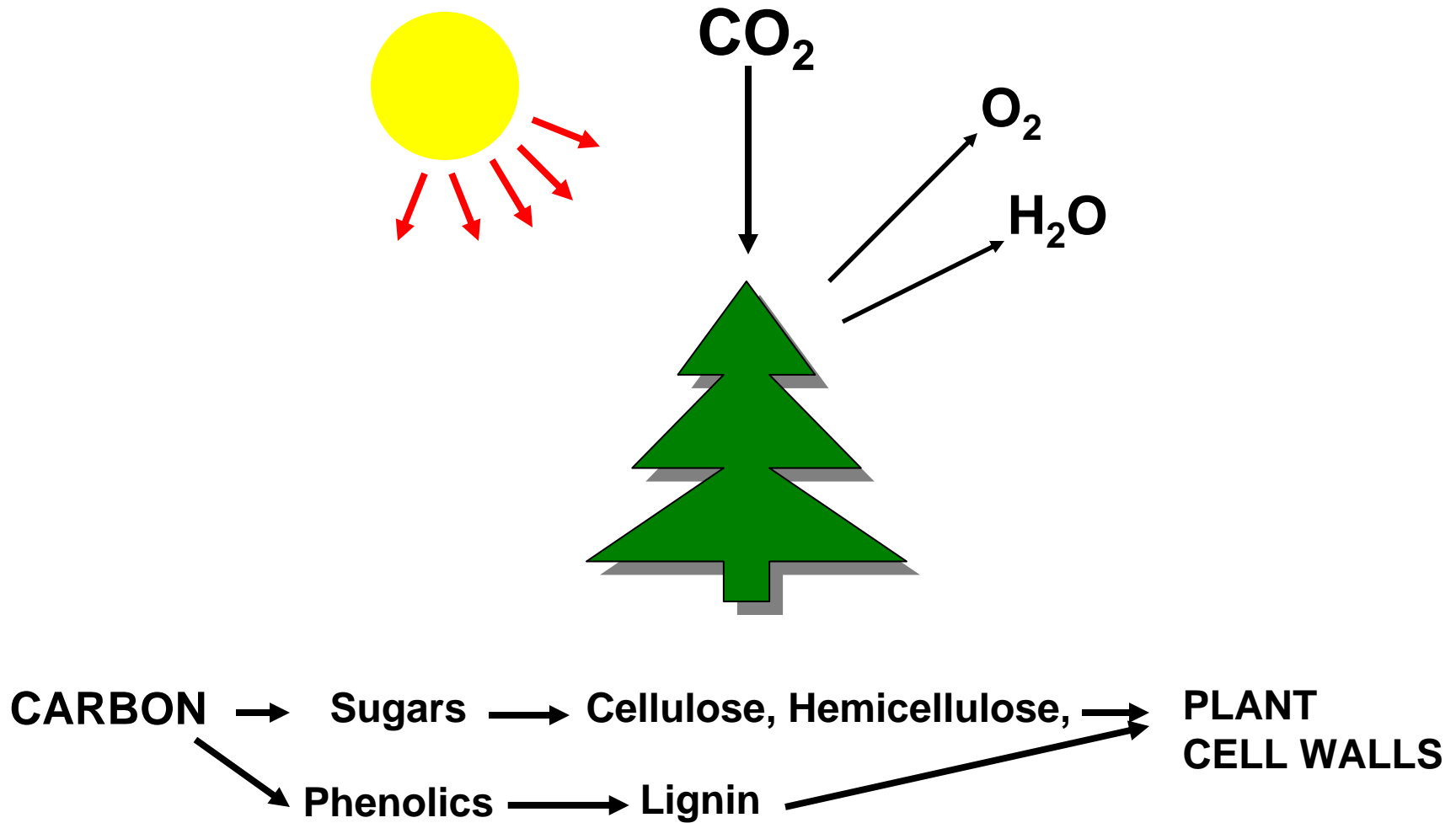
www.esd.ornl.gov/bfdp/



Jennifer Milne & Chris Somerville
Department of Biological Sciences
Stanford University
and
Carnegie Institution

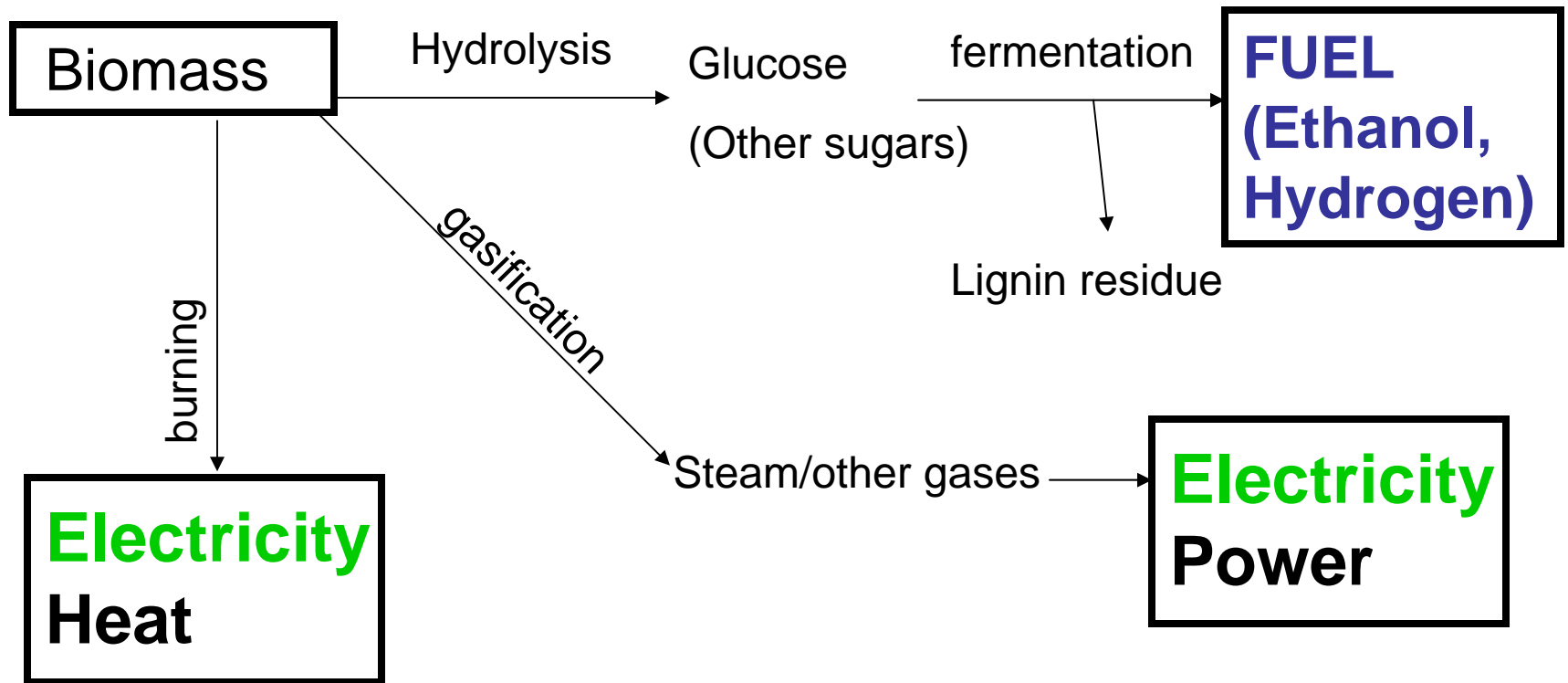


Plants are Solar Energy Harvesters and Carbon Storage Devices

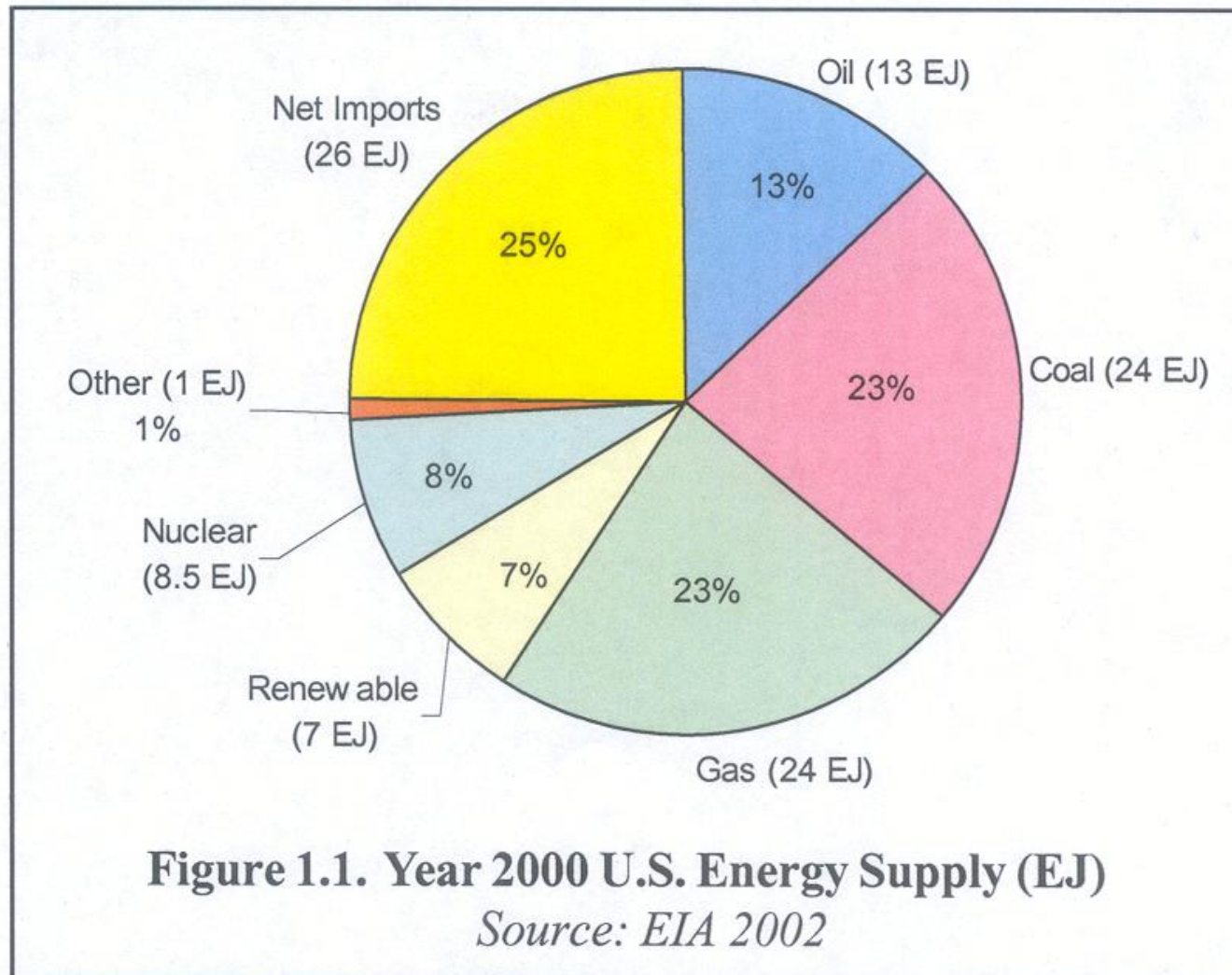


Energy from biomass

Biomass is a Carbon neutral energy resource

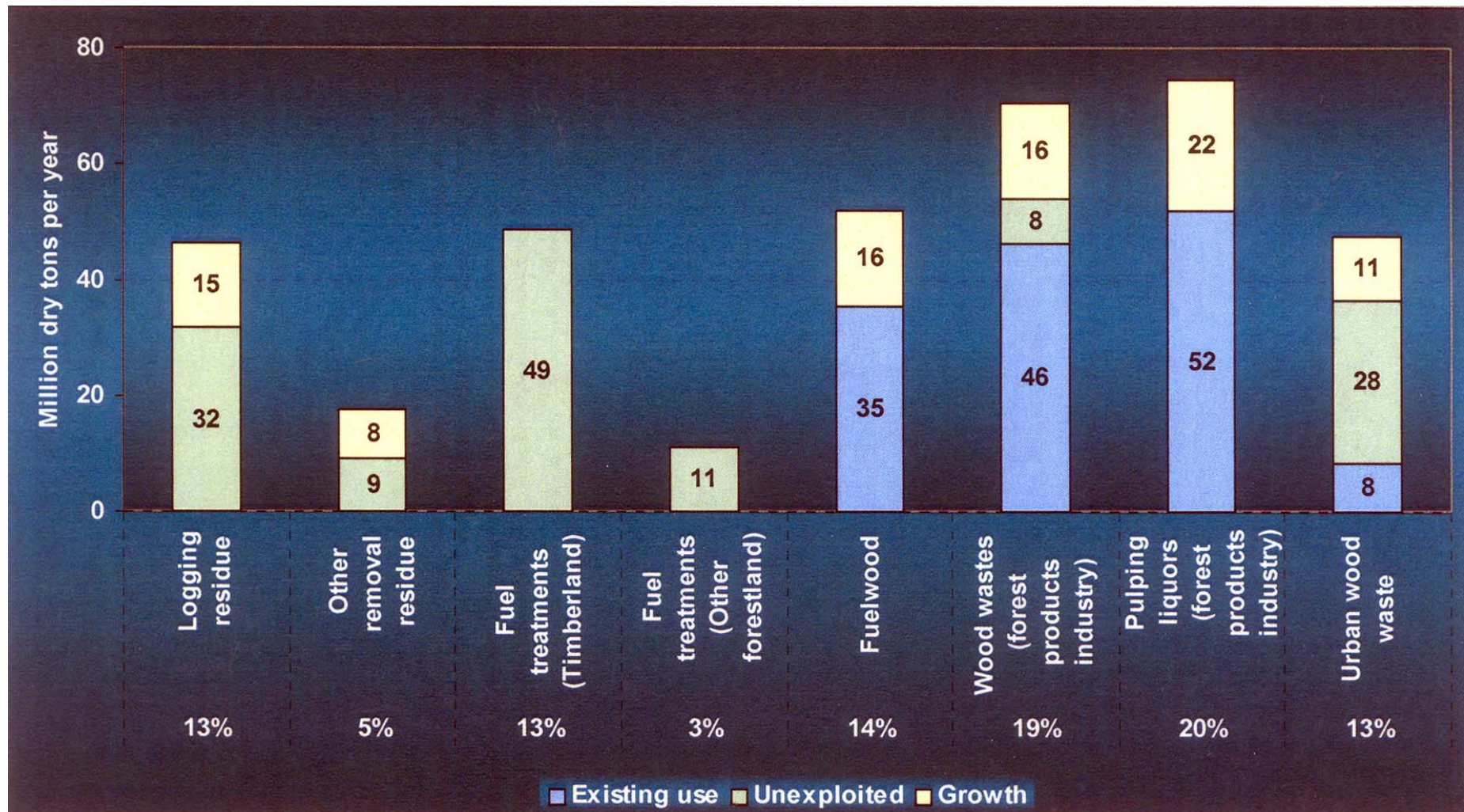


Is it Possible to Displace 30% of Fossil Fuel use with Carbon Free Renewables by the year 2030?



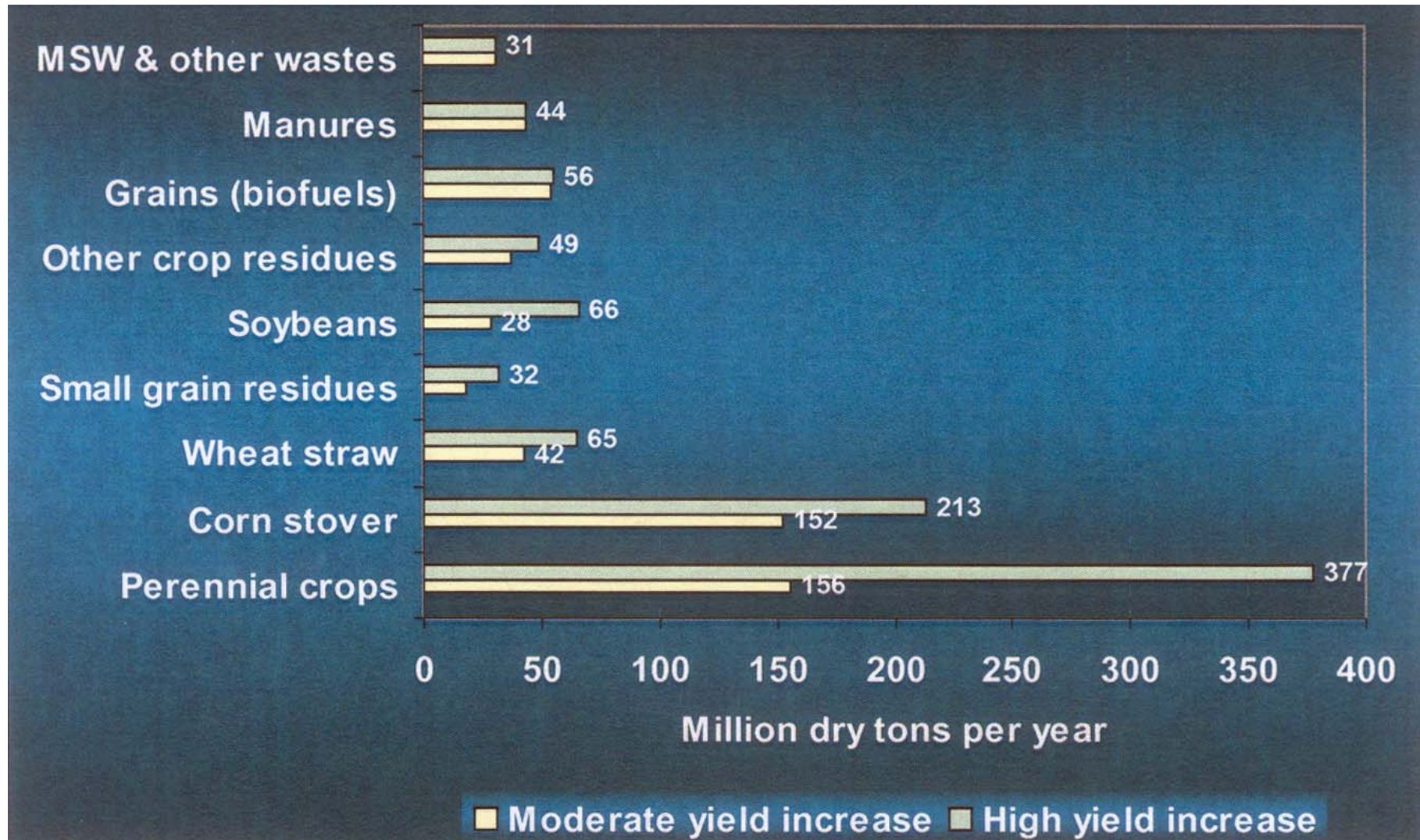
Availability of forest biomass

(137 Mt unexploited, 88 Mt growth)



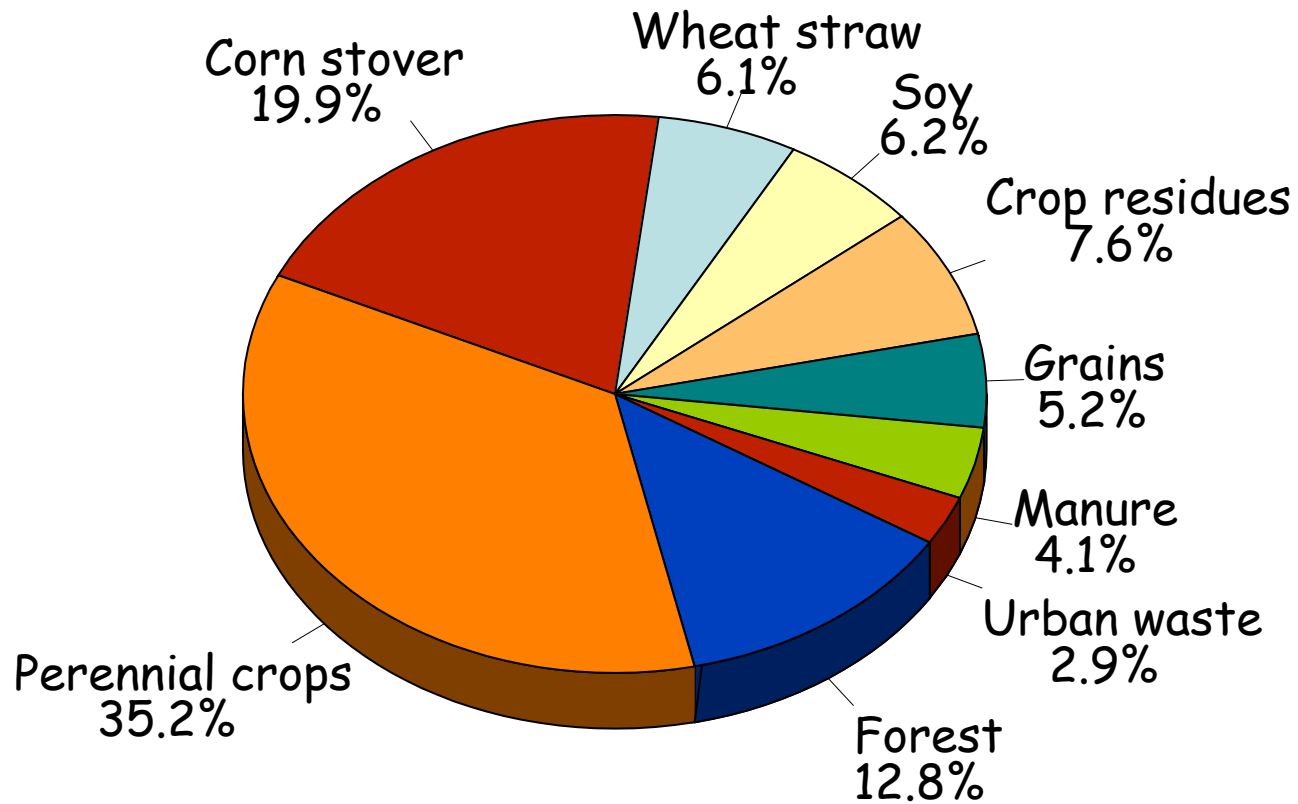
From: Billion ton feedstock supply (2005)

Availability of non-forest biomass



From: Billion ton feedstock supply (2005)

US Biomass inventory



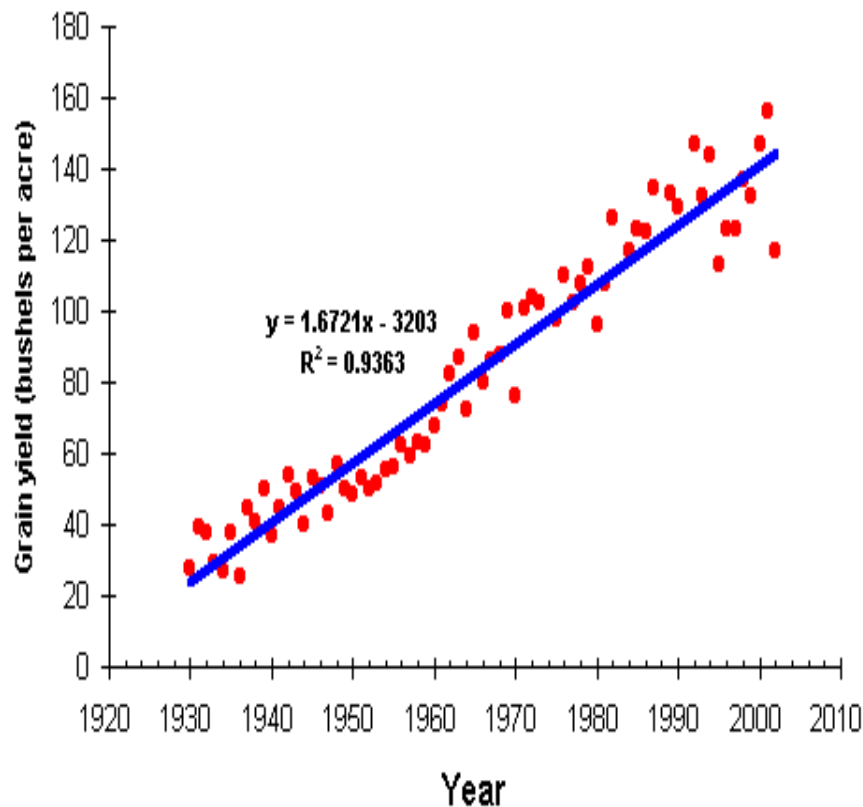
From: Billion ton Vision, DOE & USDA 2005

Comparison of a wild and domesticated tomato



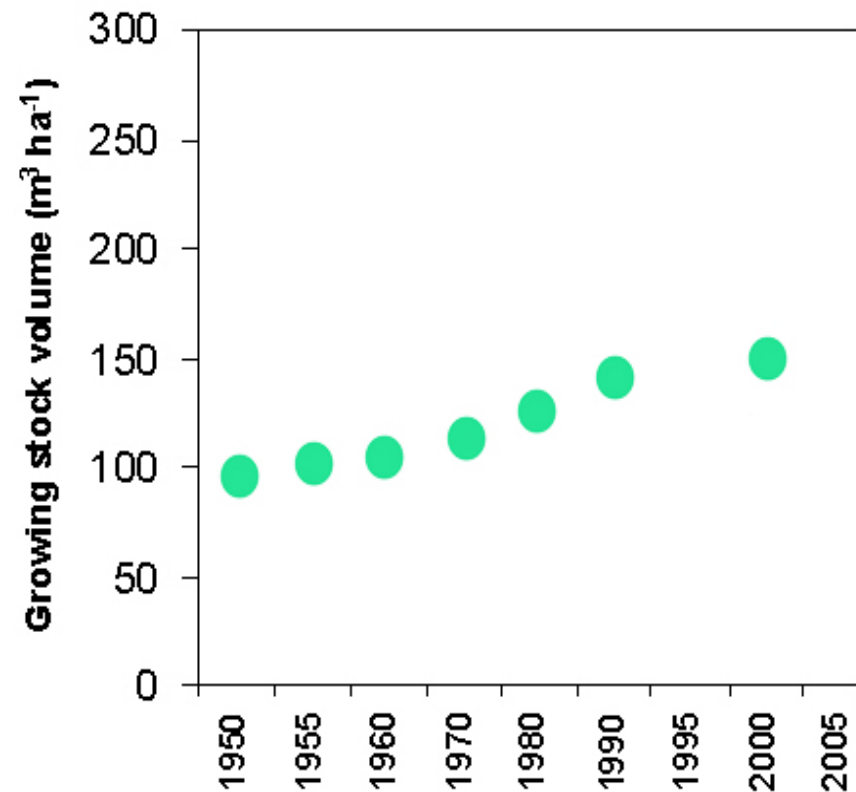
Large increases in biomass species productivity are probably possible through genetic improvement

Average Indiana corn yield



Data Source: Indiana Agricultural Statistics Service

Average European forest yield

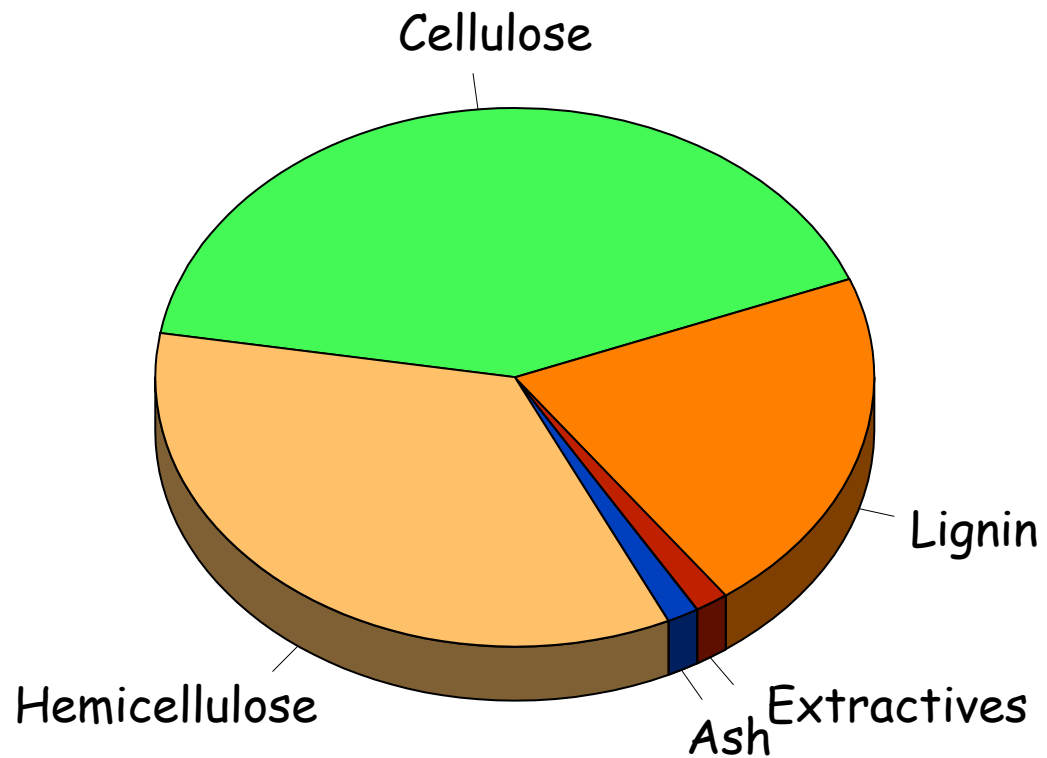


Source: European Forest Institute (www.efi.fi)

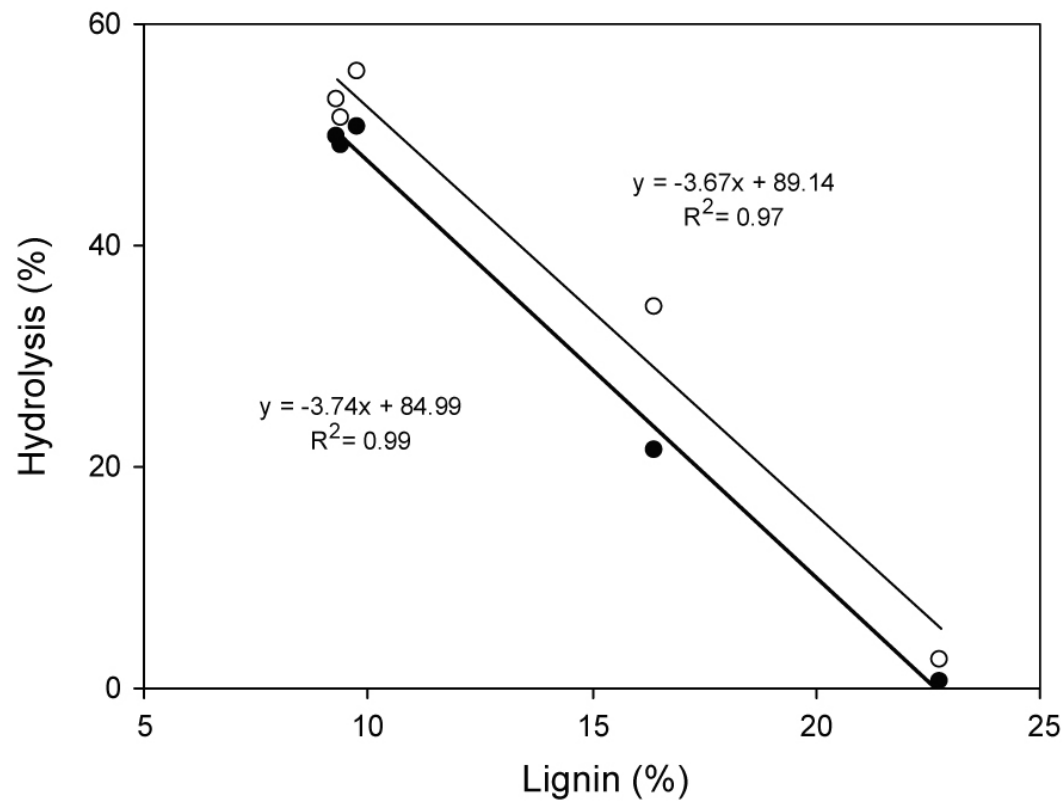
Efficiency considerations

- **Maximize recoverable energy content**
- **Maximize net photosynthesis per unit area per year**
- Minimize inputs (minerals, water, pesticides and herbicides, tillage)
- Minimize harvest and transportation costs

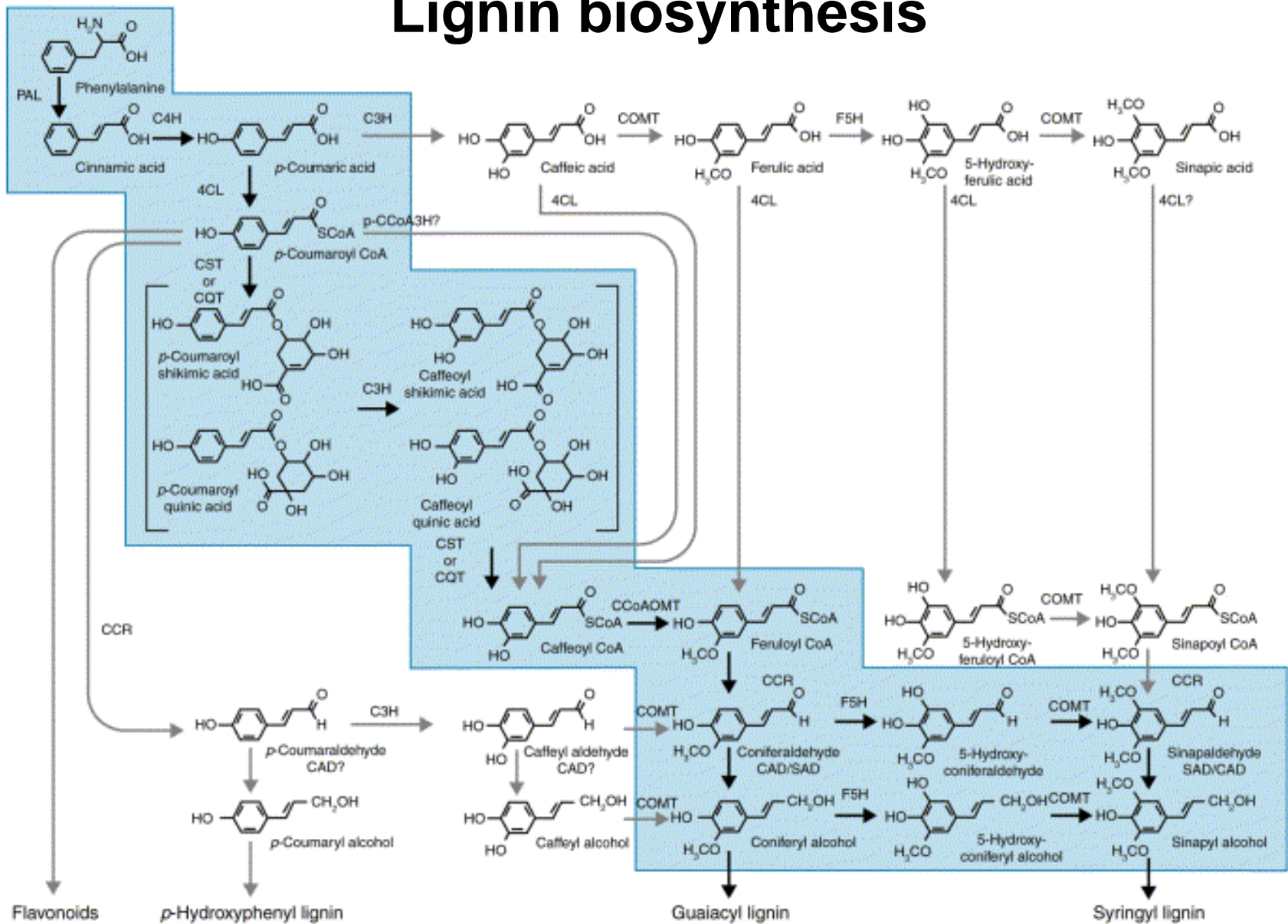
Composition of Switchgrass



Effect of lignin content on enzymatic recovery of sugars from Miscanthus

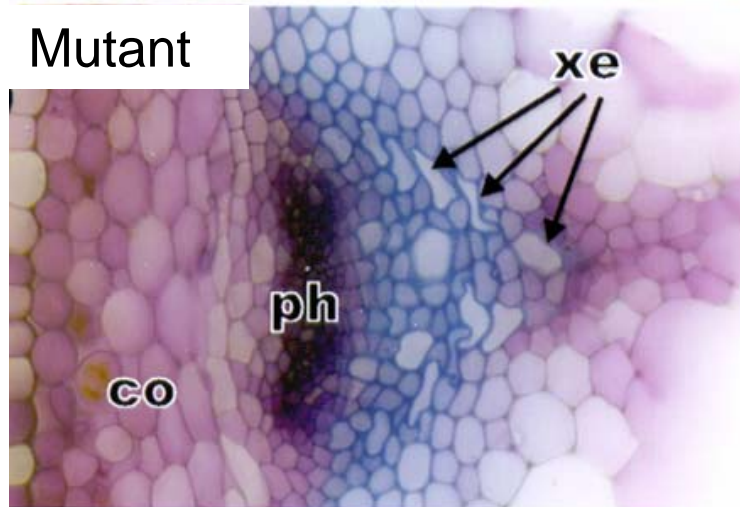
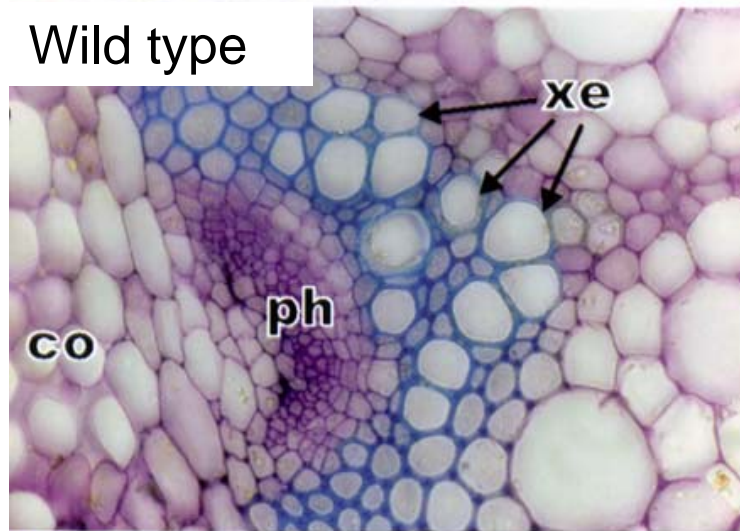


Lignin biosynthesis



Current Opinion in Plant Biology

Irregular xylem (*irx*) mutants are deficient in lignin accumulation



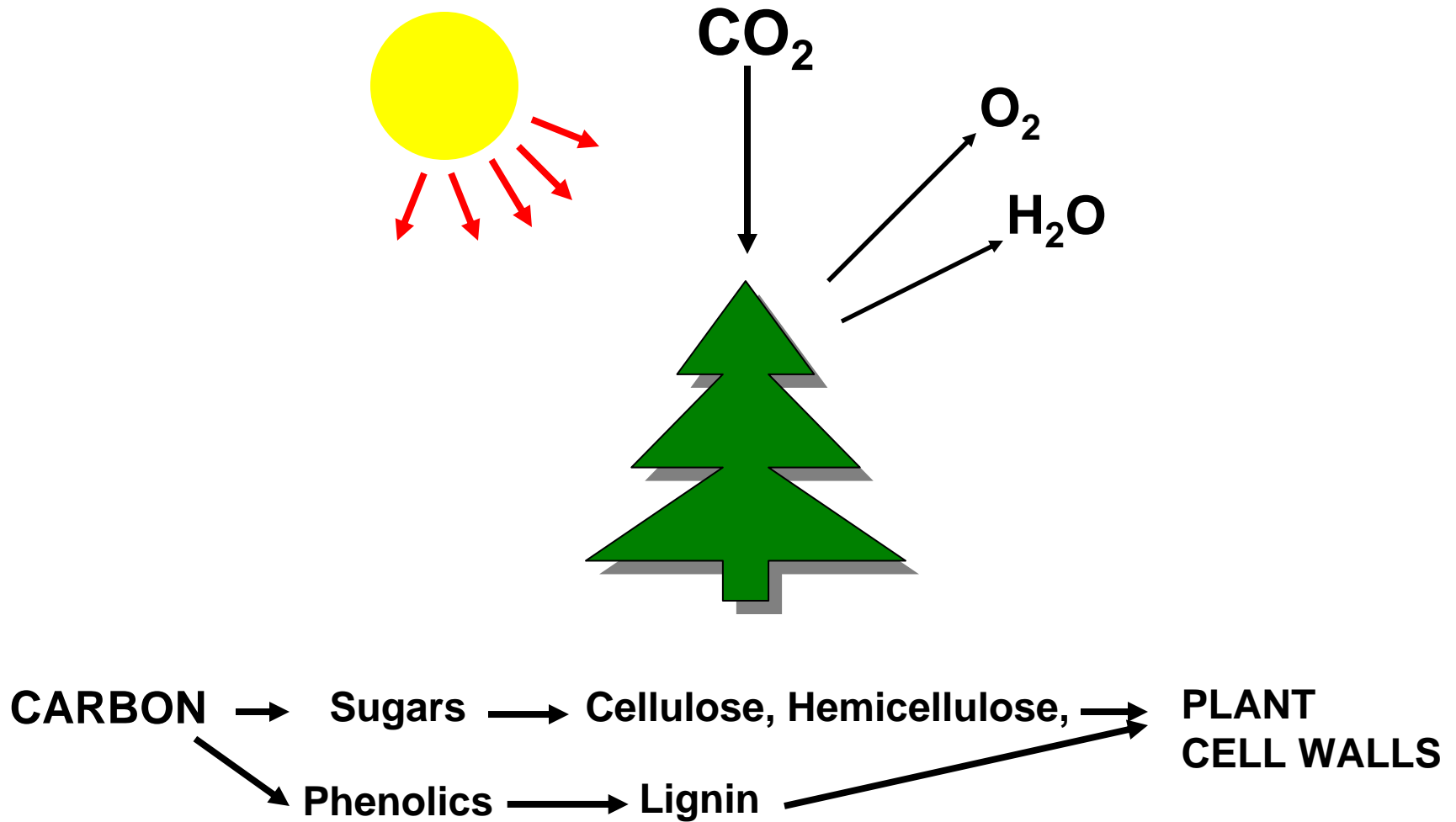
Engineering goals

- Decrease lignin
- Increase cellulose
- Increase hemicellulose

Our Goal:

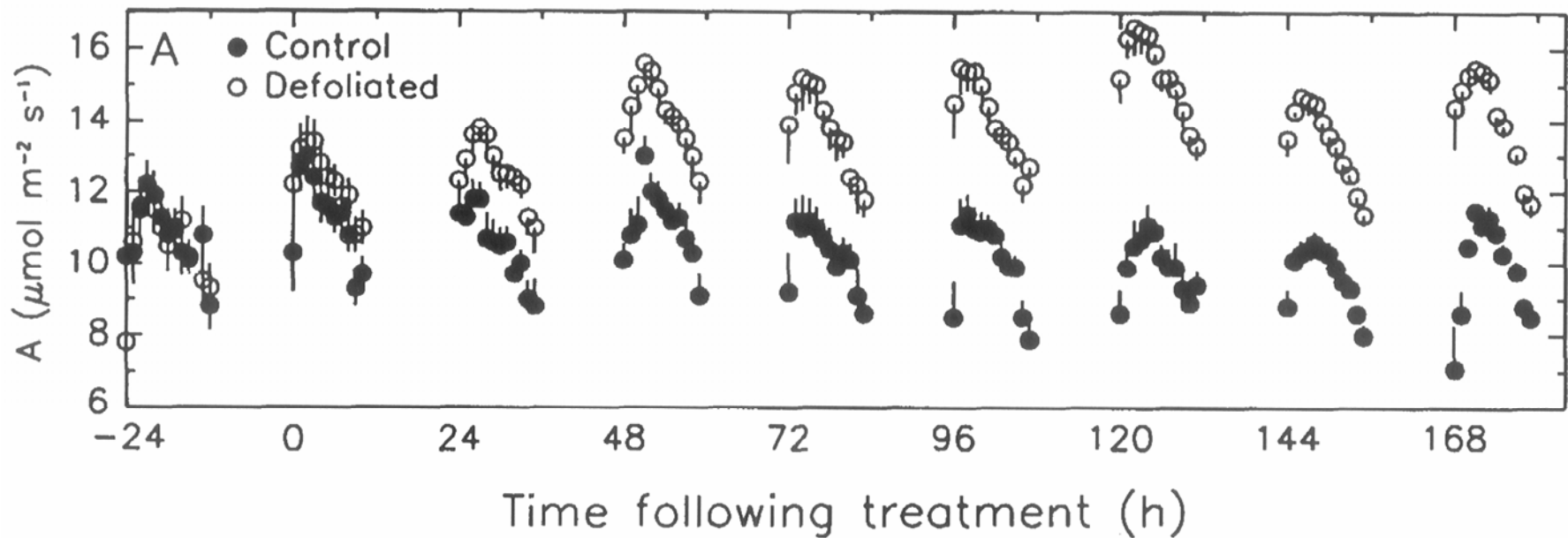
**To Increase the Energy Content of Biomass
and Maximize net Photosynthesis per Unit
Area per Year by
Enhancing Cellulose Accumulation**

Plants are not working at full capacity



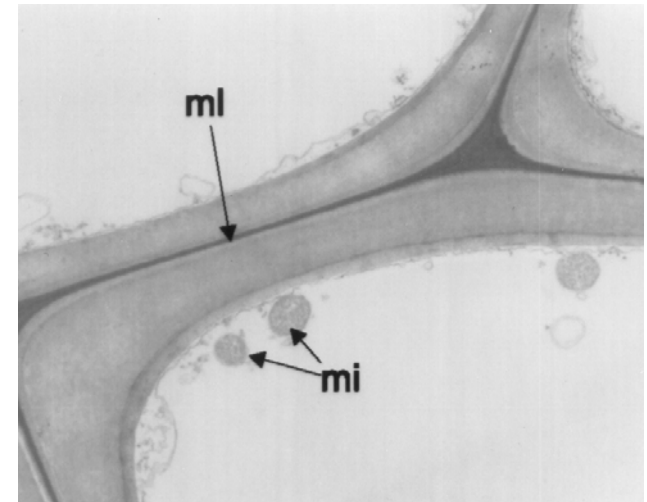
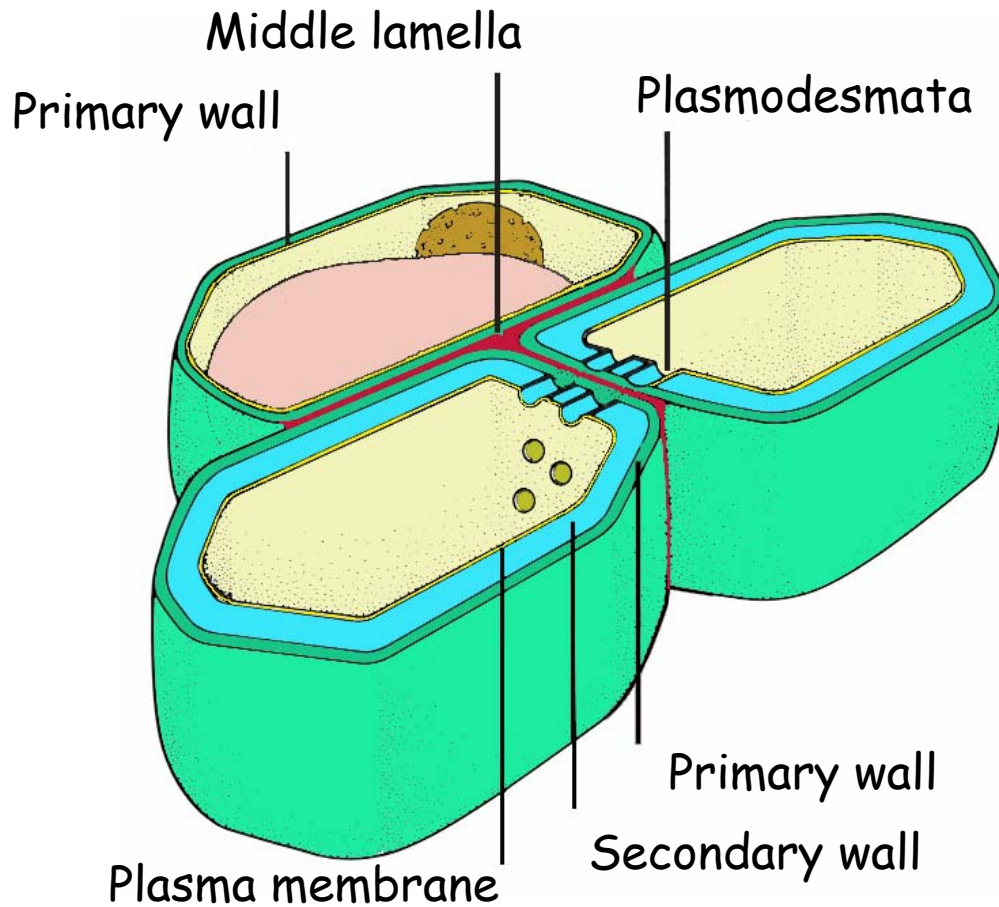
Photosynthesis is “sink limited”

Sour cherry tree experiment



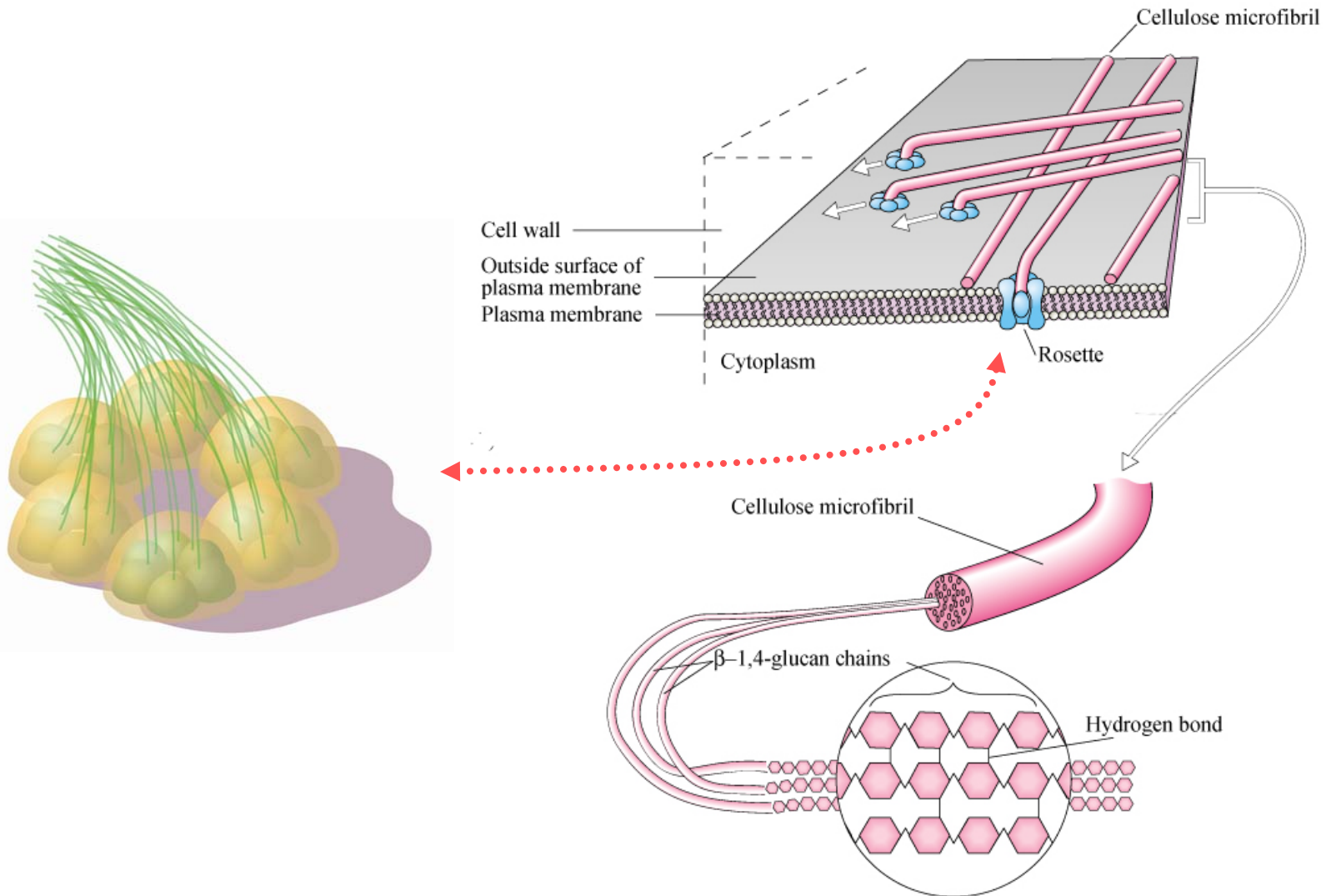
**Plants can fix more carbon than they currently do –
What happens if we Increase the DEMAND for Carbon**

Plants have two main types of cell walls

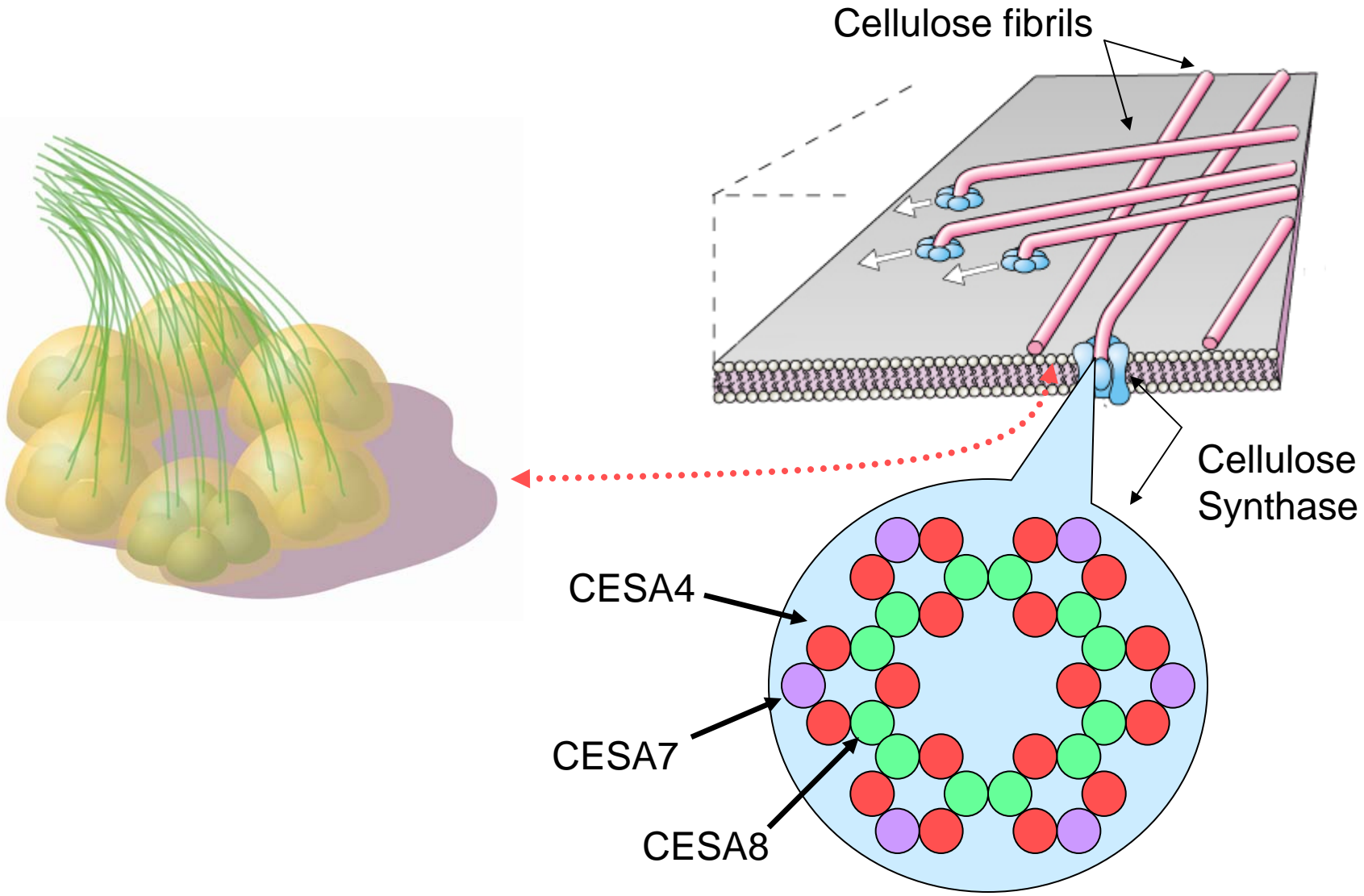


From Taiz & Zeiger Plant Physiology 1991

Cellulose is synthesized at the plasma membrane



Cellulose synthase is composed of at least three related proteins

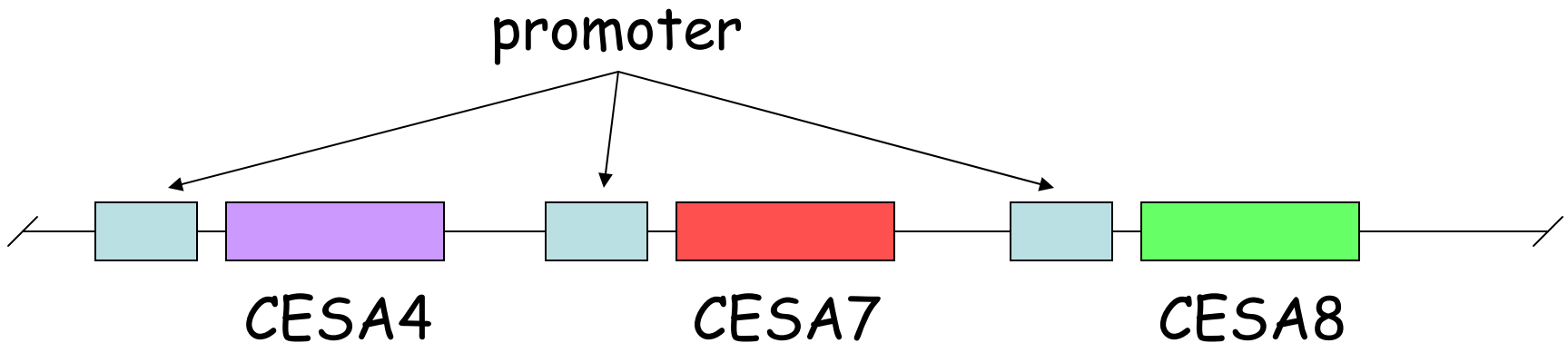


Questions

- How is cellulose synthesis regulated?
- Is it possible to substitute cellulose for lignin?
- Can we obtain significant increases in cellulose accumulation?

Experimental Strategy

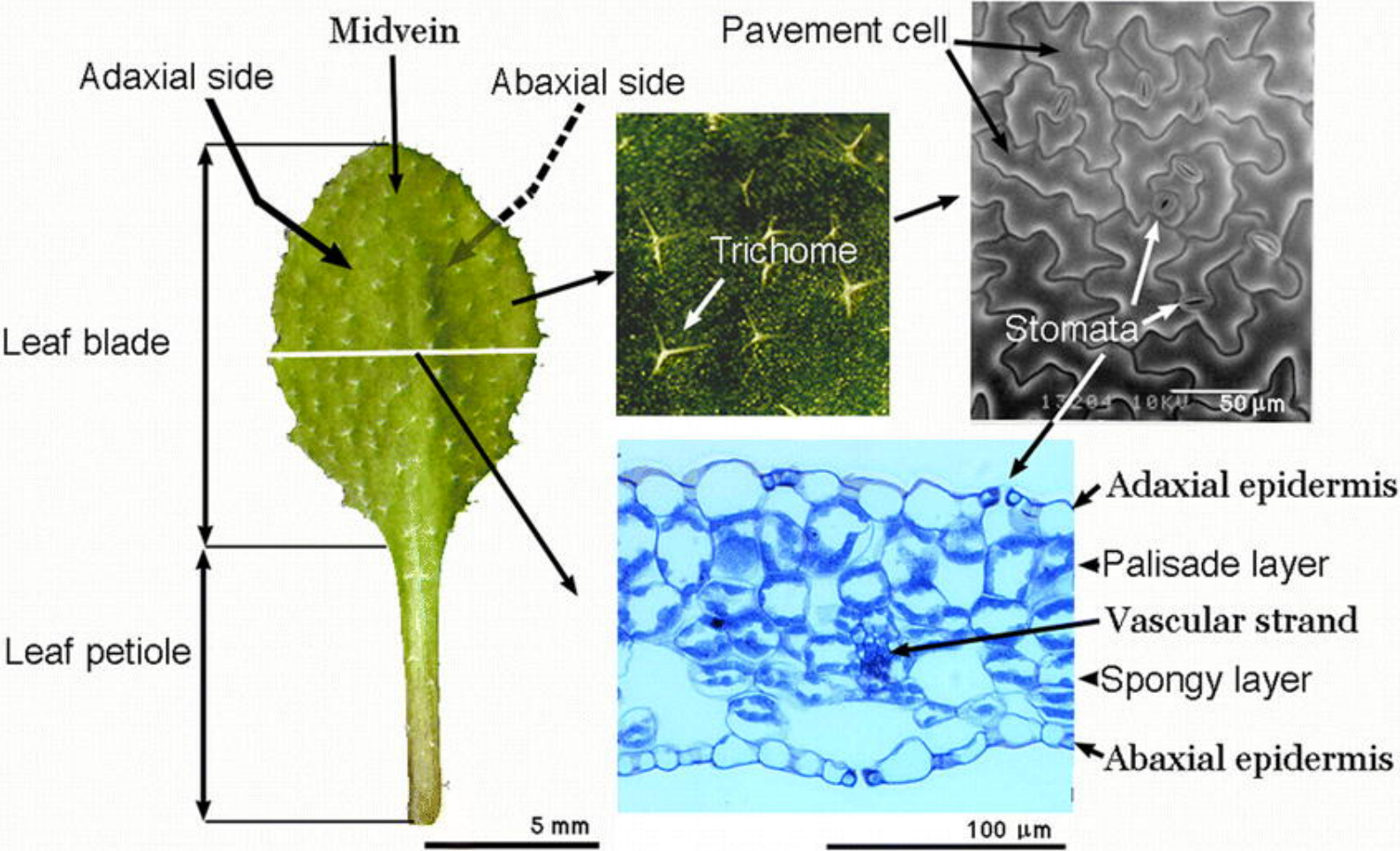
- Place CESA genes in plants under control of a chemically inducible promoter in transgenic plants



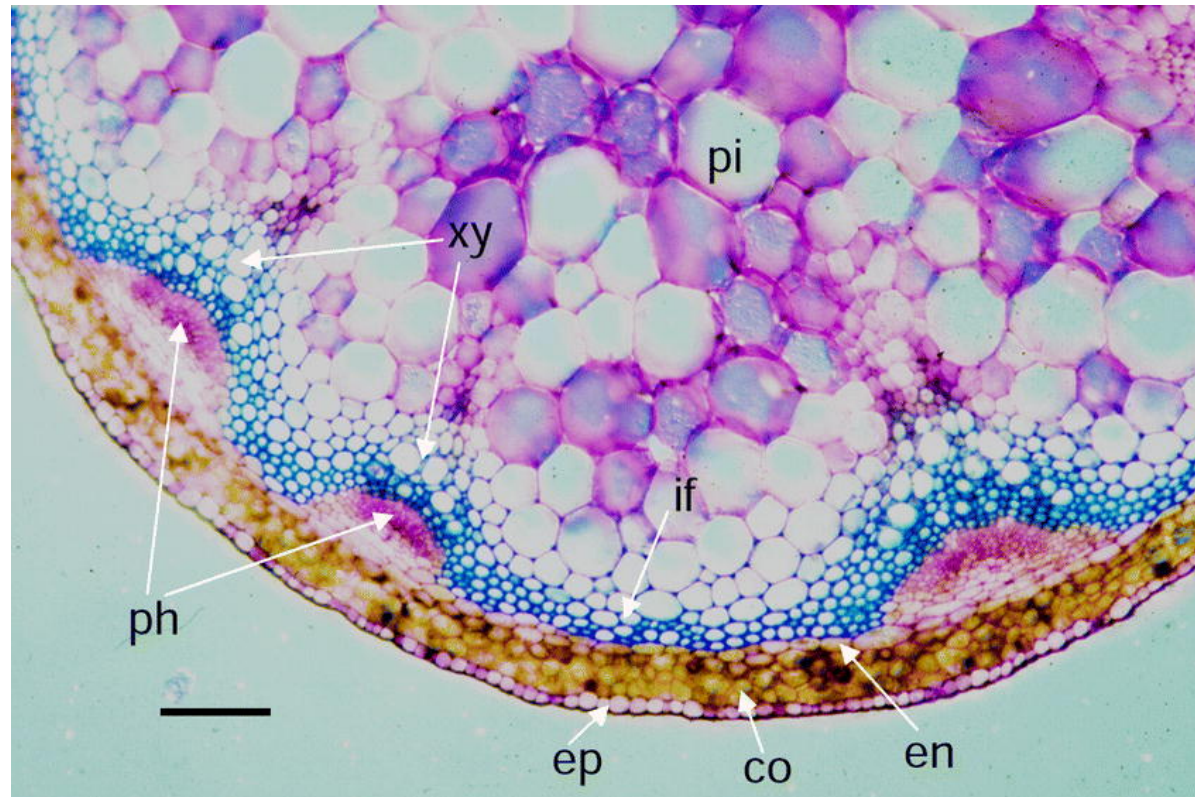
The model plant:
Arabidopsis thaliana



Cellulose Synthesis would be induced after cell division and cell expansion have ceased



Xylem cells have secondary cell wall thickenings



Some types of cells accumulate large amounts of cellulose and lignin
– suggesting feasibility

Outcomes

- We will **test** whether we understand the factors required for the control of cellulose synthesis
- Additional factors involved in cellulose synthesis can be **rapidly** tested
- We will begin to examine the effects of cellulose accumulation on the plant

Biomass crops



Switchgrass

Harvested annually



Hybrid Poplar

Harvested at age 5 to 10



Willow coppice

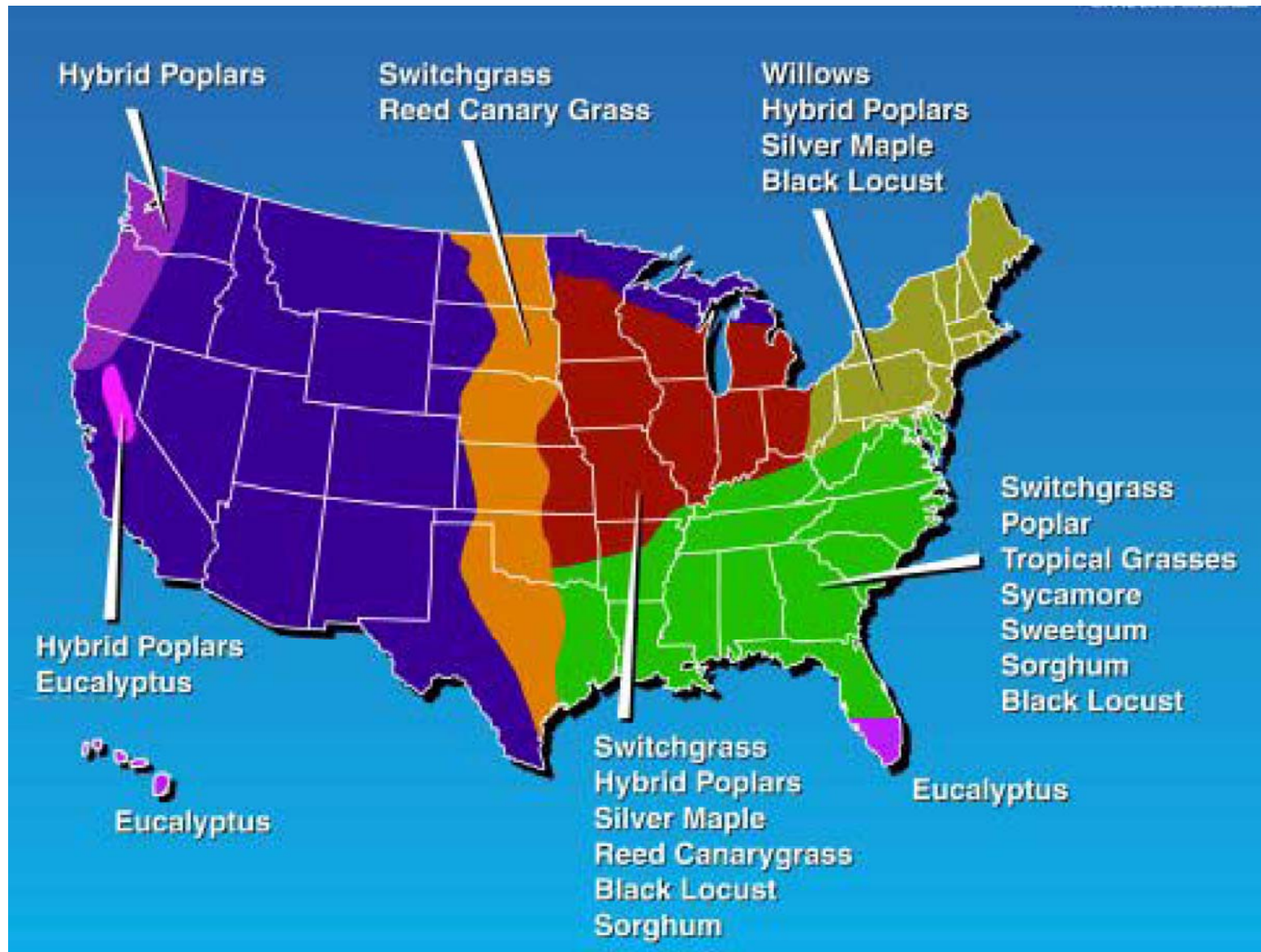
Harvested at age 3 or 4

The Potential of Switchgrass

Test plots of Switchgrass at Auburn University have produced up to 15 tons of dry biomass per acre, and five-year yields average 11.5 tons—enough to make 1,150 gallons of ethanol per acre each year.



Geographic distribution of Switchgrass and other Biomass crops



Acknowledgements

Thanks to GCEP and
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