Bridging
Forest Biotechnology and Biomaterials Engineering

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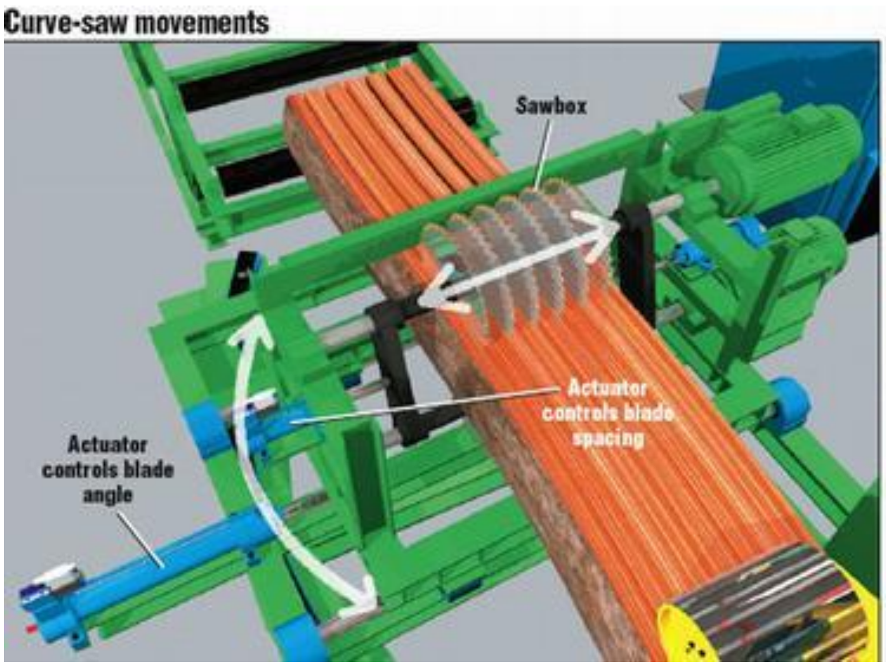
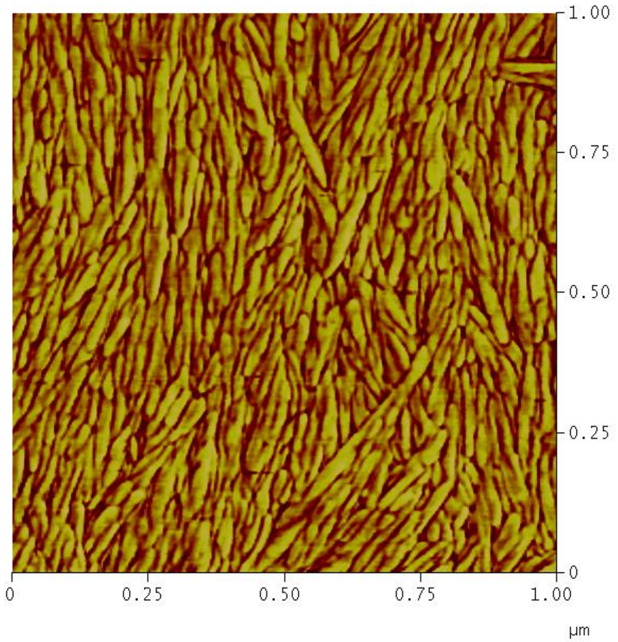
Wood Industry Successes

- Past 50 years: substantial gains in efficiency and productivity in wood processing
- 2x more usable product per log than at the turn of the 20th century

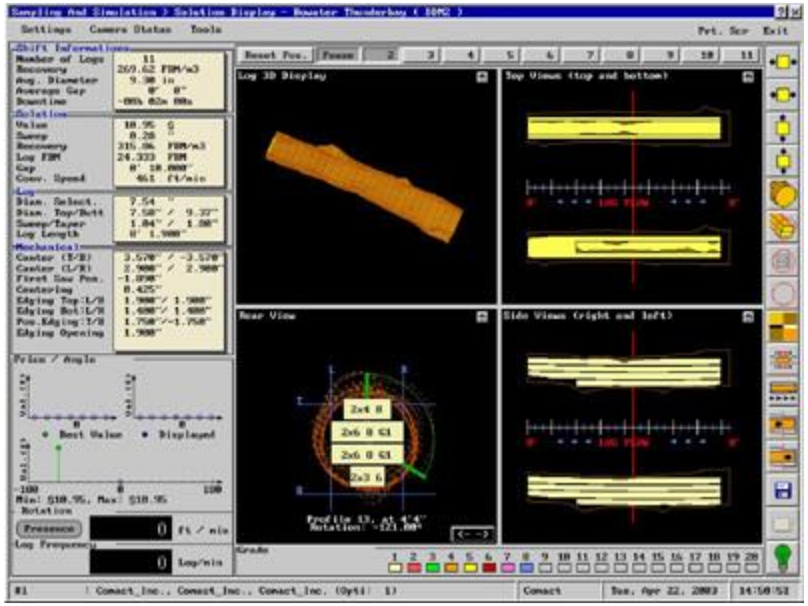
Waste minimization
Small-diameter log utilization

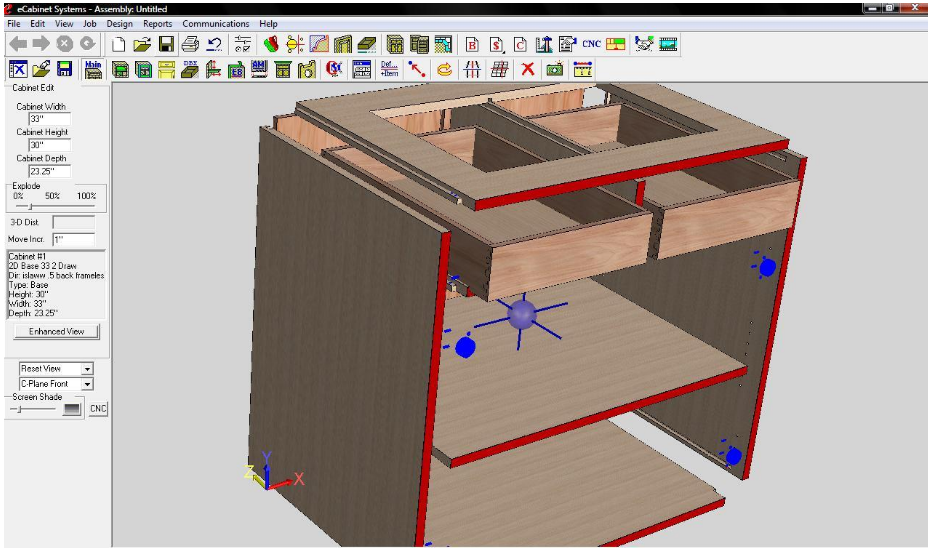


Development of engineered wood composites

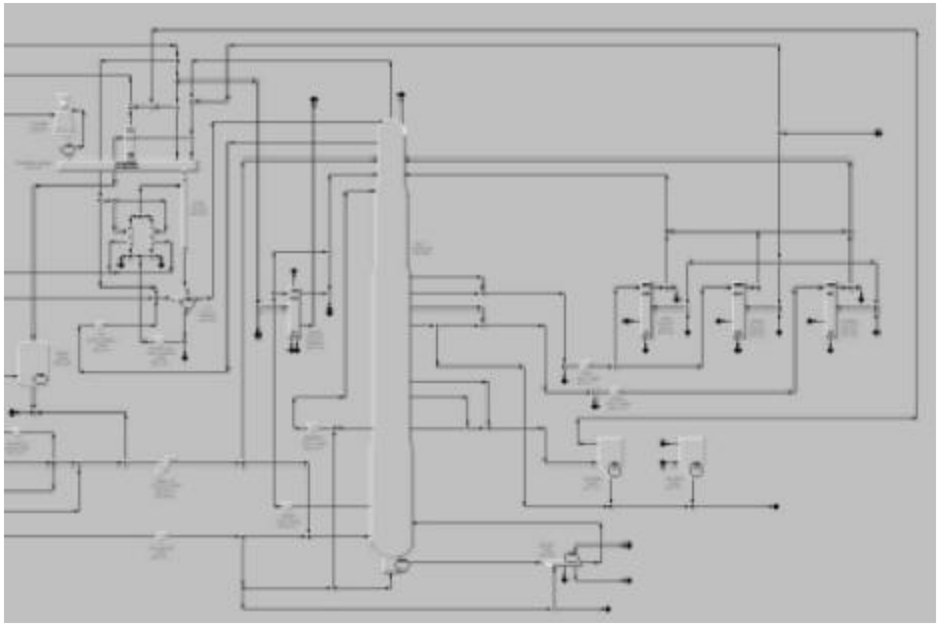


Plant automation
Optimization
Computer control



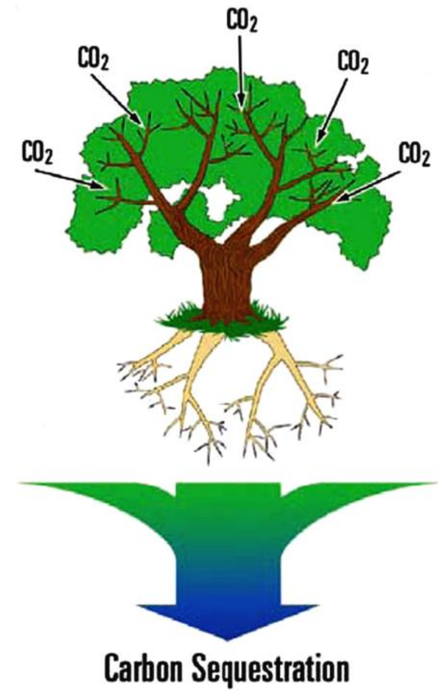


Software development
Simulation



Pressure to innovate

- By 2050: wood consumption will be 40% over current value
- Forests: supply material and fuel for a growing population
- Forests: serve as a carbon sink, and be managed for habitat conservation, aesthetics, and recreational use.

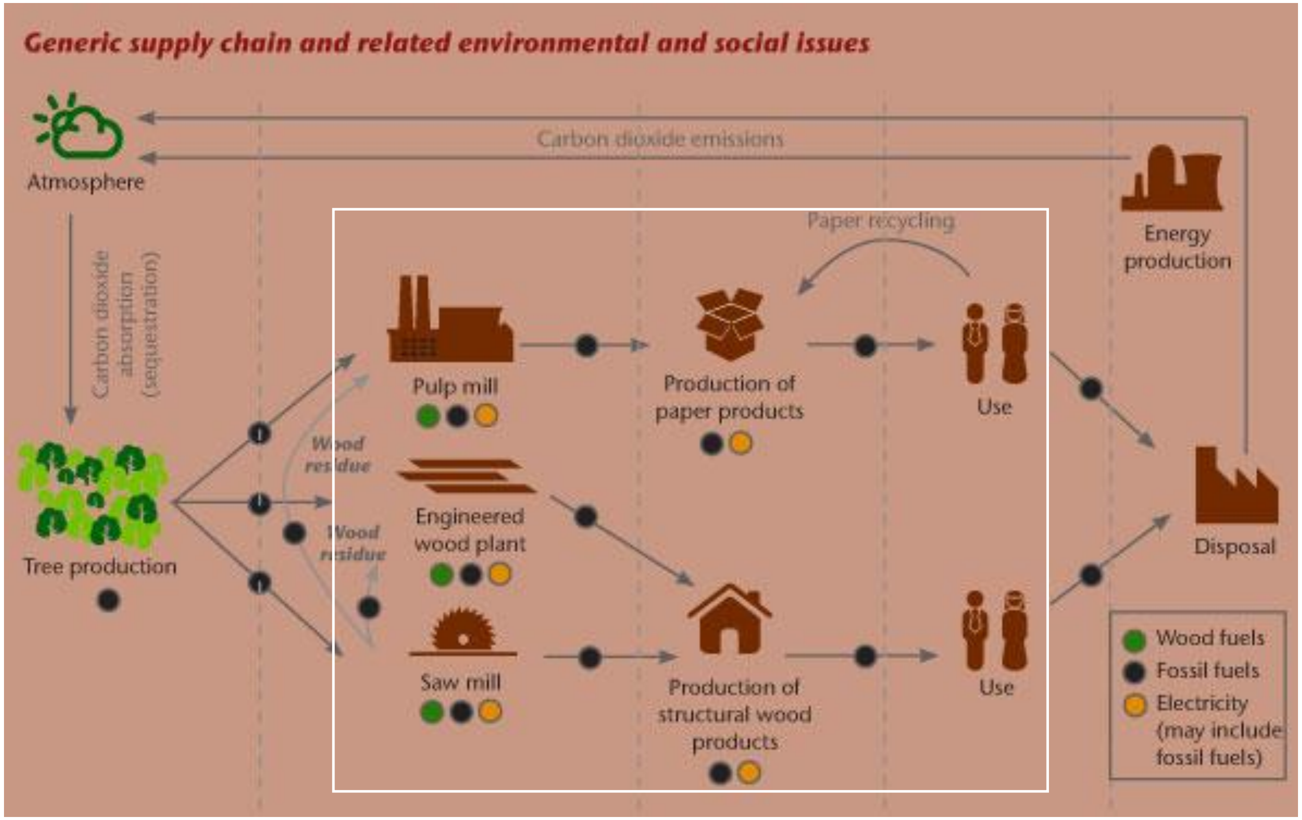


Pressure to innovate

- To meet demands on a diminishing land base, forest productivity and wood processing efficiency must be increased
- Posit: focus on wood quality

Pressure to innovate

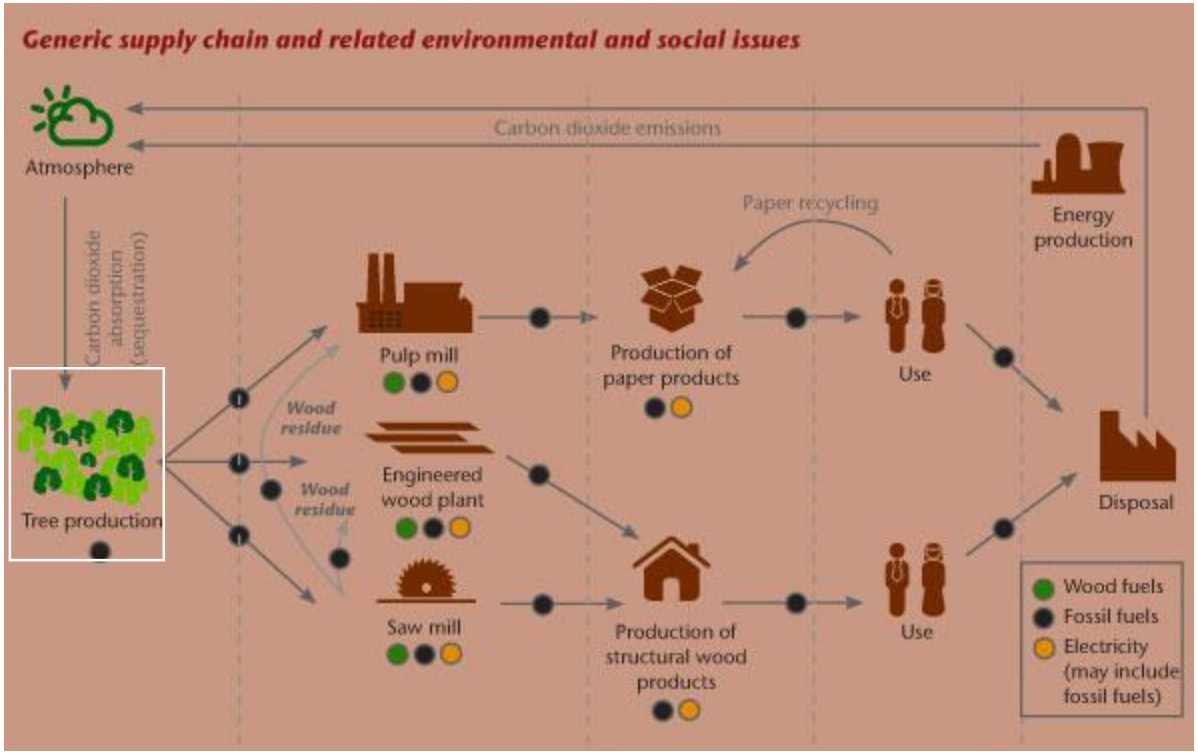
- Accomplished a lot as wood scientists and technologists: middle of the supply chain



www.sustainableforestprods.org

Wood Quality

- Push manipulation of wood properties upstream



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Wood Quality

- Tree breeding in the U.S. began 50 years ago: Based on fast growth and tree form.
- 2nd generation: incorporated wood quality (density) in the tree selection.
- Slow, tedious process

Wood Quality Improvement through Genetic Modification

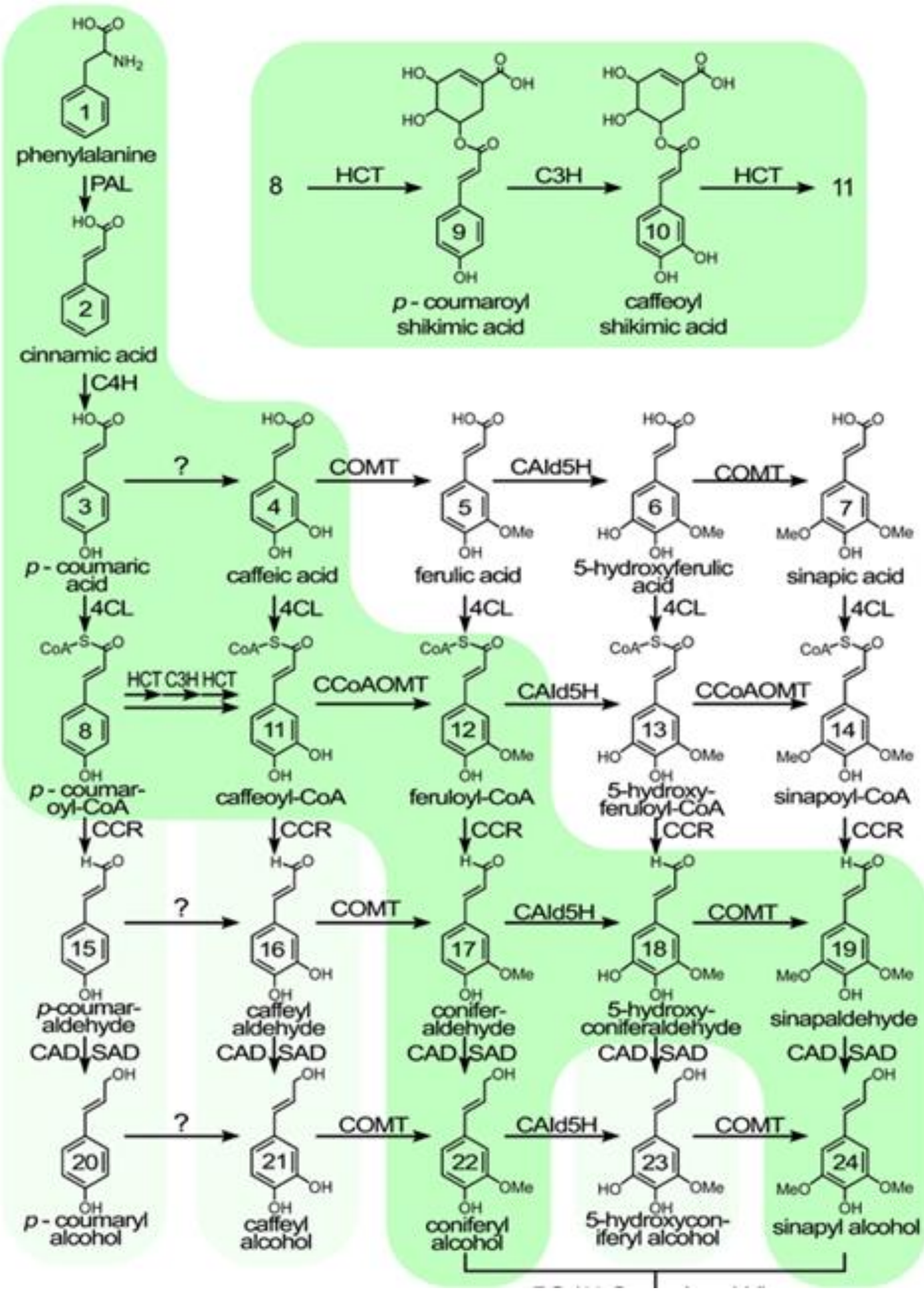
- Genetic engineering
  - can be applied to specific traits
  - modification can be realized in years instead of centuries

Genetic engineering

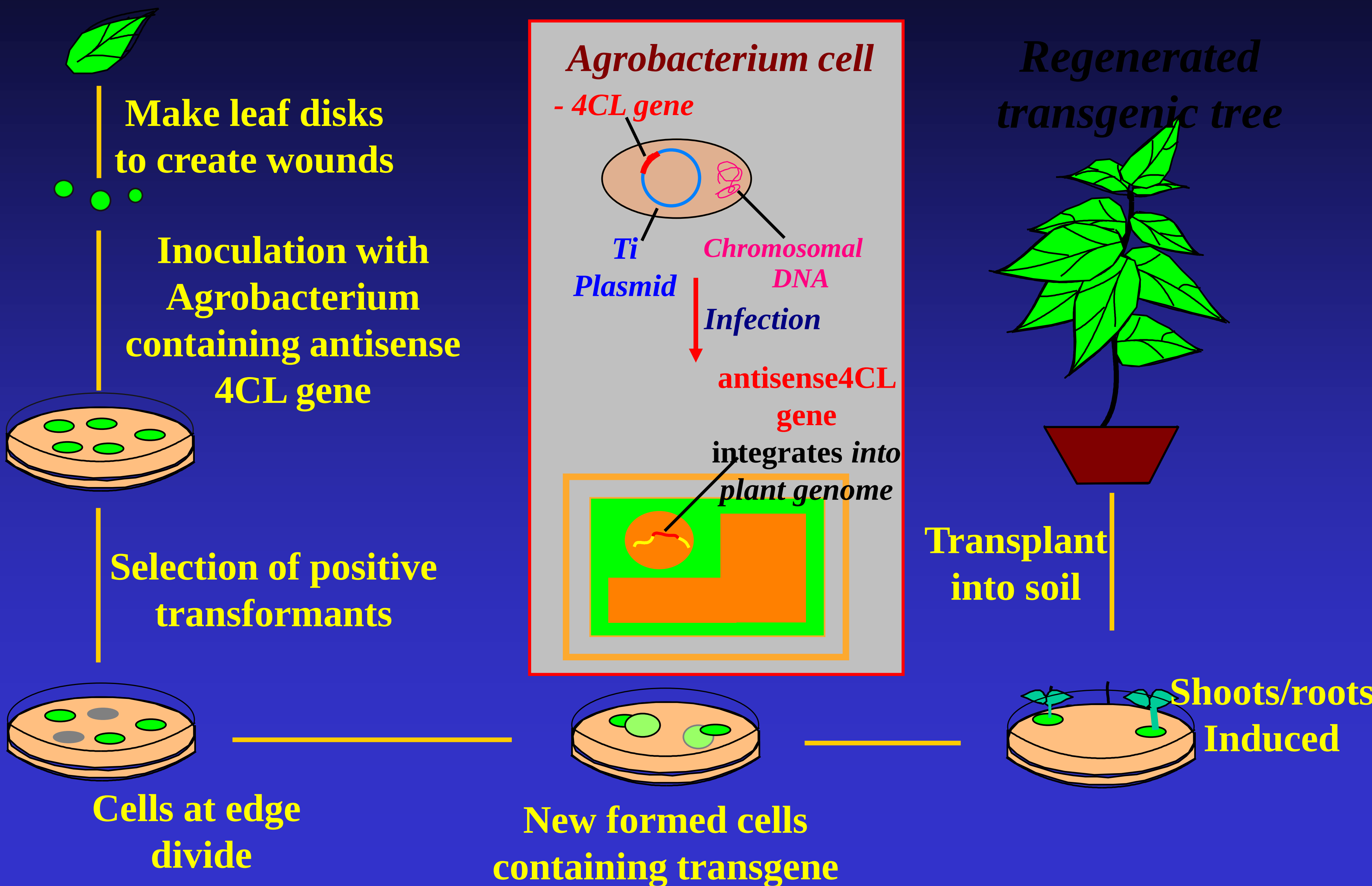
- Genetic engineering technologies hold tremendous promise in forestry
  - Herbicide, disease resistance
  - Abiotic-stress tolerance
  - Phytohormone regulation
  - Reduction of generation time
  - Suppression of flowering
  - Nutrient use efficiency
  - Cold tolerance

Genetic engineering

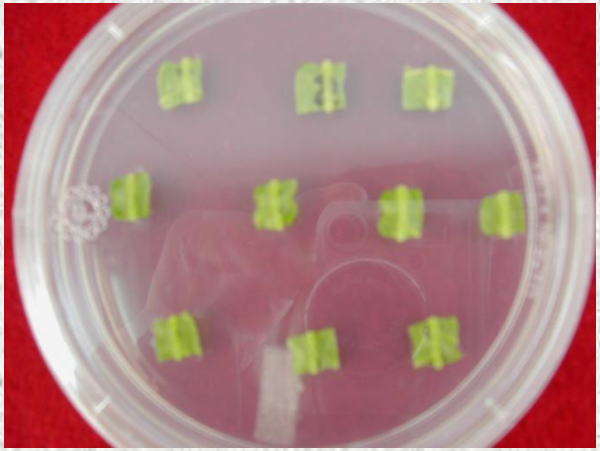
- Produced transgenics with drastic changes in wood chemical composition
- Reduced lignin content through transfer of antisense 4CL gene
- Increased S/G ratio through insertion of sense CAld5H gene



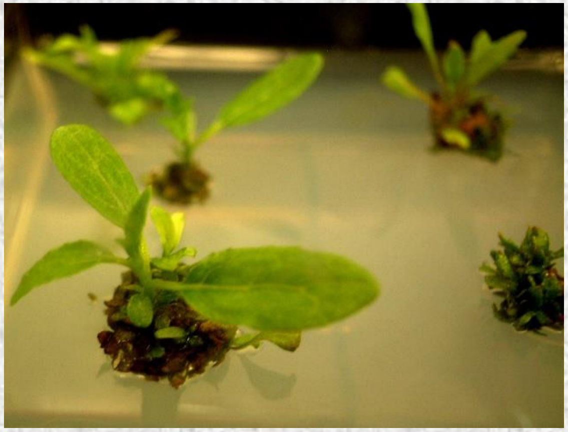
Agrobacterium-mediated gene transfer



Transformation and regeneration

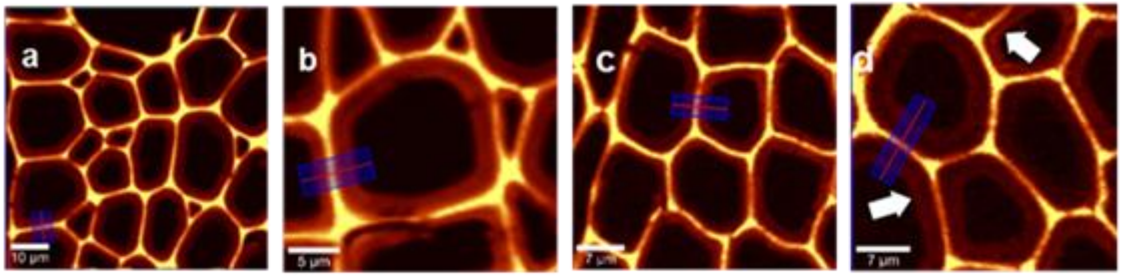




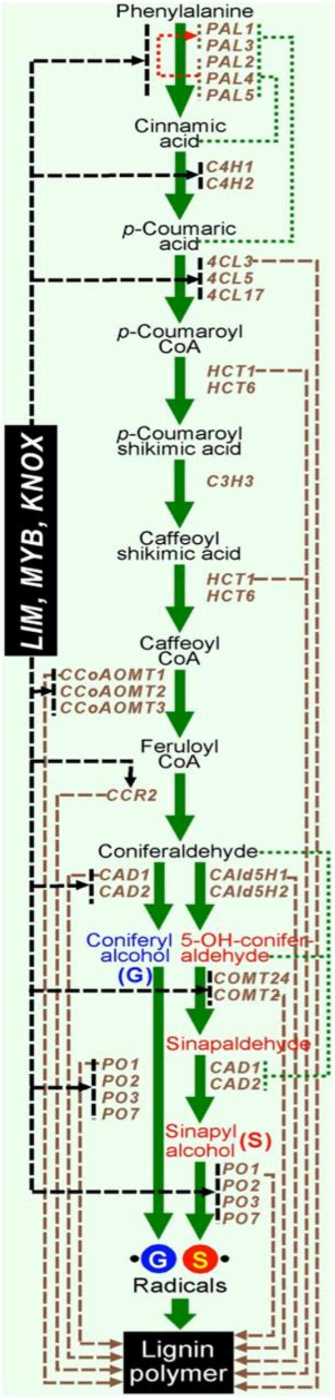
Wood Quality Improvement through Genetic Modification

- Pulp production, biofuel production
- Impact on solid wood utilization
- Evaluated the anatomical, physical, and mechanical properties of the transgenes
- Done the same on transgenics with modified cellulose and xylan



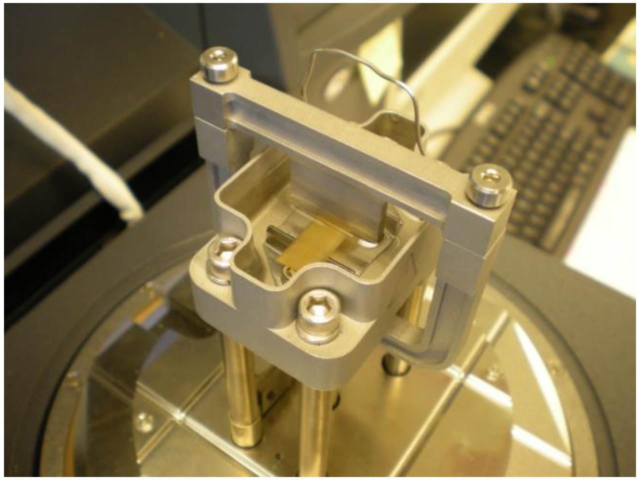
NSF “Plant Switchboard" Research

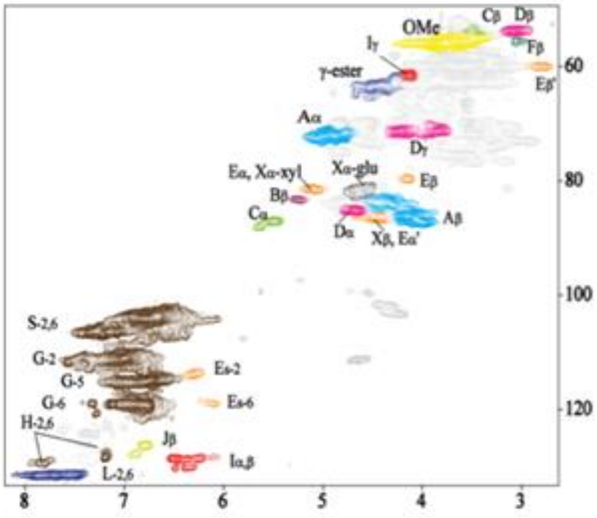
- Most comprehensive analysis of lignin regulation ever undertaken.
- Determine how each of the 33 lignin-producing genes & transcription factors impact the type and amount of lignin in wood.
- Done by eliminating each pathway gene, one at a time.



Wood Quality Improvement through Genetic Modification

- Tailoring specific clones and/or transgenics to produce lines for optimal processing and product characteristics
- Significant potential for the forest products industry in the United States and the world.





National Needs Fellowship

- Need to develop a pool of knowledgeable individuals who speak the language of both a materials scientist and a tree biologist.
- Requires a multi-disciplinary approach.
- NNF

National Needs Fellowship

- Train 2 doctoral students:
  - Engineering background → trained in biometrics and forest biotechnology
  - Forestry or biology background → educated in wood materials science, engineering, and computational biology.
- Result: cadre of researchers with the capability to tackle transformative issues.

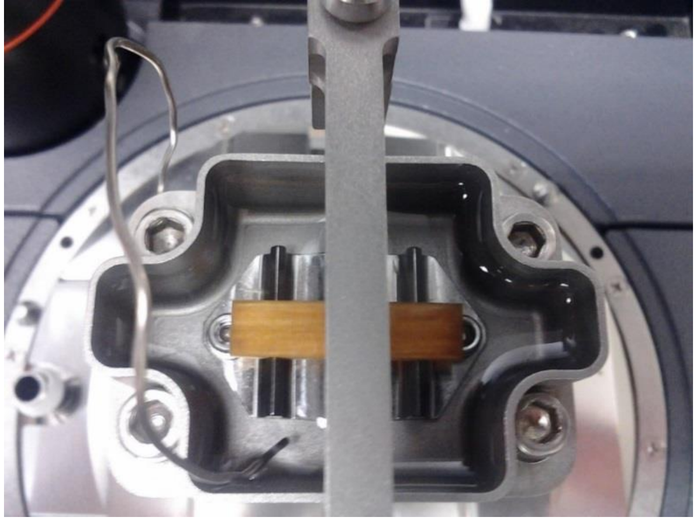
Technical core and functional competencies (Fellow 1)

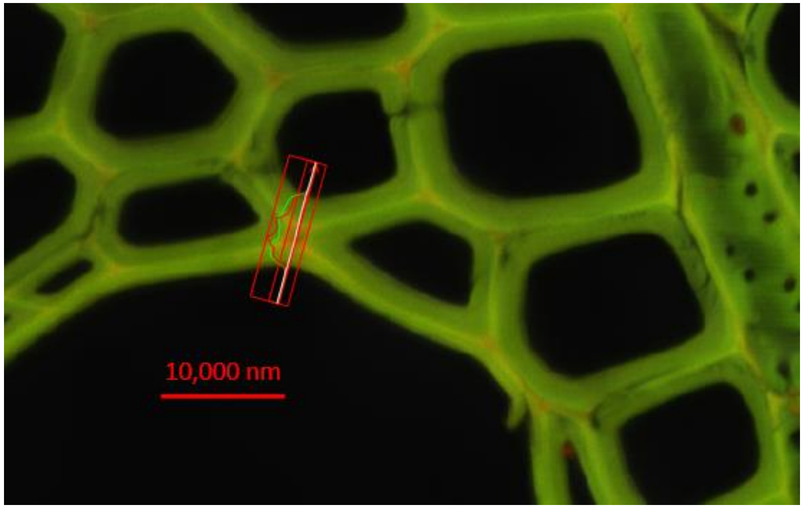
- Understanding plant metabolism
- Application of genetic principles to silviculture, management and wood utilization
- Basic research techniques in tree breeding and genetics
- Ability to use bioinformatics software

National Needs Fellow 1

- Charles Warren Edmunds
- B.S. in Biosystems Engineering (minor: Environmental Engineering), University of Tennessee
- M.S. in Biosystems Engineering (minor: Statistics), University of Tennessee
- Poster presentation: “Thermo-mechanical Properties of Genetically Modified *Populus trichocarpa*”

Viscoelastic behavior

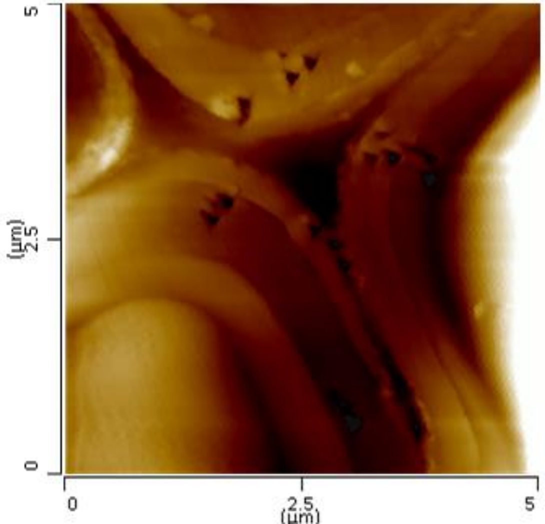




Topochemical imaging

Two-stage fungal pretreatment

Nano Thermal Analysis



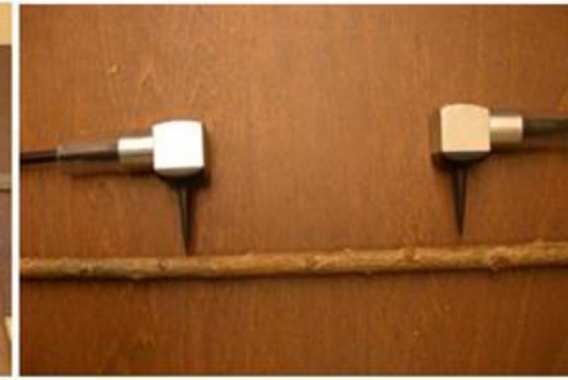
Technical core and functional competencies (Fellow 2)

- Understanding the anatomical, physical, chemical, and mechanical properties of wood and wood composites
- Understanding of engineering fundamentals and process technology for the production of biomaterials
- Proficiency with wood characterization methodologies

National Needs Fellow 2

- Zachary Miller
- B.S. in Environmental Technology (minor: Environmental Toxicology), NC State University
- M.S. in Forest Biomaterials, NC State University
- Poster presentation: “Comparing Mechanical and Chemical Properties of Young Transgenic Black Cottonwood Trees Modified for Reduction of Specific Genes in Lignin Biosynthesis”

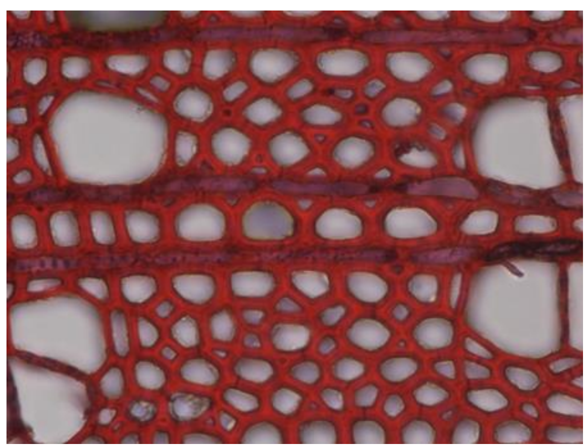
Dynamic MOE

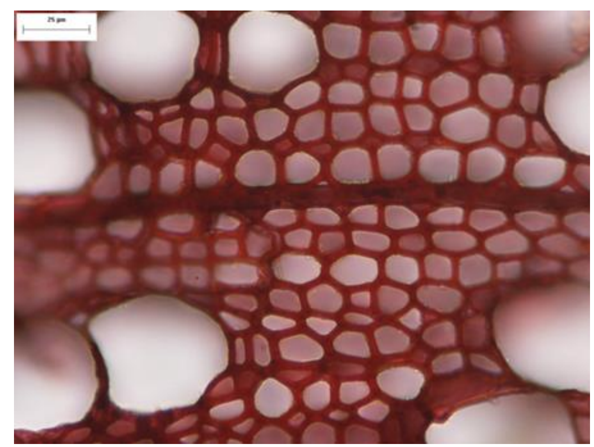


Chemistry

Sample	Glucose	Xylose	Galactose	Arabinose +Mannose	Total Lignin
NSF4-WT	48.89 ± 0.38	15.76 ± 0.72	1.96 ± 0.06	7.25 ± 0.18	23.65 ± 1.50
C4H1 Low	43.77 ± 2.25*	13.22 ± 0.16*	1.81 ± 0.07	7.16 ± 0.77	20.77 ± 0.93
C4H1 Mid	44.97 ± 1.45*	13.82 ± 1.08*	1.78 ± 0.06	7.14 ± 0.34	19.55 ± 1.21*
C4H1 High	47.80 ± 0.04	13.05 ± 1.03*	1.81 ± 0.11	7.31 ± 0.67	18.27 ± 3.19*
CCR2 Low	42.66 ± 0.08*	16.02 ± 0.04	1.16 ± 0.02*	4.56 ± 0.10*	14.47 ± 0.60*
CCR2 Mid	42.44 ± 1.14*	13.21 ± 0.49*	1.21 ± 0.05*	5.00 ± 0.20*	21.20 ± 1.27
CCR2 High	39.09 ± 1.86*	13.74 ± 0.41*	1.22 ± 0.04*	4.82 ± 0.07*	21.37 ± 0.77

Wood anatomy





Take Away

- Not a description of a project
- Philosophy: upstream vs downstream approach to innovation
- Model: establish a link between our field and other disciplines

Thank You!   Questions for Dr. Peszlen?