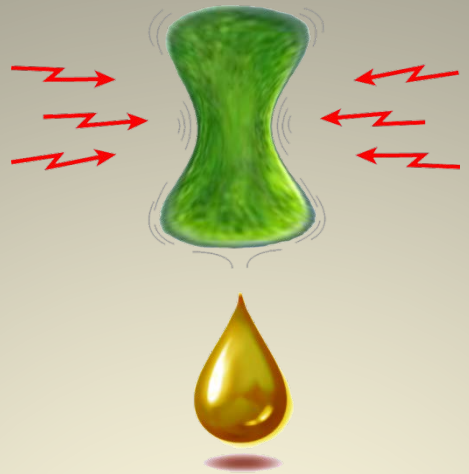

Challenges to Accurate Physical and Chemical Measurements in Biomass Processing

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Opportunity/Challenge

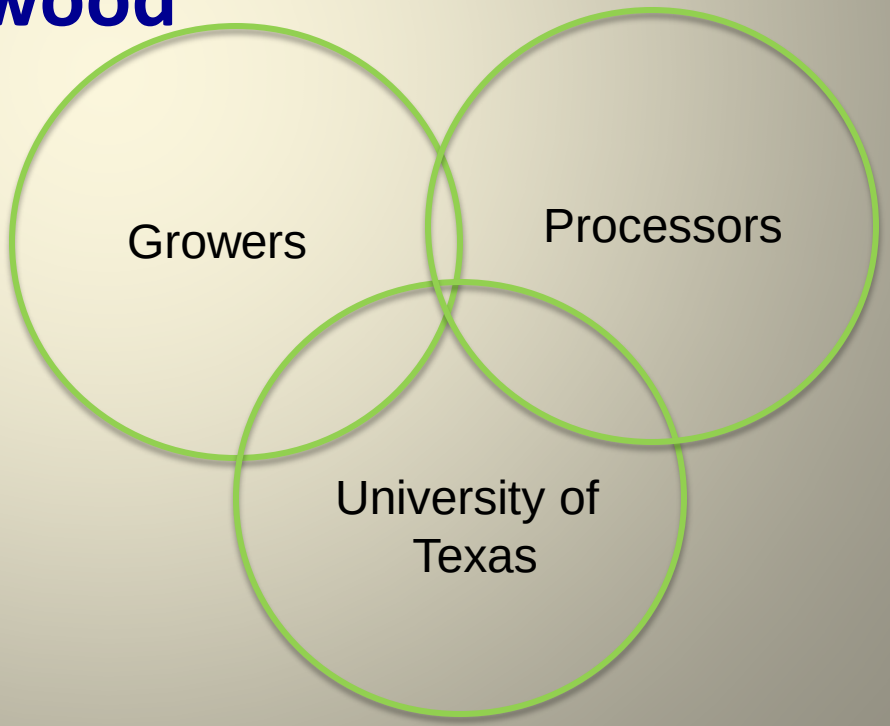
- **Fossil fuels and petrochemicals available as crude for extraction cost.**
- **Can we use technology to do the same thing in weeks rather than centuries and at less than extraction cost?**

Today the answer is no
But the derivative is very promising

University Activities

- Oil from algae
- Alcohol from sugar cane
- Clean “coal” from wood

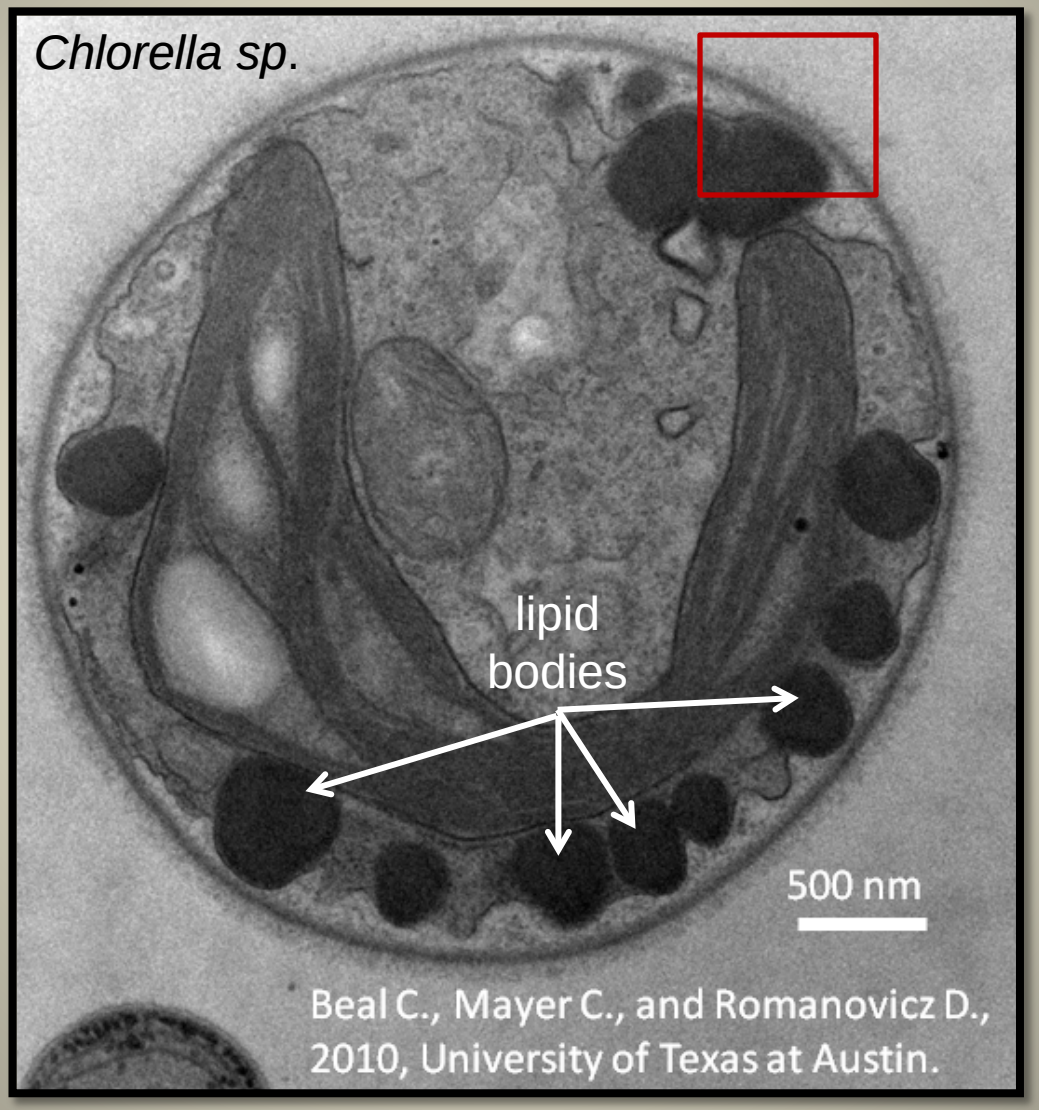
Worked with more than 30 companies over past five years



Common Theme

- Need to extract material from inside of cell
  - Product from algae and sugar cane
  - Contaminants from wood

Structure of a Microalga



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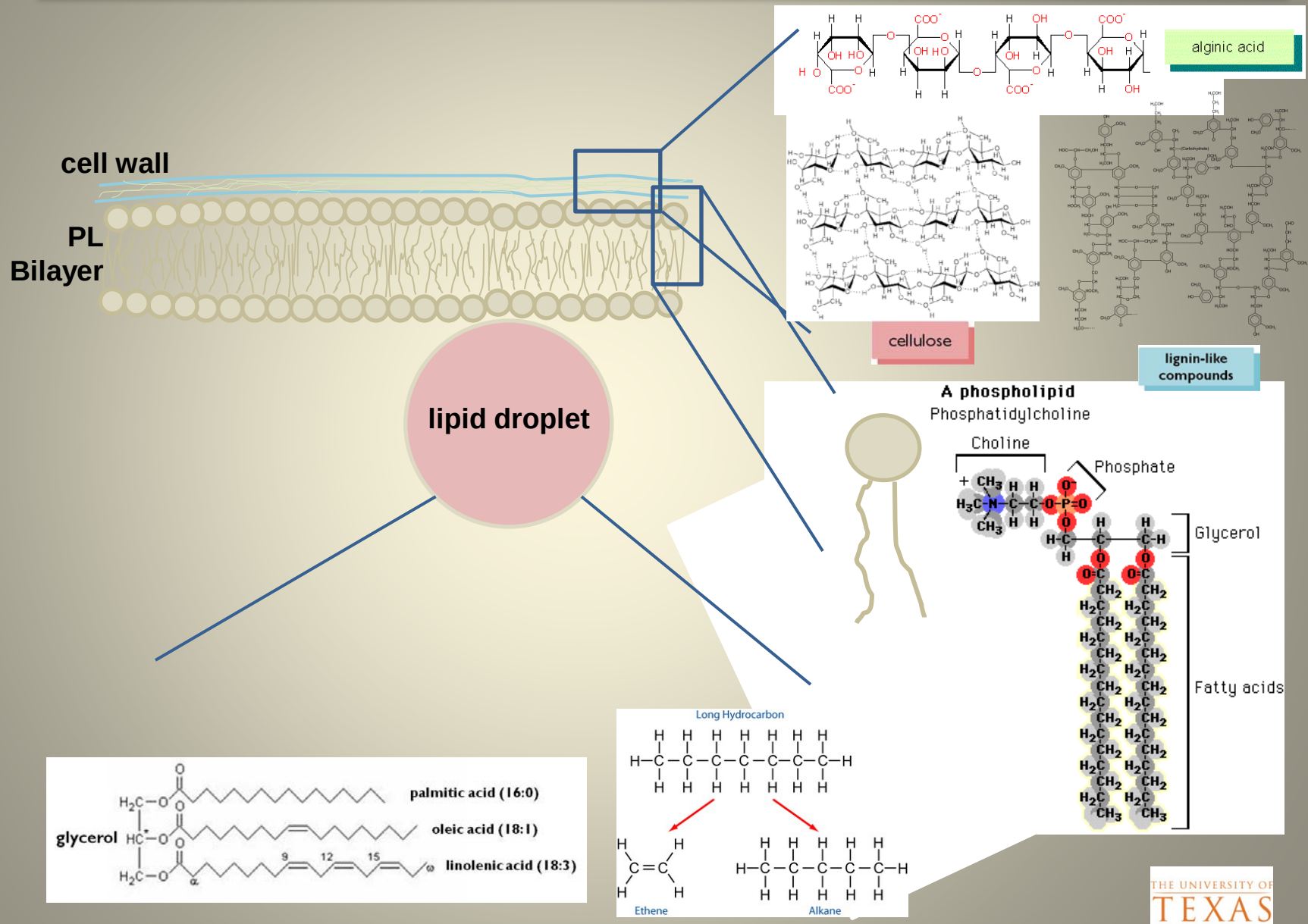
Structure of a Microalga – At the Membrane



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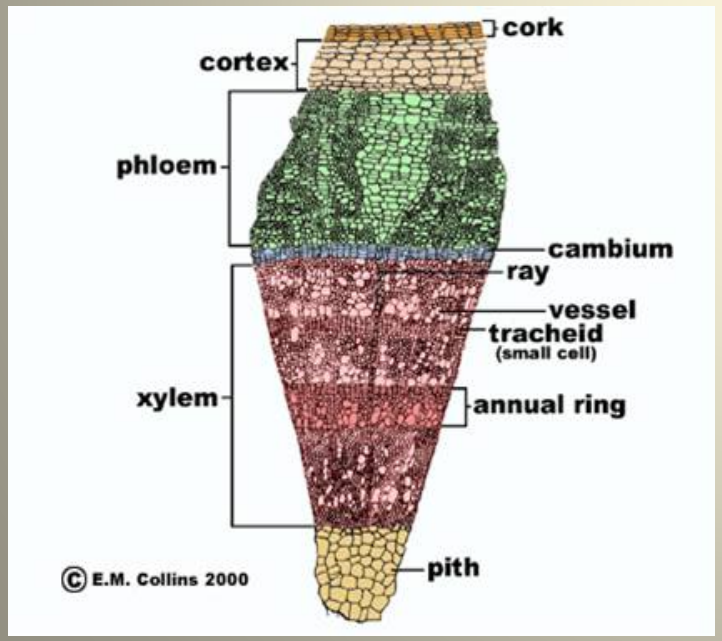
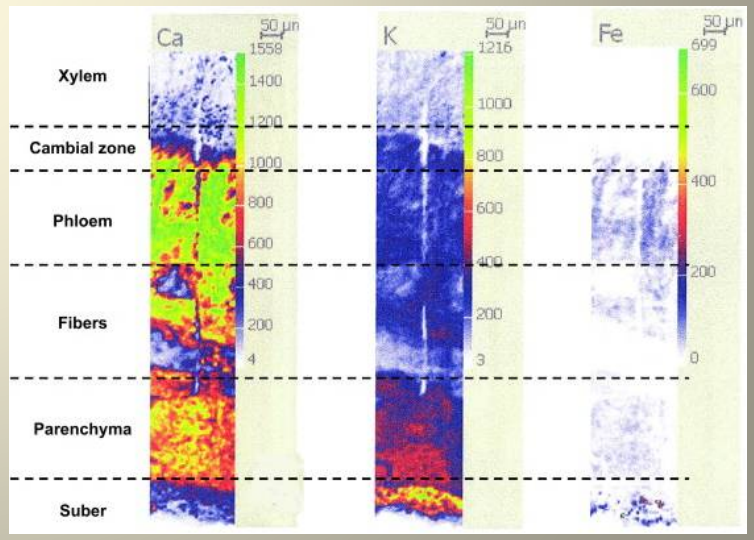
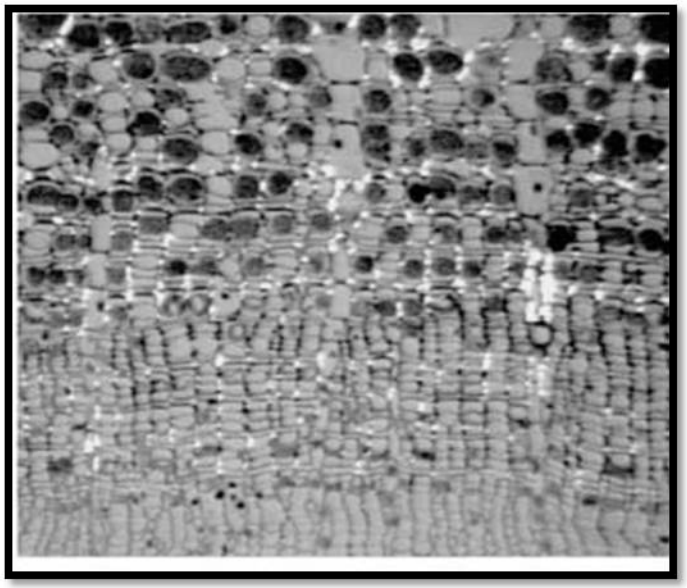
Torrefaction – Making Coal

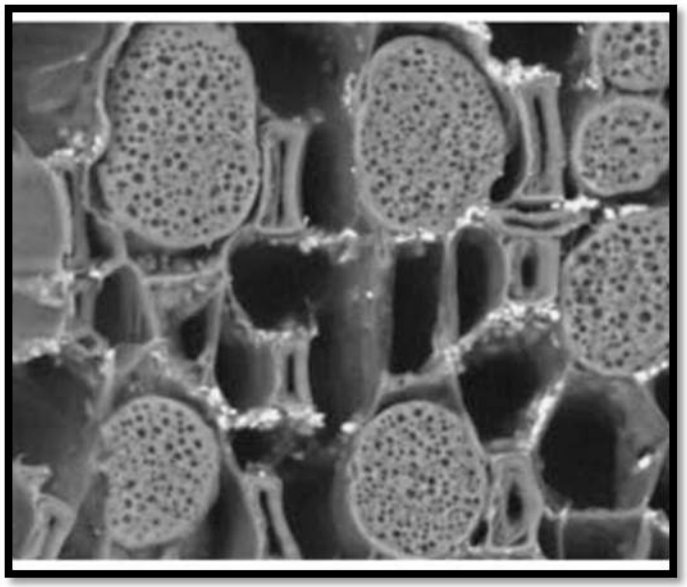
- **Companies around the world making coal**
- **UT contribution**
  - **Making cleaner coal**



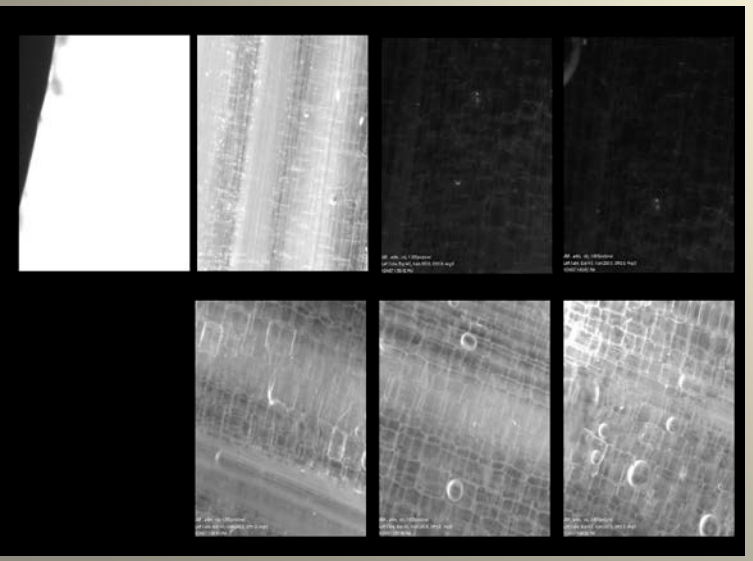


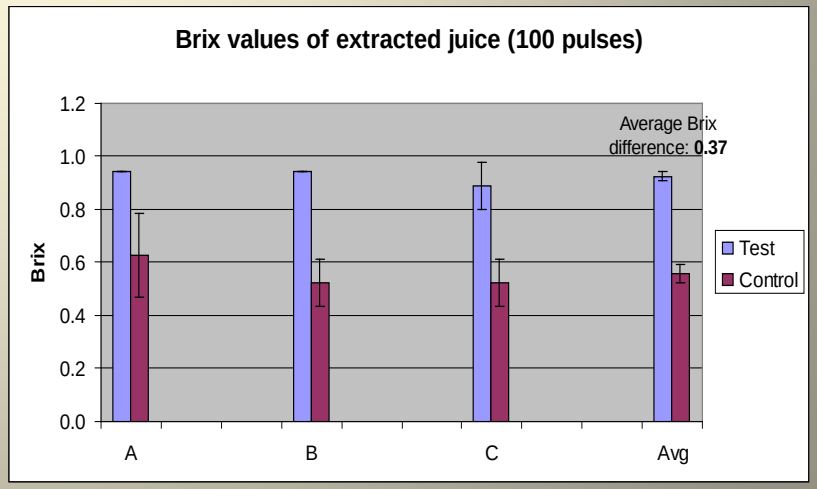
Taking a Closer Look





Remembering Sugar Cane





Algae Biomass Production Routes

Grow algae/product accumulation

↓

Harvest/Dewater algae

↓

Break algae open

↓

Recover algae products

Algae Biomass Production Route Options

Grow algae/product accumulation

open ponds
closed bioreactors
fermentation

wastewater
purchased chemicals
waste sugars

Harvest/Dewater algae

centrifuge
dissolved air flotation

flocculation
drying

Break algae open

solvents
supercritical CO_2
enzymes

bead-mill
pulsed electric field

Recover algae products

phase-partitioning w/solvents

supercritical CO_2

hollow fiber membrane

What is the Best Production Route?

No Consensus

Grow algae/product accumulation

open ponds
closed bioreactors
fermentation

wastewater
purchased chemicals
waste sugars

Harvest/Dewater algae

centrifuge
dissolved air flotation

flocculation
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Break algae open

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Recover algae products

phase-partitioning w/solvents

supercritical CO_2

hollow fiber membrane

Metrology Base Limits Progress

- **With $ billions invested and 100's of developers, EROI still generally negative?**
  - Non-standardized measurements of virtually every parameter – each method can produce wildly different results on the same culture
    - cell density
    - cell count
    - gravity settling
    - dry weight with and without centrifugation to remove salts
    - filtering

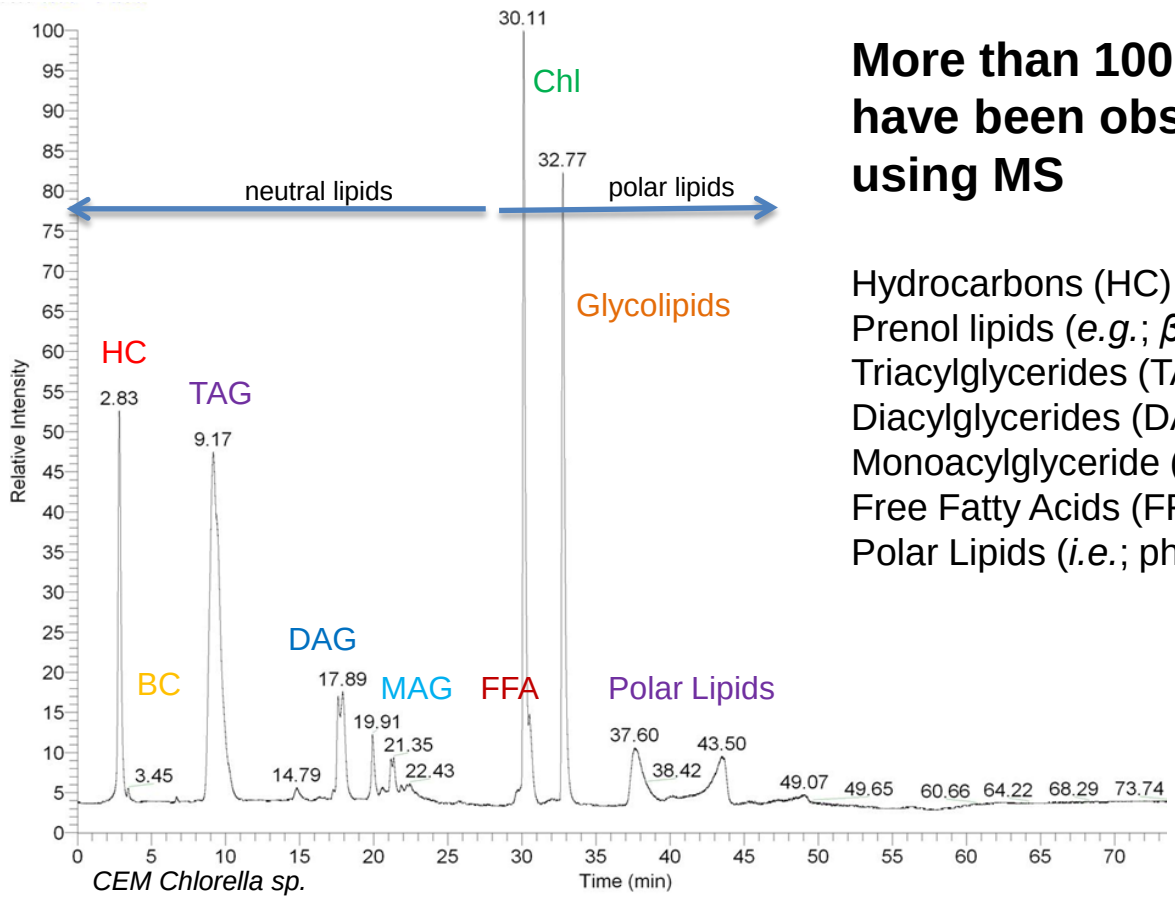
Metrology Base Limits Progress (Cont'd)

- With $ billions invested and 100's of developers, EROI still negative
  - Incomplete knowledge of membrane and cell wall electrical and mechanical properties
  - Emulsion formation dynamics of debris
  - Total oil content measurement challenges
    - Nile red (non-specifically binds to a variety of neutral lipid compounds)
    - gravimetric (anything recovered in a particular solvent – non-specific to fuel or high value products)
    - HPLC/MS – detailed quantitative lipid profiling of specific lipid classes and species of interest
    - GC/MS – detailed quantification of fatty acids

HPLC/MS

Quantitative Chemical Analysis of Oil Extraction Process

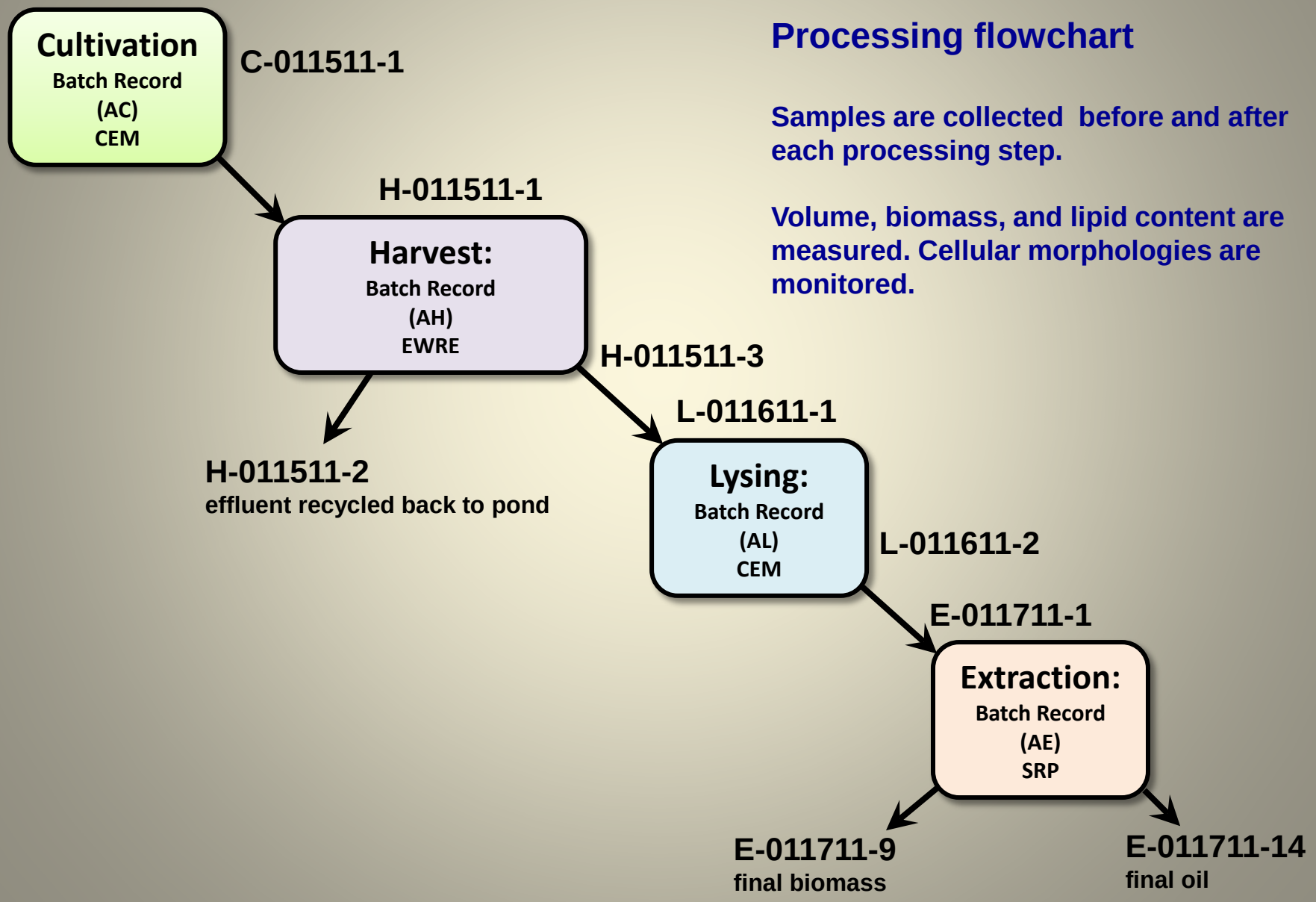
Impressively accurate, but data is historical rather than predictive



More than 100 discrete ion species have been observed in lipid extracts using MS

Hydrocarbons (HC)
Prenol lipids (*e.g.*; *β*-carotene, BC)
Triacylglycerides (TAG)
Diacylglycerides (DAG)
Monoacylglyceride (MAG)
Free Fatty Acids (FFA)
Polar Lipids (*i.e.*; phospholipids)

Integrated Mass Balance



Processing flowchart

Samples are collected before and after each processing step.

Volume, biomass, and lipid content are measured. Cellular morphologies are monitored.

Accelerating the Pace to Success

- Understand cell structures and physiology
  - Tensile strength and electromechanical properties of cell membranes and walls
  - Physiological defense mechanisms against predators
  - Impediments to oil extraction
- Standards for oil content and growth
  - Government-industry-university metrology consortium
    - International participation beneficial
  - Standard reference “algae cell” to validate metrology

Closing Thoughts

- **The metrology base needed for an industry is slowly being built**
  - **Without that base, progress is too dependant on miracles**
- **Progress is likely constrained by lack of appropriate measurements and standards**
  - **World needs to work together to establish the measurements**
    - **Progress is too slow in current mode**