What do you think green chemistry is?

On the sticky note at you're table, write one challenge related to Biofuels that you think can be addressed by green chemistry.

Not sure what Green Chemistry is? Look at the 1st paragraph of the review by Clark.

Sustainability and Green Chemistry

Sustainability

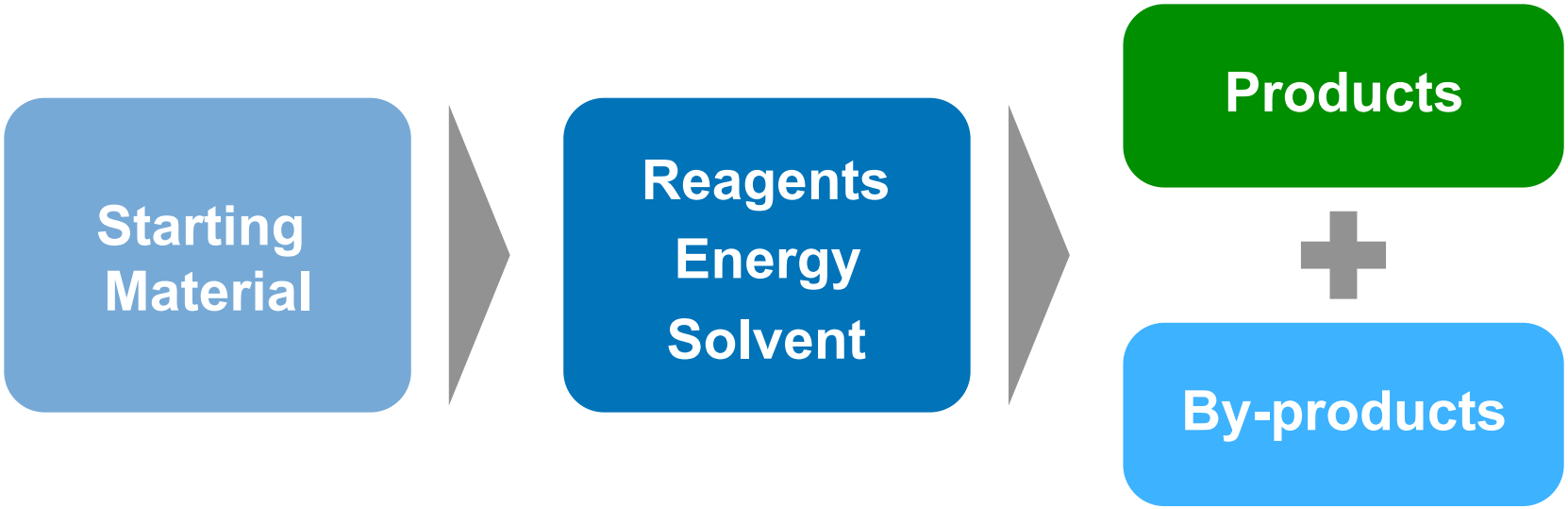
"Meeting the needs of the present without compromising the ability of future generations to meet their needs"

– *Our Common Future, Report of the Brundtland Commission, Oxford University Press 1987*

Green Chemistry

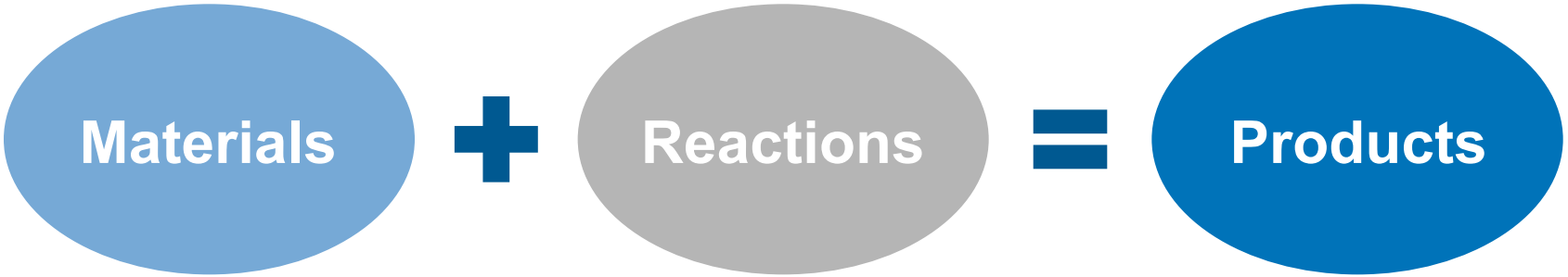
- **Sustainability at the molecular level**
- The science behind the discovery and implementation of safer, cleaner, and more efficient chemical processes and products
- Entails design of chemical products and processes that aim to eliminate the use and generation of hazardous substances
  - Seek to minimize:
    - Waste
    - Energy use
    - Resource use (maximize efficiency)
  - Use renewable resources

The (Intuitive) Principles of Green Chemistry



- What types of starting materials would you use?
- What conditions would be best to use for a green chemistry reaction?
- How would you evaluate the results of your reaction?
- What would happen to the waste?

What Is Green Chemistry?



- Bio-based
- Minimize solvent and auxiliaries
- Safer solvents

- High yielding
- Atom and energy efficient
- Room temperature and pressure
- Catalytic

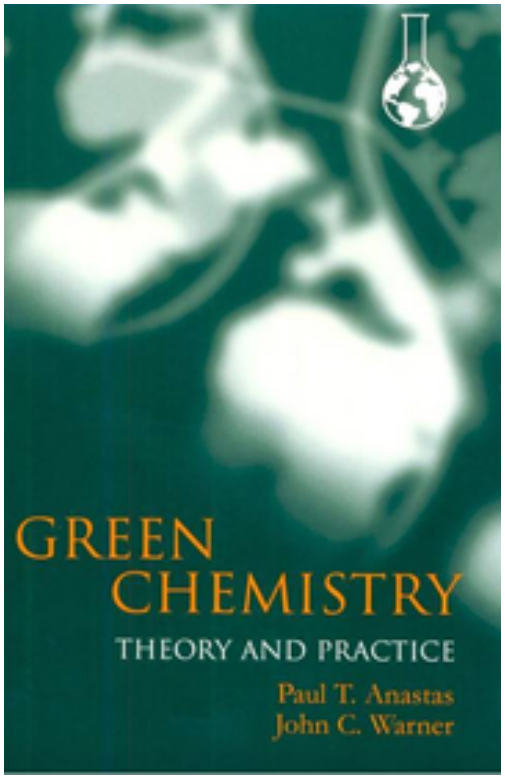
- Design for end of life (degradable or recyclable)
- Consider toxicity

Safer and More Efficient Chemistry

Anastas and Warner, Green Chemistry Theory and Practice, 1998.

12 Principles of Green Chemistry

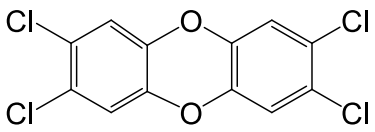
1. Prevent waste
2. Design safer chemicals and products
3. Design less hazardous chemicals syntheses
4. **Use renewable feedstock chemicals**
5. Use catalysts, not stoichiometric reagents
6. Avoid chemical derivatives
7. Maximize atom economy
8. Use safer solvents and reaction conditions
9. Increase energy efficiency
10. Design chemicals and products to degrade after use
11. Analyze in real time to prevent pollution
12. Minimize the potential for accidents



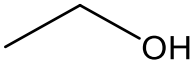
~~Are any of these molecules green?~~

Which molecules are safer?

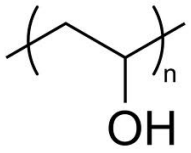
Which molecules minimize life cycle impacts?



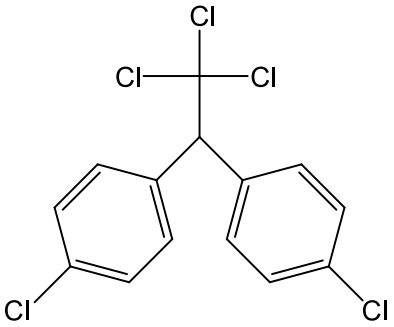
Dioxin



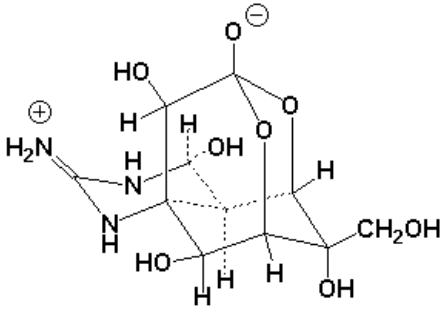
Ethanol



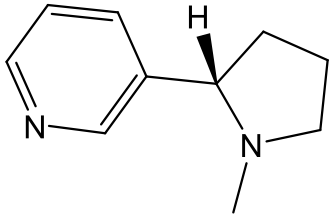
Polyvinyl Alchol



DDT



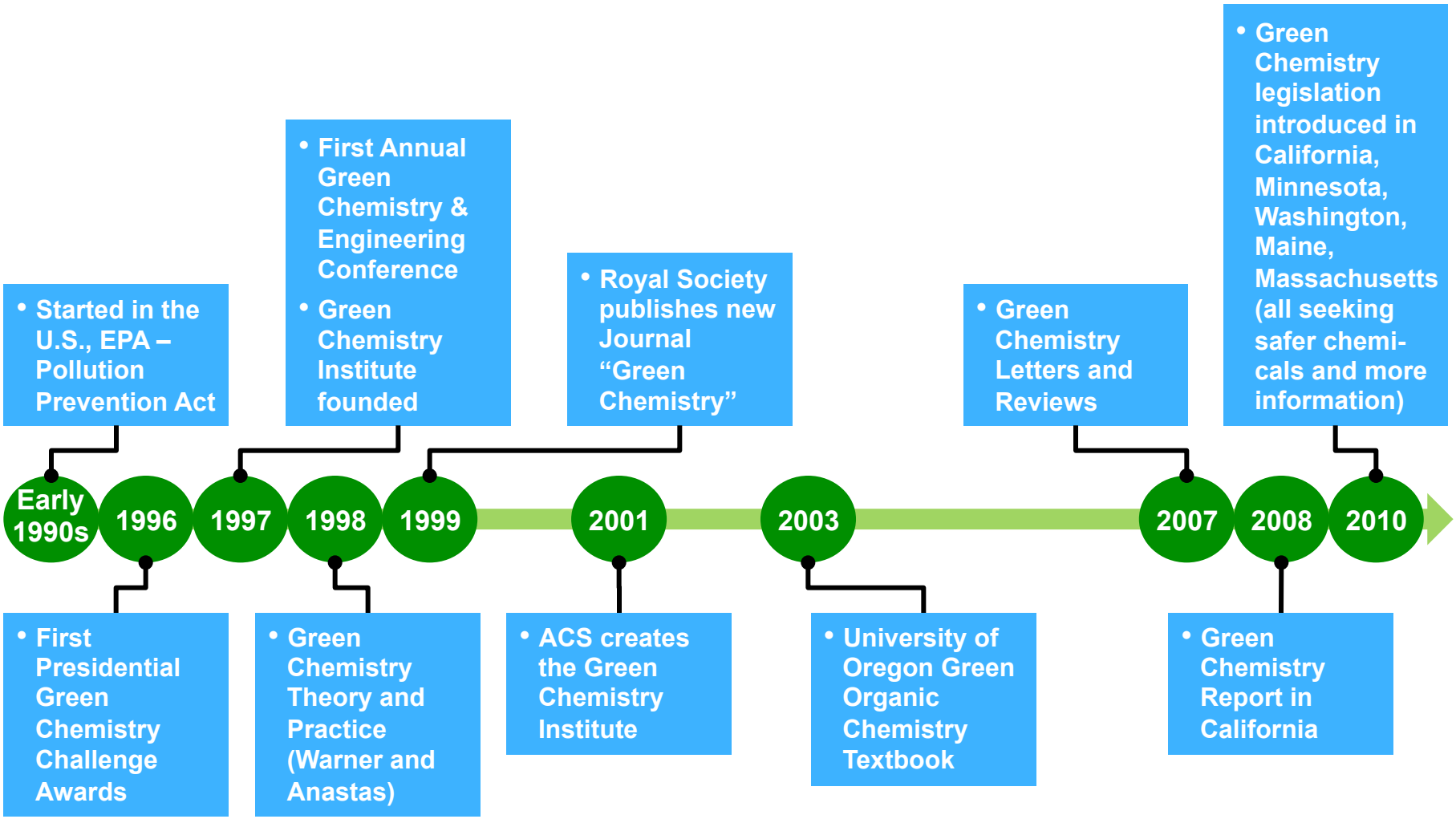
Tetrototoxin



Nicotine

You need context to answer these questions well.

Green Chemistry Timeline



Horizontal technology

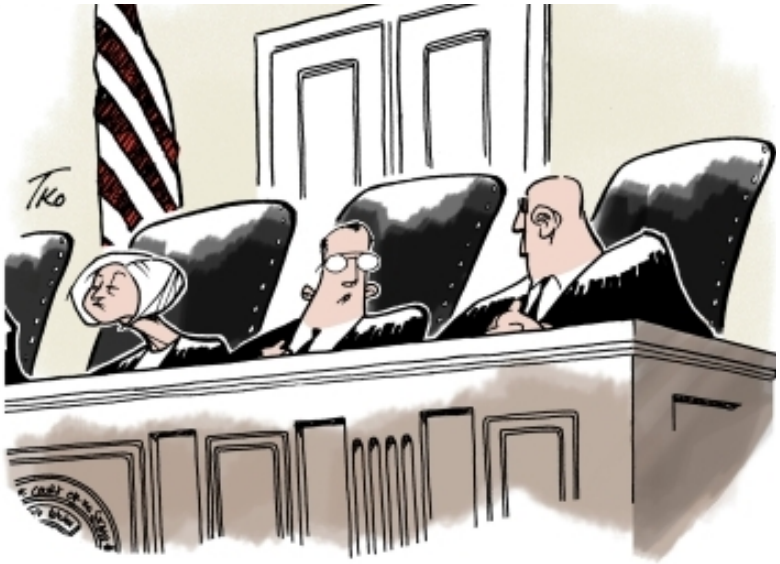
Green Chemistry: Safer and more efficient chemical processes.

Water Energy Health Food

Process rather than product oriented approach

Safer Chemistry

1 Make Better Choices

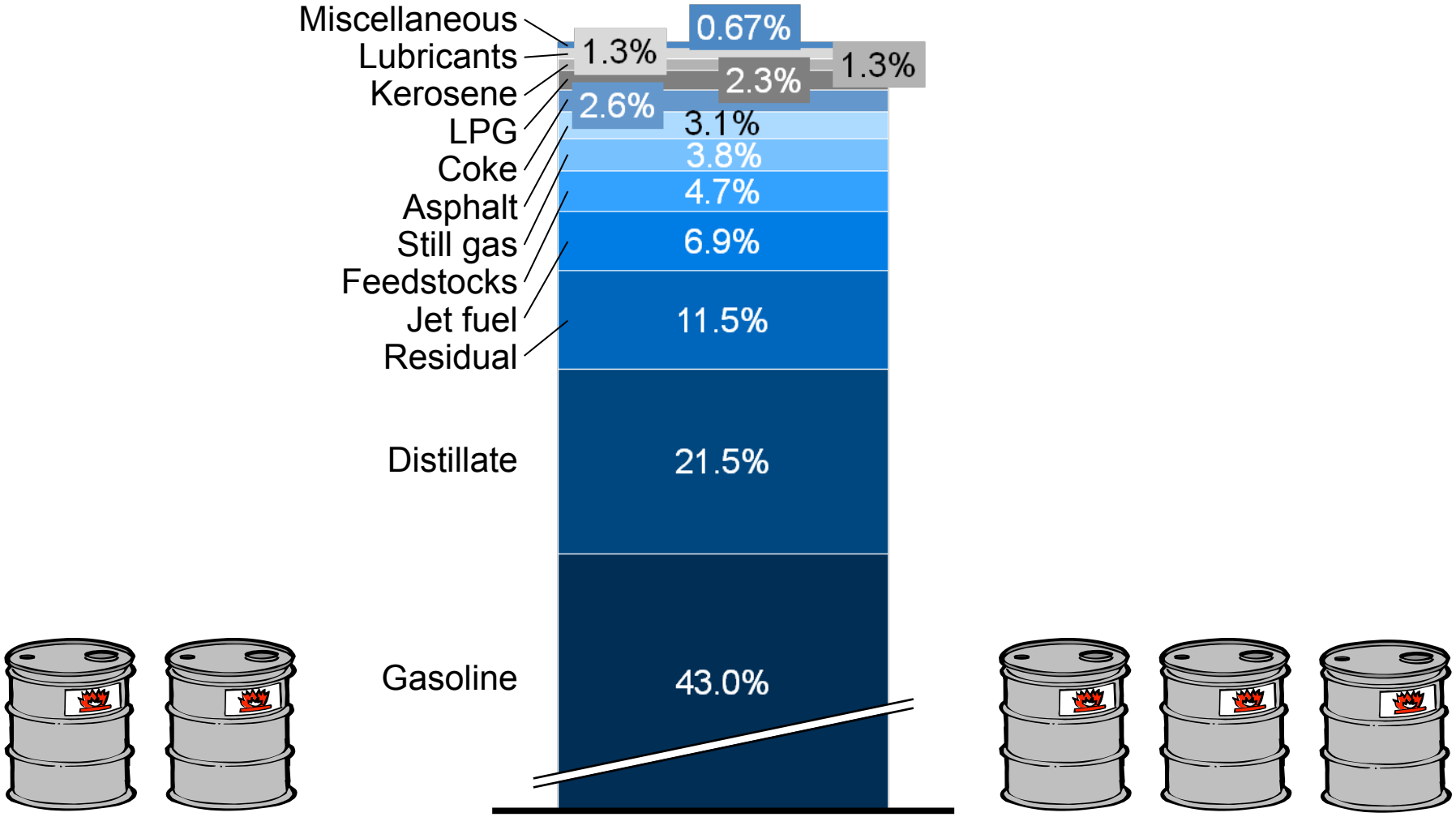


"Don't spread it around, but on the really tough ones, I just go with 'eenie, meenie, minie, moe.'"

2 Design Better Chemicals

Efficiency

One Barrel (42 gallons) of Oil Yields:

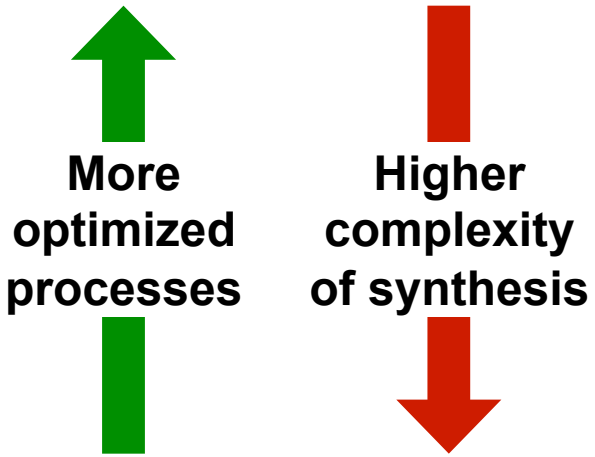


Definition of Environmental Factor

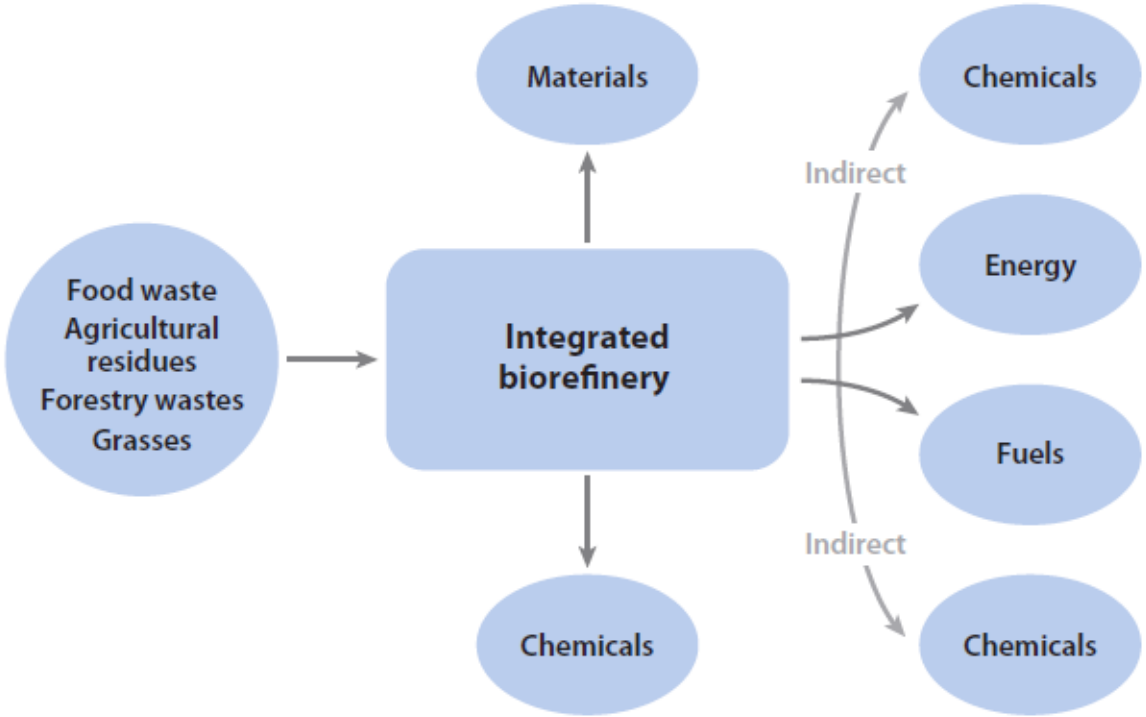
Environmental (E-Factor)

$$E = \frac{\text{Kg waste + unwanted byproducts}}{\text{Kg desired product(s)}}$$

	Volume of production Tons per year	E factor
Oil refining	10^6-10^8	0.1
Commodity chemicals	10^4-10^6	<1.5
Special chemicals	10^2-10^4	5-50
Drugs	10^1-10^4	25->100

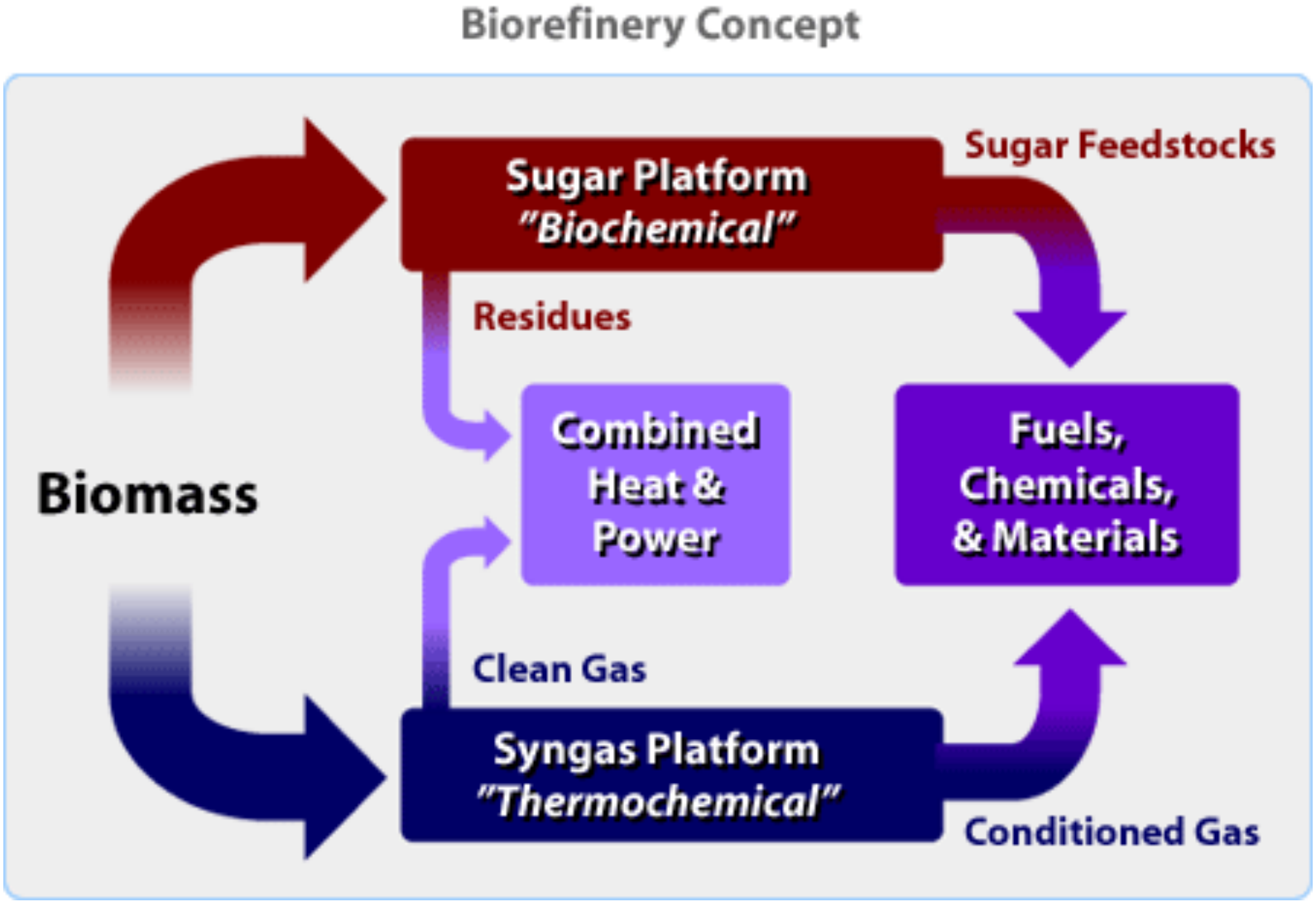


Green Chemistry, Biofuels, and biorefining



Annu. Rev. Chem. Biomol. Eng. 2012. 3:183–207

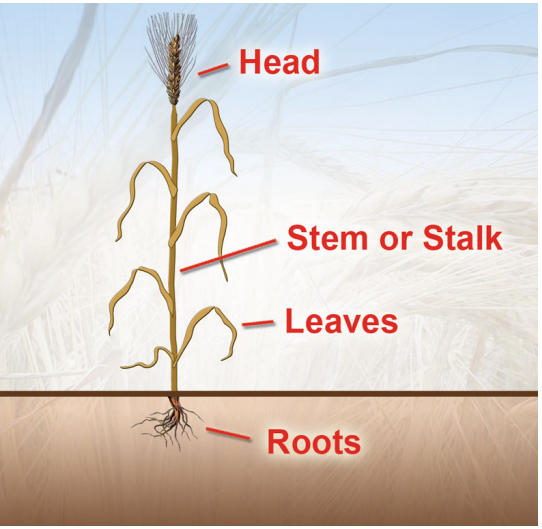
Two Approaches to Conversion of Biomass



From plant to chemicals

Types of Biomass

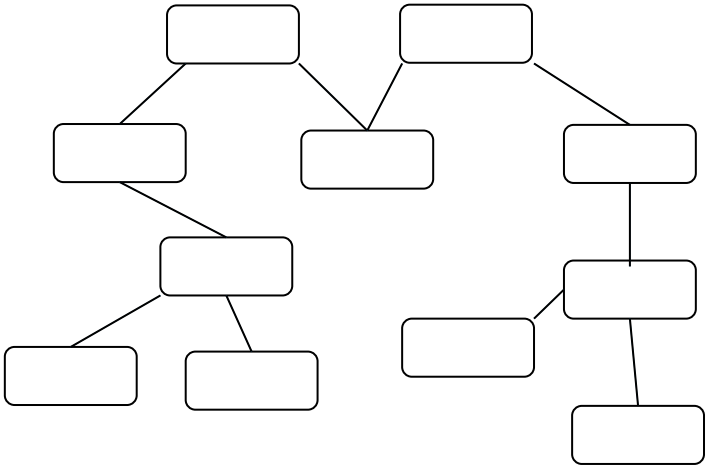
Seeds, fibers, fruits, etc.



Based on the reading or other knowledge, write down as many connections between type of biomass, chemical class, and types of fuel.

Chemical Classes

Oils, starches, sugars etc.



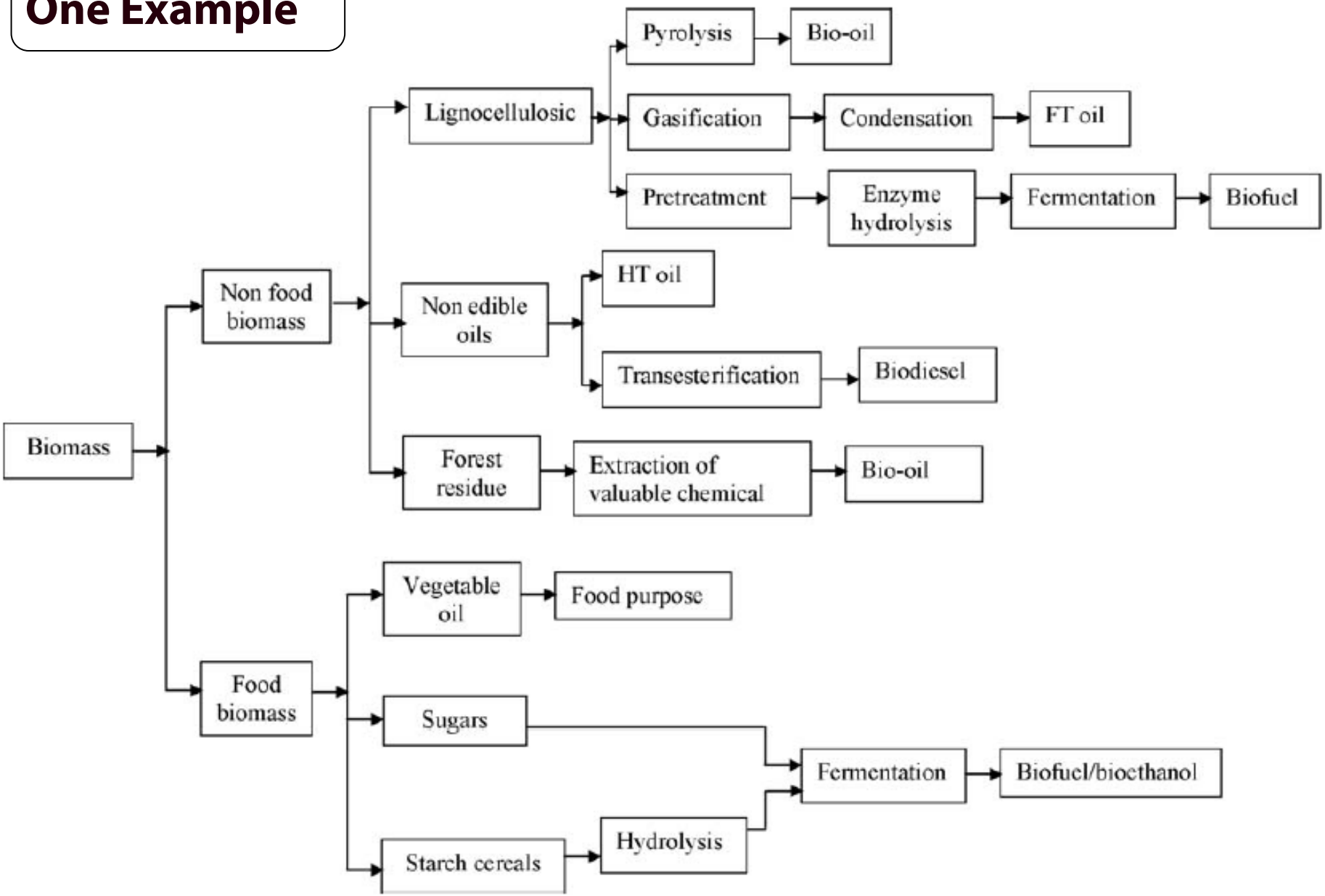
Ten minute timer

Types of Fuel

Ethanol, Diesel, methane, etc.

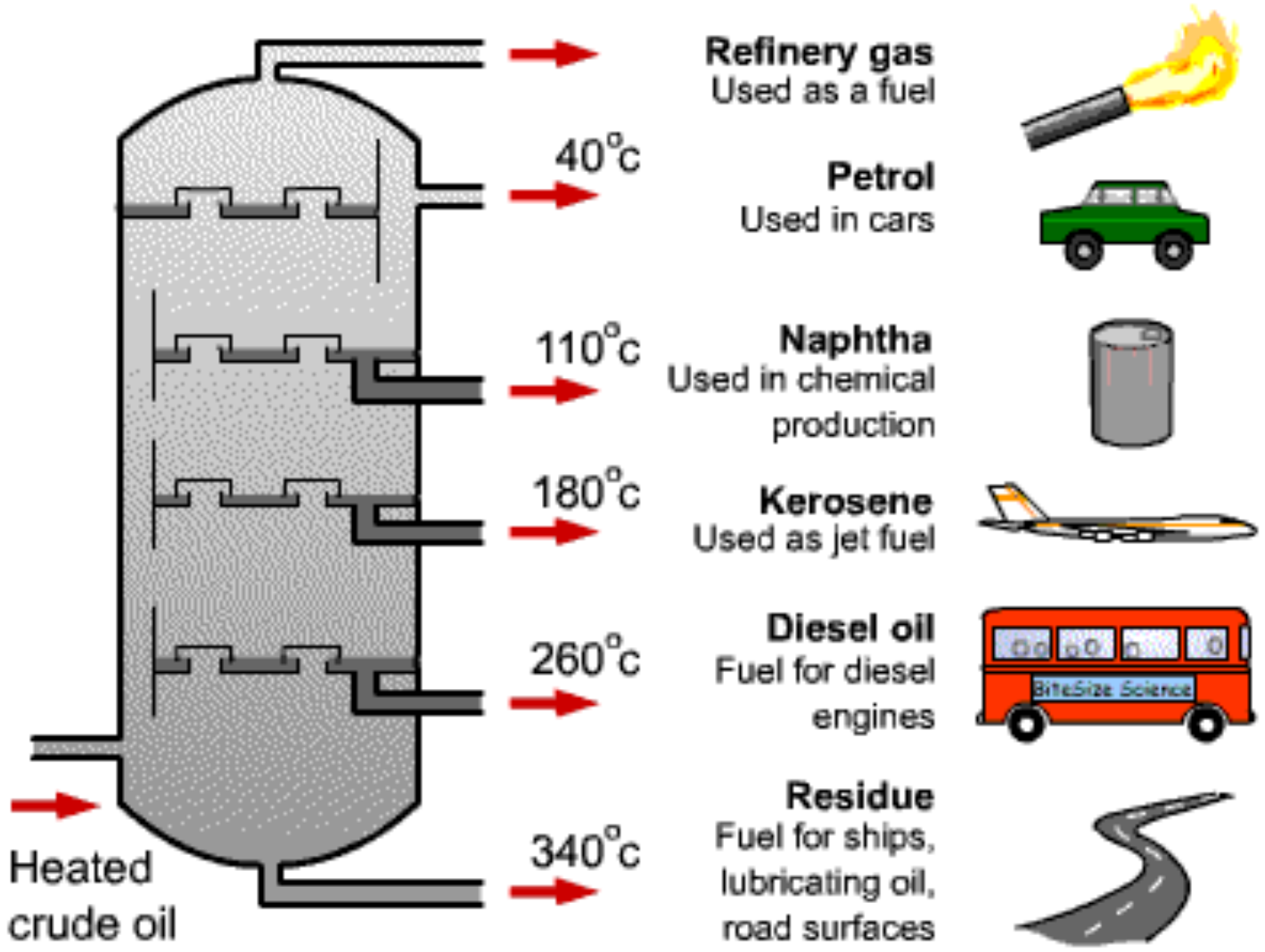
Now place your sticky notes where they belong

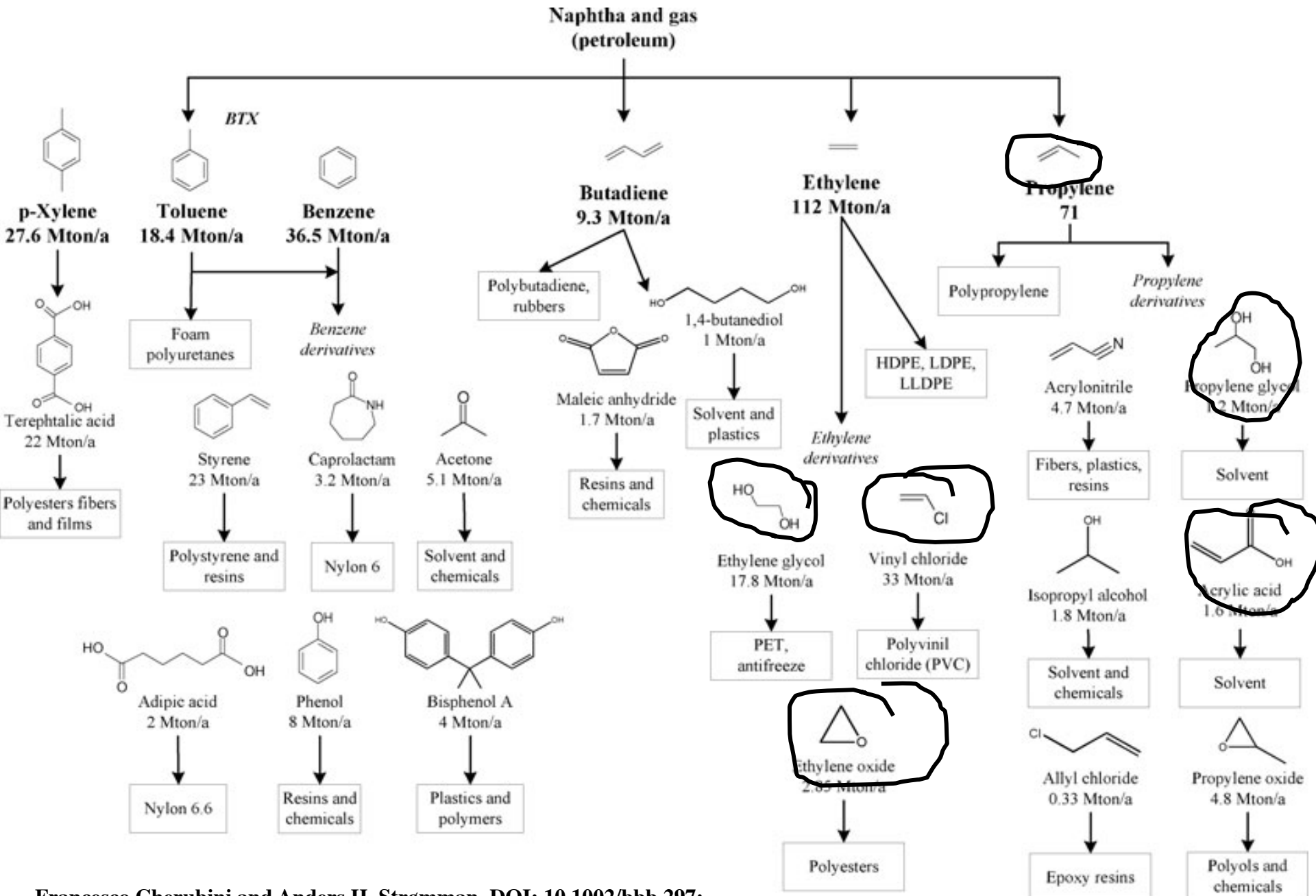
One Example



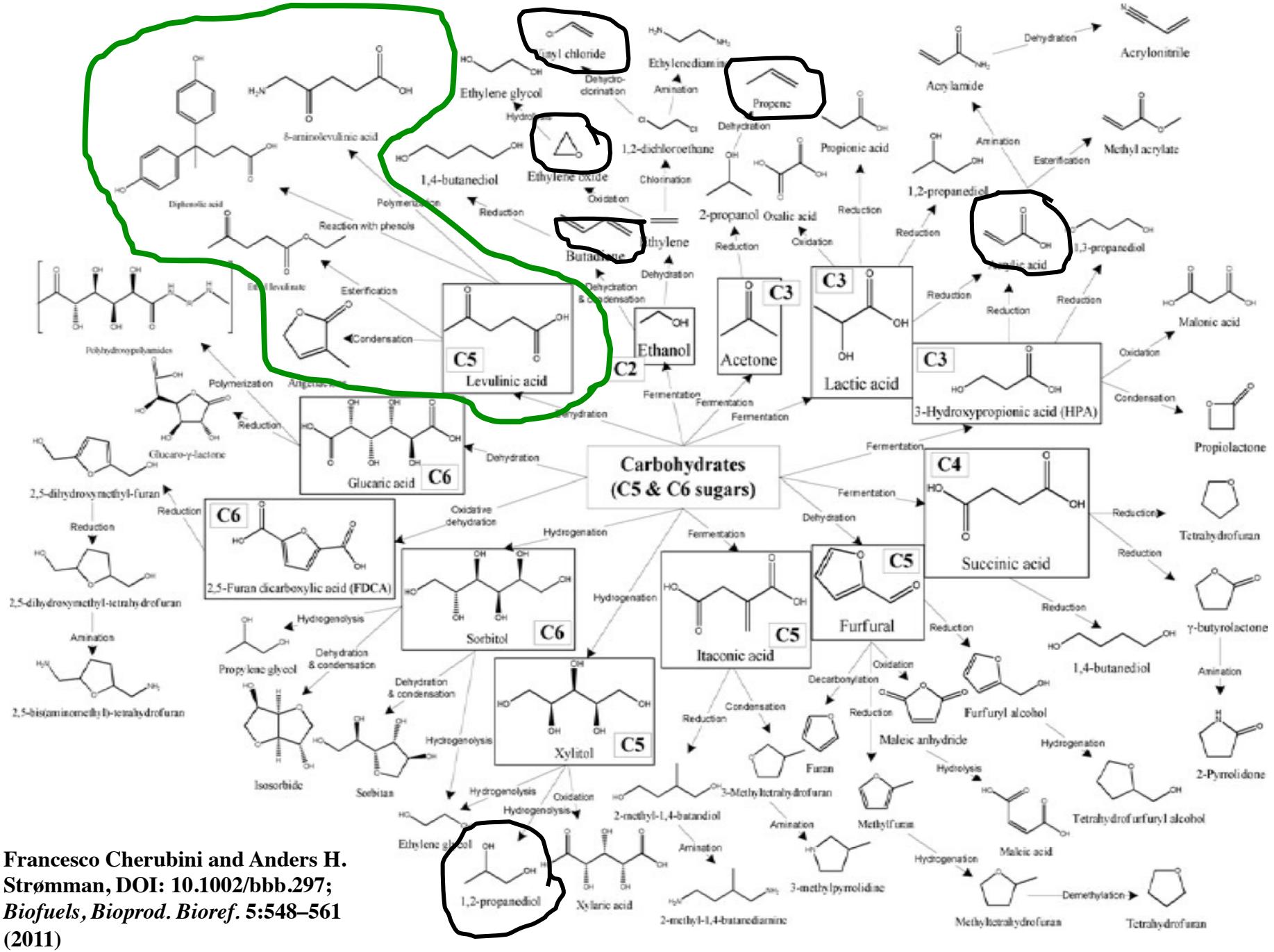
Renewable and Sustainable Energy Reviews 14 (2010) 578–597

For Petroleum the dominant process is thermochemical





Francesco Cherubini and Anders H. Strømman, DOI: 10.1002/bbb.297;
***Biofuels, Bioprod. Bioref.* 5:548–561 (2011)**



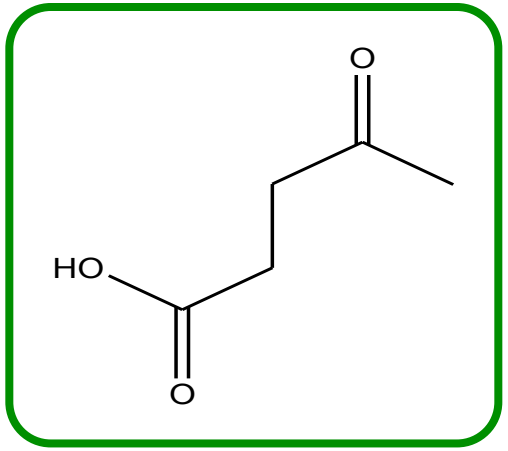
Francesco Cherubini and Anders H. Strømman, DOI: 10.1002/bbb.297; *Biofuels, Bioprod. Bioref.* 5:548–561 (2011)

Raw Materials from Renewable Resources: The BioFine Process

Paper mill sludge

Agricultural residues, waste wood

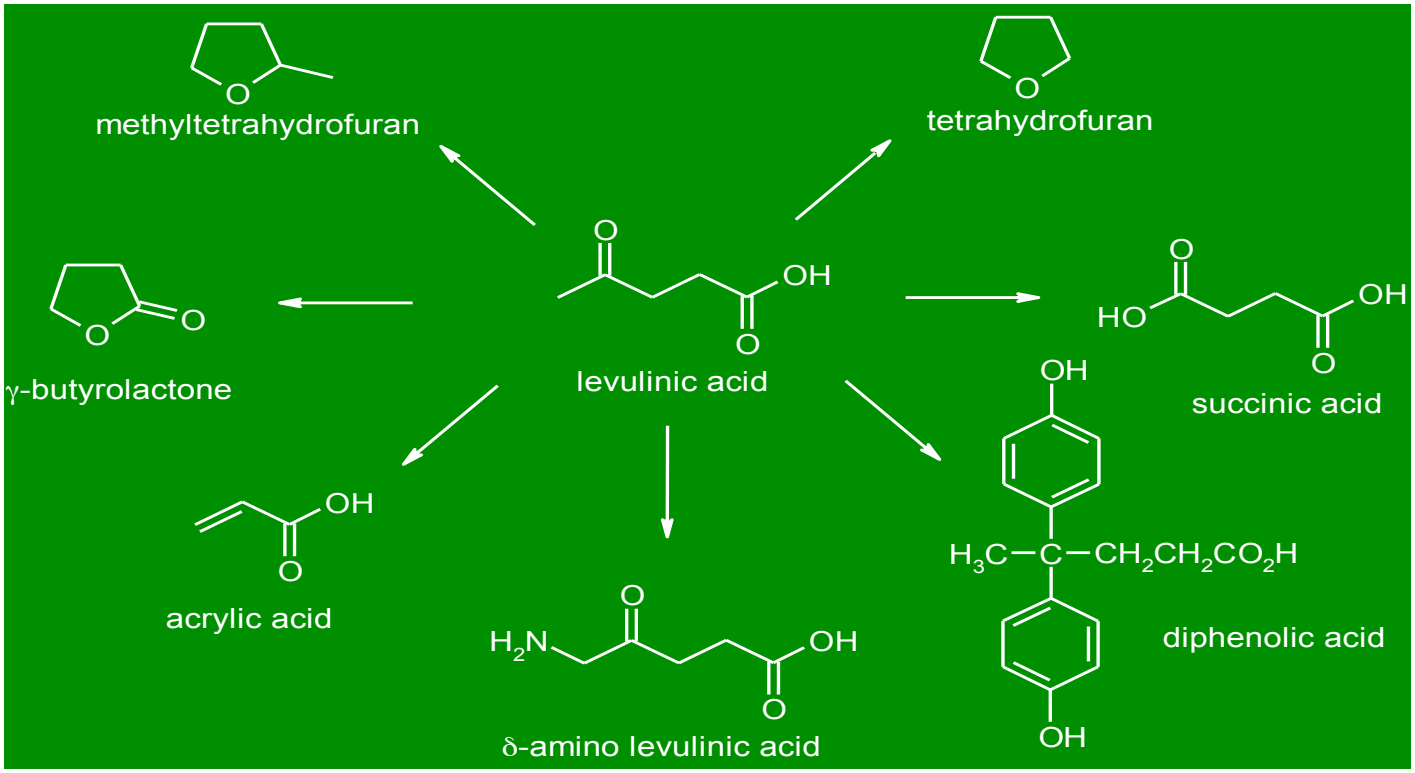
Municipal solid waste and waste paper



Levulinic acid

Green Chemistry Challenge Award 1999 Small Business Award

Levulinic Acid as a Platform Chemical



Conversion of waste biomass to levulinic acid

- Paper mill sludge, municipal solid waste,
- Unrecyclable waste paper, agricultural residues

Source: Biofine Inc.

Class Project: A review article

Deliverable

- 10,000 words, 75-125 references.
- 3-5 authors.
- Best articles will be revised for publication.

Process

- Phase 1 Context and identifying interest areas (first 7 classes)
- Phase 2 Boundary conditions, technical performance, and impact assessment (next 8 classes)
- Phase 3 Policy Implications (next 4 classes)
- Phase 4 Business and Economic factors (next 4 classes)
- Final Integration and recommendations (final 3 classes)

Grading

- 80% of your class Grade
- 10% from what you turn in at the end of the section, 30% final products
- Peer assessment will be used to assess contributions and involvement

What part of the life-cycle are you most interested in

- Organize yourselves by talking to each other from one side of the room to the other.

Crops Conversion Storage/Transport/Use Systems Organization

Now explain what specific aspects of this interest you. [need better wording]

Send by noon Friday 2/1 (marty_m@berkeley.edu)

- **Name, Year, Department**
- **Which processes and fuels interest you most and why?**
- **Other Requests**

Examples:

Marty Mulvihill, Postdoc, Chemistry

I want to work on Algae-based fuels because I do synthetic biology research.

I want to work with Joe, Chris, and Meg.

Alastair Iles, Faculty, ESPM

I am interested in land use issues and would like to look at implementation trade-offs of 1st and 2nd generation biofuels.

I can't meet after class on Wednesdays.