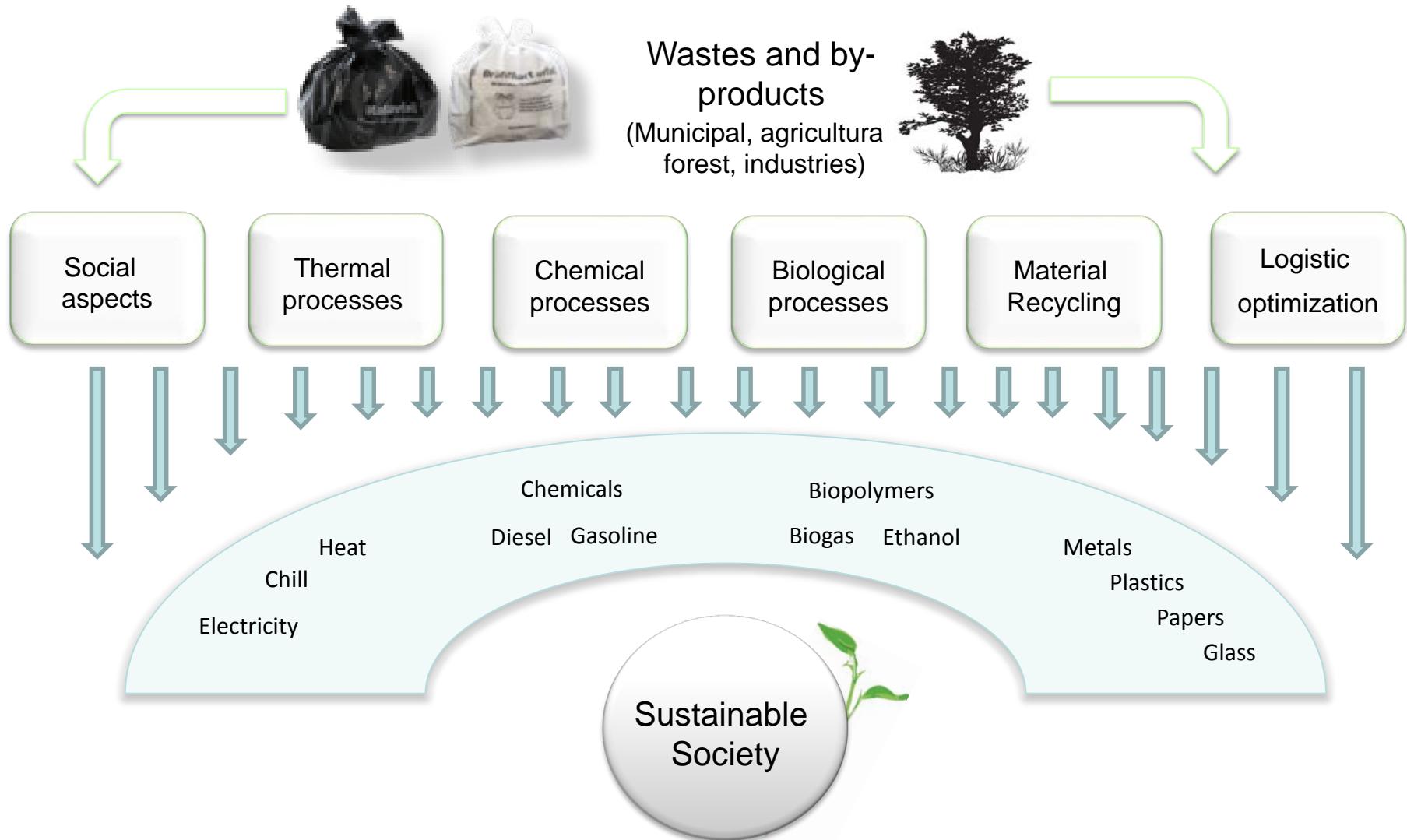


Wastes to ethanol and biogas: Biological methods

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“Swedish Centre for Resource Recovery”



Biotechnology group

- Seniors:
 - Mohammad Taherzadeh
 - Ilona Sarvari Horvath
 - Patrik Lennartsson
 - Akram Zamani
 - Päivi Ylitervo
- Postdocs:
 - Swarnima Agnihotri Kumar
 - Jorge Ferreira
- Current PhD students:
 - Ramkumar Nair
 - Mostafa Jabbari
 - Osagie Alex Osadolor
 - Regina Jijoho Patinvoh
 - Konstantinos Chandolias
 - Pedro Ferreira
 - Veronika Bátori
 - Amir Mahboobi
 - Lukitawesa
 - Steven Wainaia
 - Rebecca Gmoser

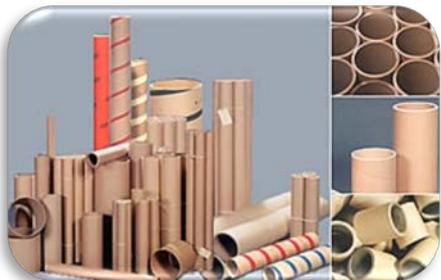


Our graduated PhDs since 2010

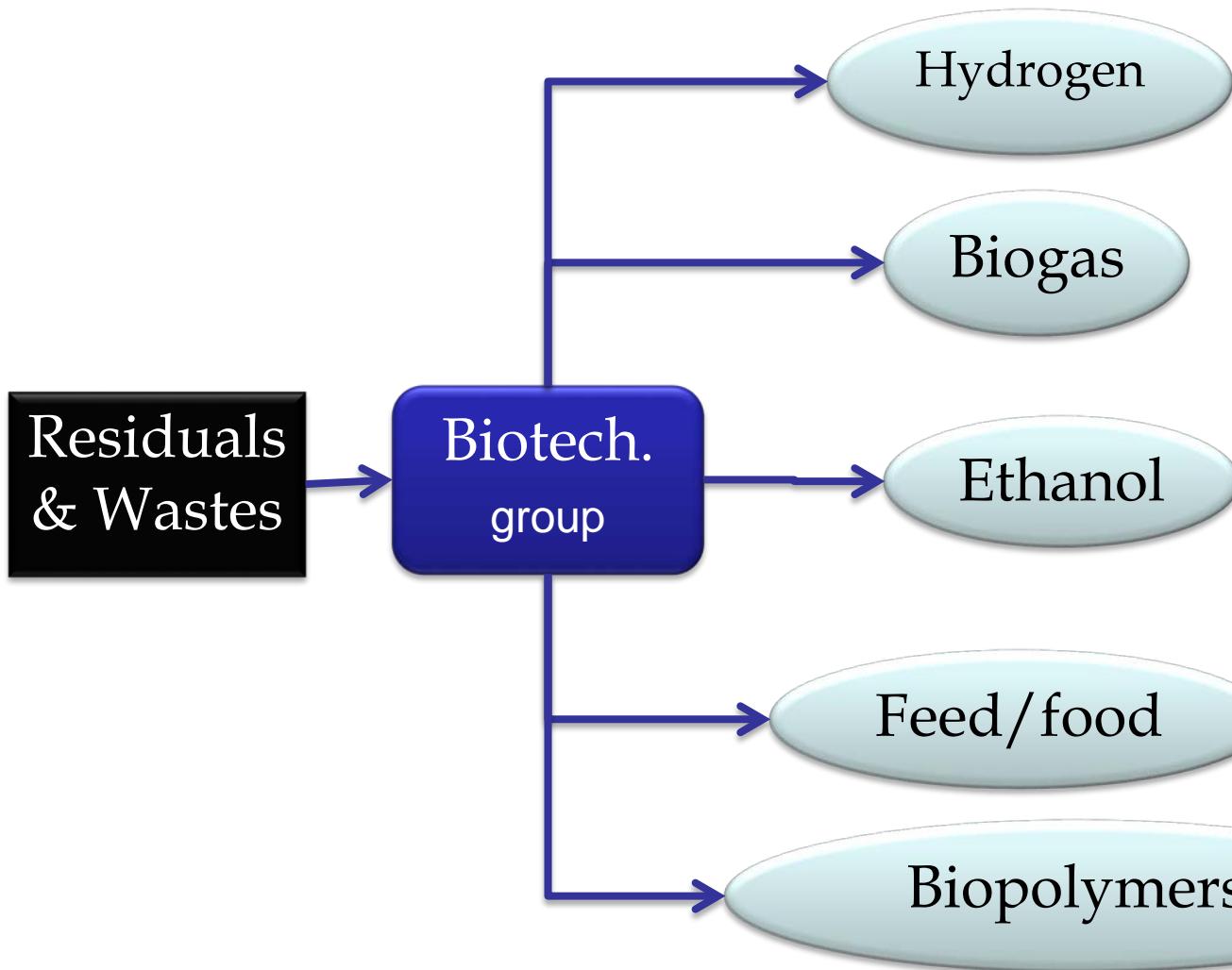
1. Mohammad Pourbafrani, 2010
2. Akram Zamani, 2010
3. Azam Jeihanipour, 2011
4. Patrik Lennartsson, 2012
5. Gergely Forgacs, 2012
6. Supansa Youngsukkasem, 2012
7. Anna Teghammar, 2013
8. Isroi, 2013
9. Johan Westman, 2014
10. Solmaz Aslanzadeh, 2014
11. Johan Westman, 2014
12. Solmaz Aslanzadeh, 2014
13. Hamidreza Barghi, 2014
14. Päivi Ylitervo, 2014
15. Mofoluwake Ishola, 2014
16. Rachma Wikandari, 2014
17. Maryam Mohseni Kabir, 2015
18. Julius Akinbomi, 2015
19. Karthik Rajendran, 2015
20. Jorge Ferreira, 2015
21. Jhosane Pagés Díaz, 2015



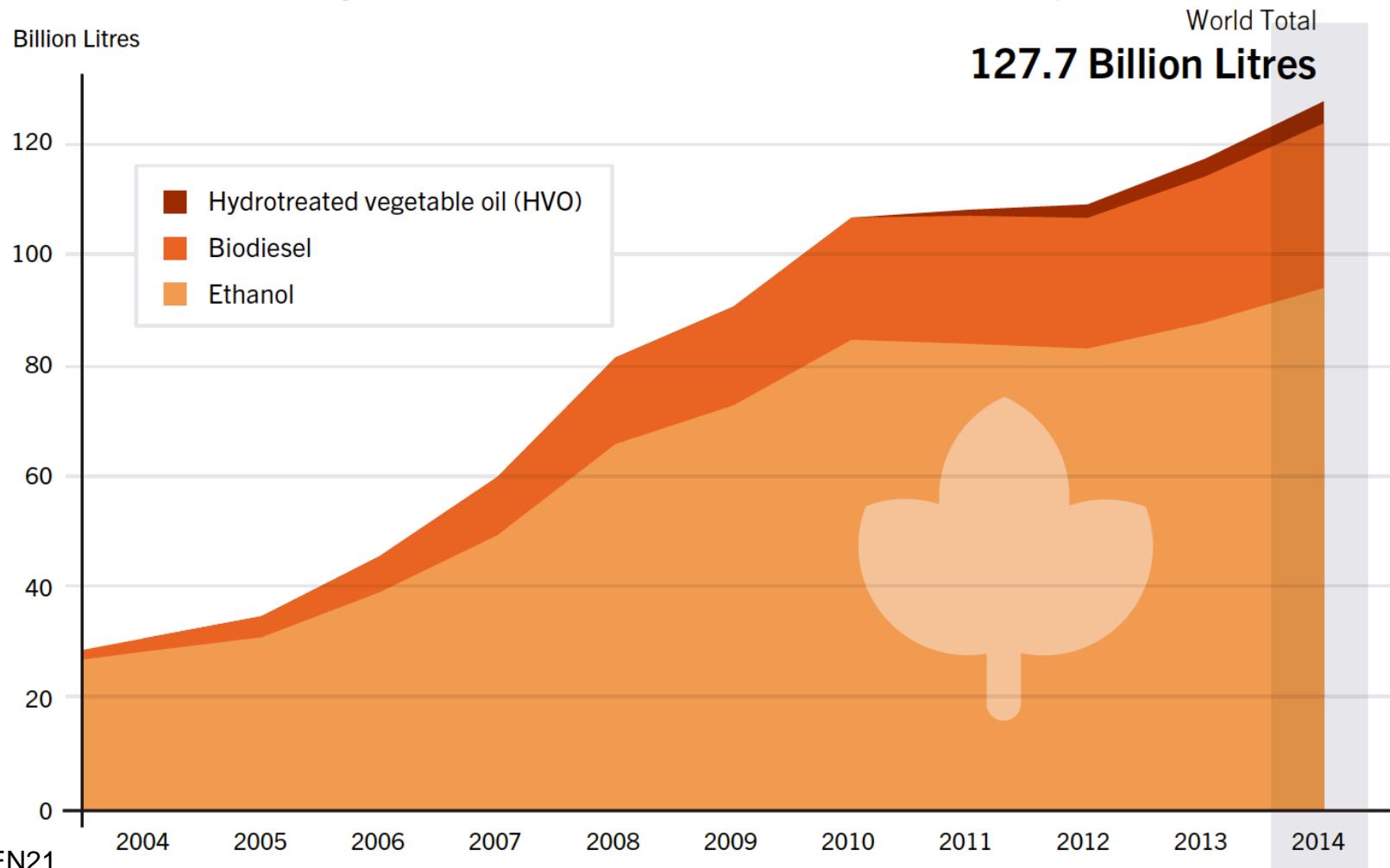
Challenging wastes = Research subjects



What we develop!



Ethanol is the leading biofuel in the market (data for 2000-2014)



What is Biogas?

Matter	%
Methane, CH ₄	50-75
Carbon dioxide, CO ₂	25-50
Nitrogen, N ₂	0-10
Hydrogen, H ₂	0-1
Hydrogen sulphide, H ₂ S	0-3
Oxygen, O ₂	0-2

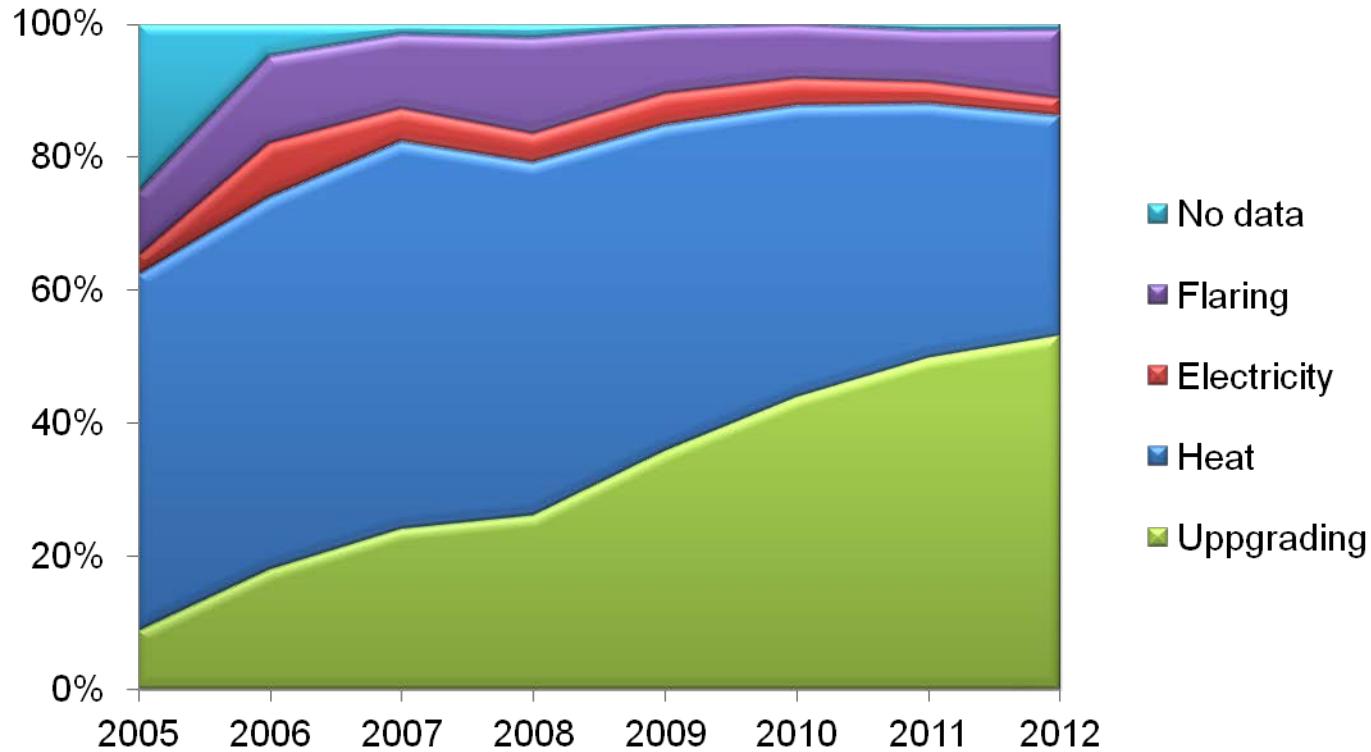


Biogas market

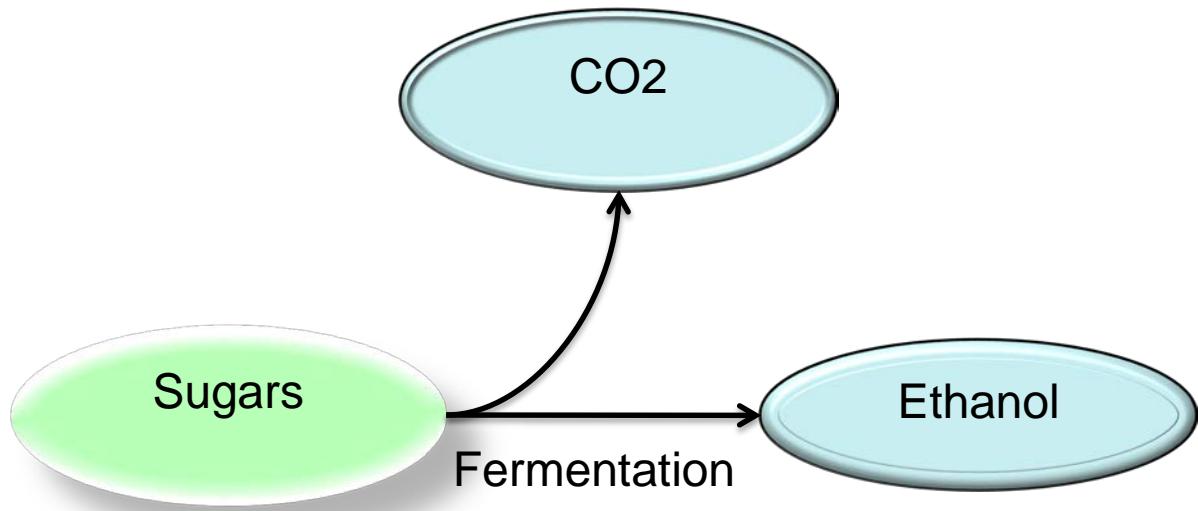
- No global data
- China:
 - 100,000 large modern plants
 - 43 million household digesters
- Europe:
 - ca 15,000 plants (ca 50% in Germany)
 - Electricity is the major market (ca 50%)
 - Agricultural products, wastes and sluge are used!



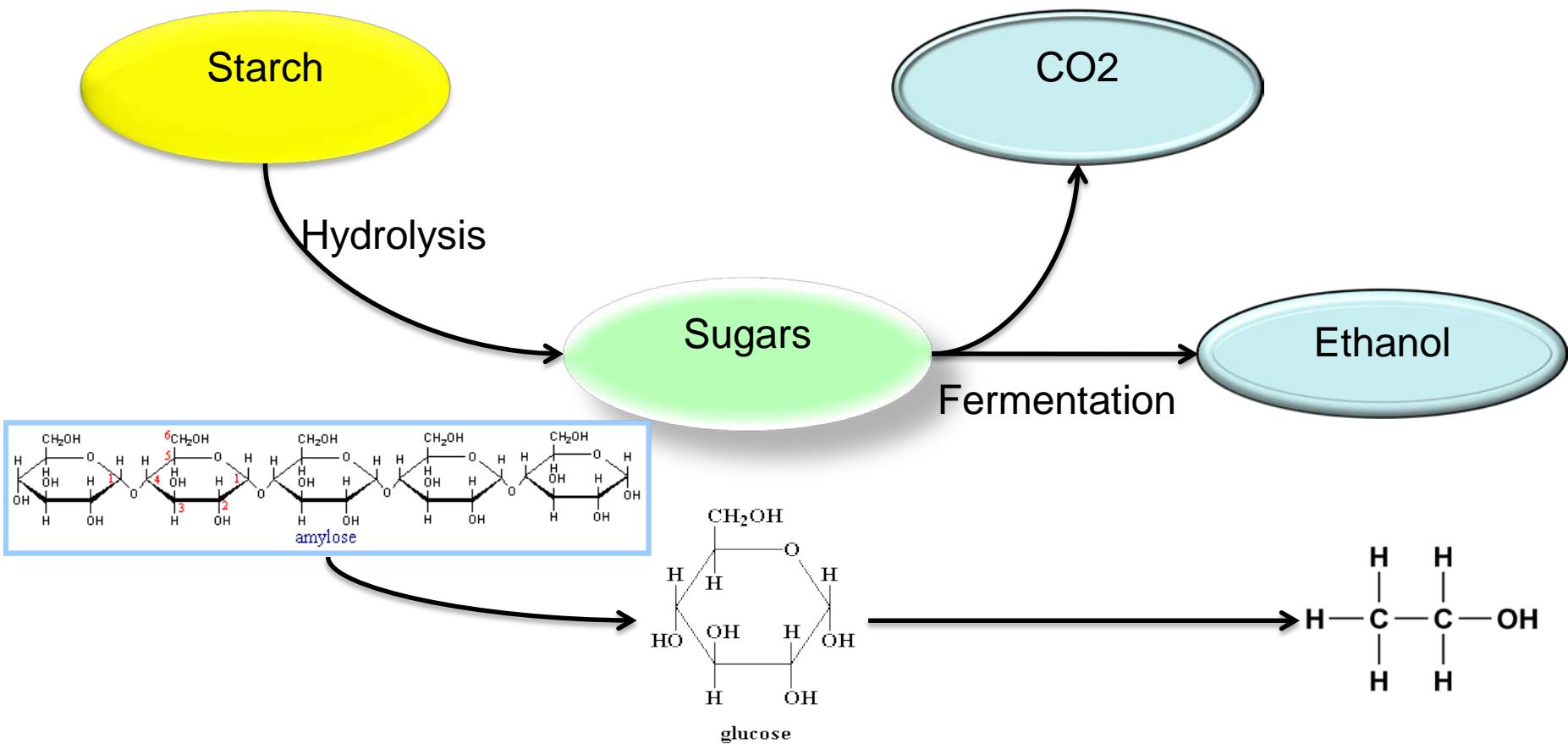
Use of biogas in Sweden 2005-2012



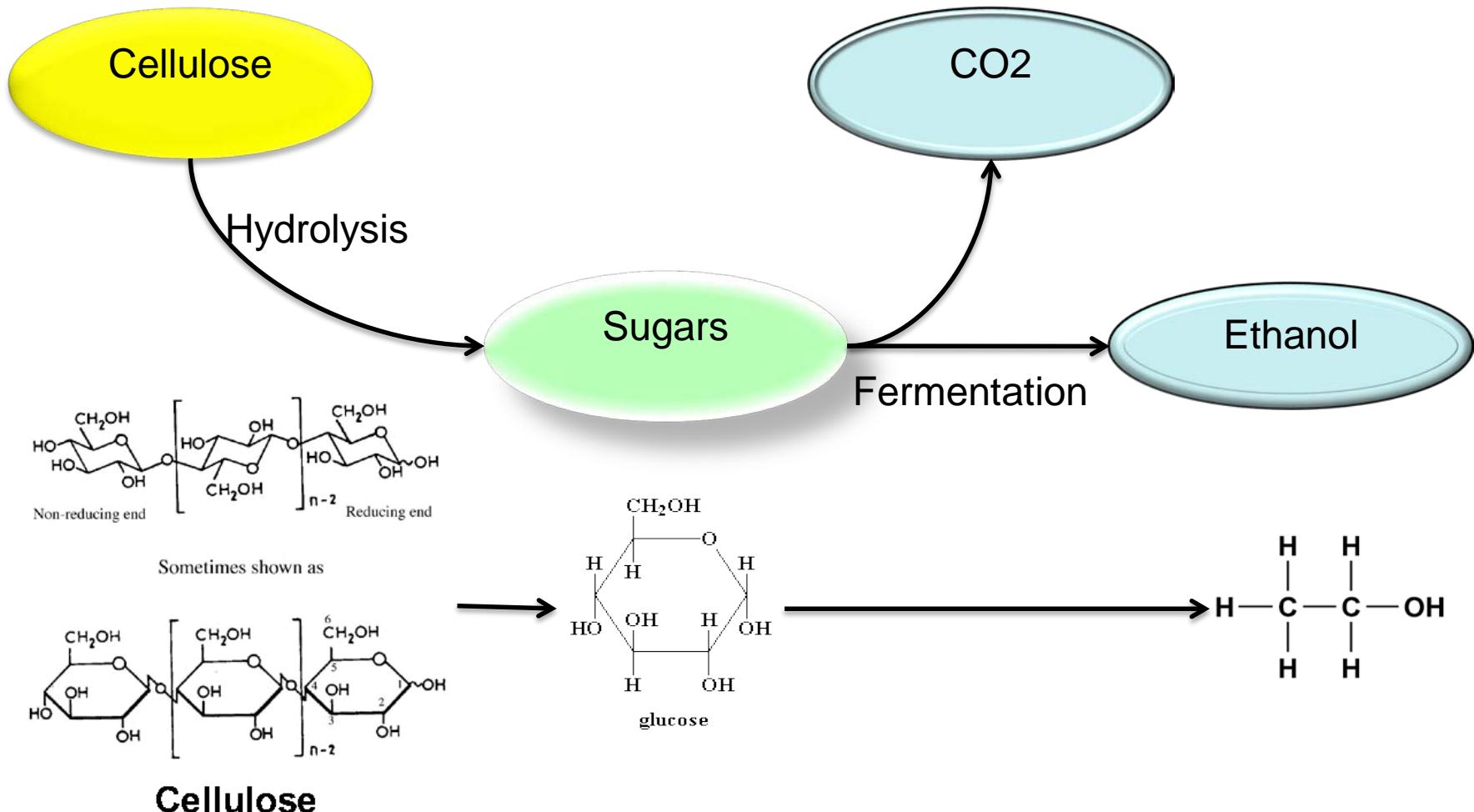
How to convert sugars to ethanol?



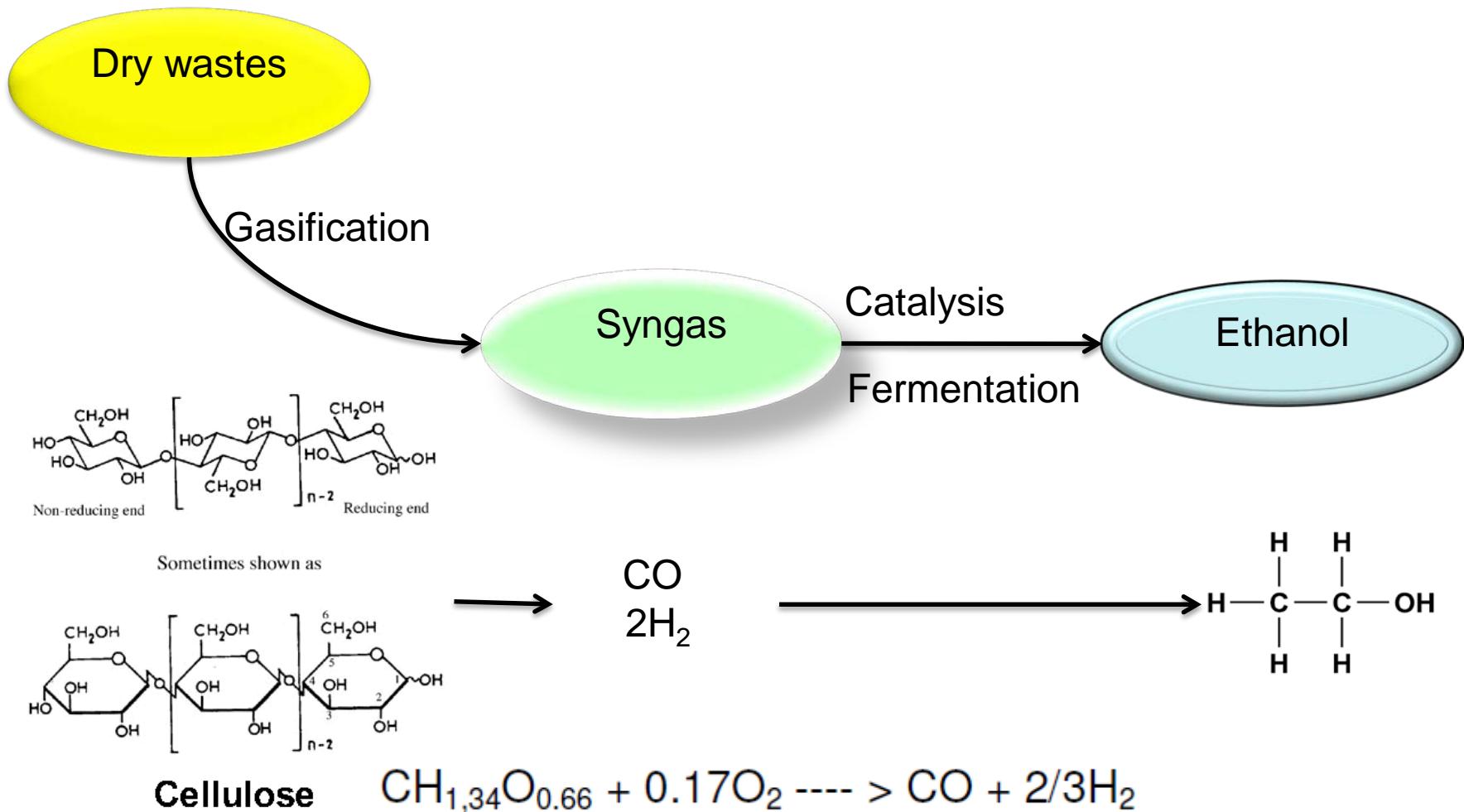
How to convert starch to ethanol?



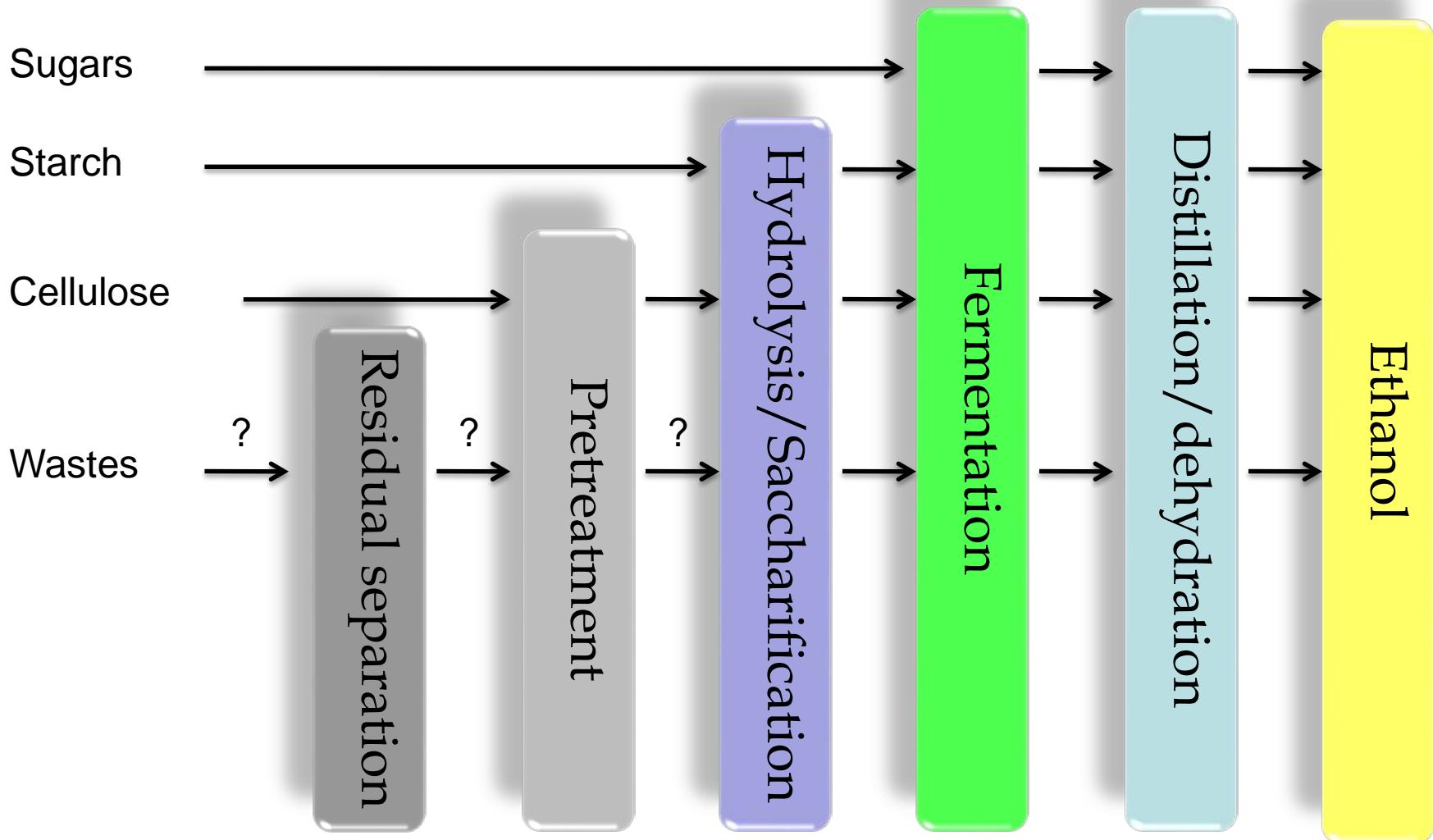
How to convert cellulose to ethanol?



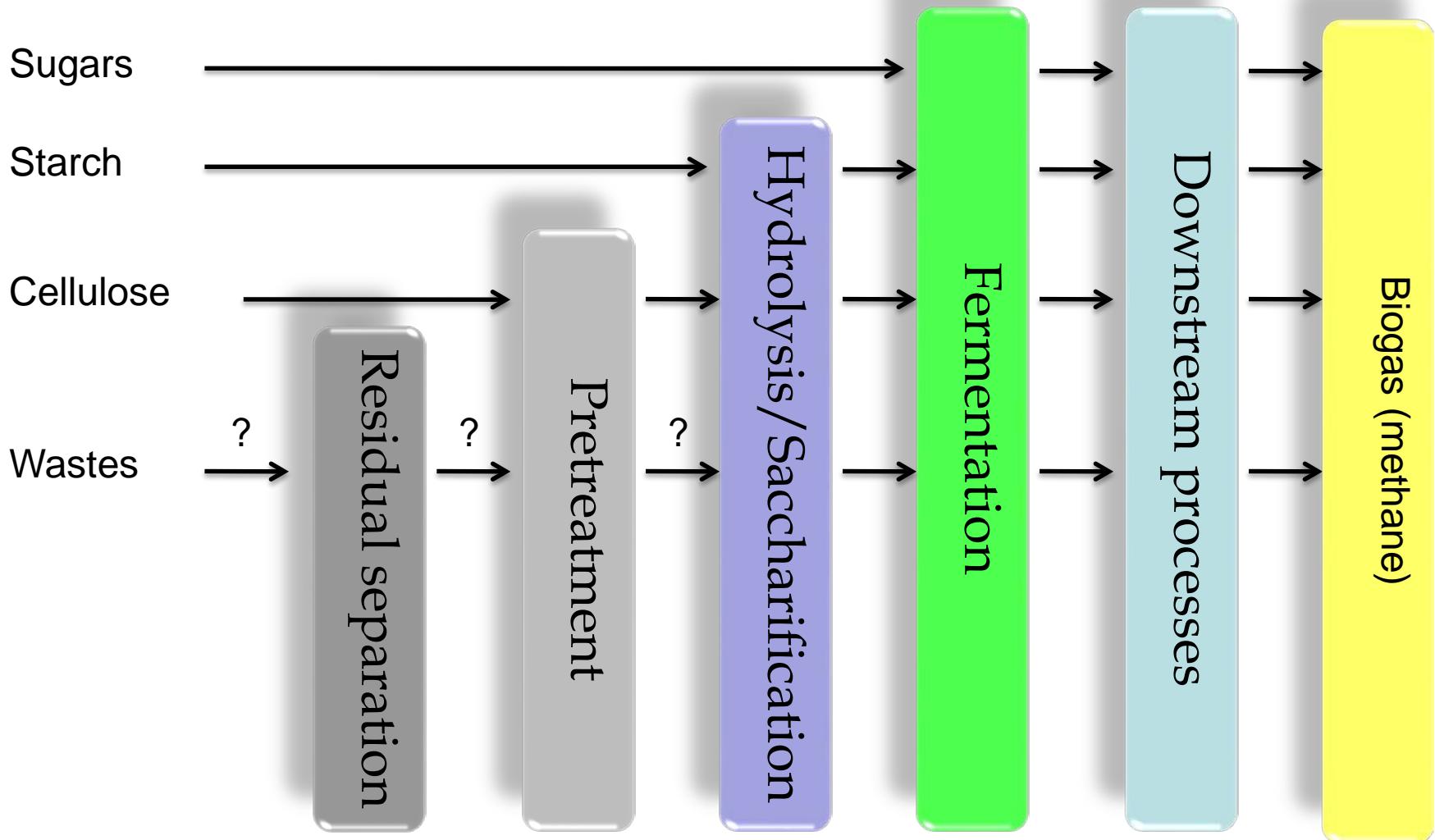
How to convert cellulose to ethanol?



Value of raw materials vs. process units for ethanol



Biogas?



Biogas: microorganisms take care of everything

1. Hydrolysis

Complex organic matter
Carbohydrates, proteins, lipids



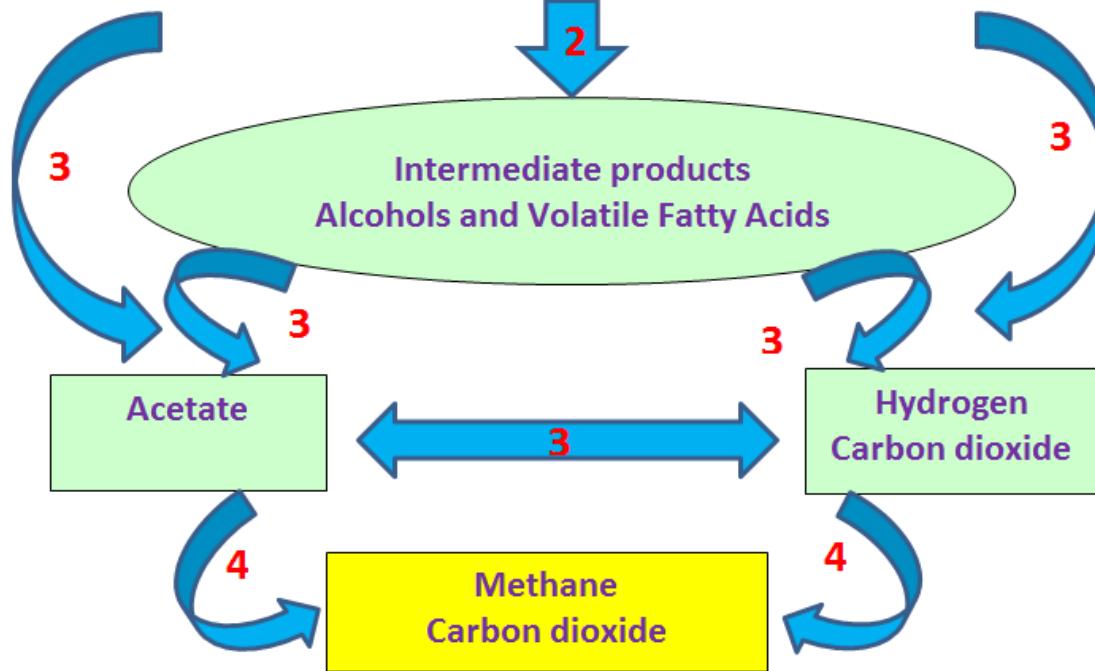
2. Acidogenesis

Soluble organic matter
Sugars, amino acids, fatty acids



3. Acetogenesis

Intermediate products
Alcohols and Volatile Fatty Acids



1. Methanogenesis



Challenges for ethanol and biogas

- Finding suitable substrate
- Pretreatment:
 - Increasing biodegradability
 - Removing inhibitors
 - Removing indigestible materials
- Reducing costs:
 - Cheaper process?
 - Faster process?
 - Using current infrastrucure (e.g. integration of 1st and 2nd generation ethanol)



A typical substrate with problem: Citrus wastes

Yields of the carbohydrates released during enzymatic hydrolysis of the orange peels.



Carbohydrate	% (of total solid)	
Glucose	22.9 ± 2.4	As hemicellulose
Fructose	14.1 ± 1.3	
Galactose	4.0 ± 0.2	As hemicellulose
Arabinose	7.1 ± 0.5	
Xylose	0.4 ± 0.1	
Galacturonic acid	19.0 ± 1.7	As pectin
Total	67.5	

Int. J. Mol. Sci. **2007**, 8



Limonene ca 0.5%

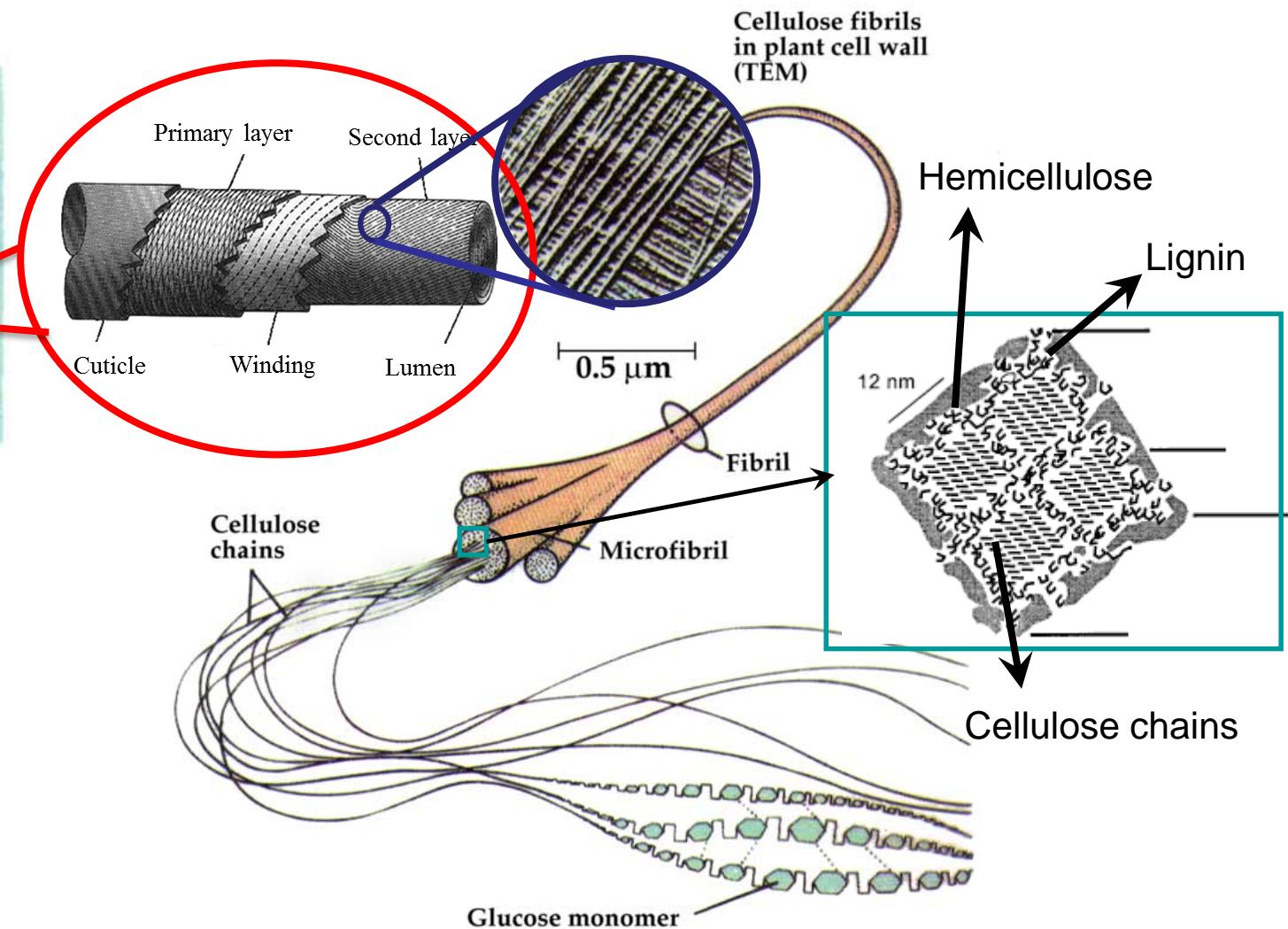
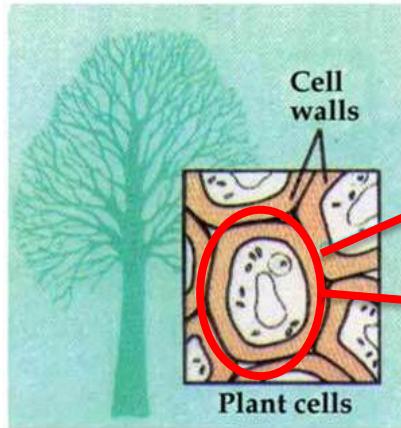


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Lignin and crystallinity in lignocelluloses



Similar problems with Keratins: The recalcitrant proteins



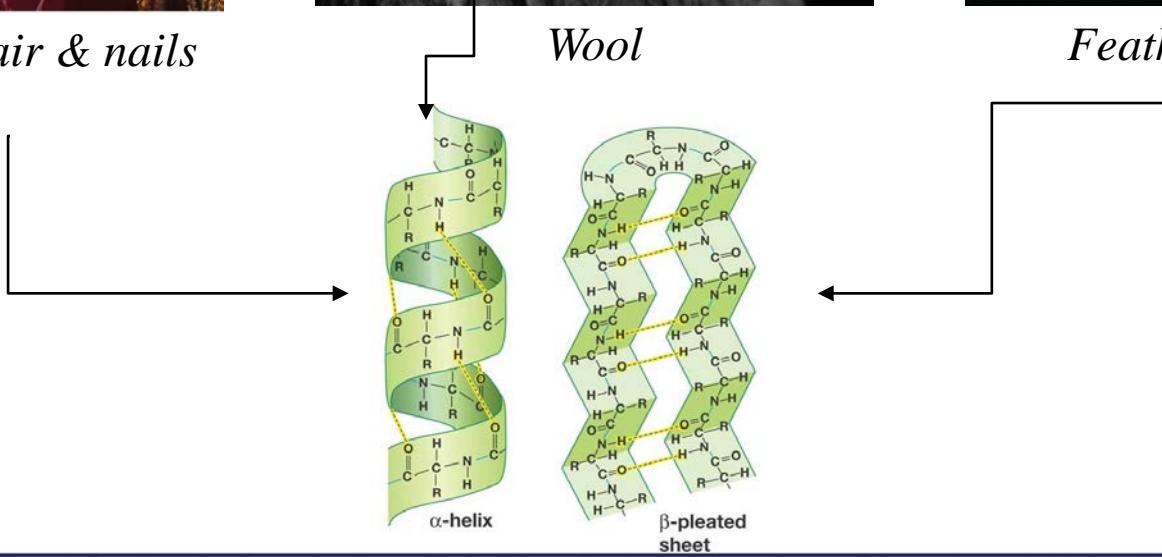
Human hair & nails



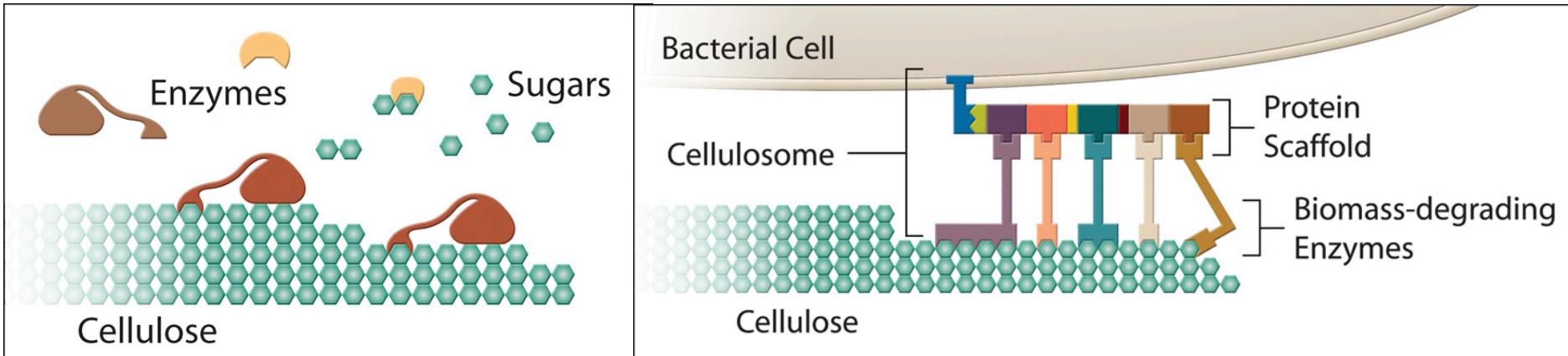
Wool



Feather



Degradation of cellulose by: Cellulase enzyme vs. Bacterial *cellulosome*



It is preferred in industry!

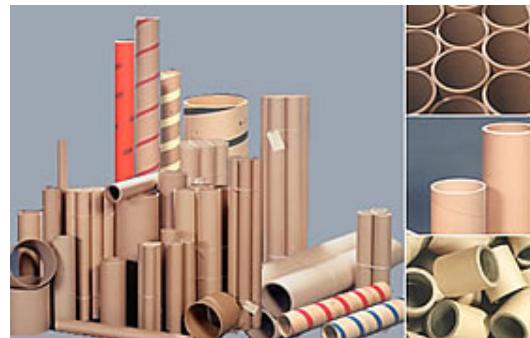
anaerobic bacteria produce much less cellulolytic enzymes than do the fungi:



Physical Pretreatments

Millings	Irradiation	Others
Ball milling	Gamma-ray irradiation	Hydrothermal
Two-roll milling	Electron-beam irradiation	High pressure steaming
Hammer milling	Microwave irradiation	Expansion
Colloid milling		Extrusion
Vibro energy milling		Pyrolysis

Int. J. Mol. Sci. **2008**, *9*: 1621-1651



Chemical & physico-chemical Pretreatments

Explosions	Alkali	Acids	Gases	Oxidizing agents
Steam explosion	Sodium hydroxide	Sulfuric acid	Chlorine dioxide	Hydrogen peroxide
Ammonia fiber explosion (AFEX)	Ammonia	Hydrochloric acid	Nitrogen dioxide	Wet oxidation
CO ₂ explosion	Ammonium Sulfite	Phosphoric acid	Sulfur dioxide	Ozone
SO ₂ explosion				

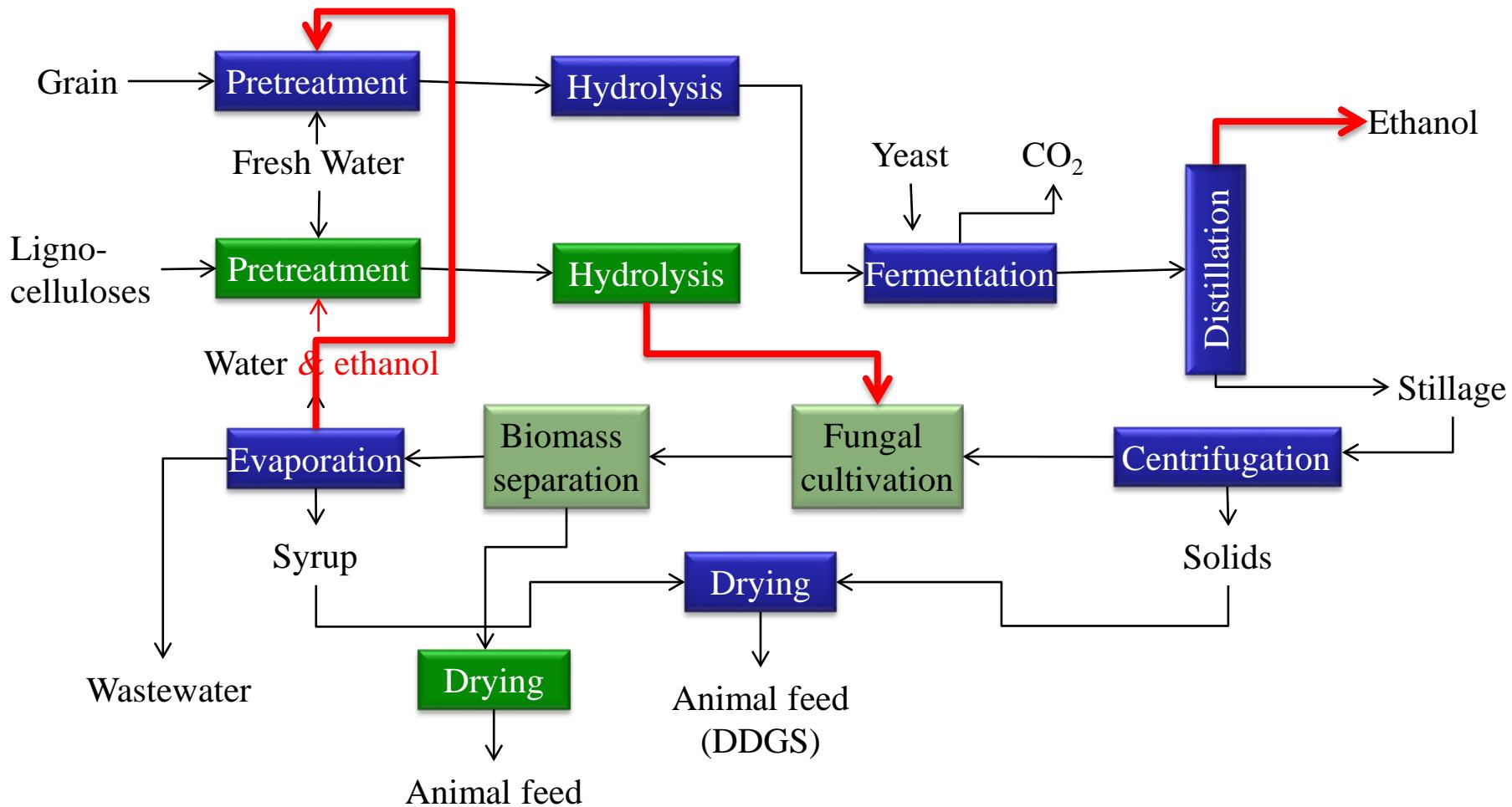
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Textile reactors for biogas & ethanol



Integration on 1st and 2nd generation ethanol using fungi



Turning ethanol plant to biorefinery using edible fungi



Thank you!



Questions?



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