Enzymatic Hydrolysis of Cellulose Coupled with Electricity Generation in Microbial Fuel Cells.

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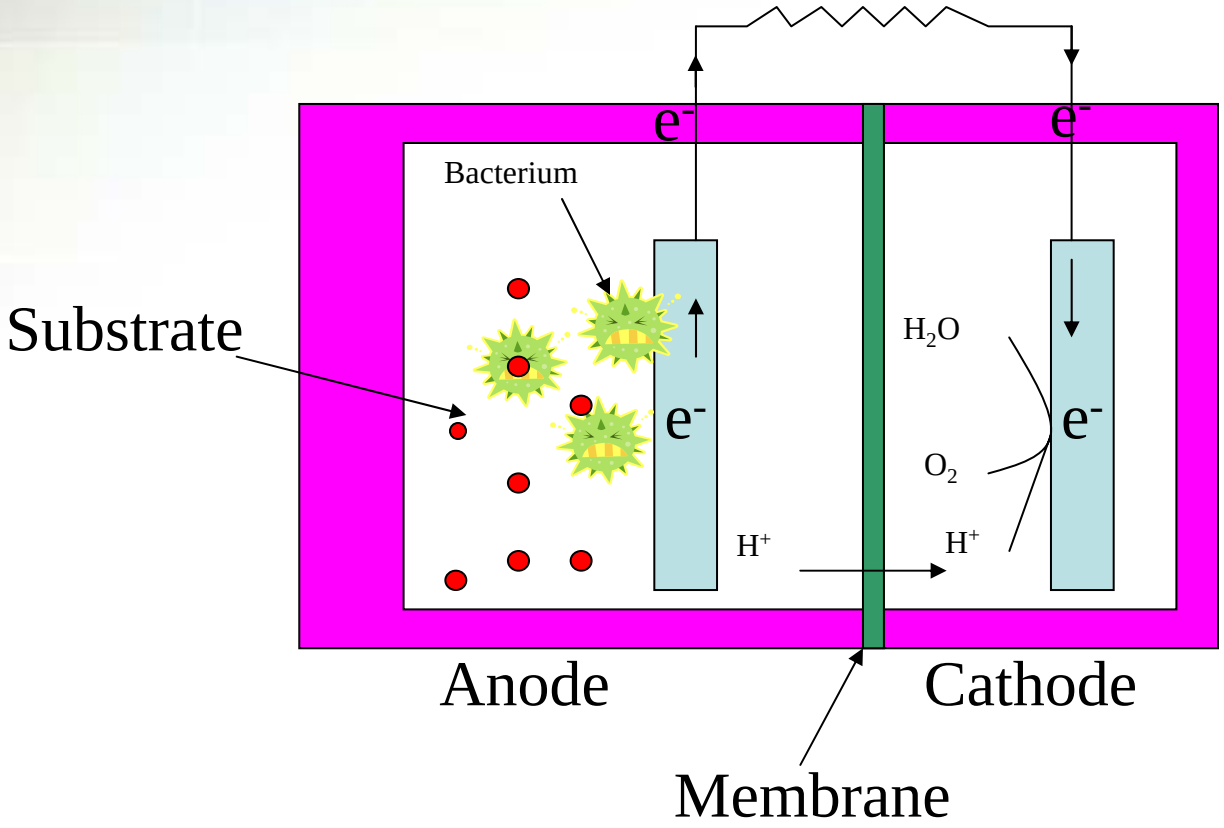
Microbial Fuel Cell (MFC)



Schematic illustration of a microbial fuel cell (Modified from Logan et al., 2006)

MFC substrates

- Simple substrates:
  - Glucose
  - Acetate

- Complex substrates:
  - Wastewater
  - Protein
  - Cellulose (Lignocellulosic Material)
  - Chitin

Main challenge when using particulate substrate

- Complex structure of particulate substrate
- Slow hydrolysis rates
- Different bacteria are needed for hydrolysis and electricity generation

Previous studies on cellulosic MFC

- Rumen bacteria
  - simultaneously hydrolyzed cellulose and 55 mW/m^2 electricity (Rismani-Yazdi et al. 2007) .
- Co-culture *Clostridium cellulolyticum* and *Geobacter sulfurreducens*
  - Ferricyanide
  - Power generation from soluble cellulose 143 mW/m^2.
  - Power from non-soluble cellulose (MN301) 59.2 mW/m^2 (Ren et al. 2007).
- Mixed culture
  - Power density from cellulose as substrate in Sediment Enhanced Microbial fuel cell (SEM) varied from 29 ± 12 to 62 ± 23 mW/m^2 (Rezaei et al. 2007).

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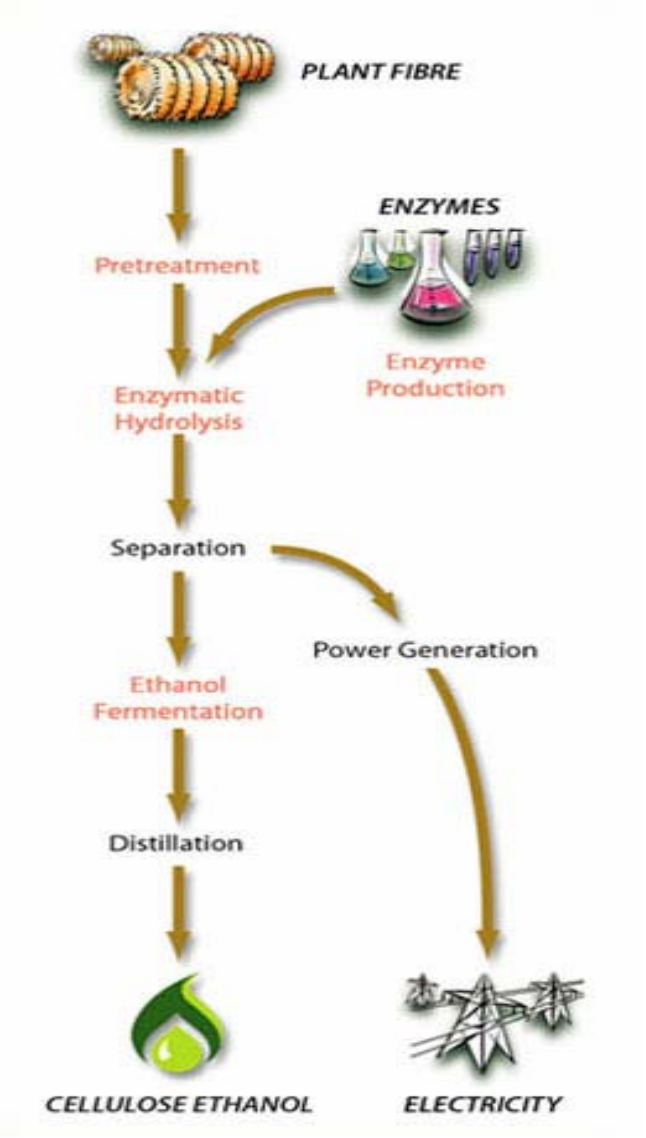
- Problem
  - Limited previous success in using non-soluble cellulose to generate electricity comparable to electricity produced by simple substrates.
- Goals
  - Increase the hydrolysis rate of cellulose degradation
  - Improve the power generation from cellulosic MFCs

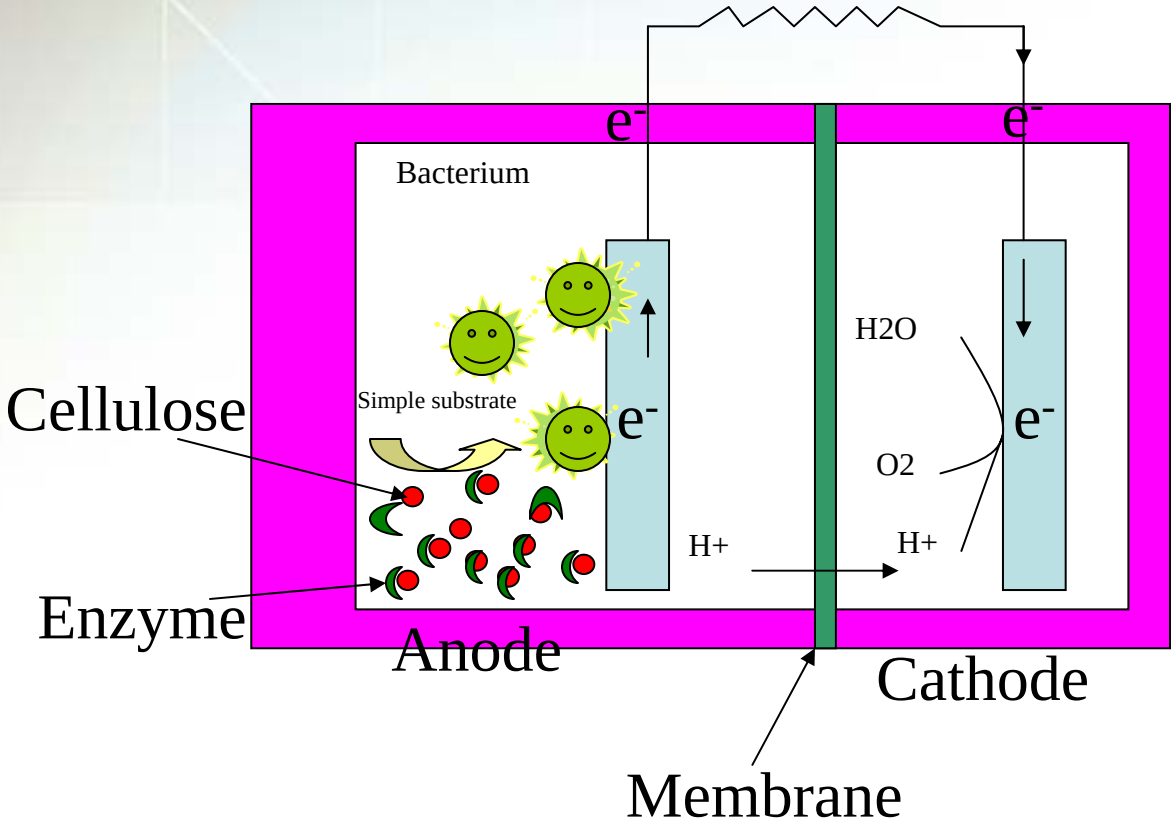
Enzymatic hydrolysis

- Cellulases are the enzymes to hydrolyze cellulose.
- Cellulases are produced from variety of bacteria and fungi.
- Cellulases are used to achieve rapid conversion of cellulose to sugar for ethanol production.
- Cellulases has not been previously examined inside MFC.



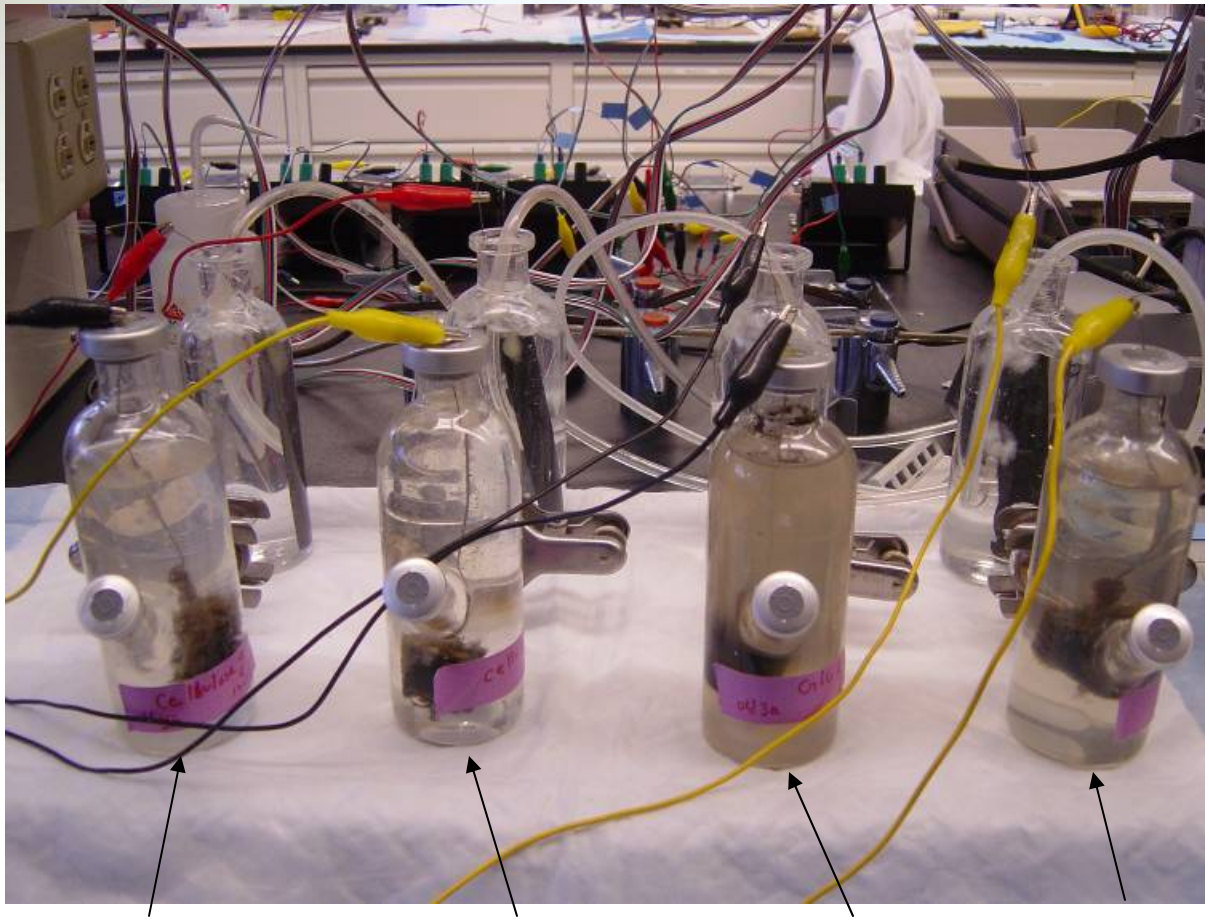
http://www.iogen.ca/cellulose_ethanol/what_is_ethanol/process.html

Hypothesis



Added cellulase enzyme will increase the average power generation from cellulosic MFC.

MFC Reactors



Cellulose **Cellulose + Enzyme** **Glucose** **Enzyme**

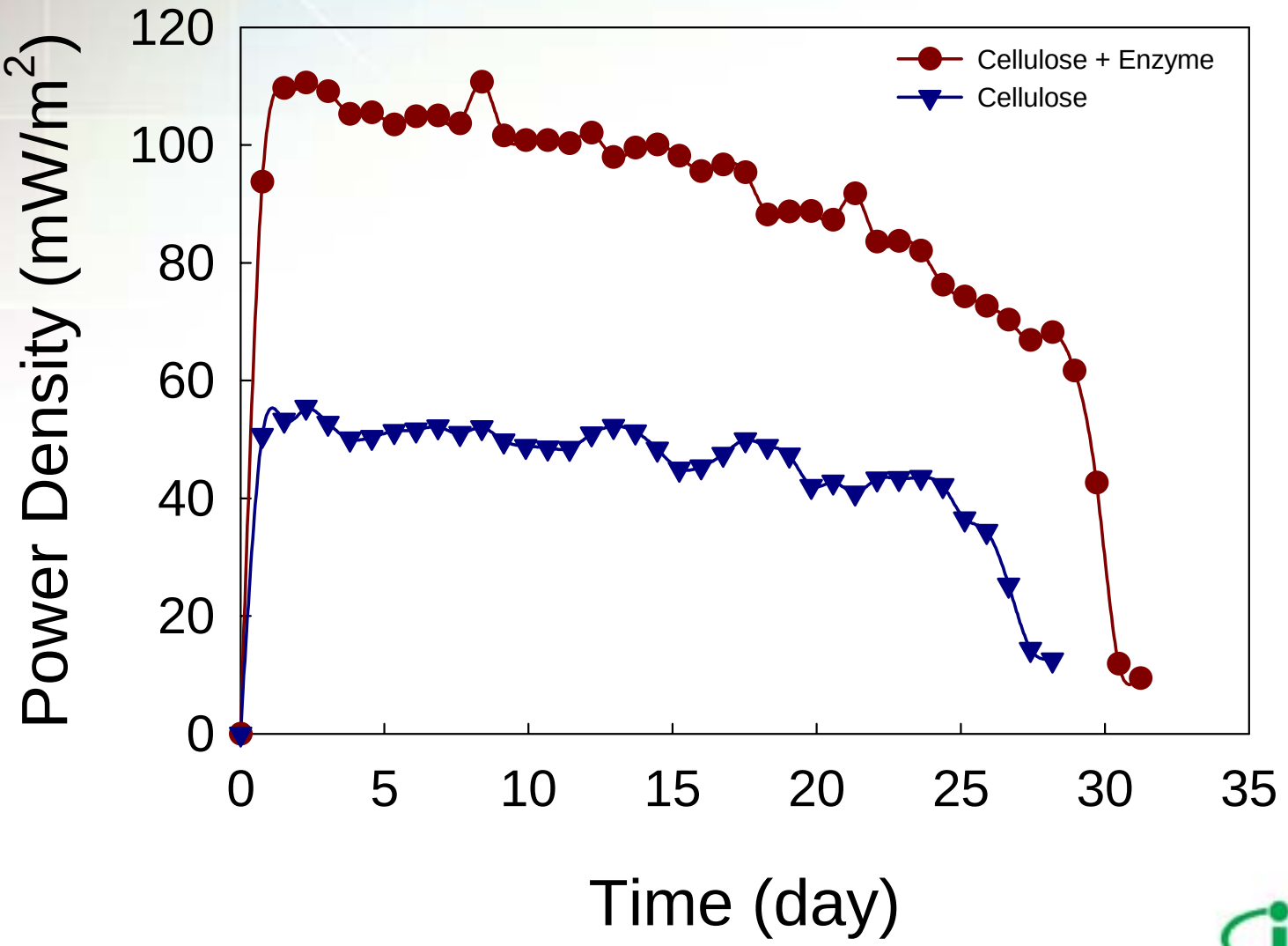
Abiotic cellulose hydrolysis

- Autoclaved GM media containing 1 g/L cellulose.
- Filter-sterile enzyme (same ratio).
- Collect sample aseptically.

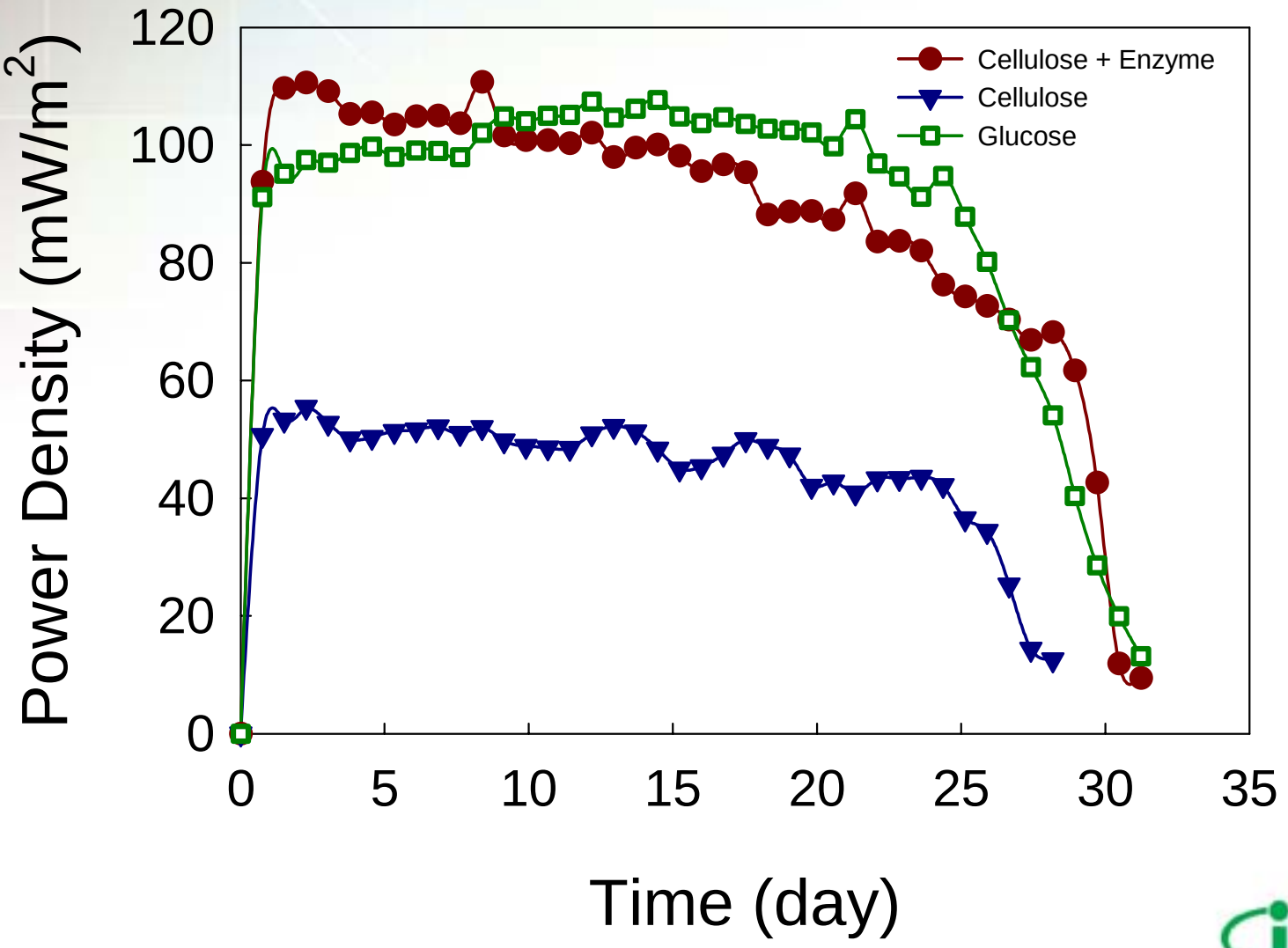
Results

Results

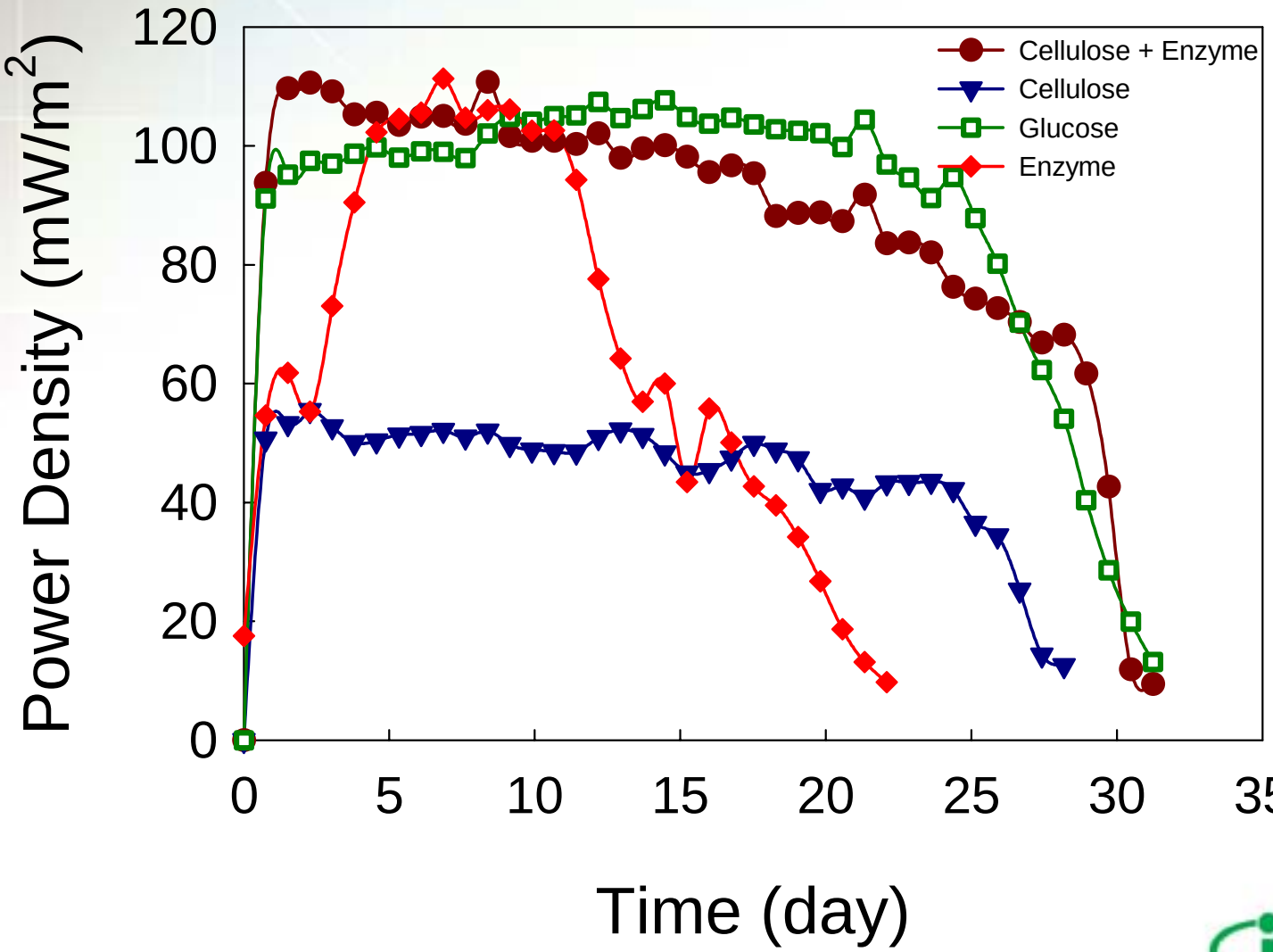
Adding enzyme increases power



Results


Power Density (mW/m^2)
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
Time (day)
Cellulose + Enzyme
Cellulose
Glucose

Results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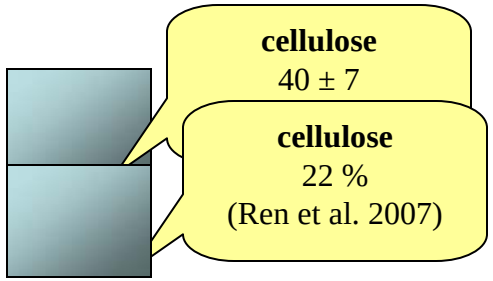
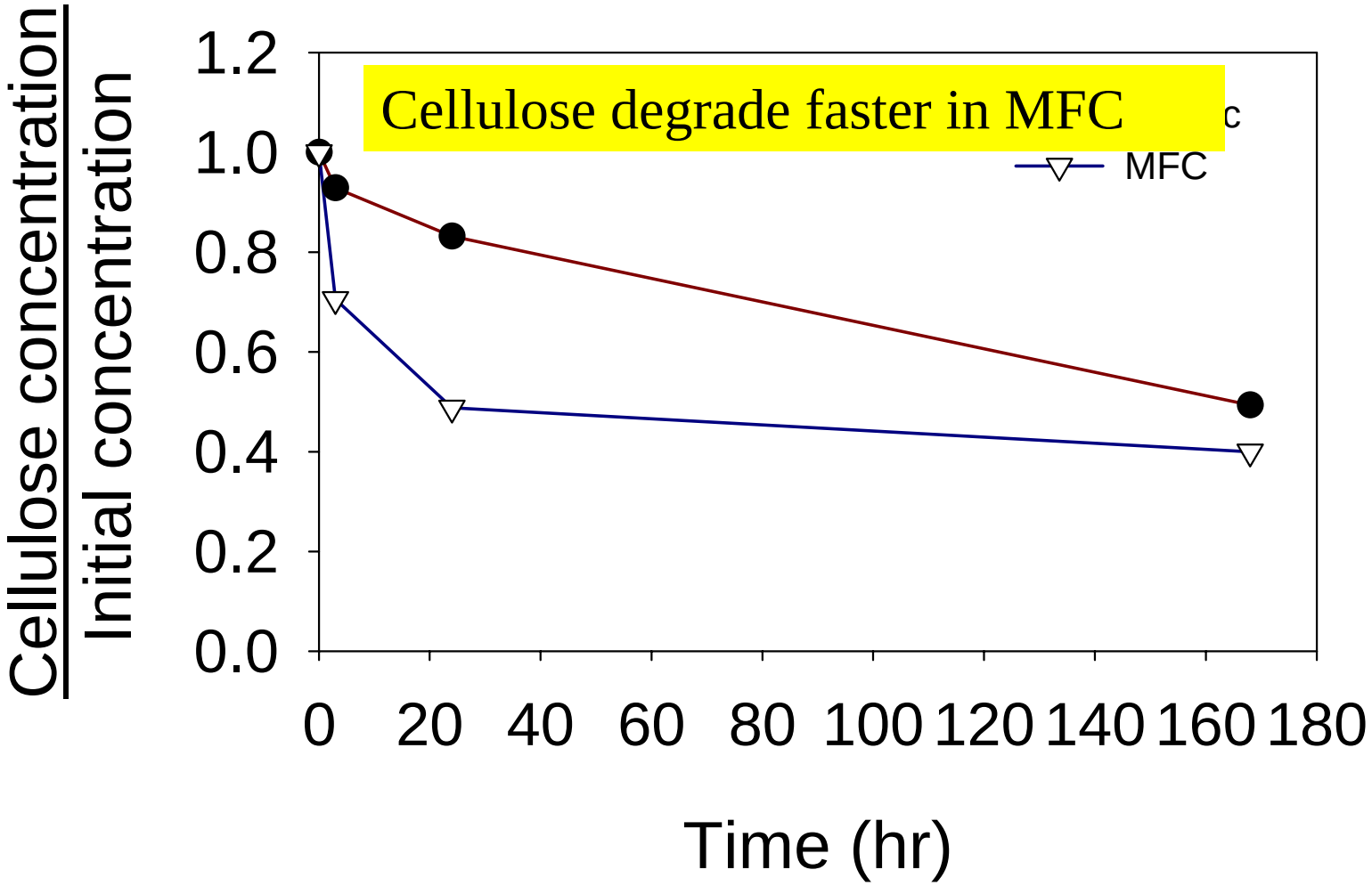
Time (day)
Cellulose + Enzyme
Cellulose
Glucose
Enzyme

Substrate removal and Coulombic efficiency

Parameters (%)	*Cellulose + Enzyme*	*Enzyme*	*Glucose*
Cellulose consumption			N/A
Coulombic efficiency			48
Enzyme consumption	56	64	N/A
Enzyme Activity Lost	34	74	N/A

Cellulose degradation with and without microbes



Conclusions

- Adding enzyme improves the power generation in an MFC fed cellulosic feedstocks.
- Cellulose combined with enzymes produced electricity at up to 80% of the maximum power generation of reactors fed glucose as substrate.
- Adding enzyme improved coulombic efficiency, power generation, and cellulose degradation as compare to the reported data on reactor fed with cellulose alone.

Future studies

- Try to isolate cellulolytic bacteria from different mixed culture
- Improve the power generation from cellulosic MFC using more efficient microorganisms.

Acknowledgement

- Department of Ag and Biological Engineering
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- All members of Dr. Logan and Richard's lab
- Dr. John Regan and Zhiyong Ren!
- Dr. Megan Marshal (From ABE)

Questions??

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Materials

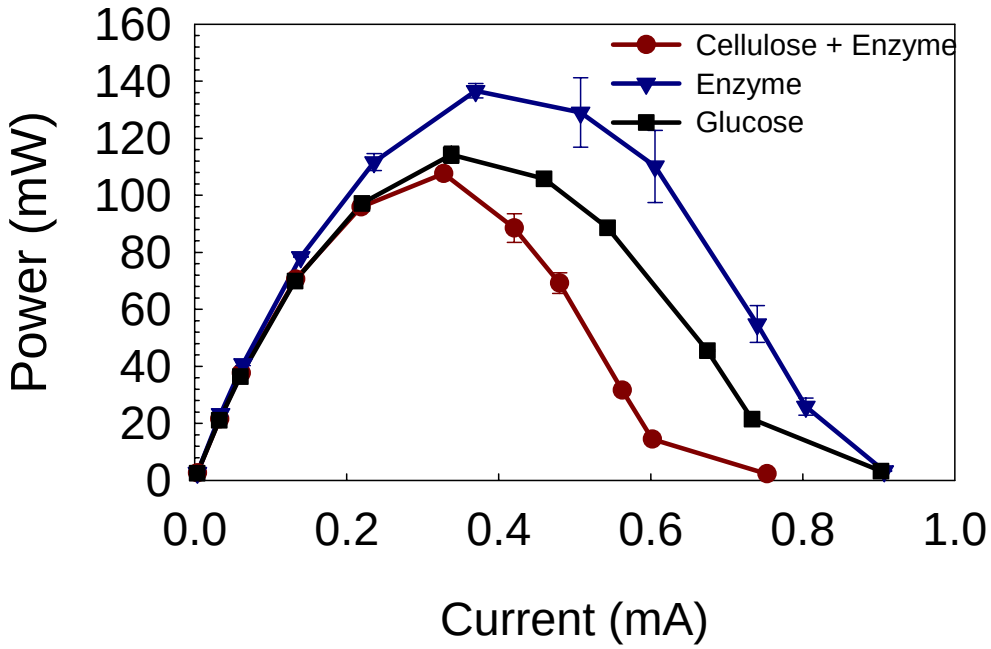
- ***Cellulose and Cellulase:***
  Sigmacell® Cellulose
  30 CBU *Novozyme 188*: 15 FPU *Celloclast* 1.5 per gram of cellulose.

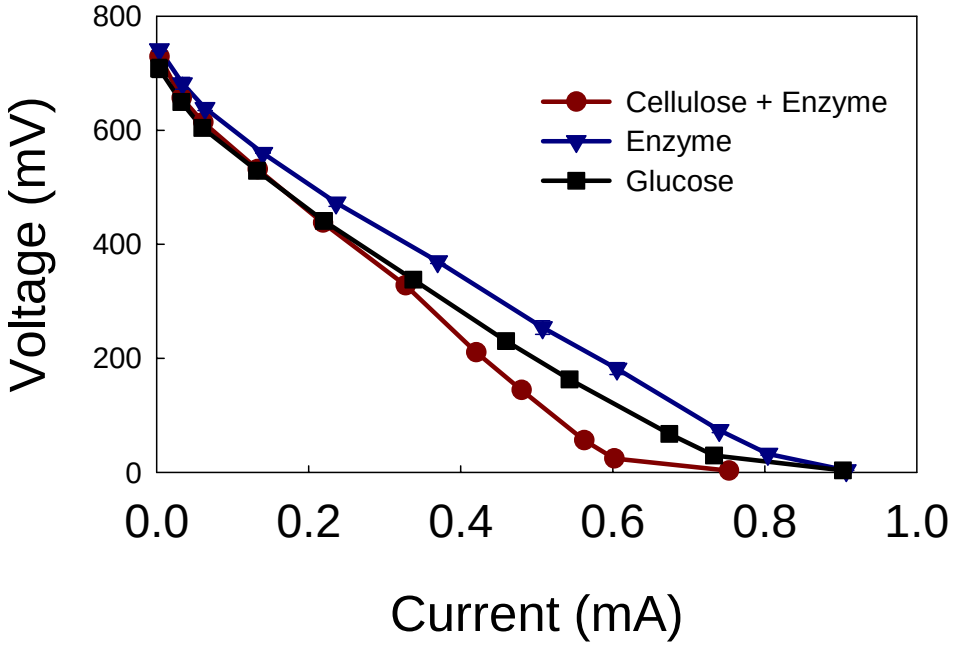
- ***Media:***
  GM media (phosphate buffer + Mineral + vitamin)

- ***Microorganisms:***
  Mixed culture (Sludge from secondary clarifier)

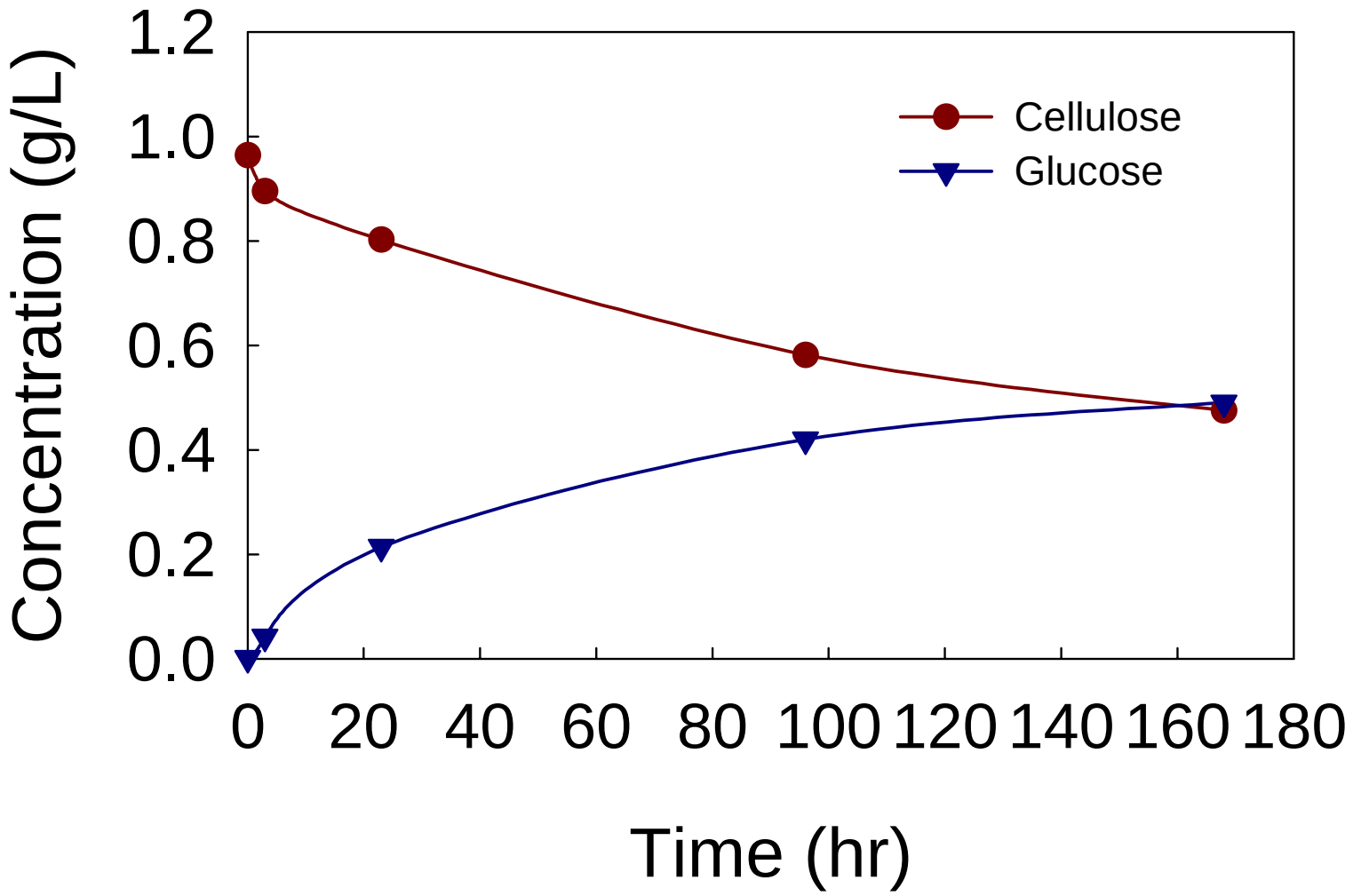
Results

Maximum power generation

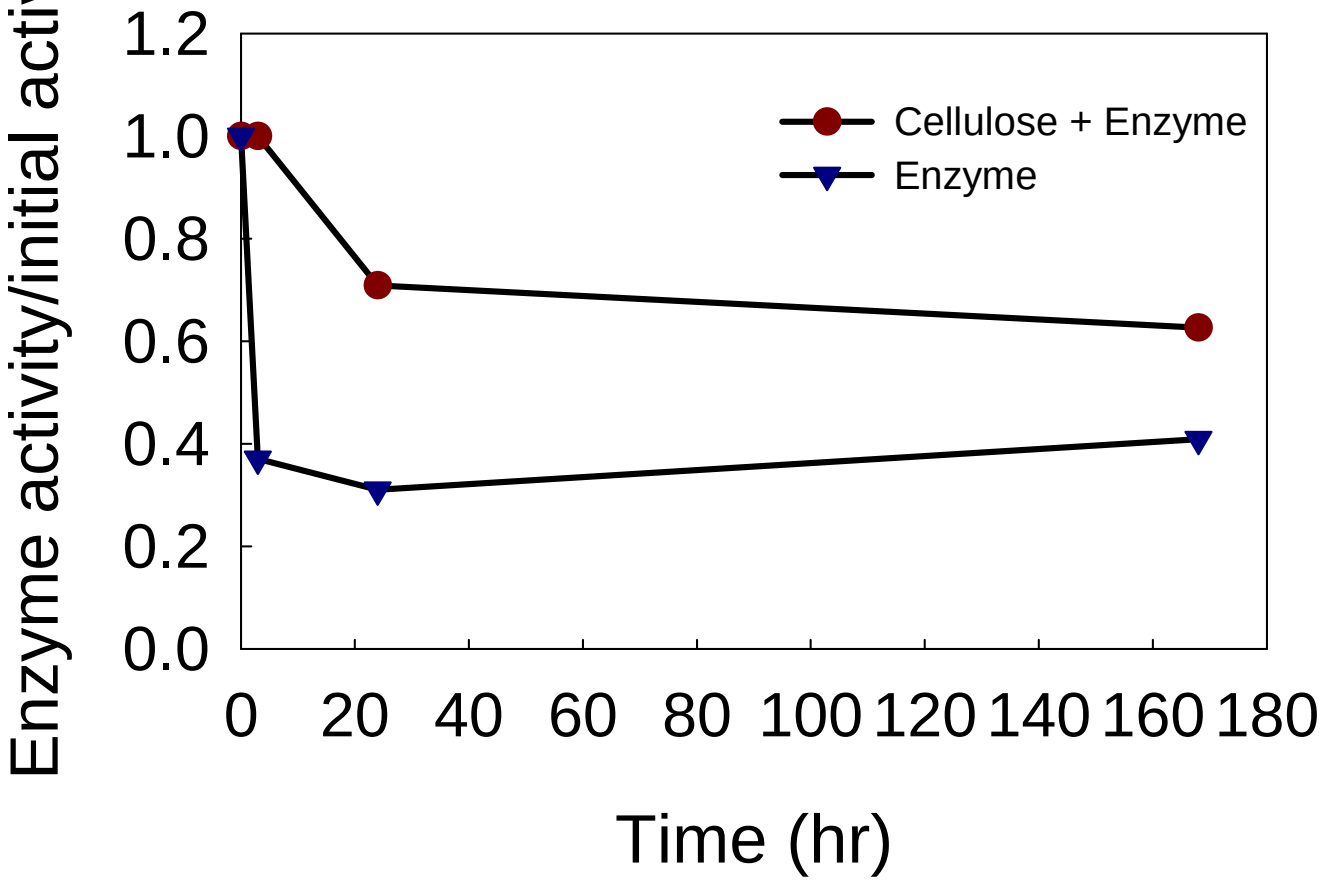


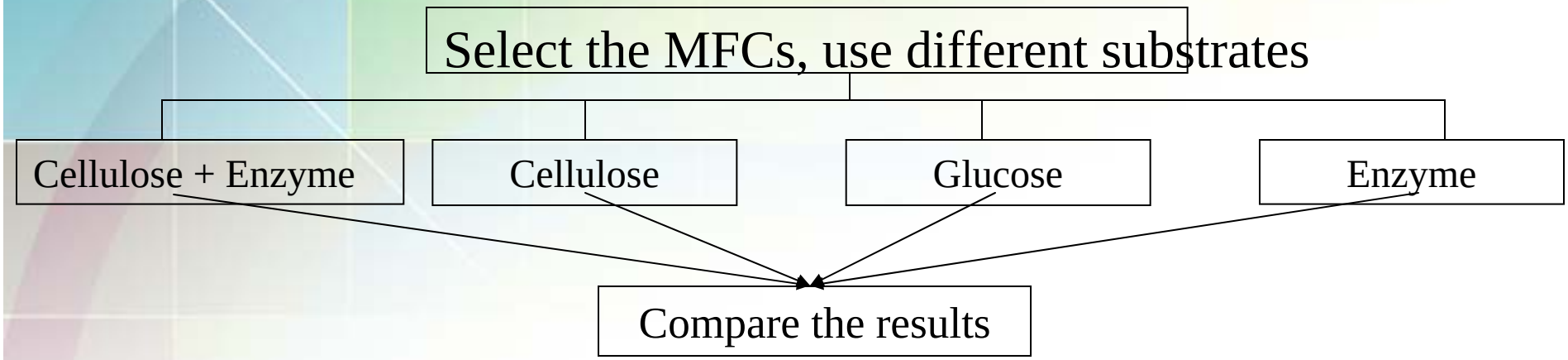


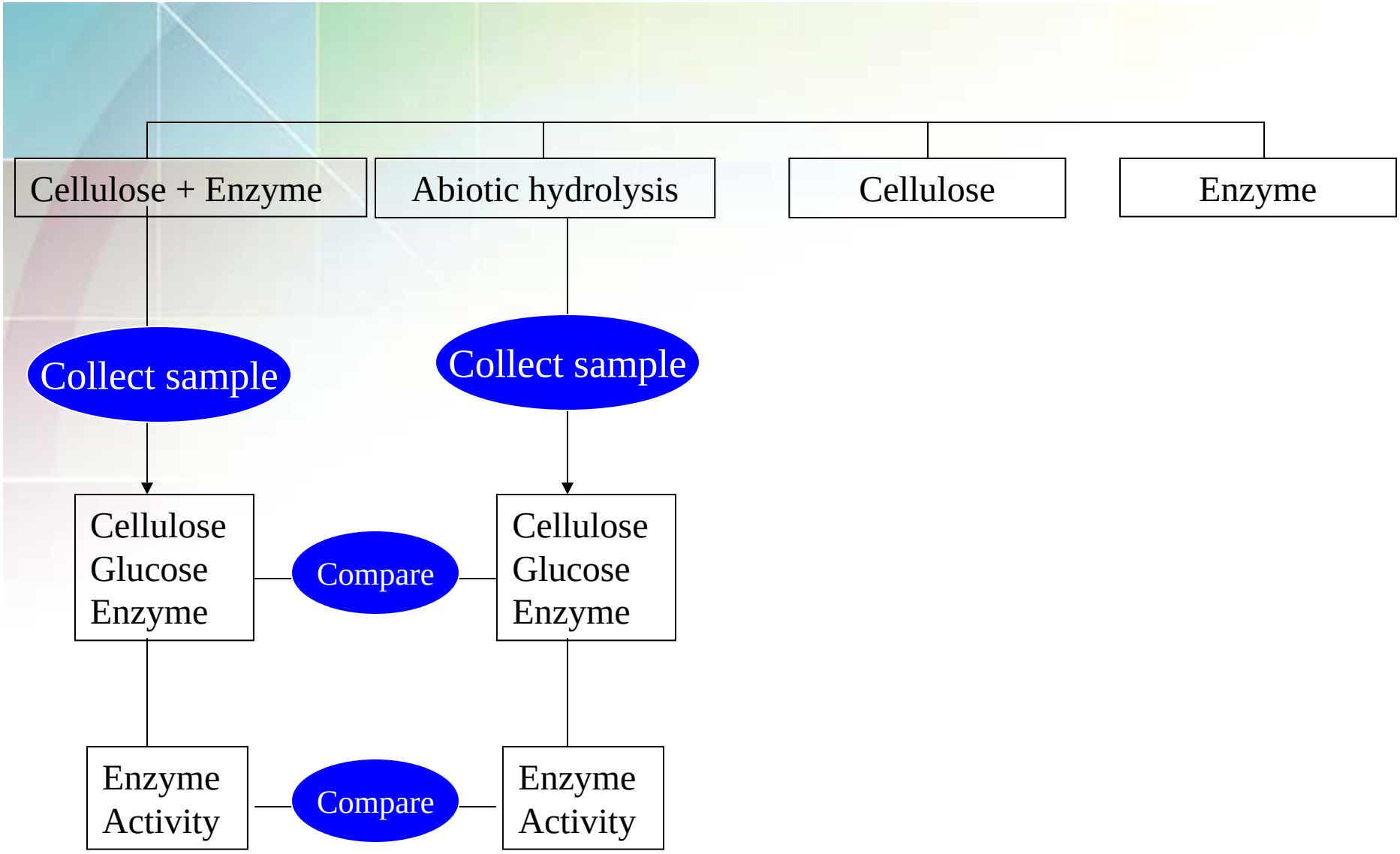
Abiotic cellulose hydrolysis

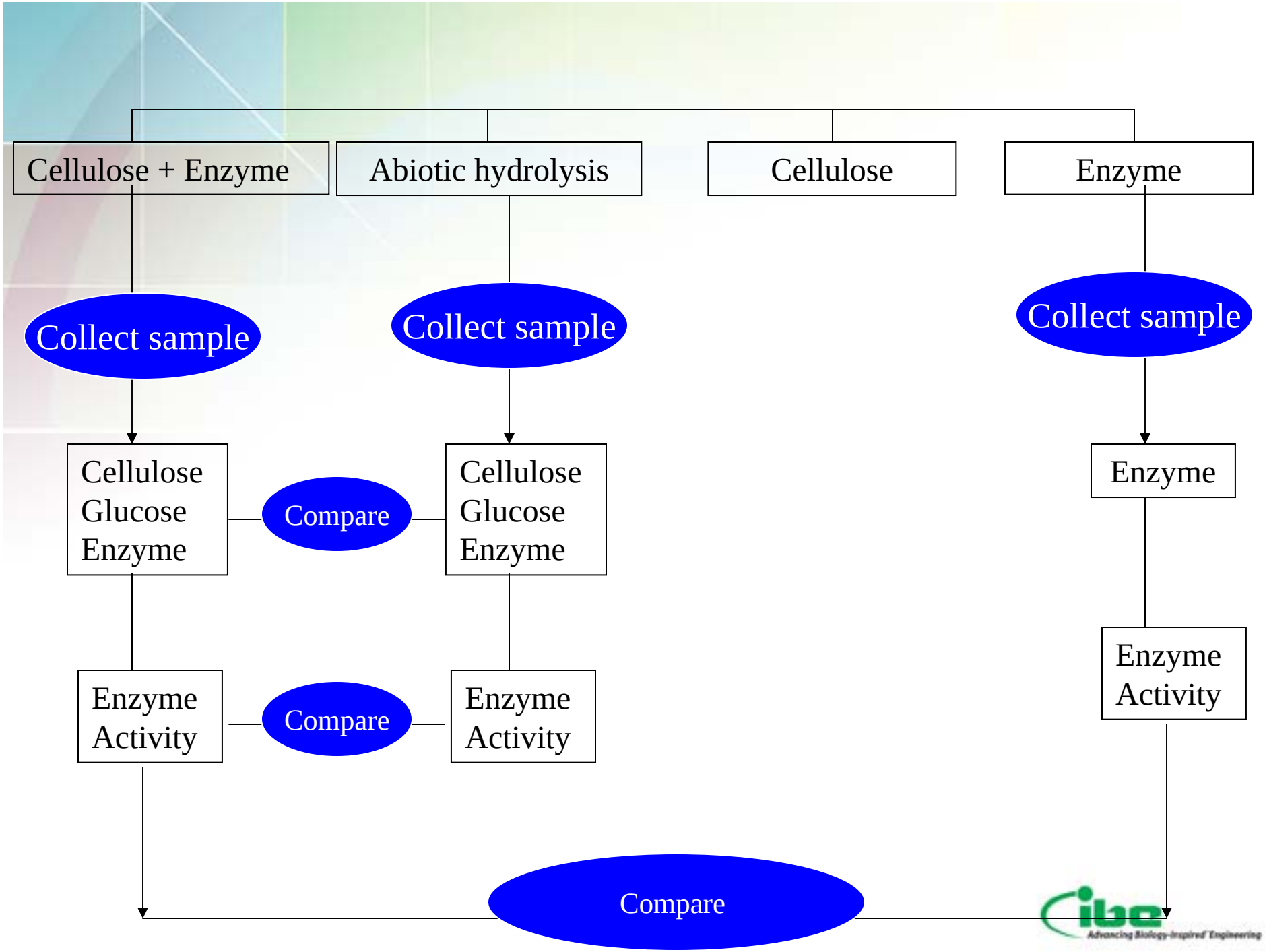


Enzyme activity




Select the MFCs, use different substrates
Cellulose + Enzyme
Cellulose
Glucose
Enzyme
Compare the results


Cellulose + Enzyme
Abiotic hydrolysis
Cellulose
Enzyme
Collect sample
Collect sample
Cellulose
Glucose
Enzyme
Compare
Cellulose
Glucose
Enzyme
Enzyme
Activity
Compare
Enzyme
Activity


Cellulose + Enzyme
Abiotic hydrolysis
Cellulose
Enzyme
Collect sample
Collect sample
Collect sample
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Glucose
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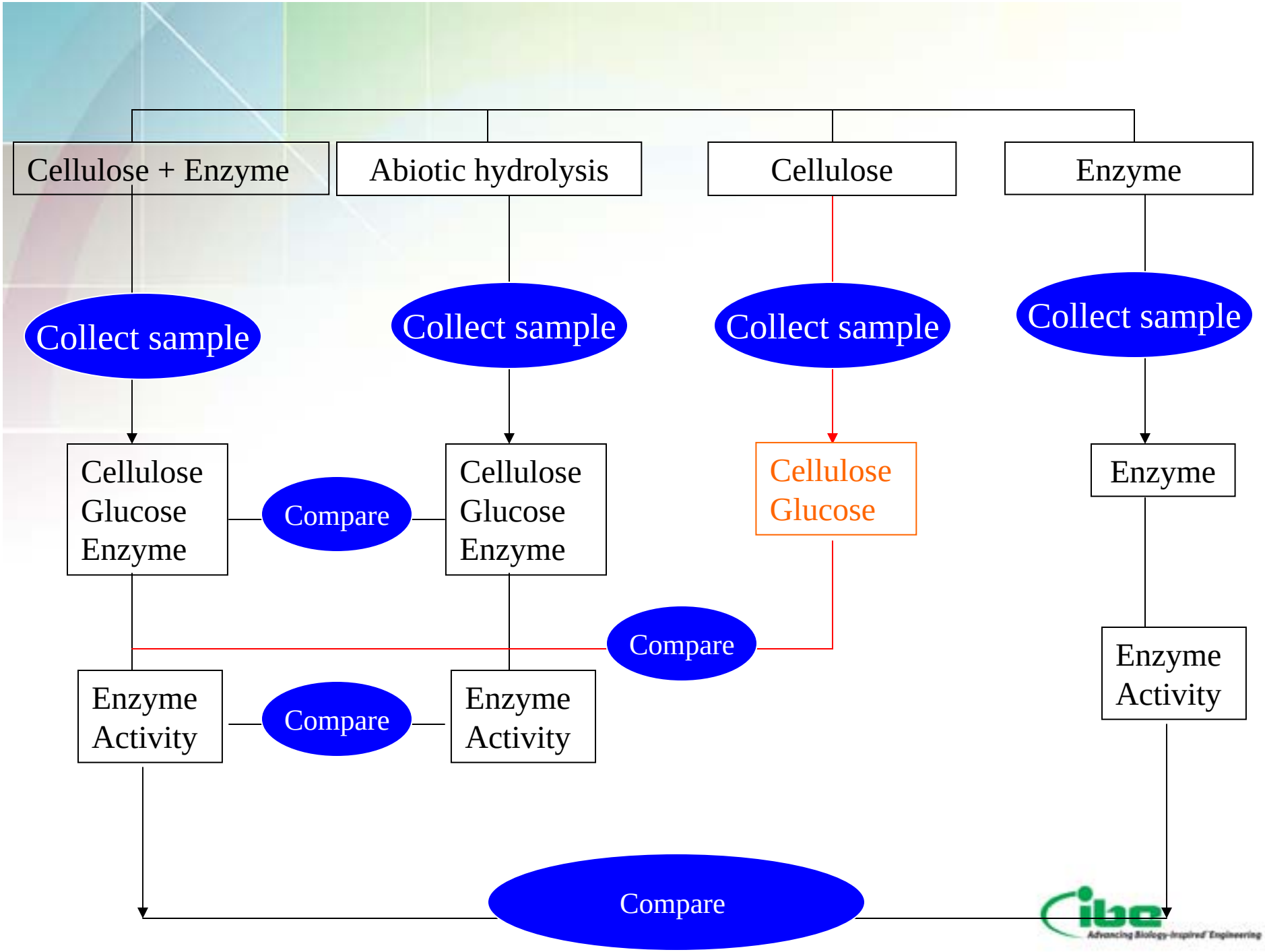
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