September 2008

A novel biocatalyst for Cellulosic Ethanol Production

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First Annual TIMBR Conference on Cellulosic Biofuels

University of Massachusetts Amherst ~ September 19, 2008

A novel biocatalyst for cellulosic ethanol production

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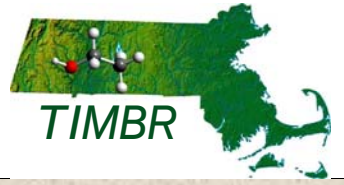

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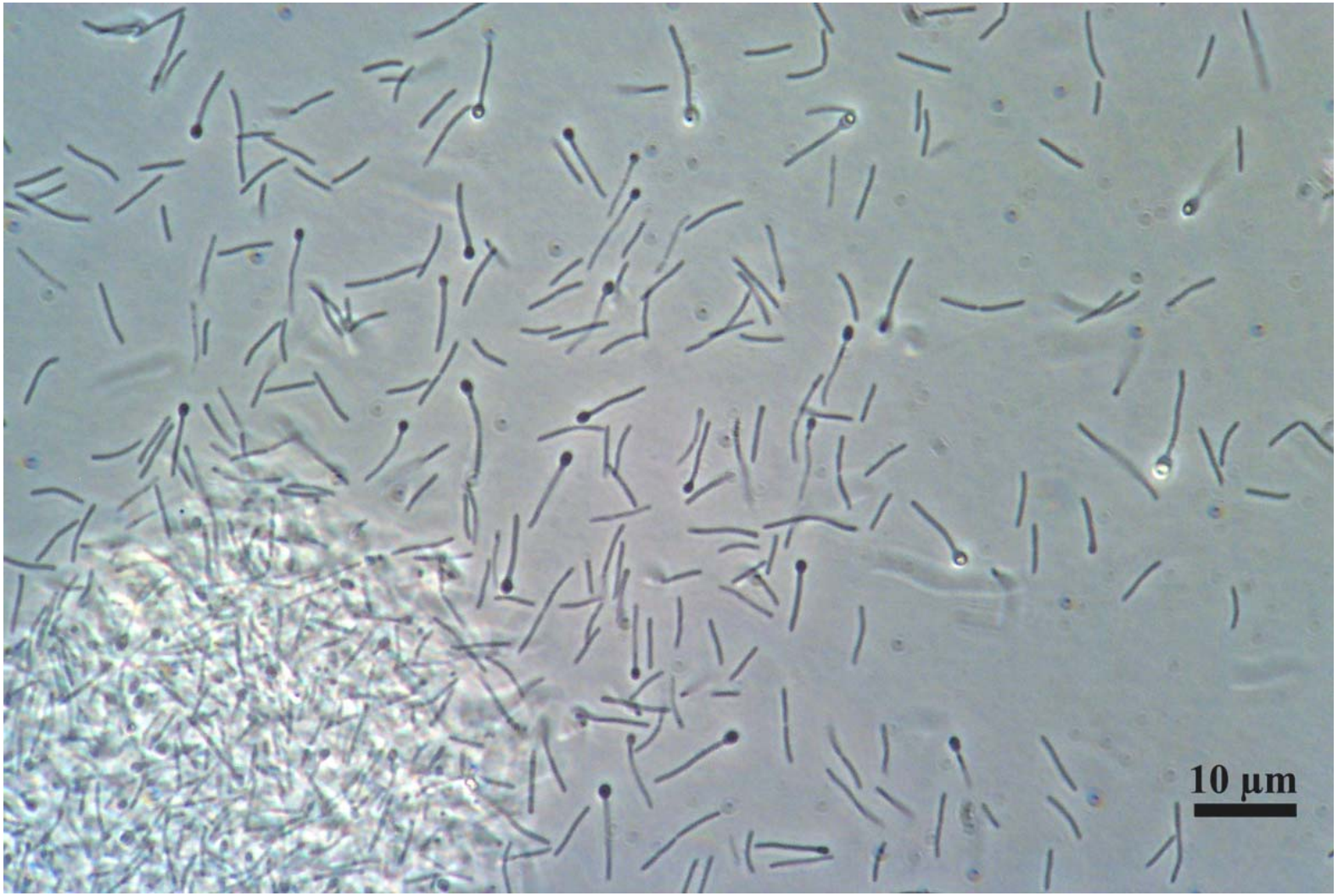
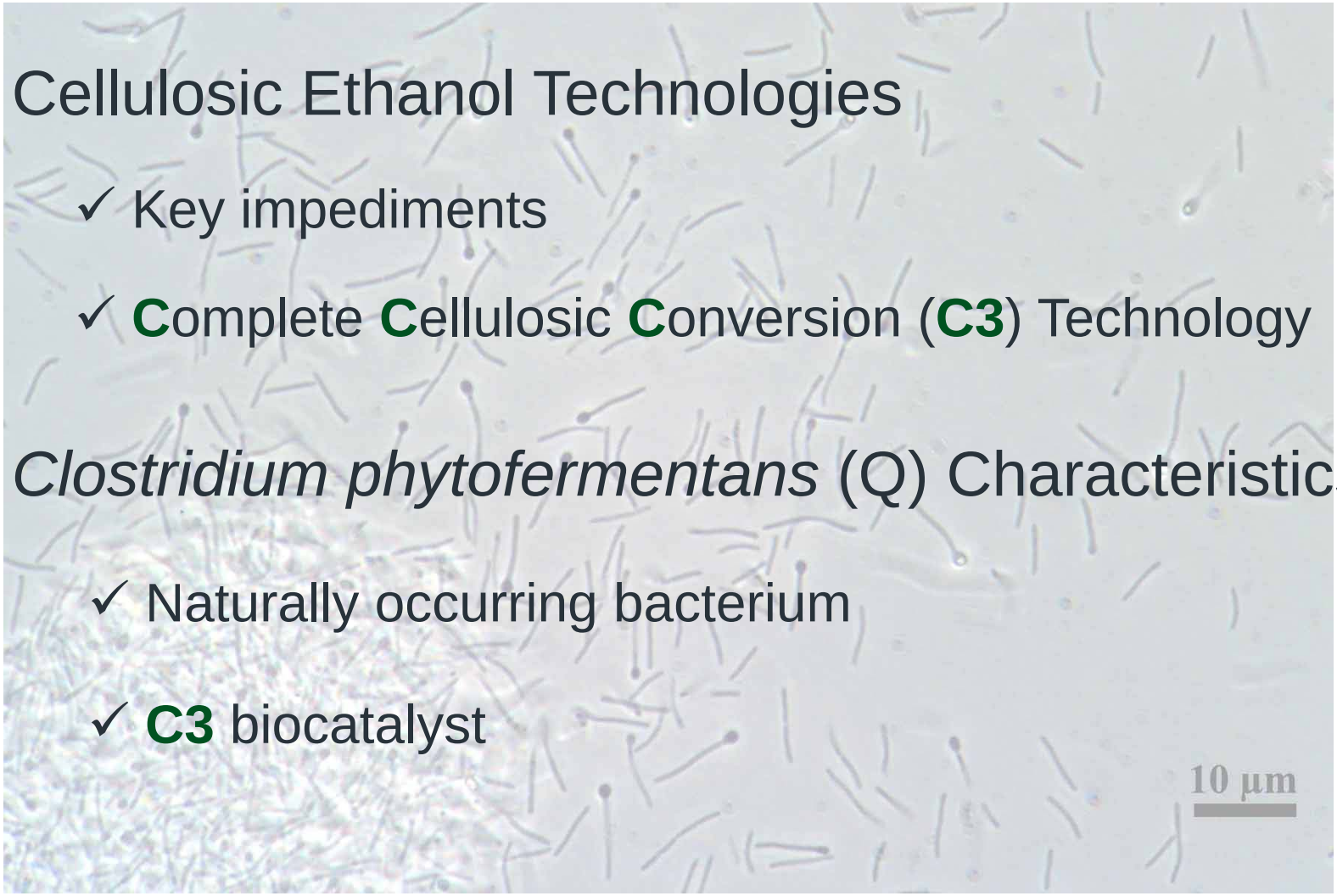


Clostridium phytofermentans ~ Q Microbe™

A novel biocatalyst for cellulosic ethanol production

- Cellulosic Ethanol Technologies
  - ✓ Key impediments
  - ✓ **C**omplete **C**ellulosic **C**onversion (**C3**) Technology
- *Clostridium phytofermentans* (Q) Characteristics
  - ✓ Naturally occurring bacterium
  - ✓ **C3** biocatalyst



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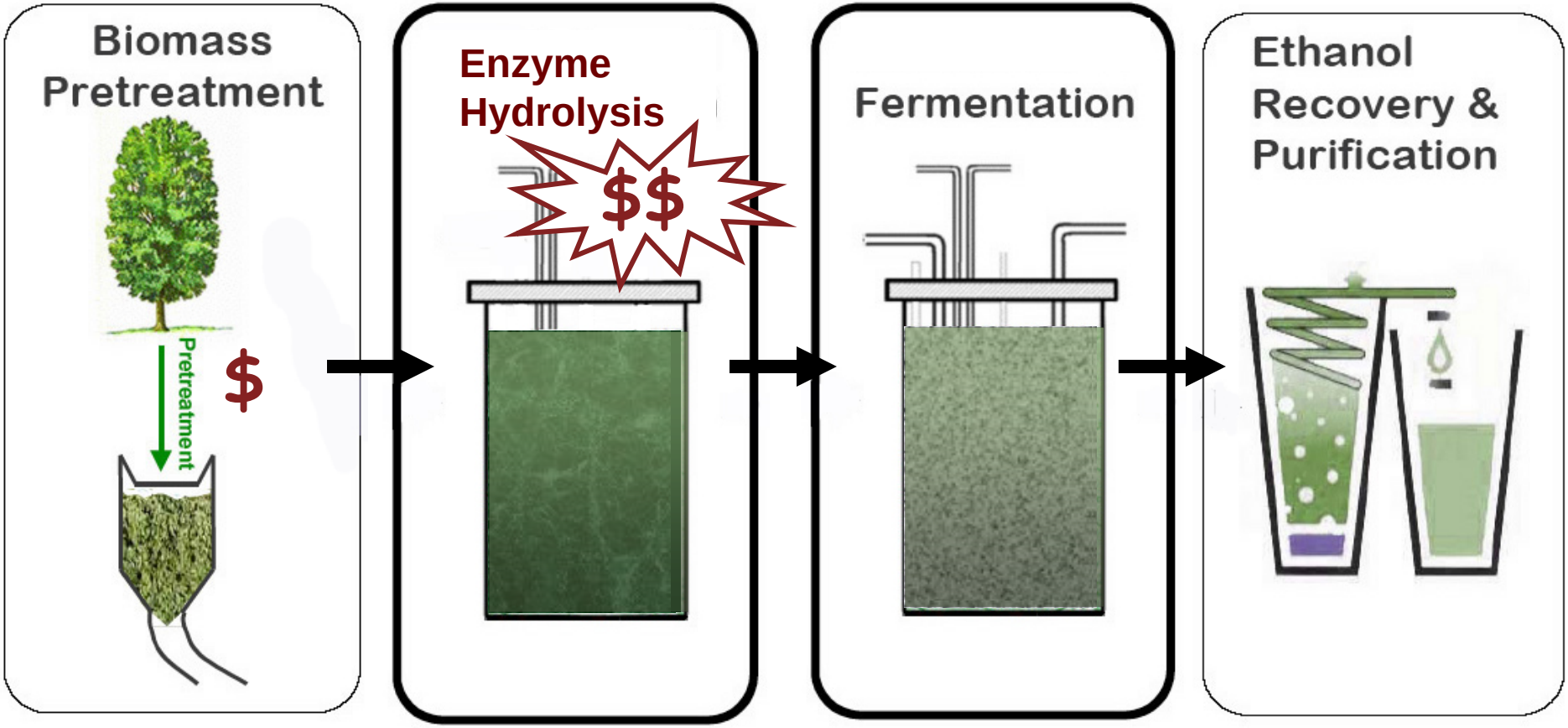
Cellulosic Ethanol

- Fossil fuel combustion has led to global warming.
- As we meet our energy ne
  greenhouse gas emissions.
- The only form of energy that c
  substantially to meeting tra portation fuel needs at costs competitive with fossil fuel is solar energy captured by photosynthesis and stored in biomass.

Key Impediment!

Cellulosic Ethanol Technologies

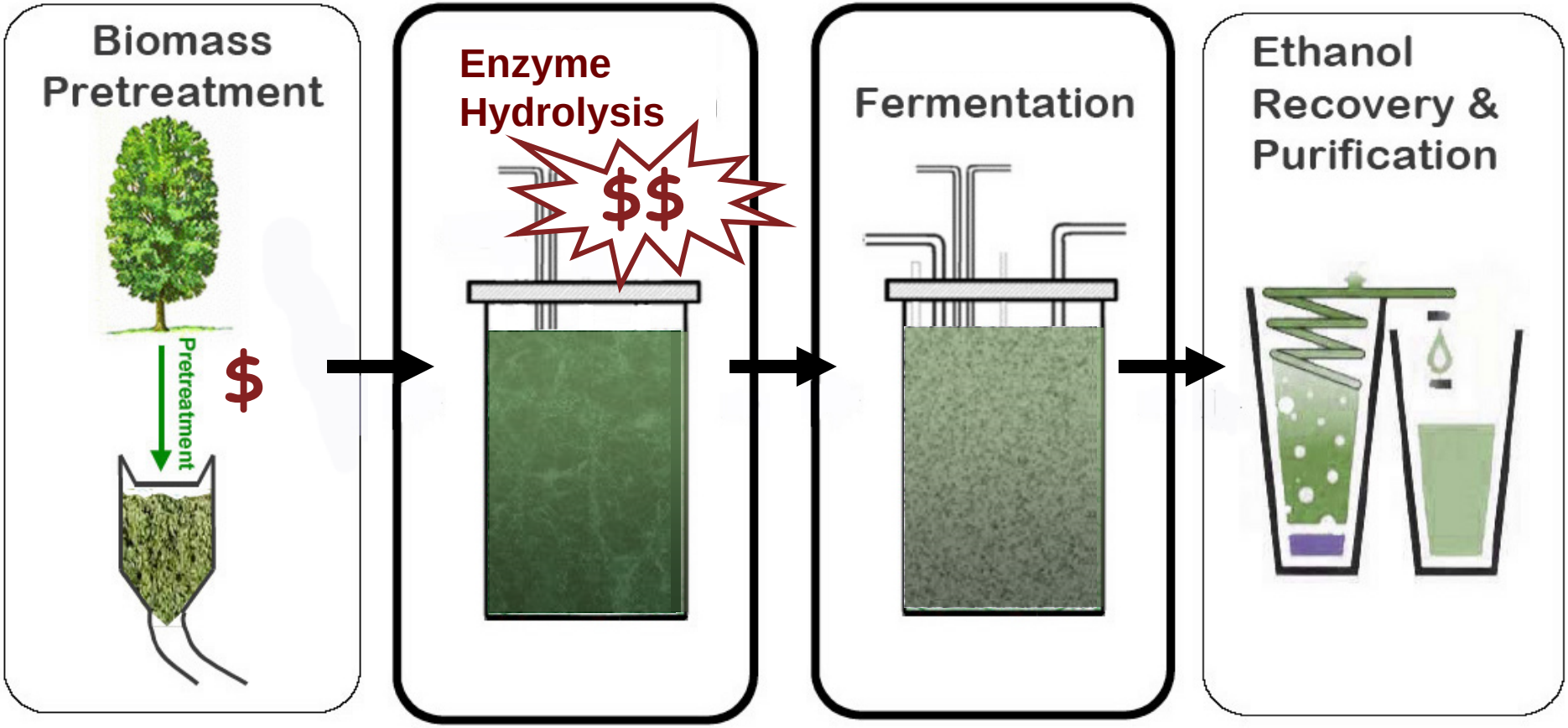
Conventional Technology



Current cellulosic ethanol processes require enzymes $$

Cellulosic Ethanol Technologies

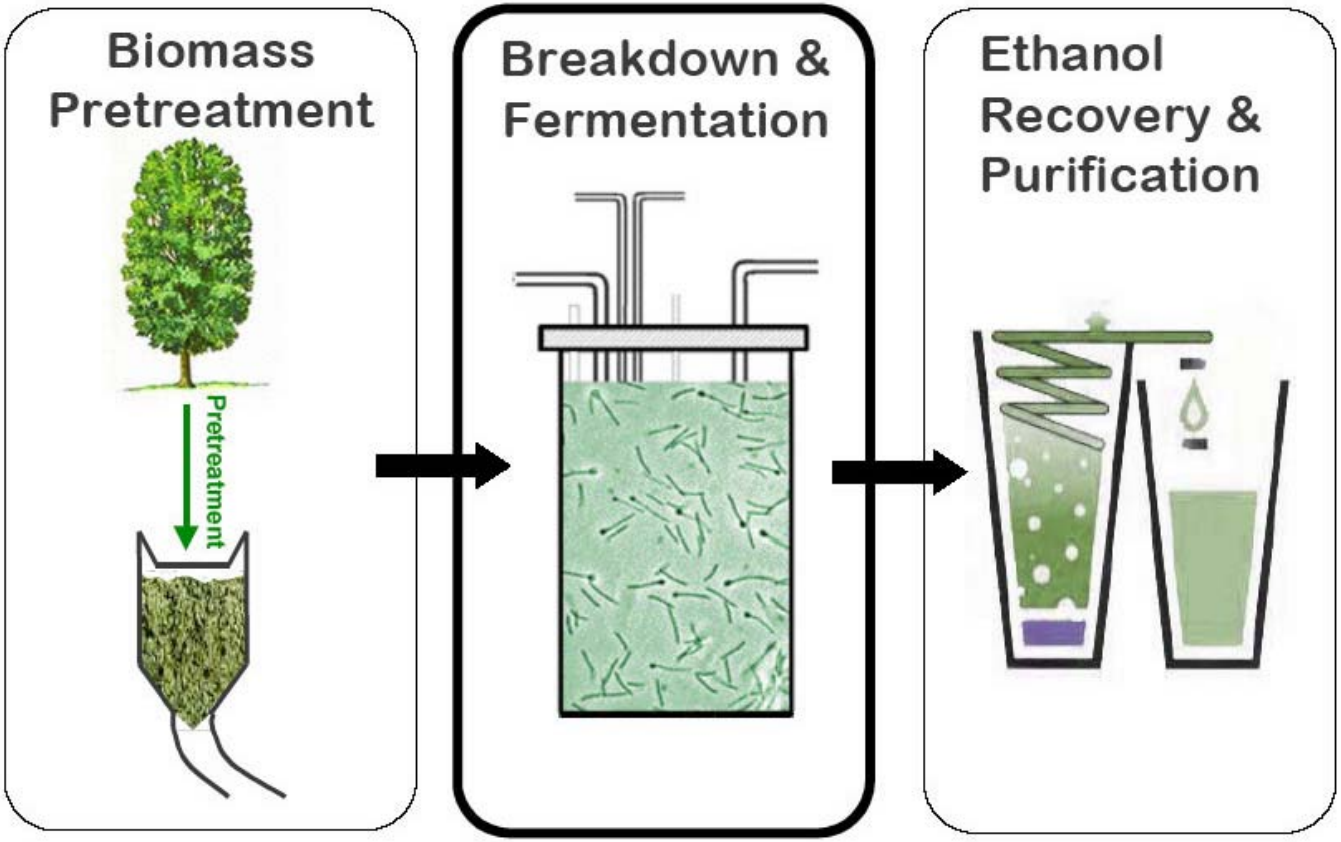
Q Microbe – C3 Technology



Enzyme production, cellulose breakdown, fermentation are consolidated in a single step in a bioreactor

Cellulosic Ethanol Technologies

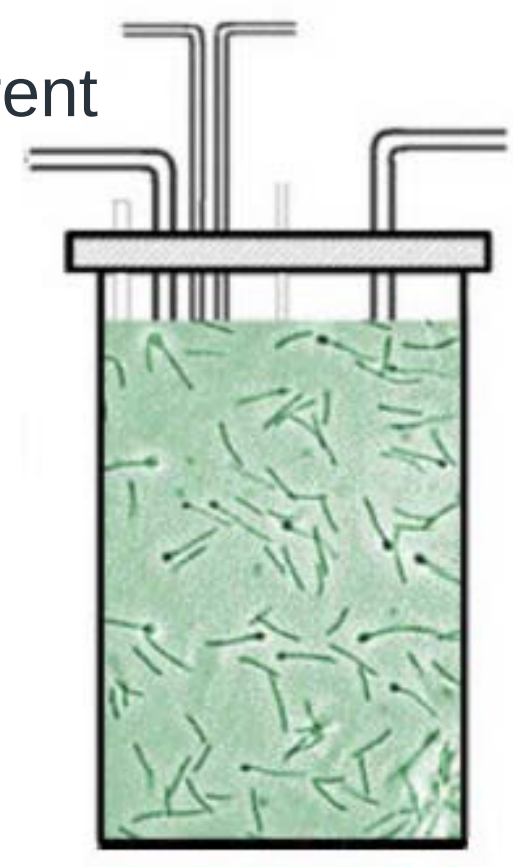
Q Microbe – C3 Technology



DOE Biofuels Roadmap: "*The ultimate low-cost configuration*" for cellulosic ethanol production.

Properties of a C3 Microbe

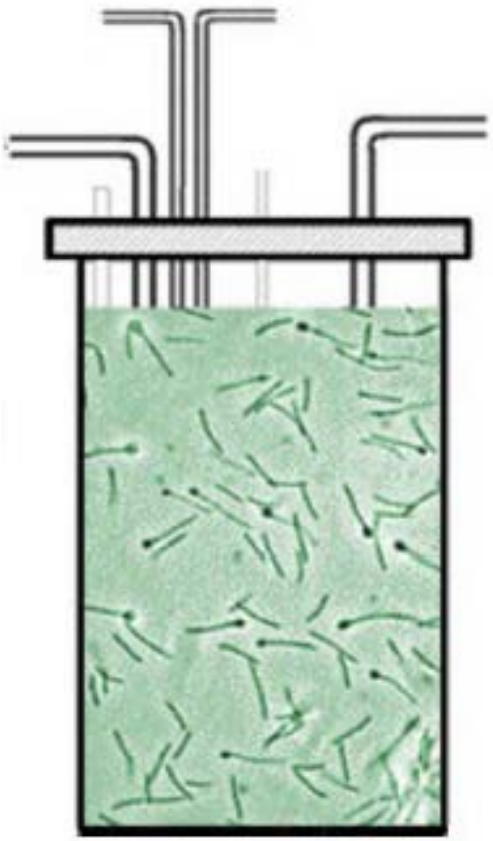
- ✓ simultaneously ferment multiple different components of biomass
- ✓ ferment high concentrations of biomass
- ✓ produce ethanol as primary product of fermentation
- ✓ exhibit ethanol tolerance



Q fits the bill!

SunEthanol, Inc.

- ✓ biofuels technology company
- ✓ headquartered in Amherst, MA
- ✓ commercializing the ***Q-Microbe™- C3*** technology for cellulosic ethanol production



Q fits the bill!

Q Microbe is a novel, naturally occurring C3 microbe

- Isolated from forest soil near Quabbin Reservoir
- Part of a study:
  Diversity of anaerobic cellulose-decomposing microbes
- Role in the global carbon cycle

Tom Warnick

Cellulose-fermenting microbes are at the base of the anaerobic food chain

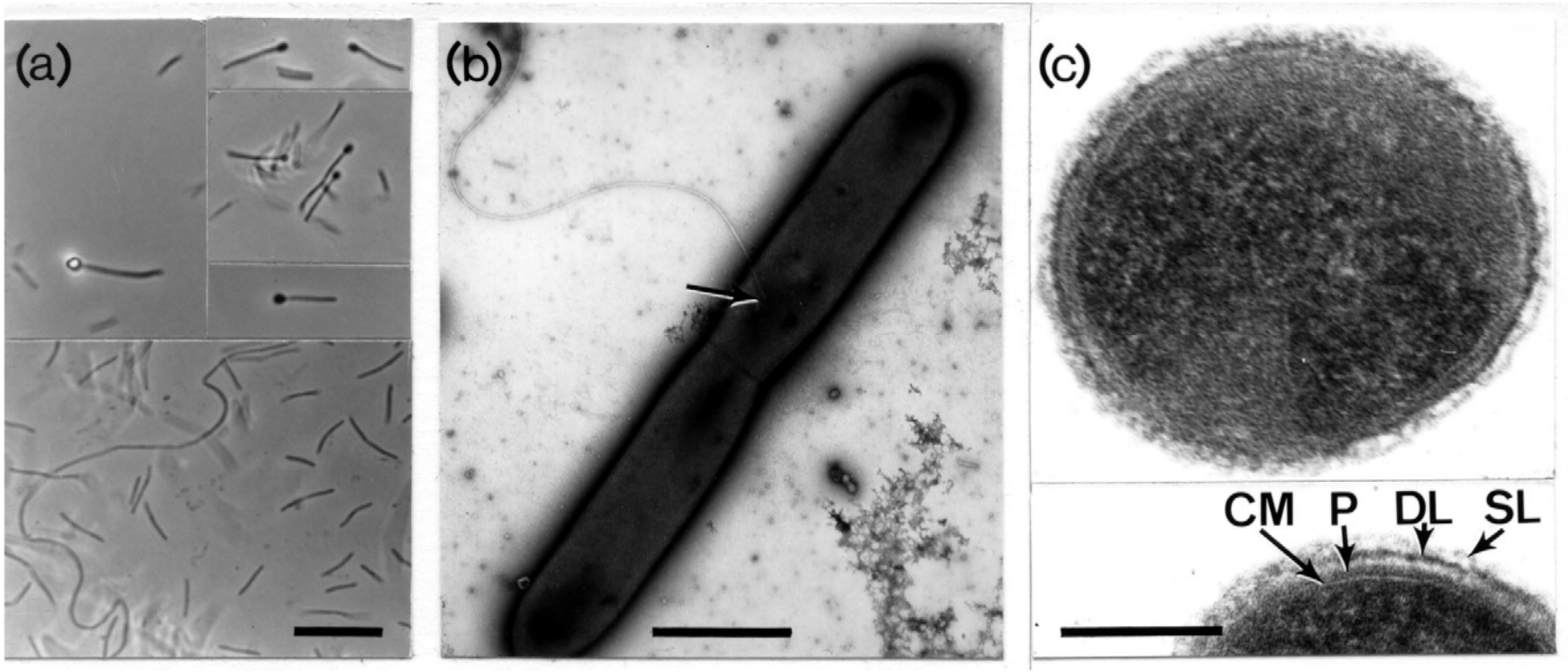
Cedar Swamp, Woods Hole

Diversity of cellulose-fermenting bacteria from soils and sediments

Most Isolates:

- morphologically & physiologically similar
- closely related, members of “Cluster III” of clostridia

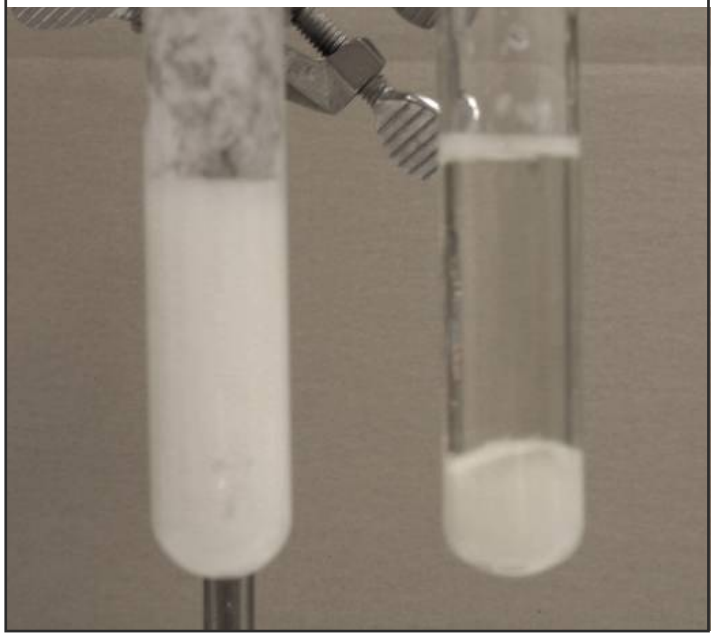
Q is a novel microbe “Cluster XIVa”



Uncommon properties of Q make C3 technology possible

- Directly converts all fermentable components of biomass (cellulose, xylan, pectin, & starch) to ethanol at >90% theoretical efficiency
- Ethanol is its primary product
- Ferments broad range of feedstocks - e.g., paper sludge, corn stover, grass clippings - *very versatile!*
- Efficiently decomposes plant cell walls

Q digests paper

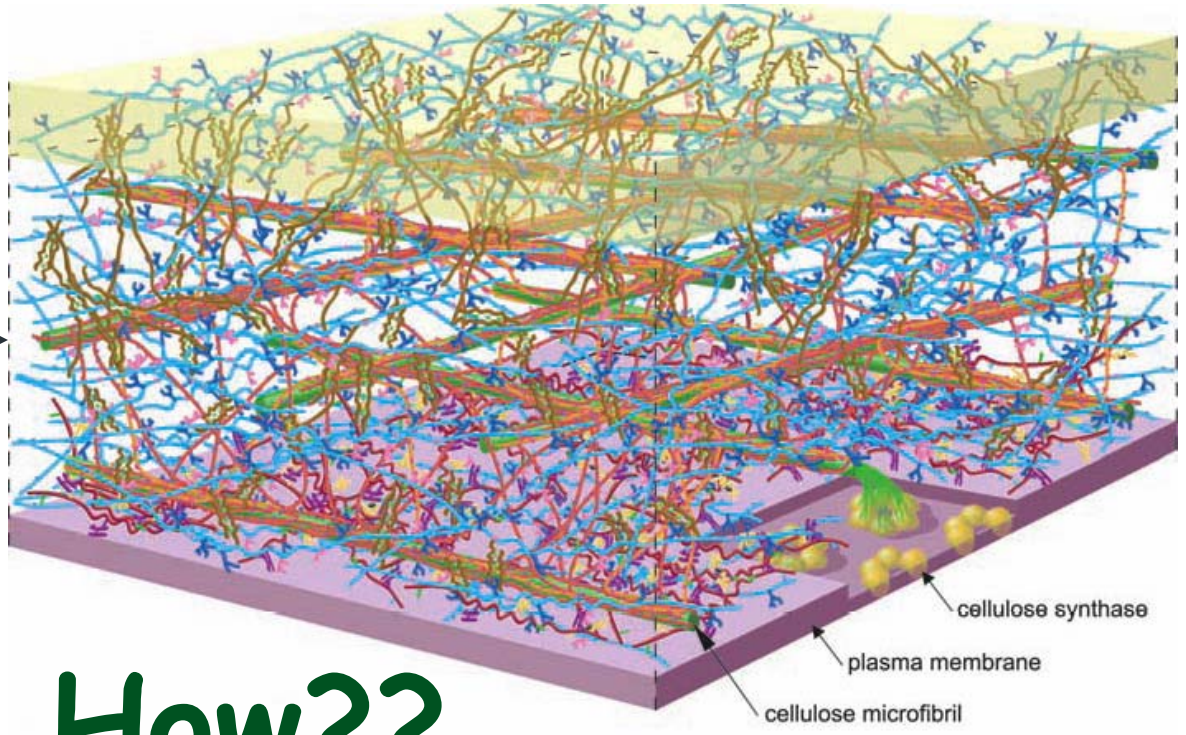


How??

Plant Cell Walls are Tough & Complex!

- Composed mostly of high molecular weight polysaccharides
- Cellulose is the primary structural component
- Provides strength and a barrier to infection by pathogens

Model of the polysaccharides in a leaf cell



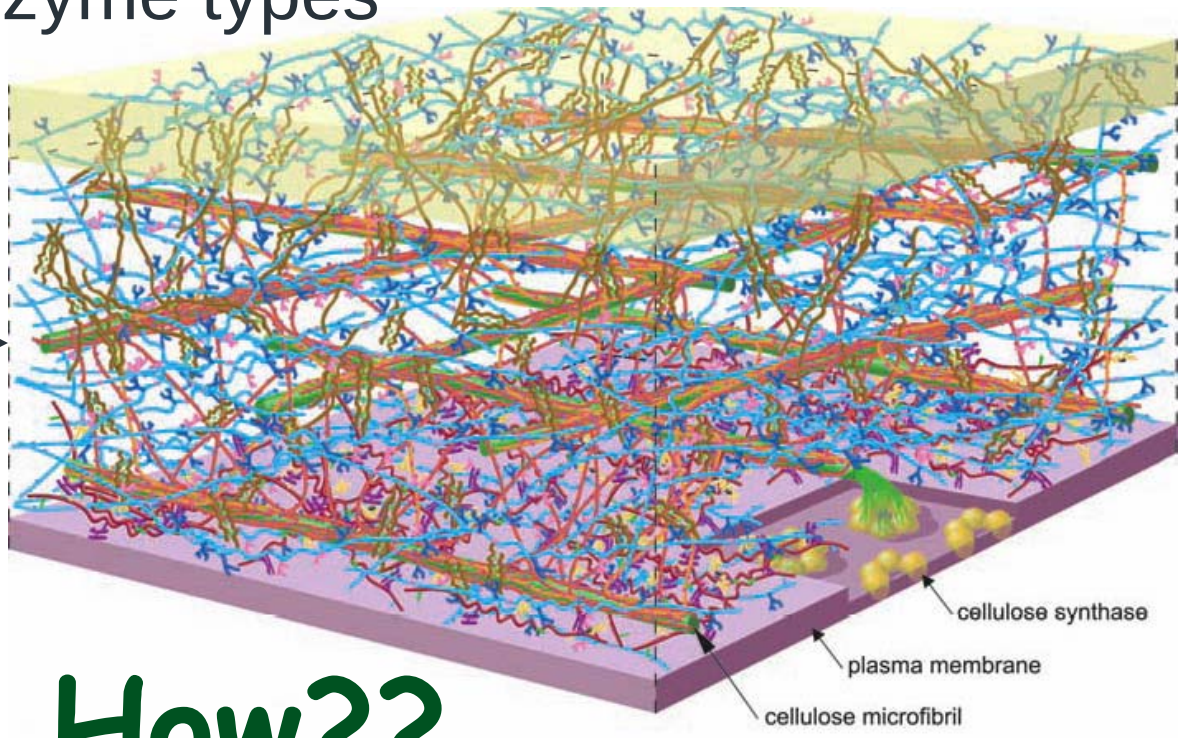
How??

Somerville, 2004

Common Theme for Efficient Degradation of Plant Cell Walls

- Efficient binding of enzymes to substrate
- Synergy between enzymes & microbe
- Multiplicity of enzyme types

Model of the polysaccharides in a leaf cell



How??

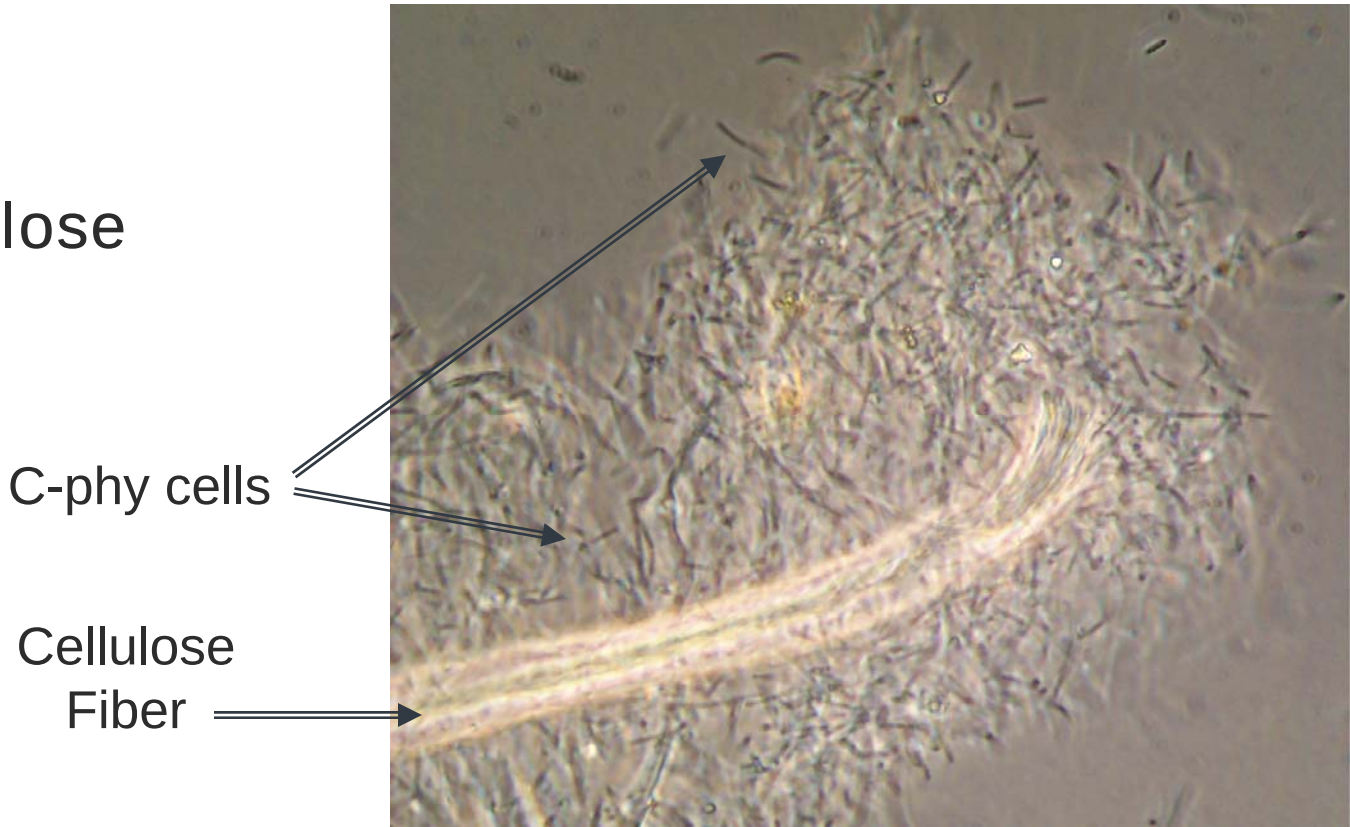
Somerville, 2004

“Enzyme-Microbe Synergy”

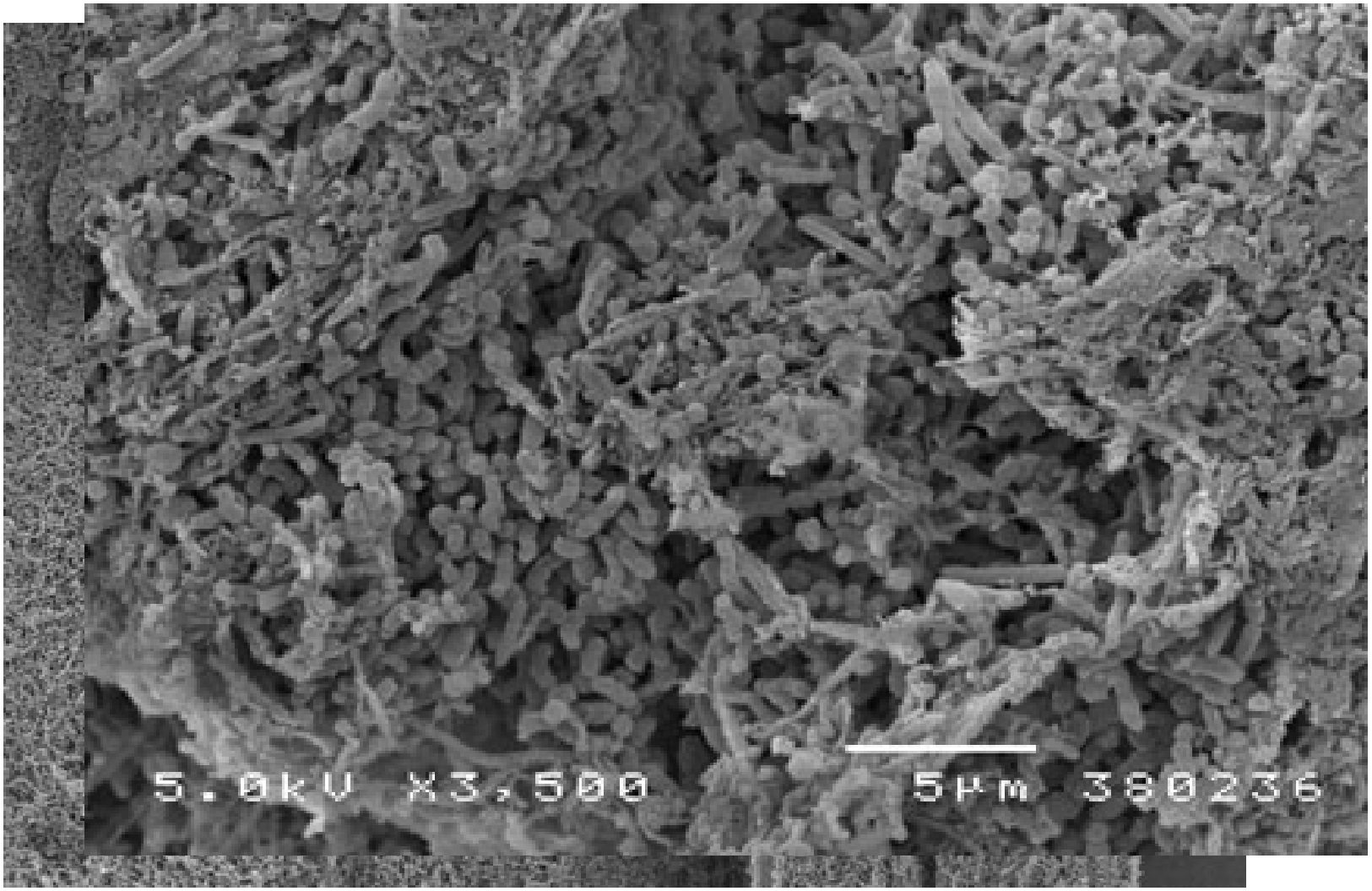
Cells form cellulose-enzyme-microbe complexes

- Specific cellulose hydrolysis rates by cells > purified cellulase preparations (Lu, Zhang, Lynd, 2006)
- Suggests an advantage of C3
- Q grows as a

  biofilm on cellulose



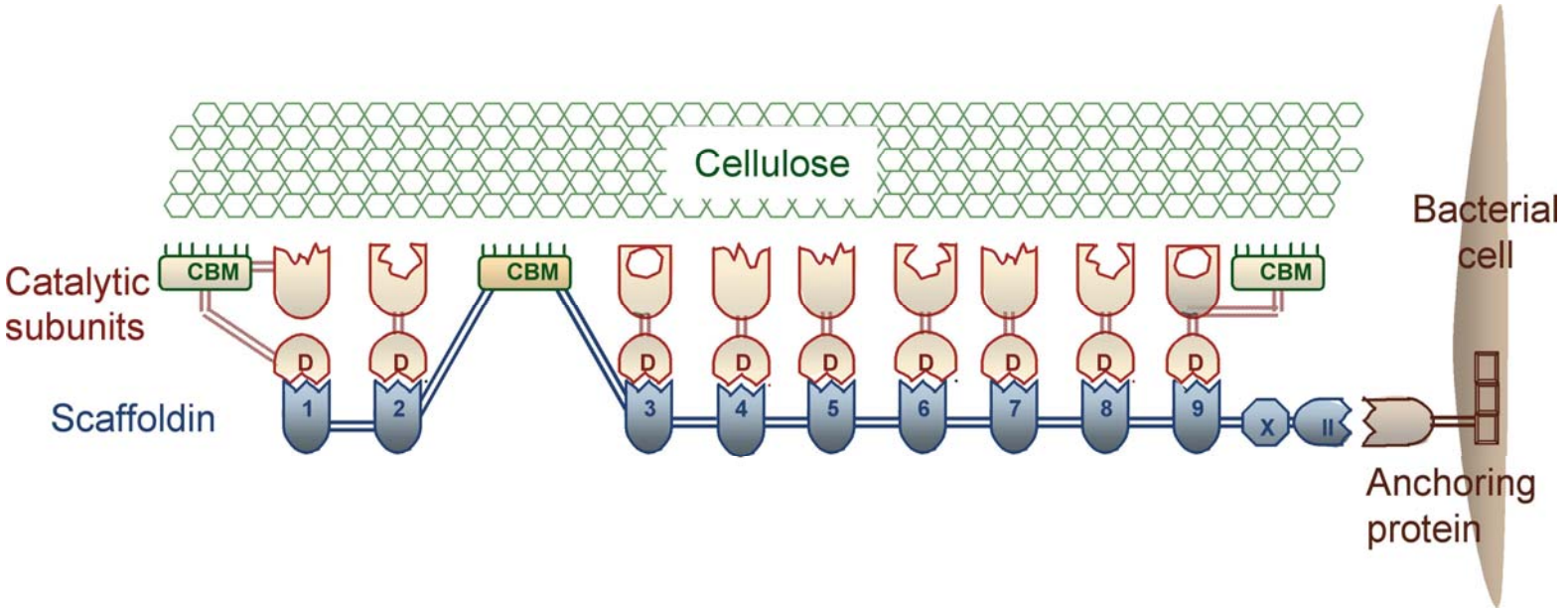
Q grows as a biofilm on cellulose



What is the nature of Q's enzyme system?

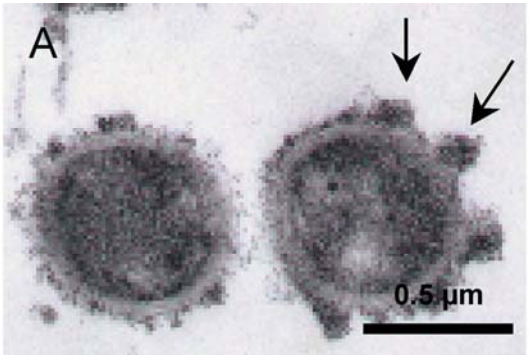
- Cellulolytic bacteria produce extracellular enzymes
- Multiple enzymes digest insoluble biomass

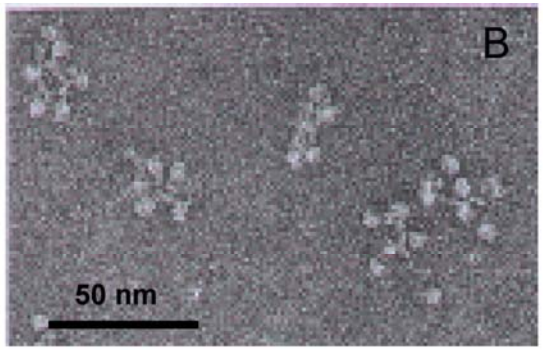
Most cellulolytic anaerobes produce multiprotein enzyme complexes: **Cellulosomes**

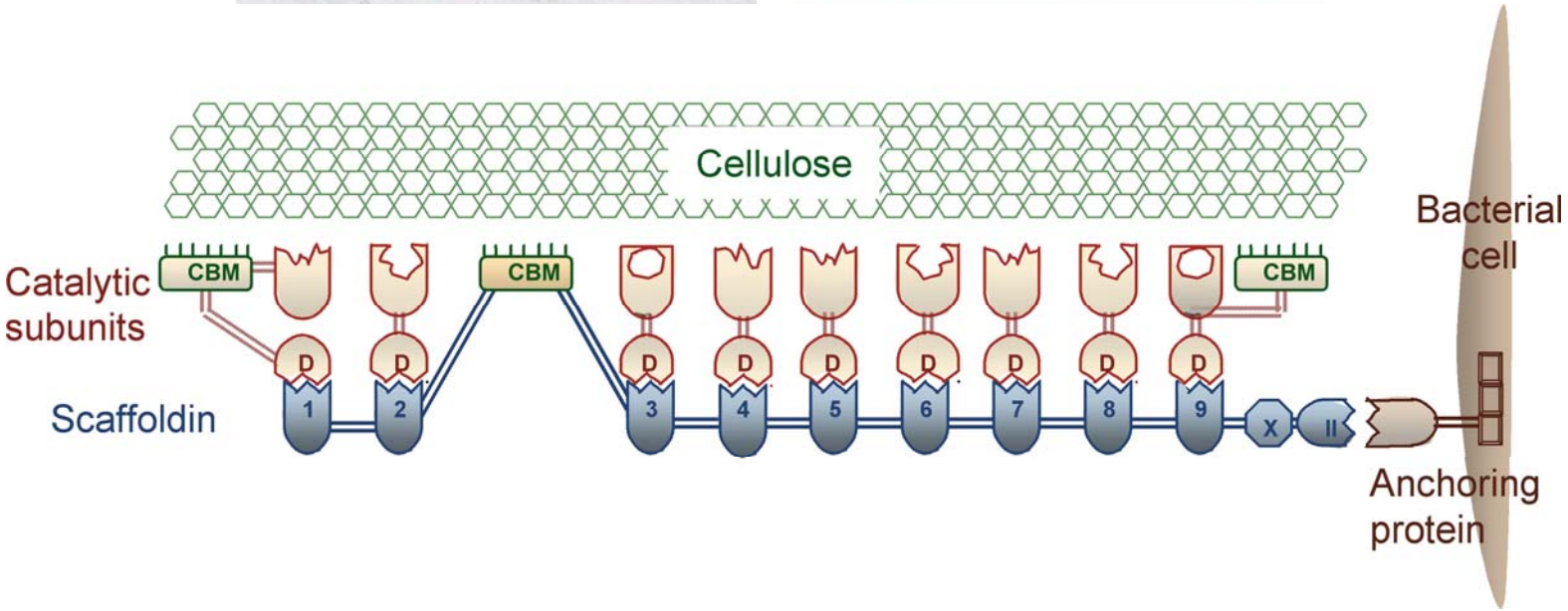


Cellulosomes

Multi-protein enzyme complexes that degrade cellulose







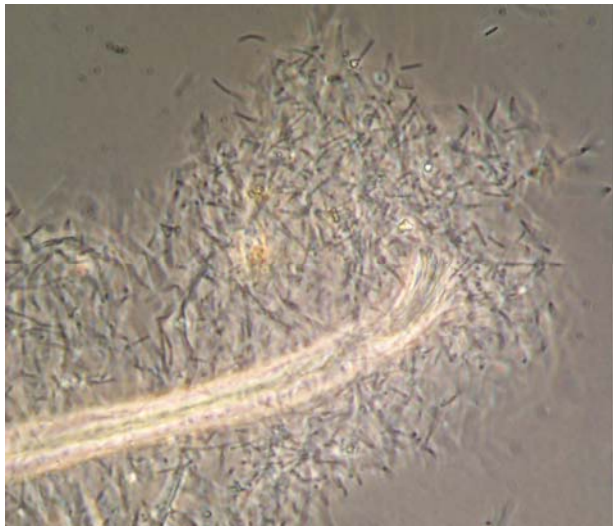
Q produces a multi-component non-complexed cellulase system

(non-cellulosomal)

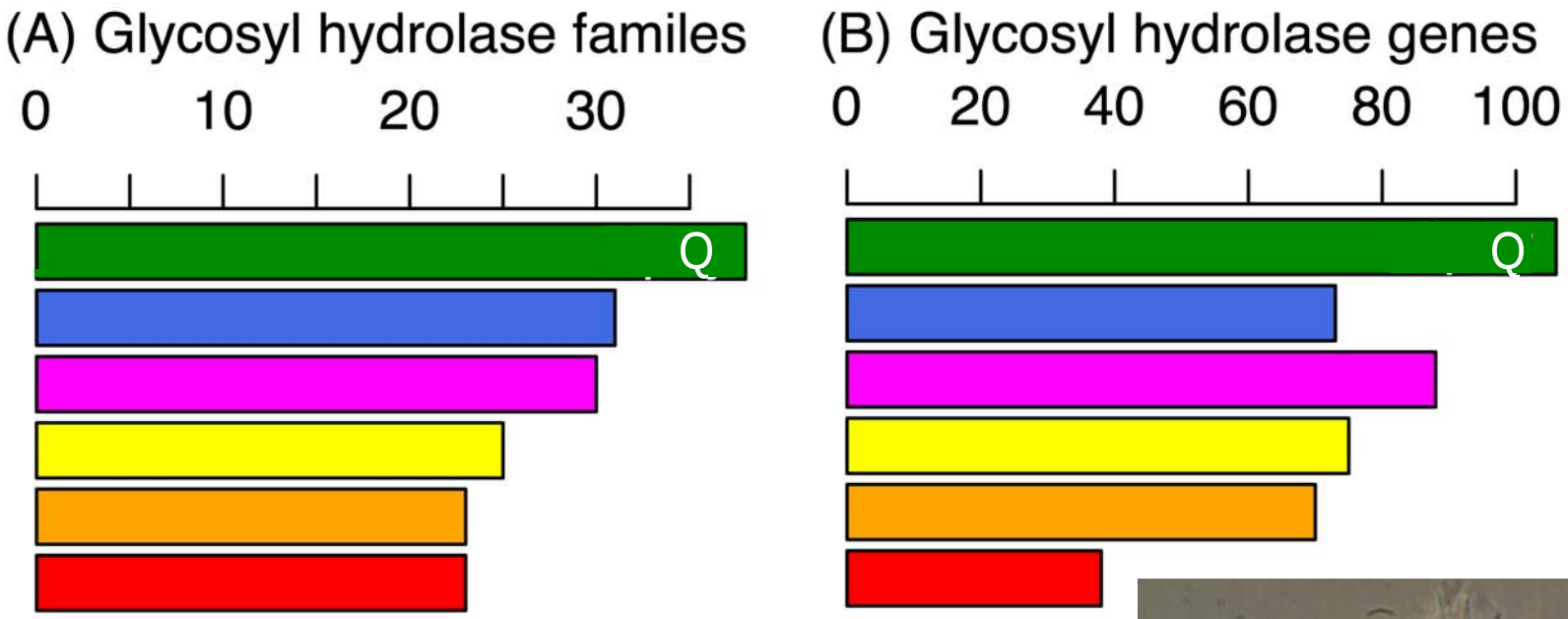
Based on analyses of Q's genome sequence:

- No evidence for scaffoldin-like proteins
- No evidence for dockerin-containing carbohydrate-active enzymes (e.g., hydrolases)

No evidence for cellulosomes!



The genome of Q contains a great diversity & abundance of plant-degrading enzymes



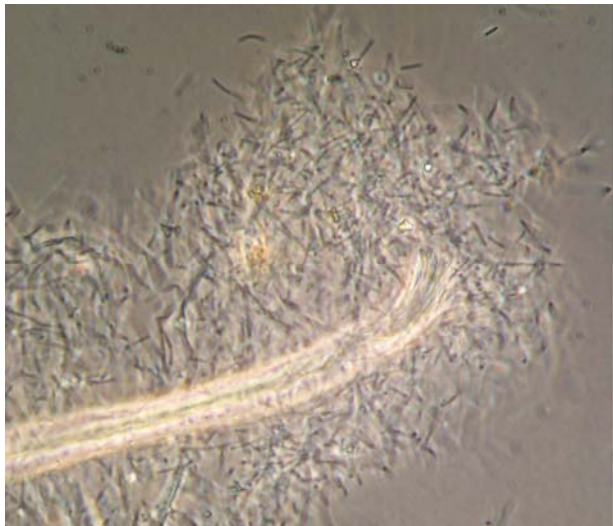
Explains substrate versatility

What's next for *Q*?

Analyses of the Q genome & gene expression

UMass TIMBR Team

- Q **adjusts** its metabolism & production of enzymes in response to feedstock.
- Q **produces** cellular machinery & metabolic pathways
  - ✓ to process sugar products of feedstock degradation
  - ✓ to generate energy for growth
- Q naturally **integrates** complex cellular processes



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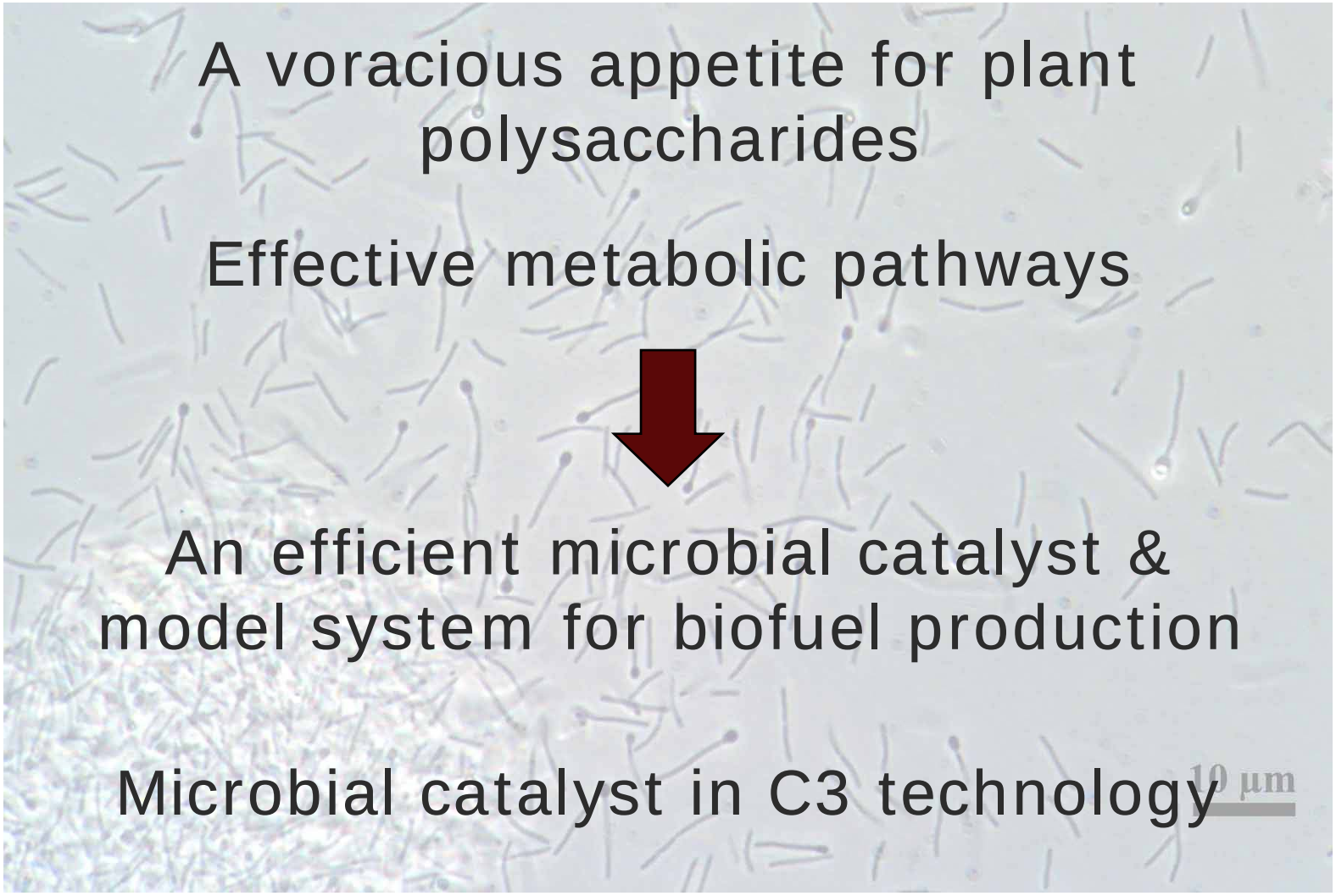

SunEthanol

Acknowledgements

Jeff Blanchard
Elsa Petit
Danny Schnell
Tom Warnick
Supriya Deshpande

Supratim Mukherjee
Maria Campo
Devin Currie
Teresa Repasy
Adam Glickman
Almaris Alonso

Greg LaTouf
& others @SunEthanol

Harvard:
Andy Tolonen
George Church

Central Microscopy Facility at UMass: Dale Callaham

Funding: US Dept. of Energy, USDA, SunEthanol

Thank you!

TIMBR