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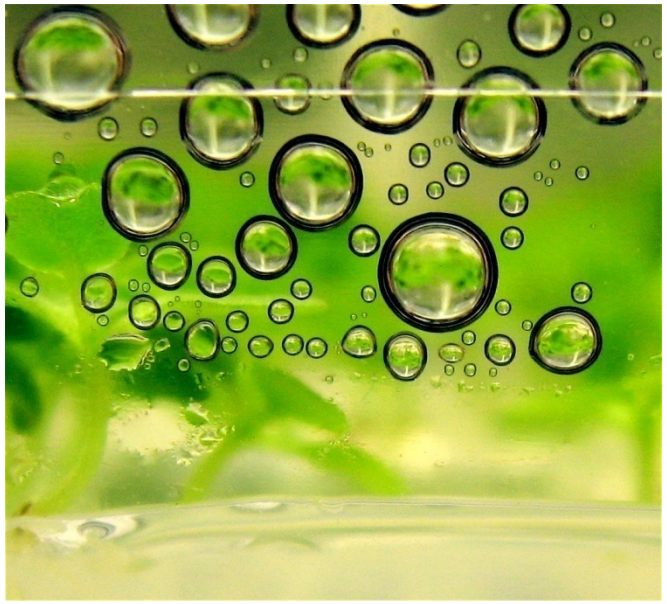
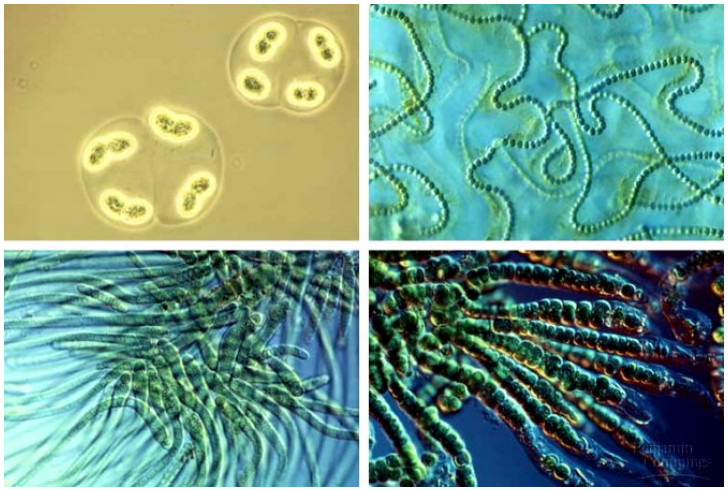
# Enhancing Algal Biodiesel Through the Use of Waste Products



**Renewable Energy in West Virginia**

**June 5, 2014**



Derrick R. J. Kolling

Department of Chemistry

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# Overview

- Biofuels research justification
  - Why do we need biofuels?
- Algal biodiesel
  - TAGs
- Research projects
  - Photomixotrophically grown algae
  - Using glycerol to increase algal biodiesel yields

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# Rene

- Biofuels
- Solar power
- Wind power
- Tidal power
- Hydropower
- Geothermal








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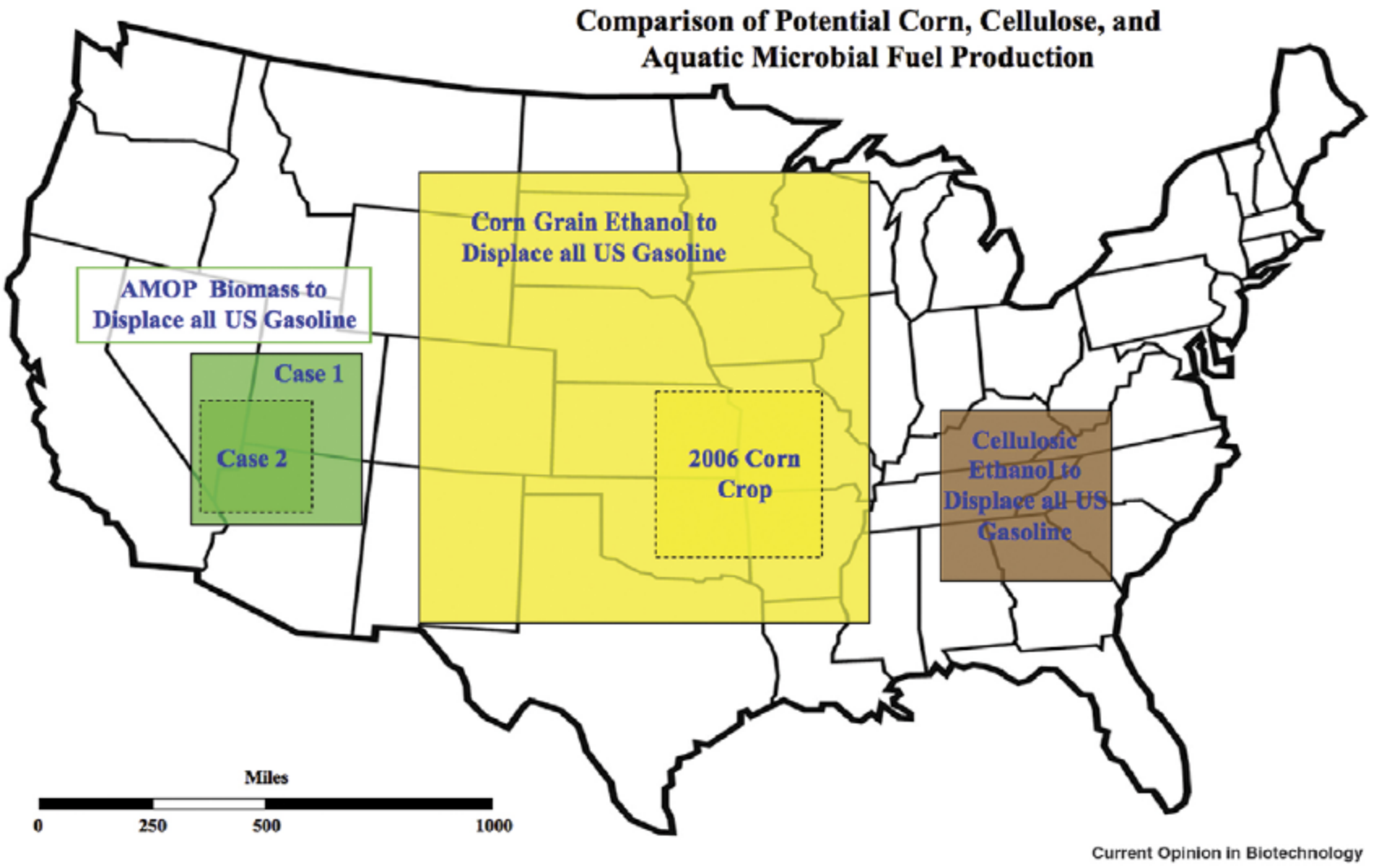
# Biofuel Footprint




Dismukes *et al*. (2008)

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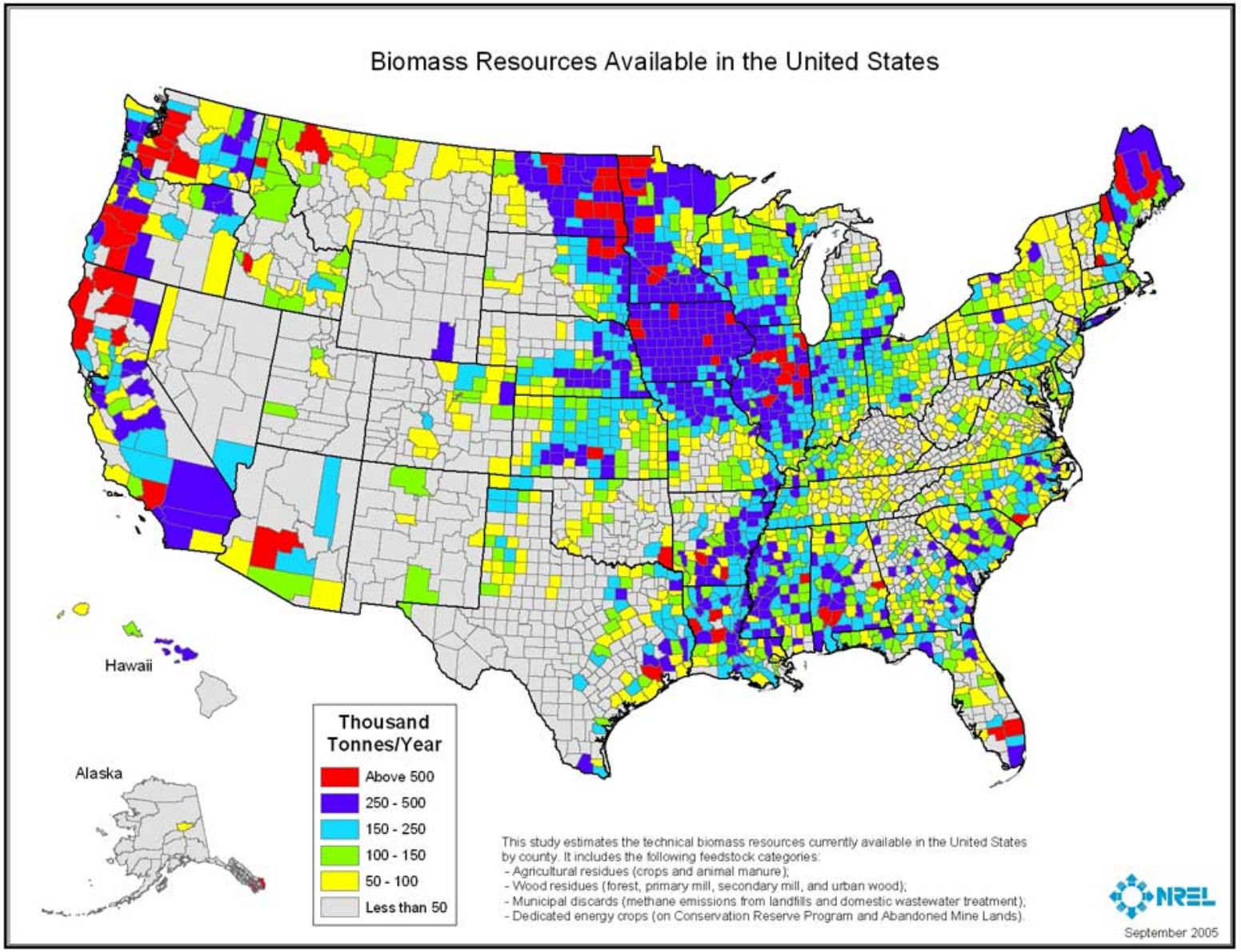
# Available Biomass



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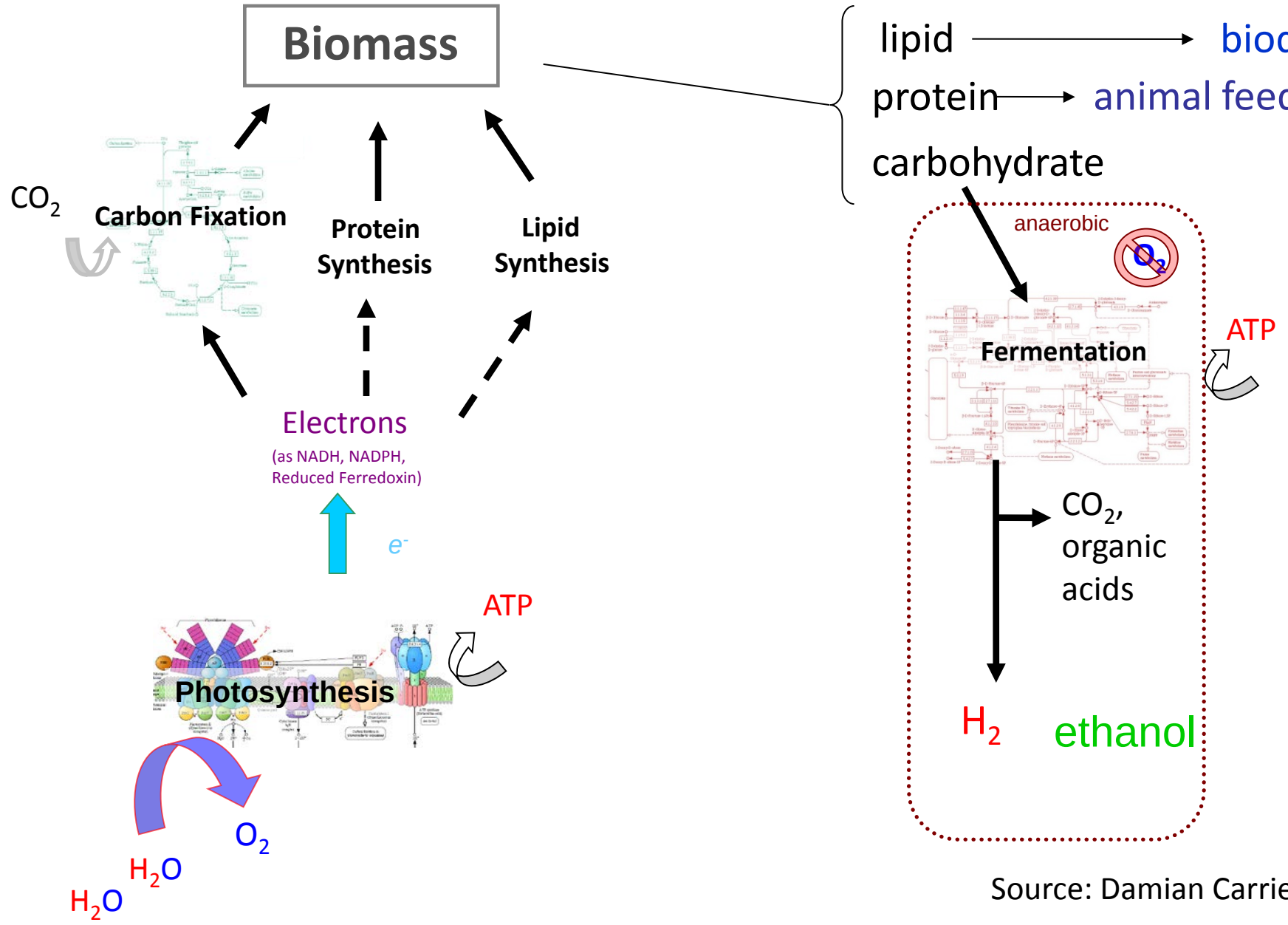
# Algal Biofuel




Source: Damian Carrieri

# Algal Biofuel

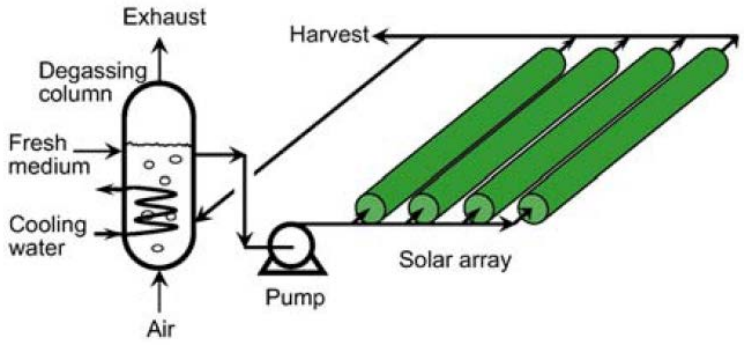



Fig. 2. A tubular photobioreactor with parallel run horizontal tubes.

Fig. 5. Microalgal biomass recovered from the culture broth by filtration moves along a conveyor belt at Cyanotech Corporation (www.cyanotech.com), Hawaii, USA. Photograph by Terry Luke. Courtesy of Honolulu Star-Bulletin.

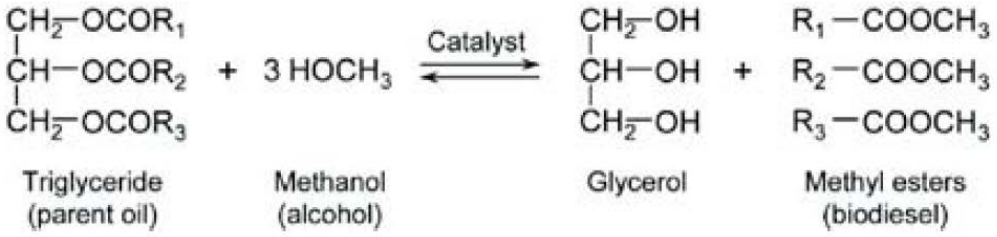



Fig. B1. Transesterification of oil to biodiesel. $R_{1-3}$ are hydrocarbon groups.

Chisti (2007) *Biotech. Advances*

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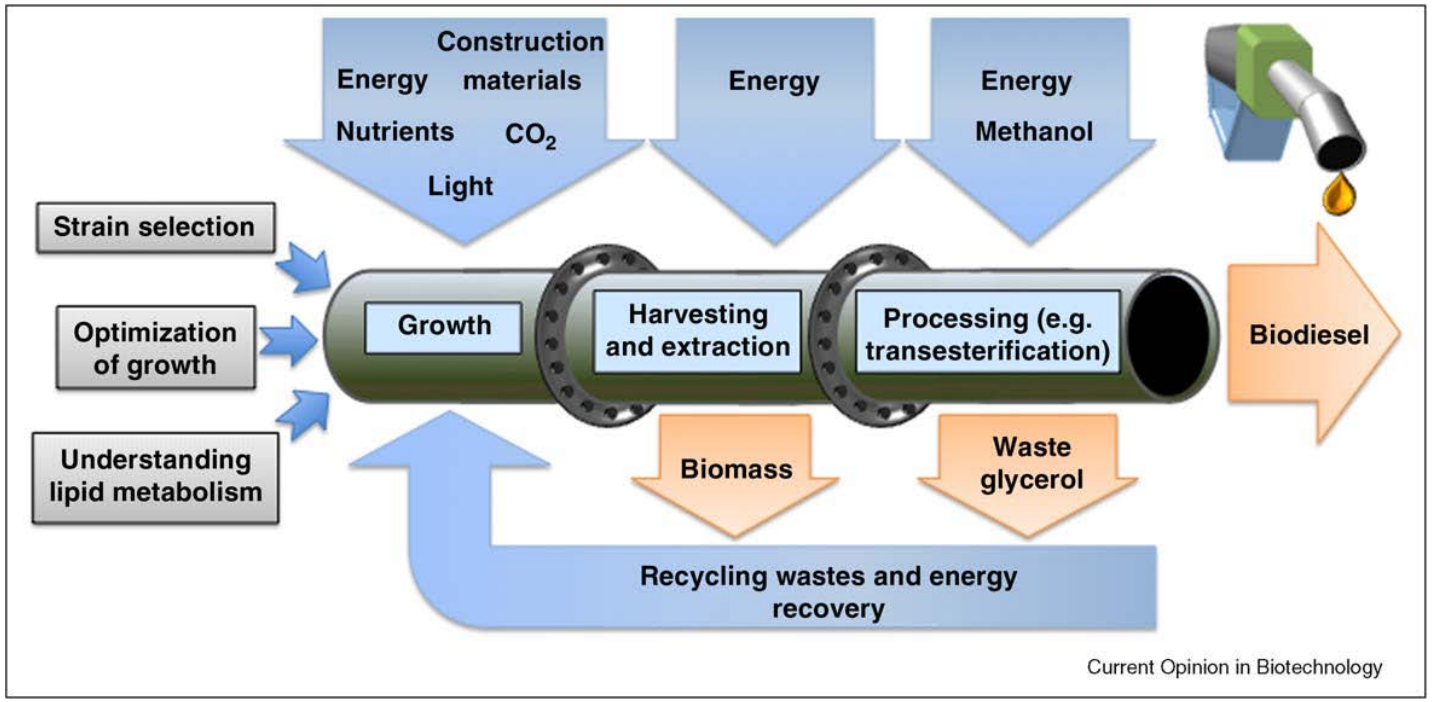
# Algal Biofuel

| Crop | Oil content per tonne of biomass (wt% dry mass) | Oil production (t/ha/y) | Biodiesel yield (L/ha/y) |
|---|---|---|---|
| Oilseed . (UK) [2] | 40–44% (of seed) | 1.4 | 1560 |
| Soya [1••] | 20% (of seed) | 0.48 | 544 |
| *Jatropha* [45] | 30% (of seed) | 2.4 | 2700 |
| *Chlorella vulgaris* [26] | Up to 46% | 7.2§ | 8200 |
| *Nannochloropsis* [12•] | Up to 50% | 20–30§ | 23 000–34 000 |




Scott *et al.* (2010) *Current Opinion in Biotechnology*

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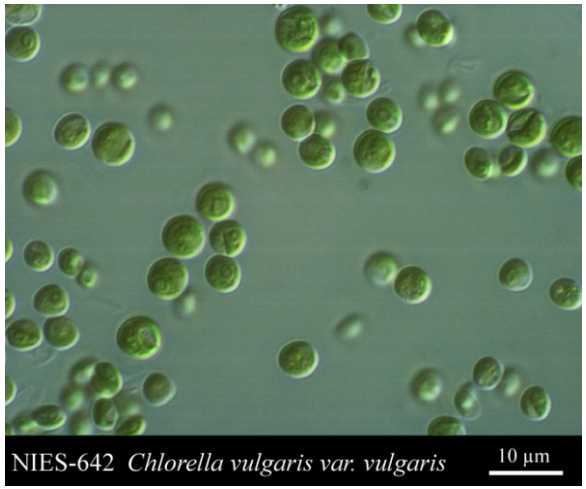
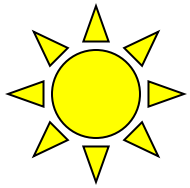
Comparison of lipid accumulation in photomixotrophically and heterotrophically grown *Chlorella vulgaris*



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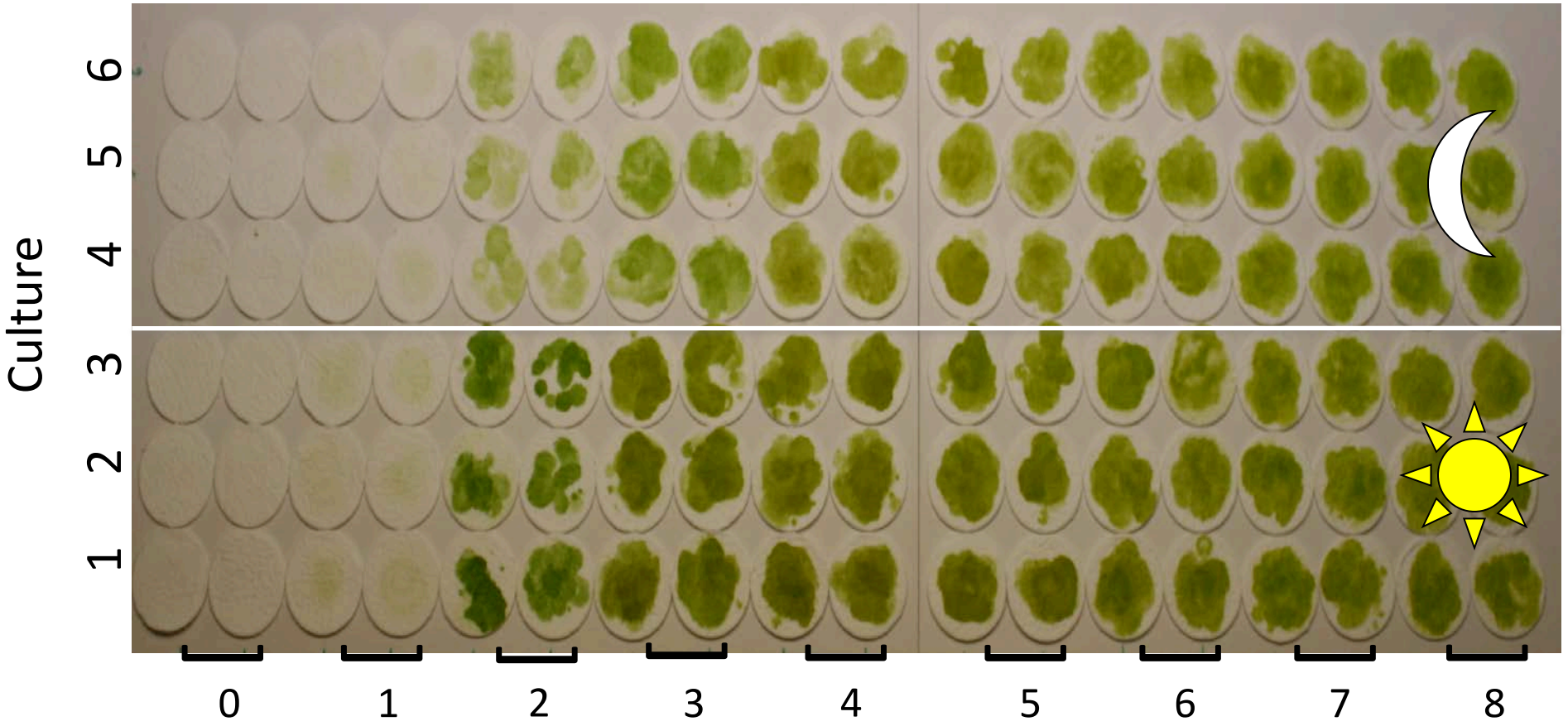
Measured:

-[Chl *a*] -turbidity

-dry weight -lipid dry weight



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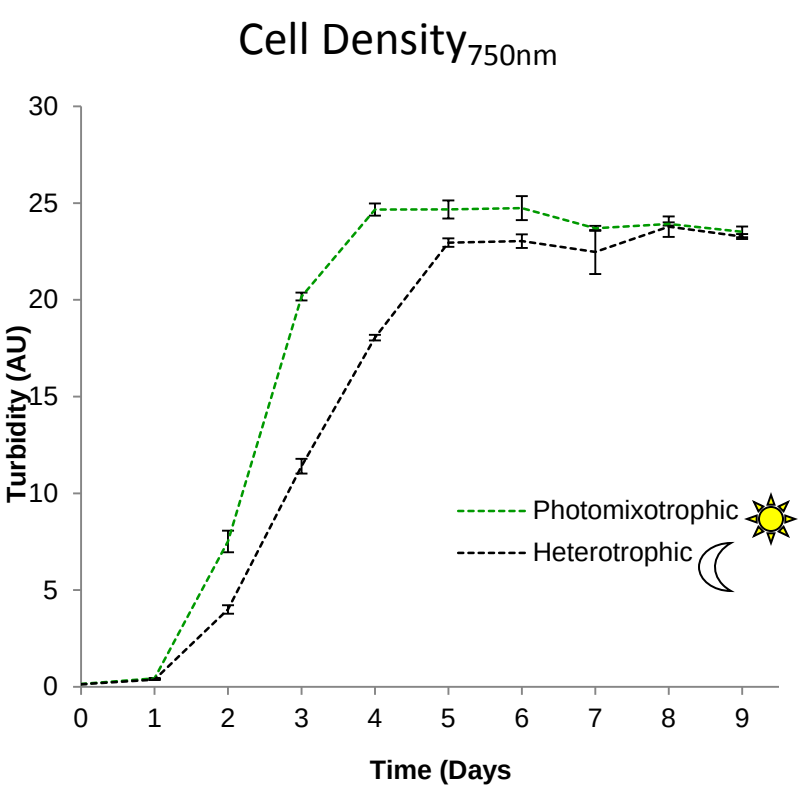


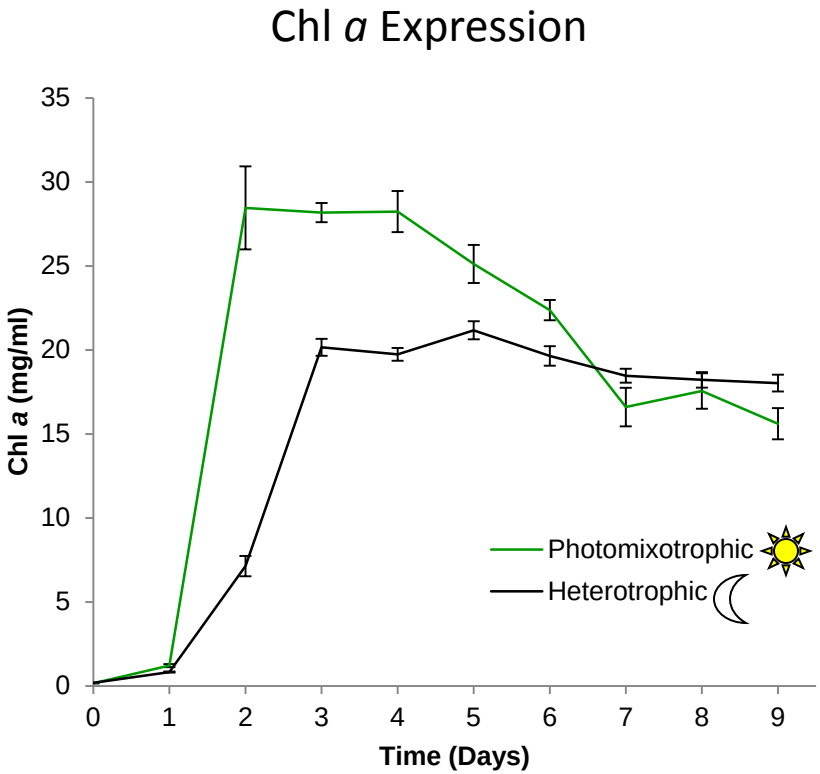

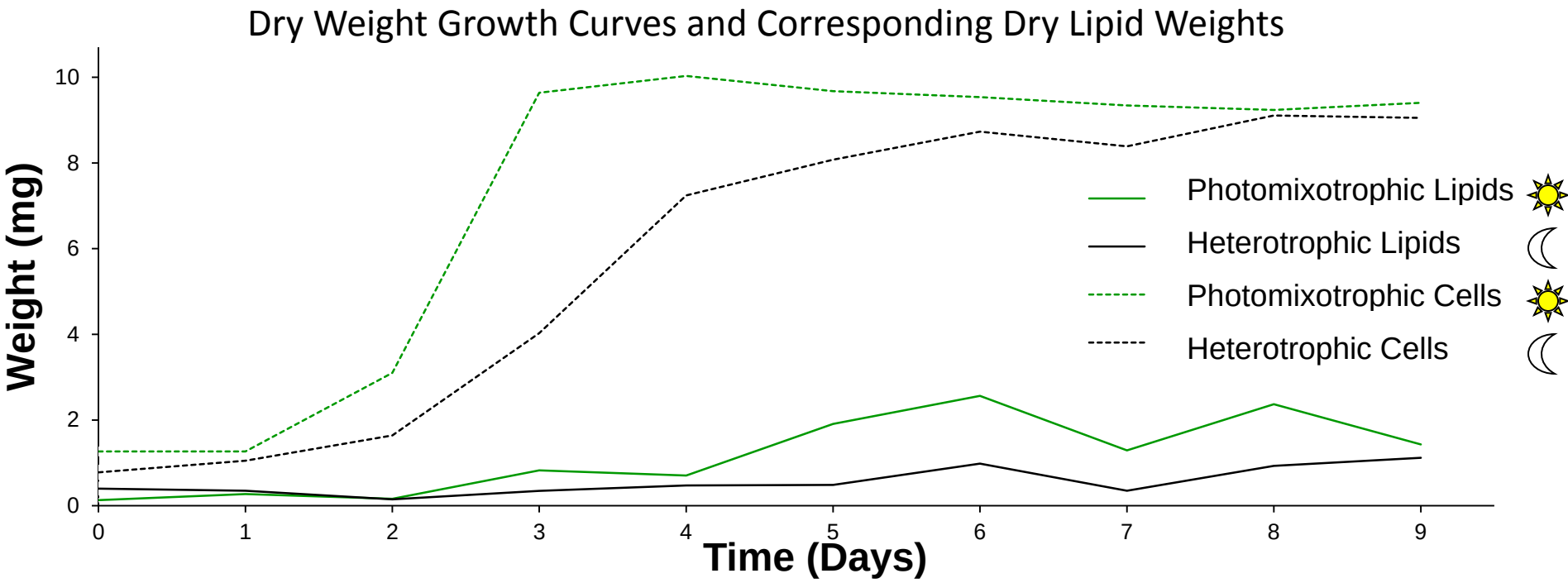


C 16: palmitic acid

C 18: stearic acid

C 18:1(n-9): oleic acid

C 18:2(n-6): linoleic acid

## Findings

- Photomixotrophically grown cells produce 2X as many lipids as do heterotrophically grown cells
  - This increased to 5X under N deprivation (50 %)
- Photomixotrophically grown cells reach stationary phase and higher biomass sooner
  - Cyclic electron transfer
- Cells produce palmitic, stearic, oleic, and linoleic acids

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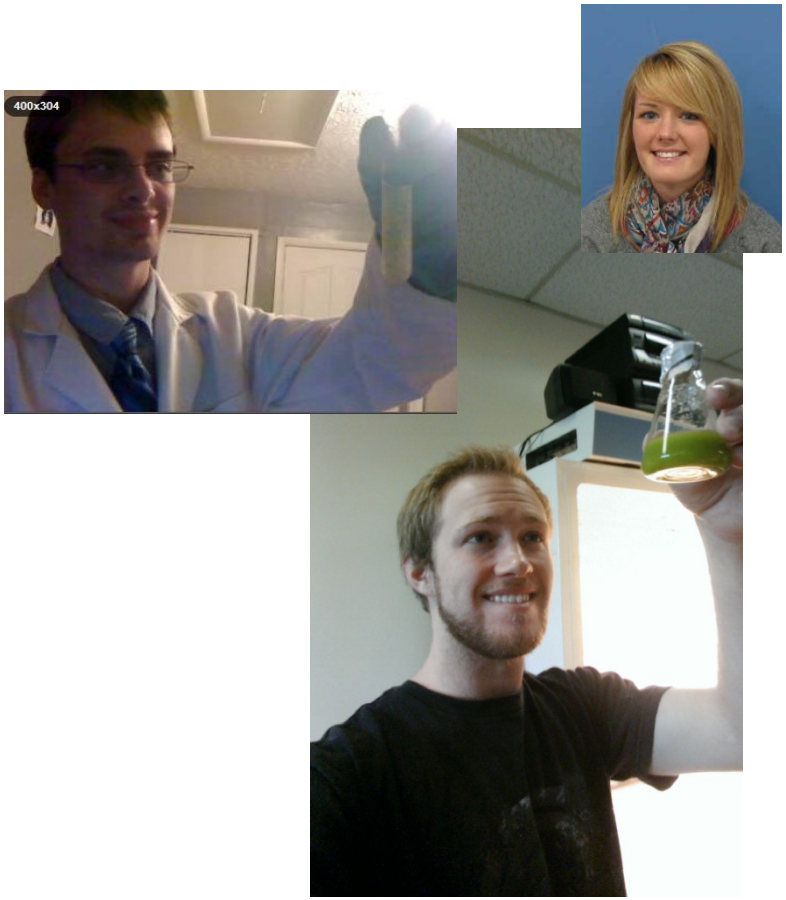
# Using glycerol to maximize lipid production in *Chlorella vulgaris*



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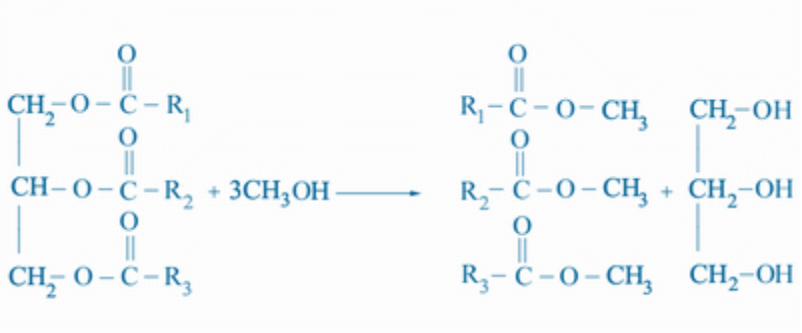
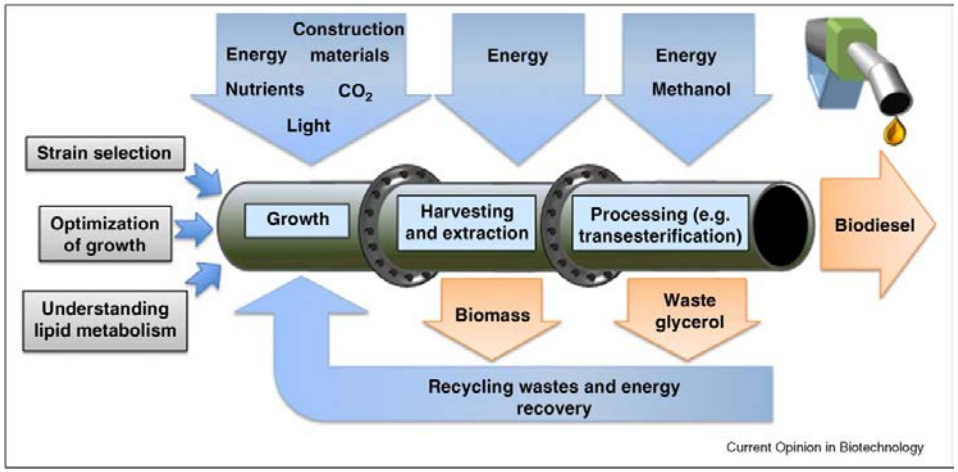
# Working hypothesis: Increased glycerol availability will increase the production of TAGs in *C. vulgaris*






Scott *et al.* (2010) *Current Opinion in Biotechnology*

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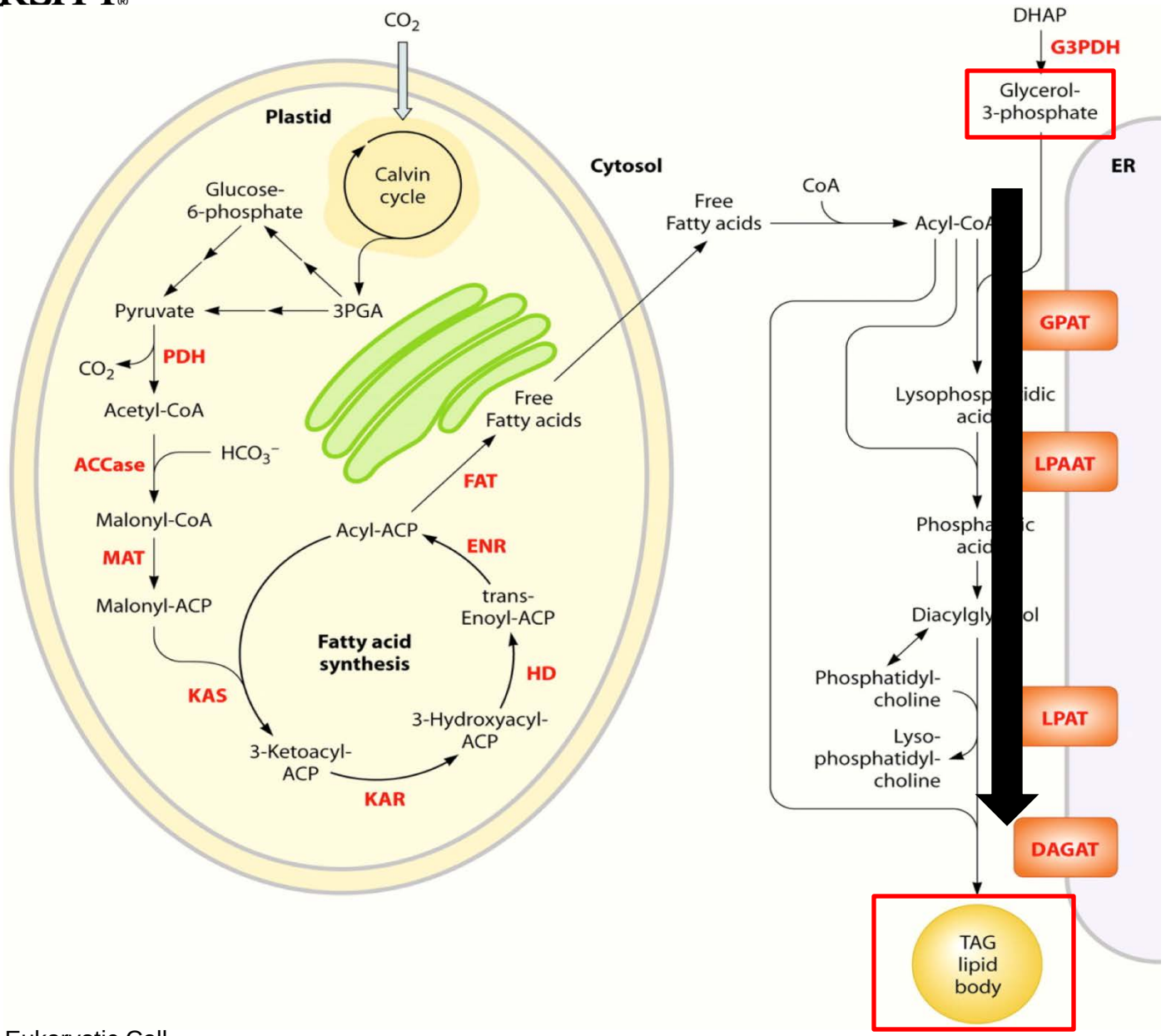
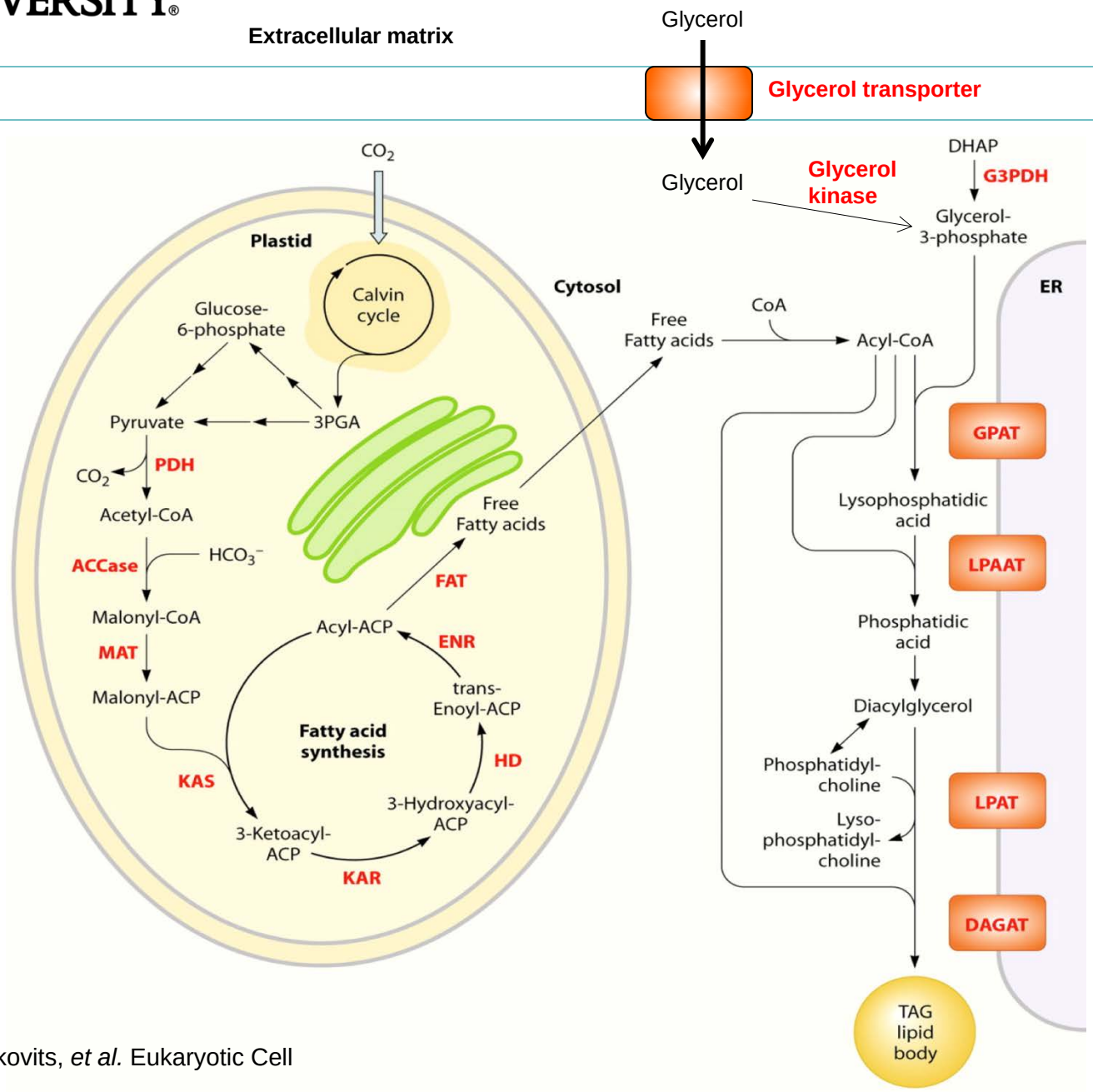



Radakovits, *et al.* Eukaryotic Cell




Modified from Radakovits, *et al.* Eukaryotic Cell

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Stationary phase cells were exchanged into control or N-deplete medium that contained 1% glycerol

Figure 2: Growth of *Chlorella vulgaris* in CV+ medium with and without nitrogen and glycerol

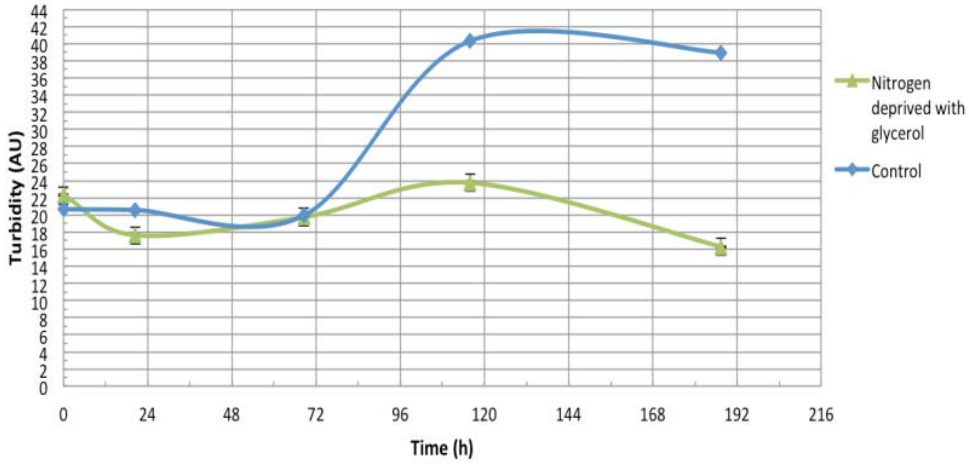
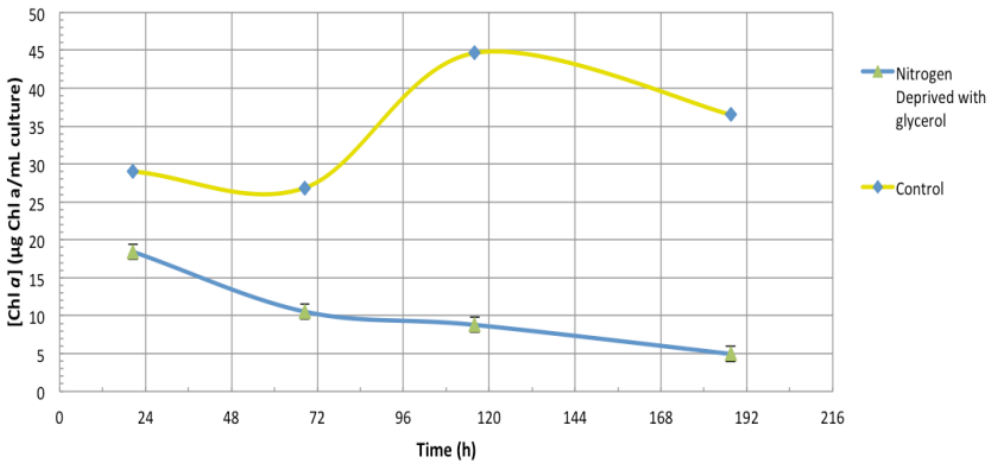



Figure 3: [Chl *a*] vs time for cultures of *Chlorella vulgaris* in CV+ medium with and without nitrogen and glycerol



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# Findings

- N-deprived cells accumulated ~%50 biomass of control
- %20 of biomass in N-deprived cells was lipids vs. %15 in the control

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# Acknowledgements


- **Algal biodiesel**
  -Ben Woodworth, Tony Stephenson, Rebecca Mead, Courtney Nichols, Morgan Stickler, Kasey Stickler, Mallory McDonald, Aaron Holland
- **OEC photoassembly**
  -James Board, Hope Cook, Ben Blodgett, Matt Thompson, Shane Kagen, Chase Turner, Ben Weiner, Justin Erwin, Jordan Hilgeford
- **Bioethanol from invasive algal species**
  -Kevin Militello, Shaheed Elhamdani


## Funding


RESEARCH CORPORATION for SCIENCE ADVANCEMENT

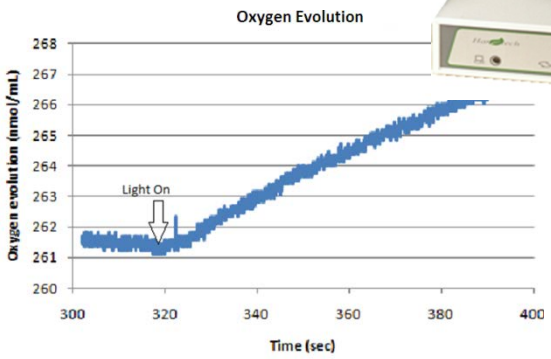
West Virginia Higher Education Policy Commission

NSF

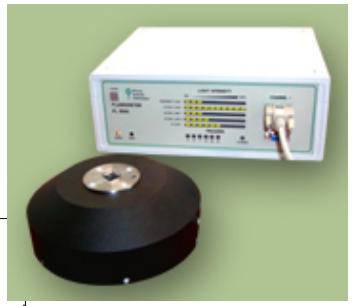
NASA West Virginia Space Grant Consortium

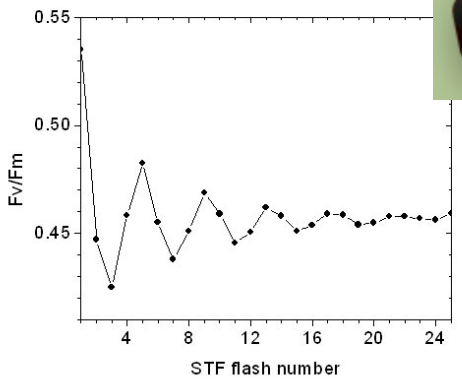
# Research Tools

- **Oximetry**

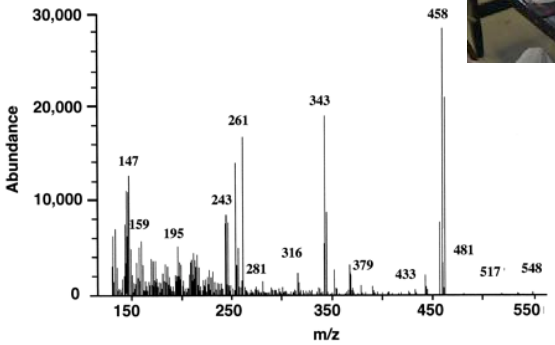




- **Fluorescence**

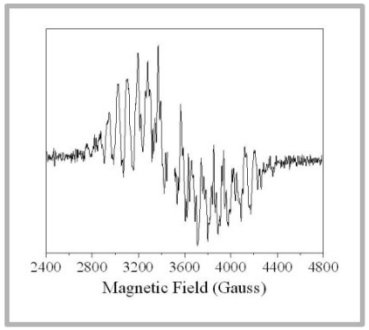


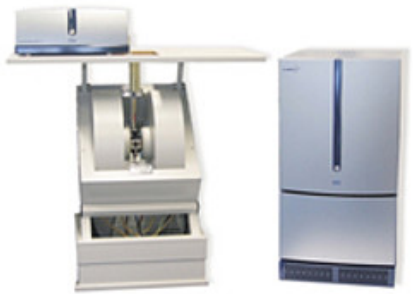



- **GC-MS**




- **Electron Paramagnetic Resonance**



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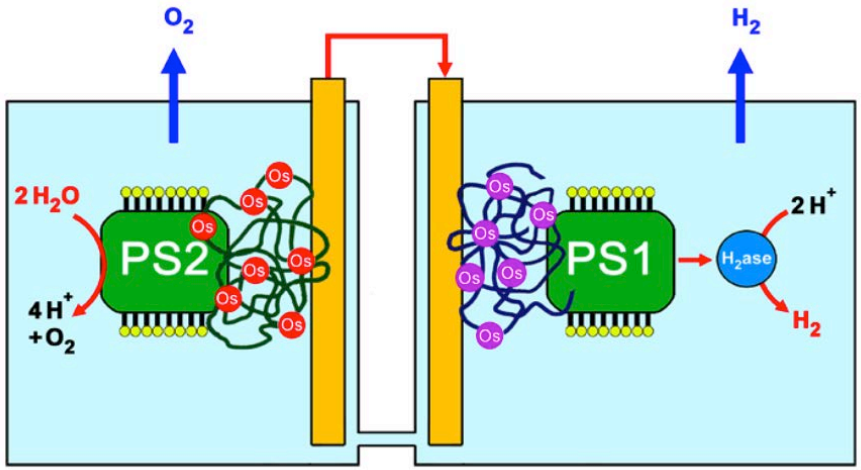
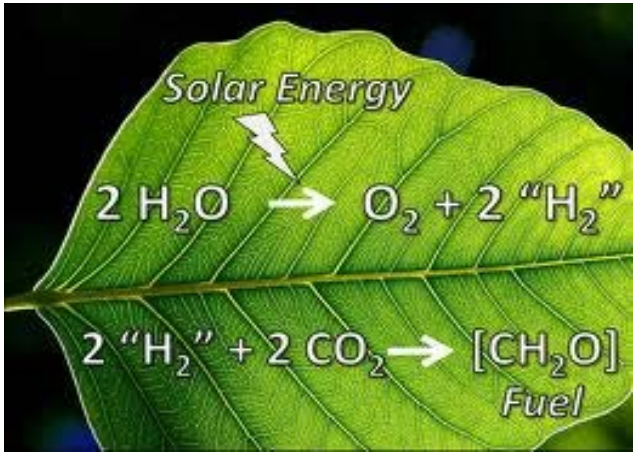
# OEC Photoassembly Application

## Bioinspired/biomimicked System

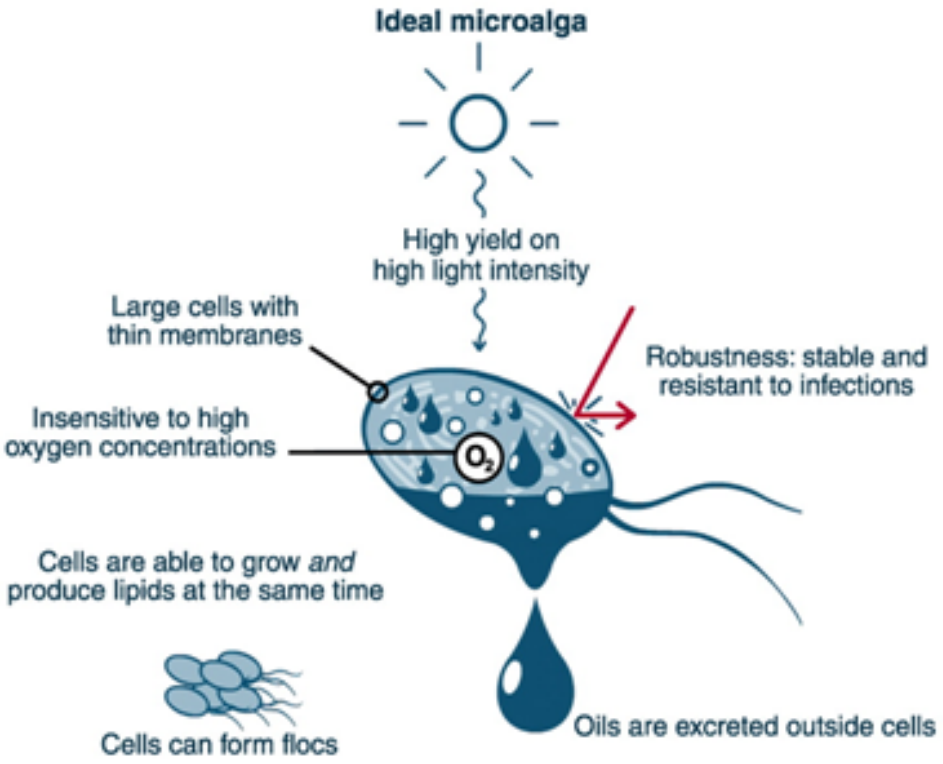



www.ruhr-uni-bochum.de/h2design/profile/main.html

## Artificial Leaf




www3.imperial.ac.uk




Wijffels, R.H. and Barbosa, M.J.2010 Science