

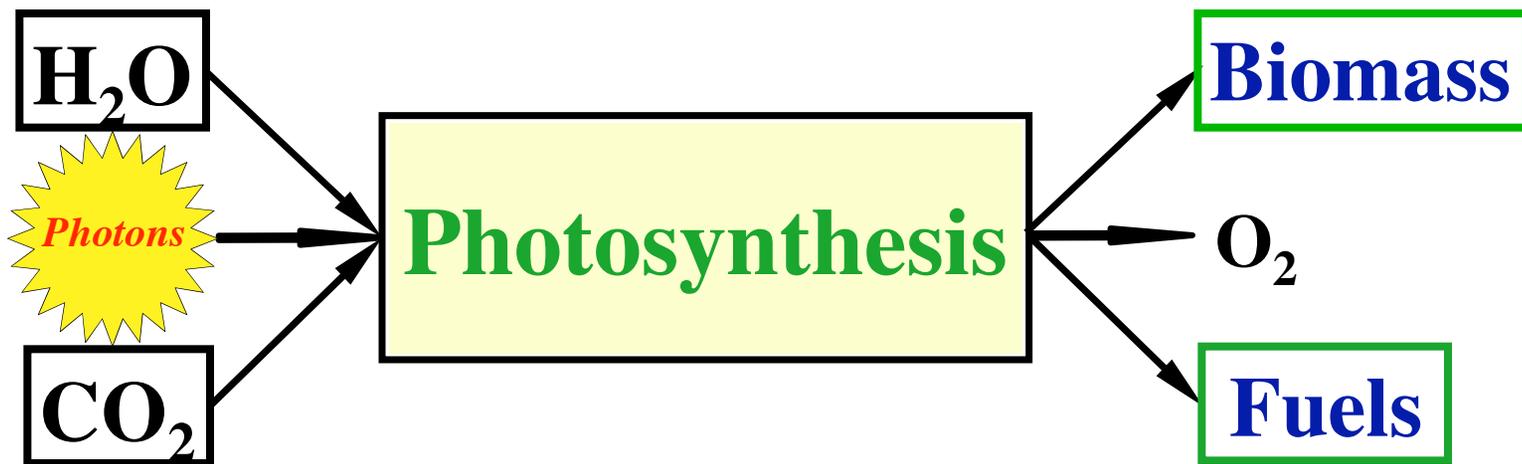
Photosynthesis to Fuels

ARPA-E Workshop on Applied Biotechnology for Transportation Fuels

Tasios Melis, UC Berkeley



Feedstock and products



**Process offers a renewable energy supply
and mitigation of climate change.**

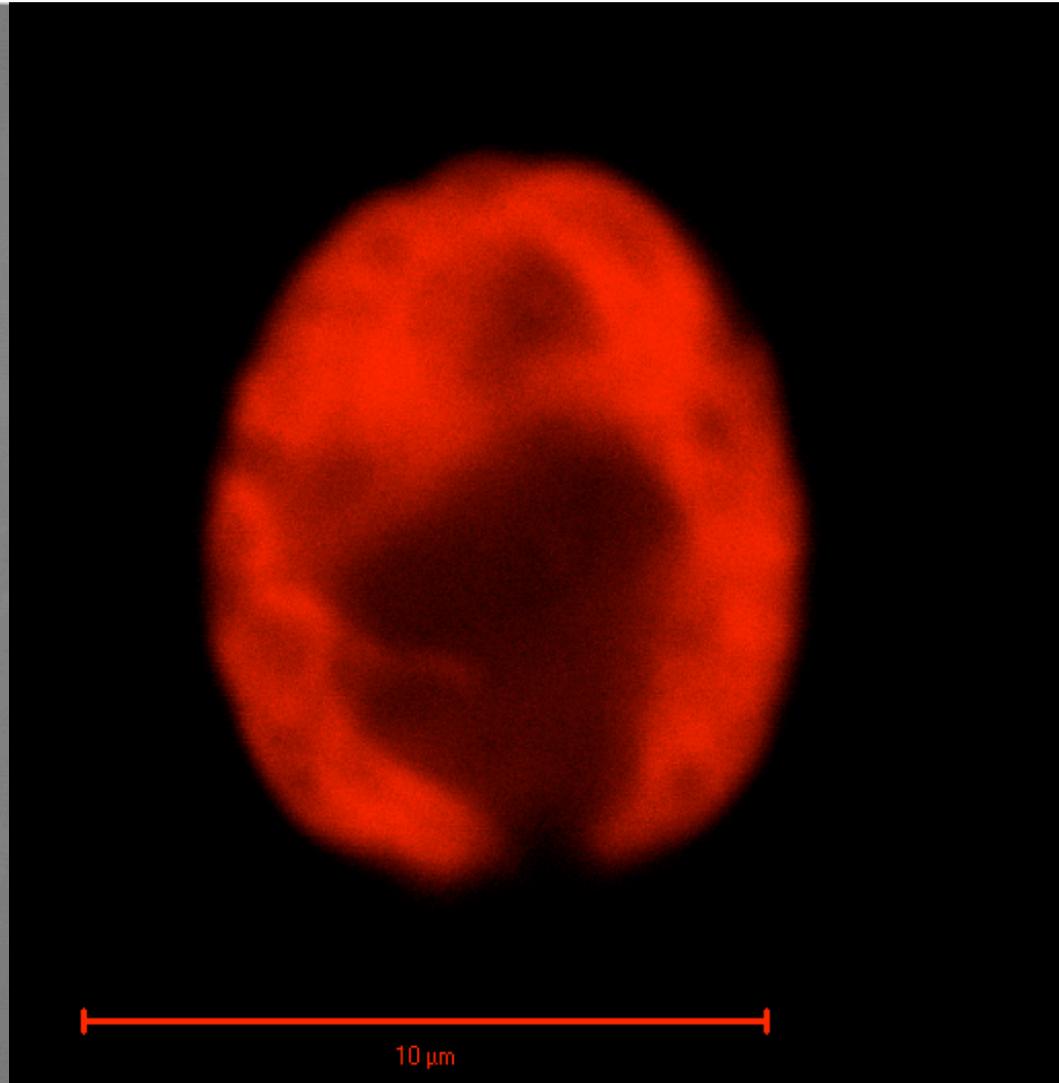
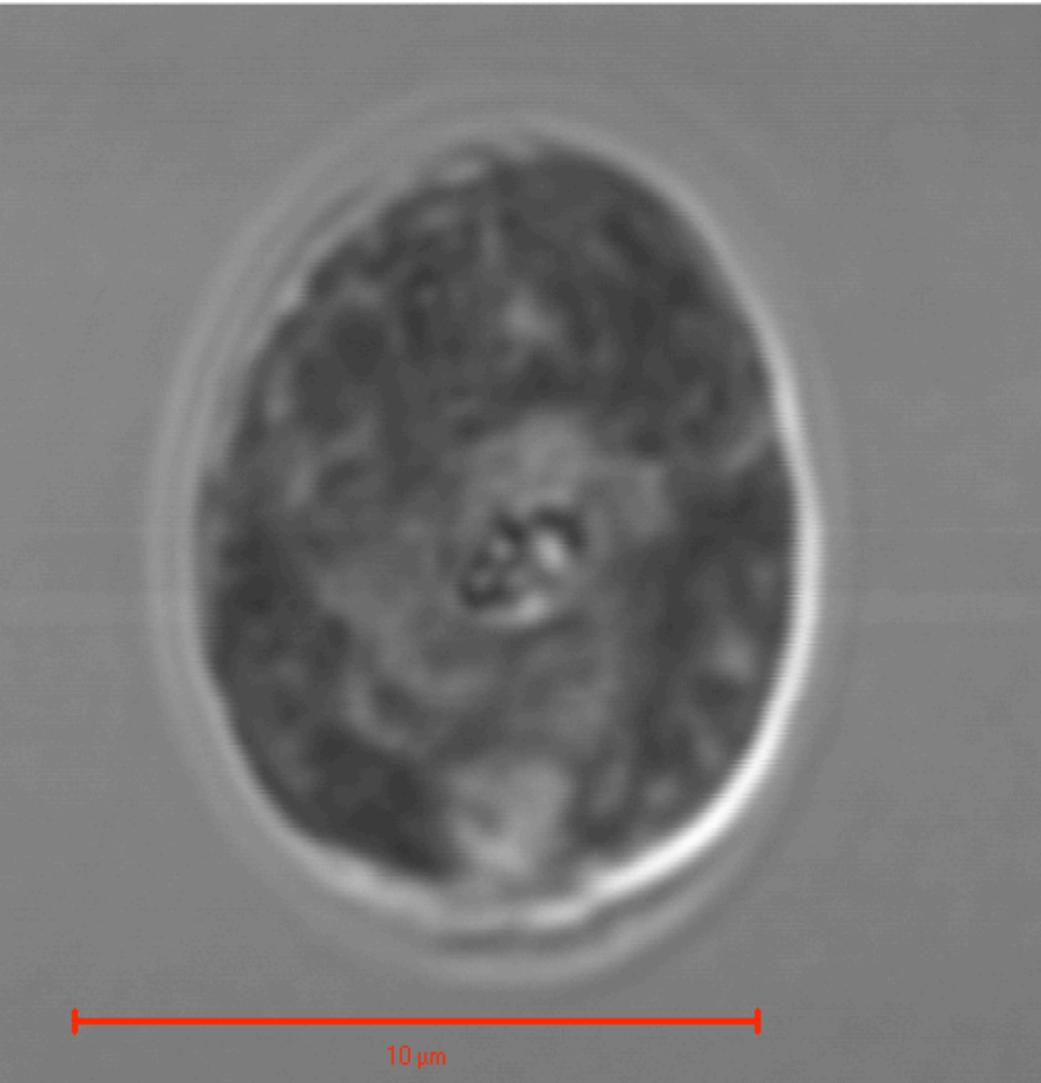


Properties and attributes of photosynthetic microorganisms

- **Microalgae**
- **Cyanobacteria**



The green microalga *Chlamydomonas reinhardtii*

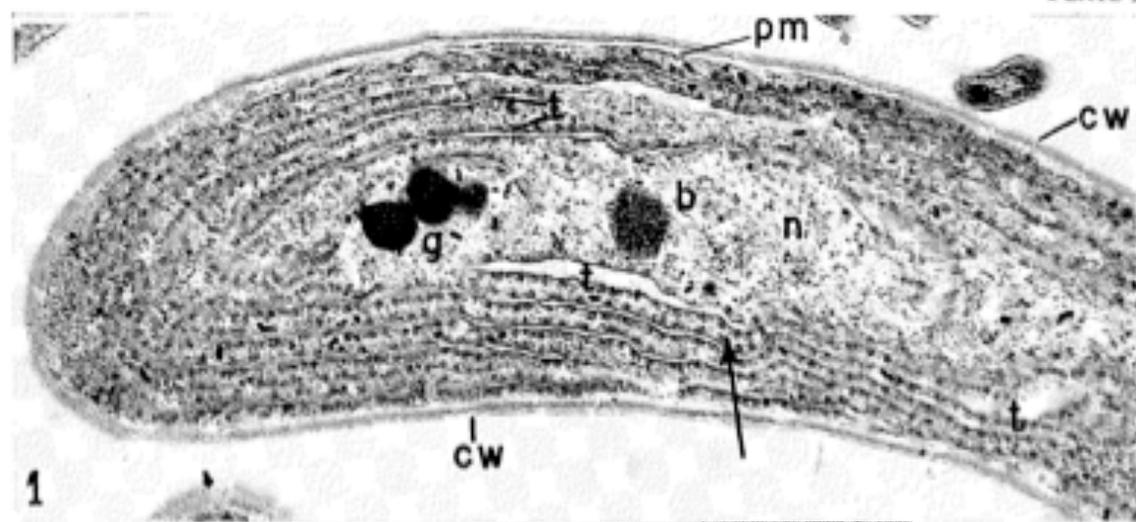
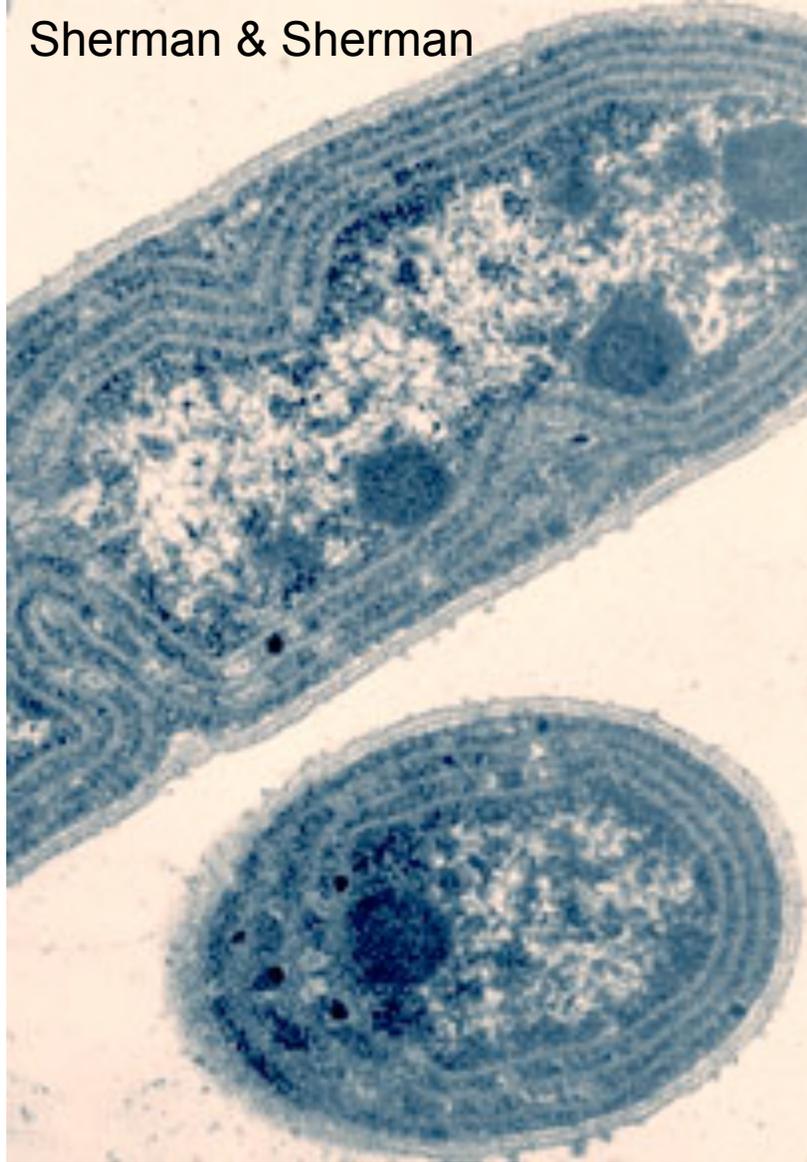


Differential Interference Contrast

Chlorophyll Fluorescence



Sherman & Sherman



Edwards & Gantt

Thermophilic cyanobacterial strains

Thermosynechococcus elongatus & *Synechococcus lividus*



Features of microalgae and cyanobacteria

- **High rates of photosynthesis**
- **Easy to cultivate**
- **Require “containment” in a photobioreactor**



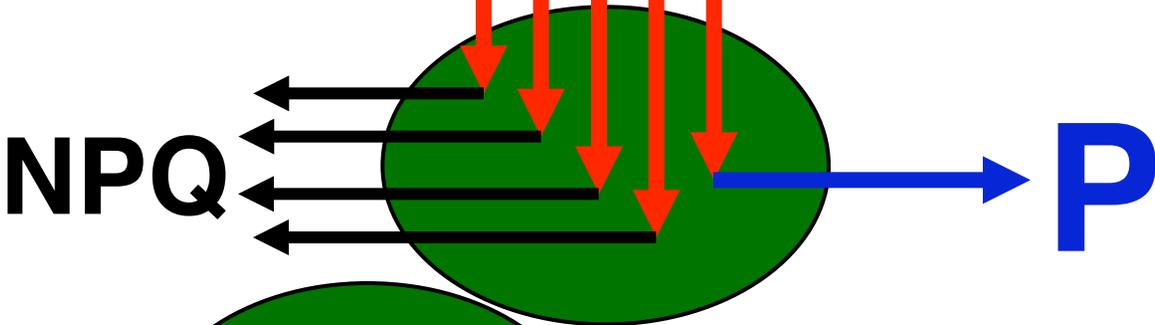
vent

**Hydrogen production
in a backyard**

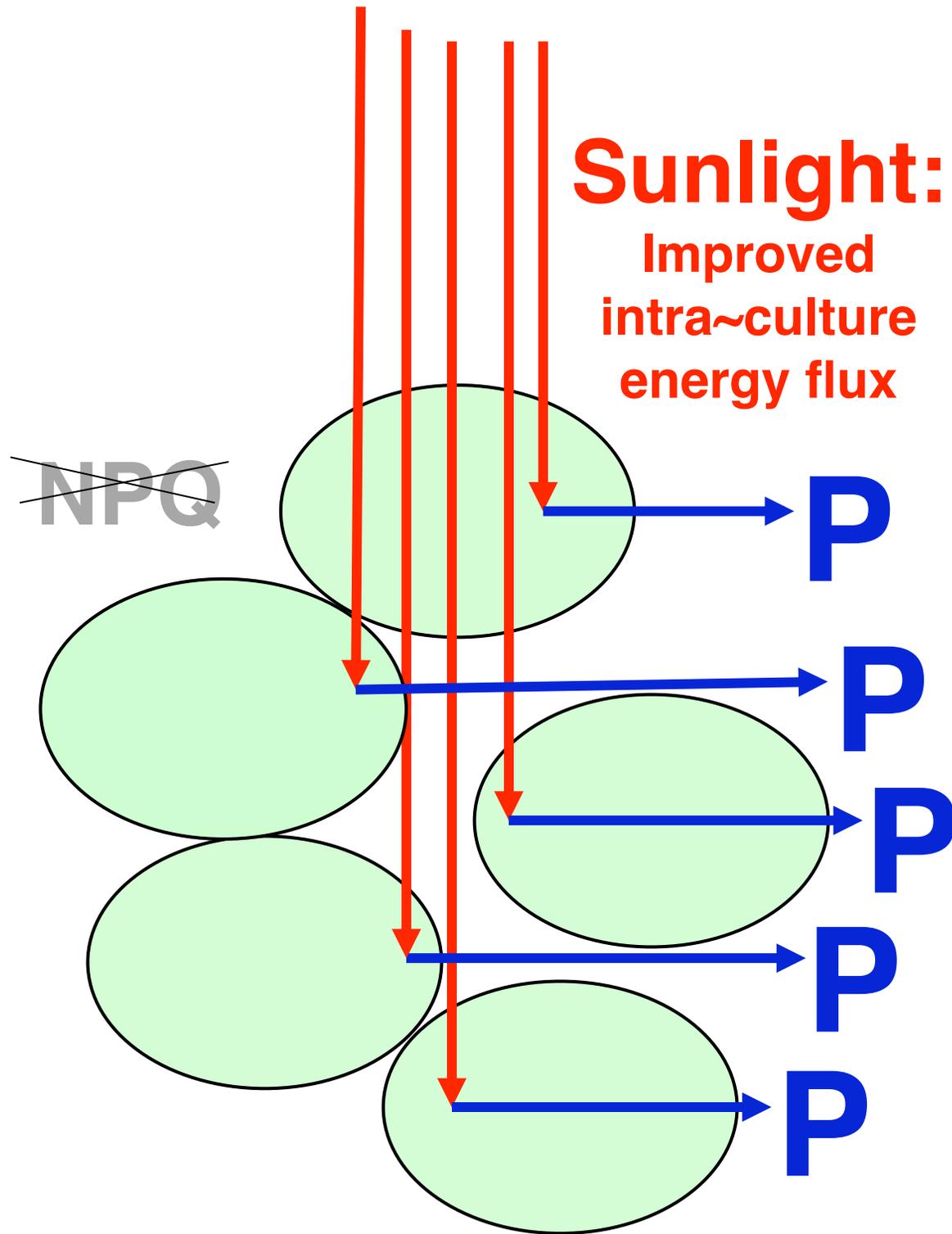
Chlamydomonas reinhardtii mass culture



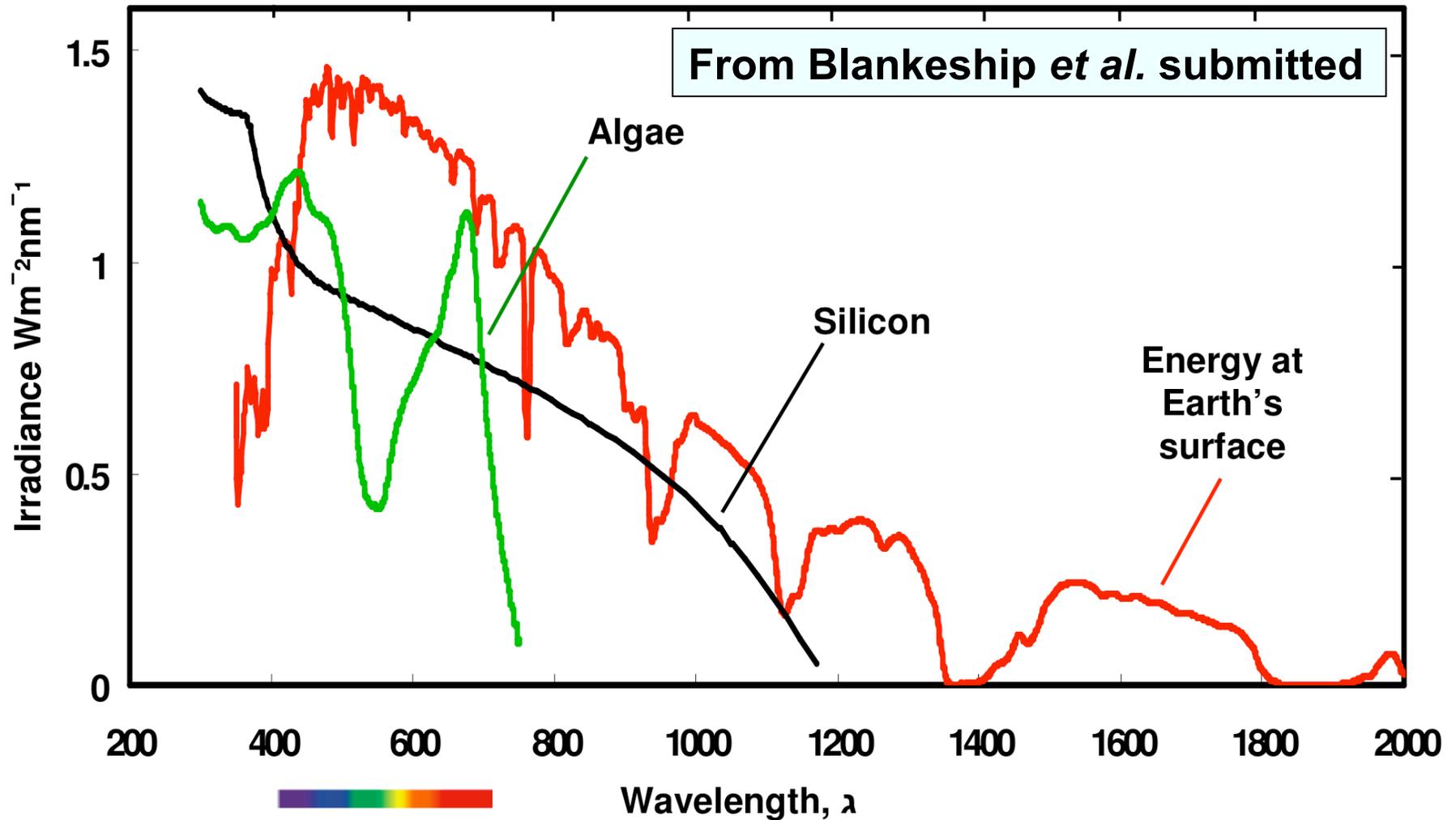
Sunlight:
Over-absorption
and dissipation



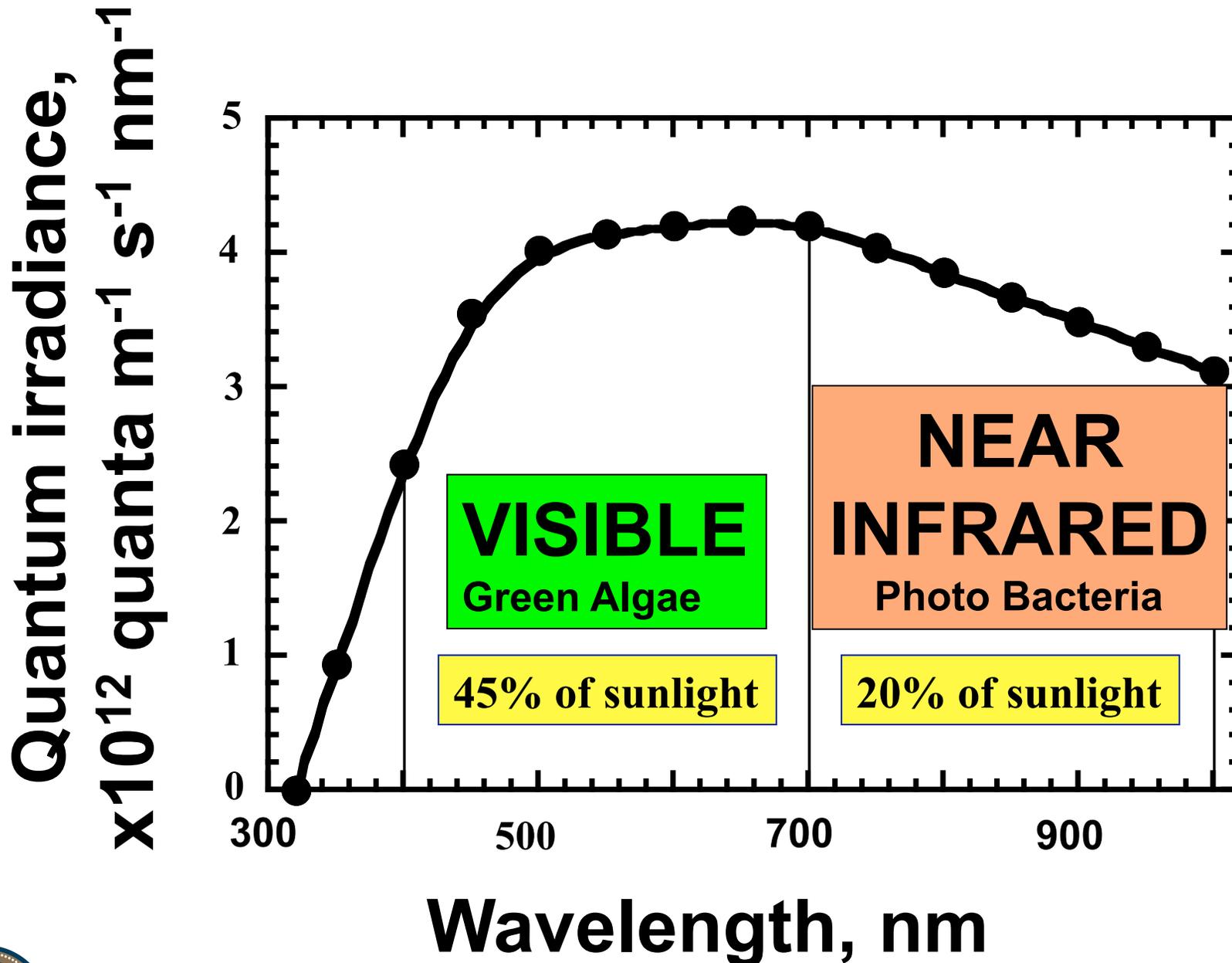
Sunlight:
Improved
intra~culture
energy flux



Photosynthesis and Photovoltaics



Sunlight absorption & utilization



A two-dimensional problem in sunlight utilization

- **Over-absorption and wasteful dissipation of excess sunlight at the surface.**
- **Steep gradients in sunlight penetration through a high density culture/canopy.**
- **Short range (400-700 nm) of photosynthetically active radiation.**
- **Possibility of extending PAR to 950 nm.**



Tools required

- **Transformation technologies for the genetic engineering of chloroplasts, microalgae and cyanobacteria:**
 - **Excellent in many cyanobacteria and in *Chlamydomonas reinhardtii*.**
 - **Poor in most other microalgae.**
 - **Species-dependent in vascular plants.**

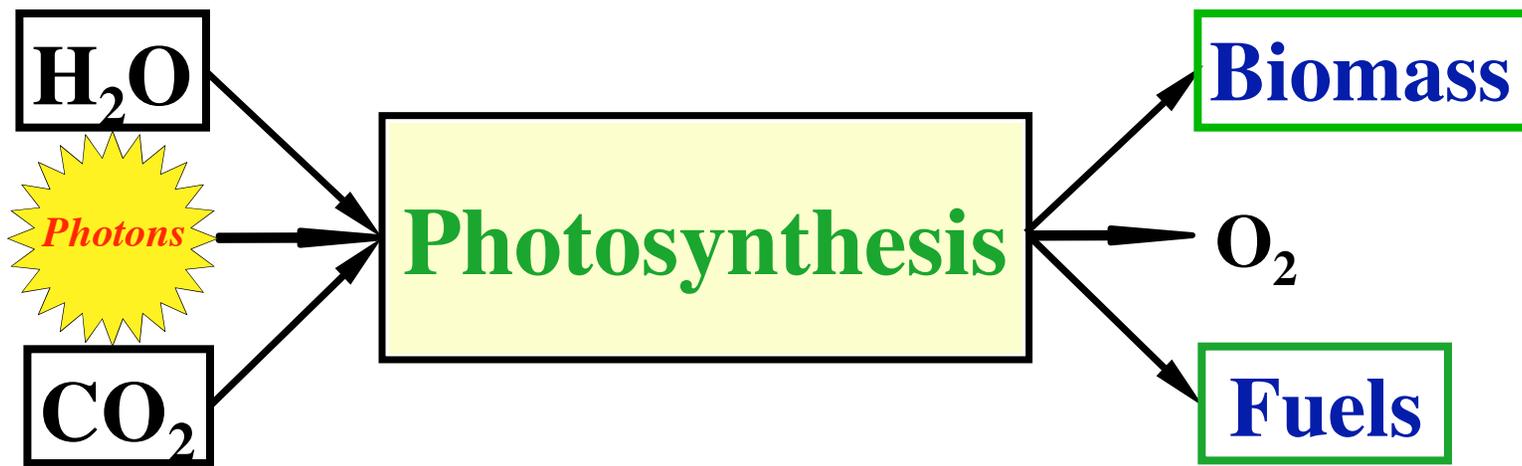


Benefits to be accrued

- **Substantially improved sunlight absorption and utilization.**



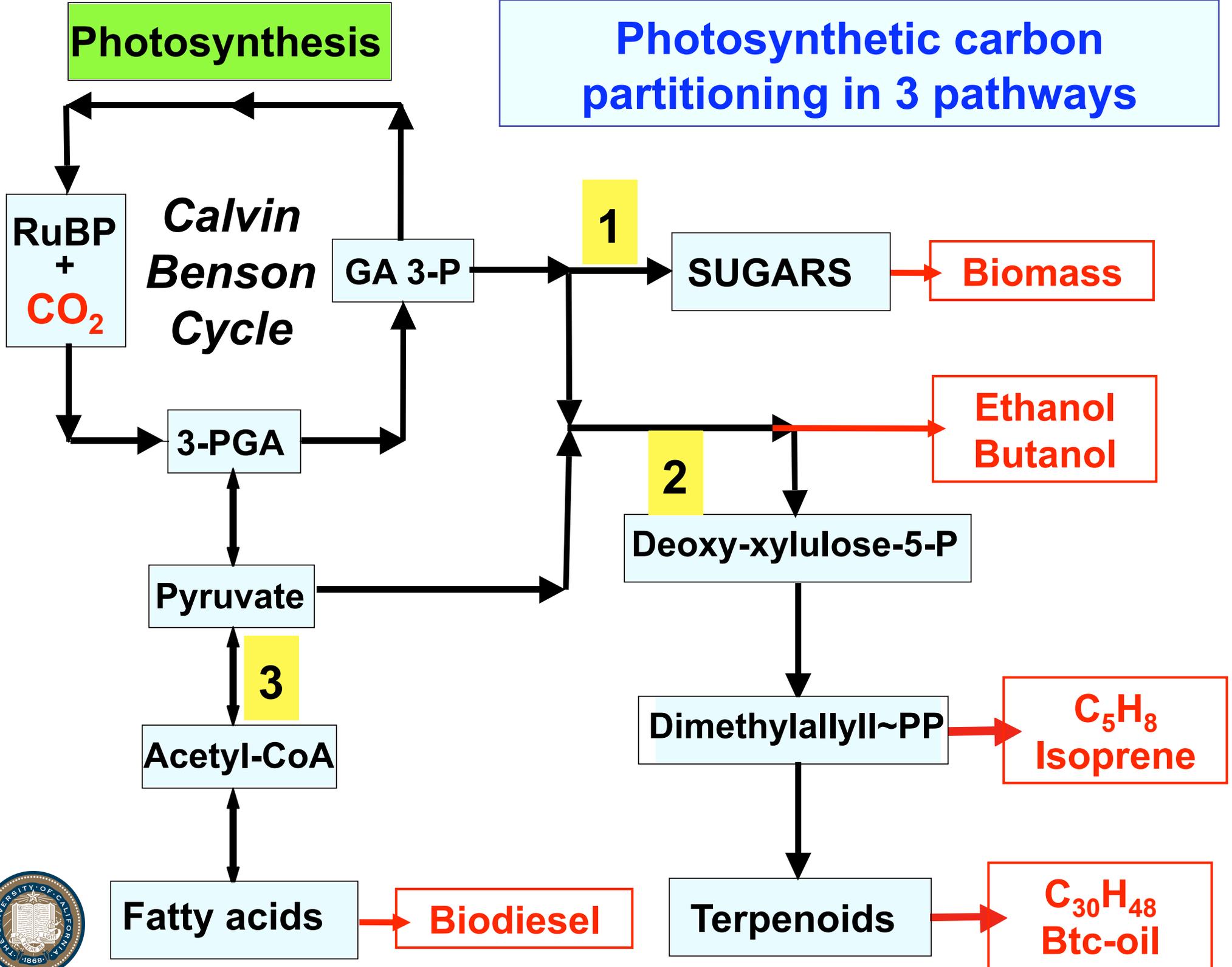
Feedstock and products



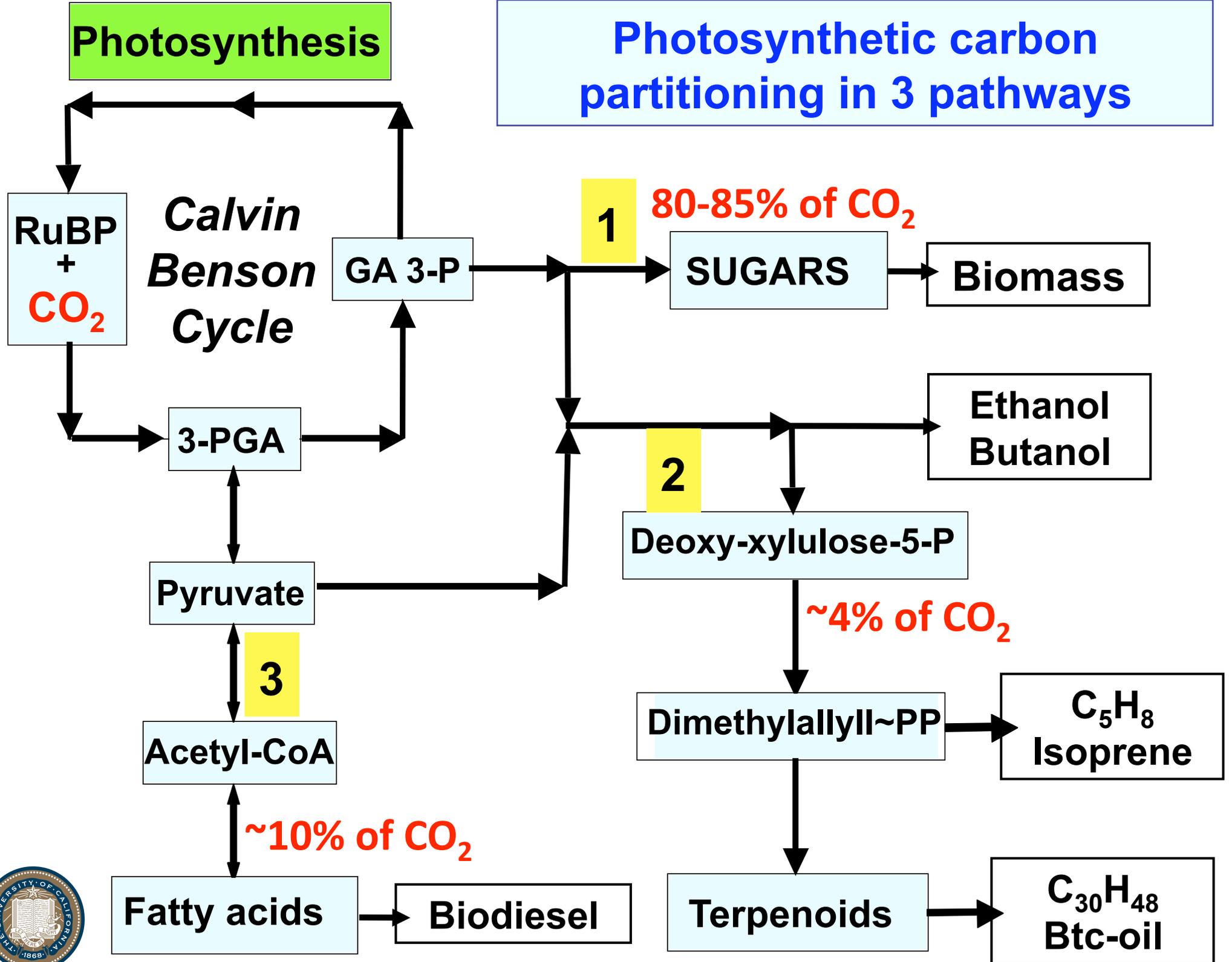
The problem of **carbon partitioning**
between fuel and biomass



Photosynthetic carbon partitioning in 3 pathways



Photosynthetic carbon partitioning in 3 pathways



Productivity Features

- **Fuel / Biomass** carbon partitioning ratios are currently low (they need to be greater than 20%)



Tools required

- **Metabolic engineering approaches to alter carbon flux toward fuel in photosynthetic organisms.**



Benefits to be accrued

- Enhancing the **Fuel / Biomass** carbon partitioning ratio improves the economics of the process.



**Thank you for your
attention**



Photosynthetic Productivities

Theoretical productivity:

$\sim 75 \text{ g DW m}^{-2} \text{ d}^{-1}$

(8-10% solar energy conversion efficiency)



Photosynthetic Productivities

Theoretical productivity:

$\sim 75 \text{ g DW m}^{-2} \text{ d}^{-1}$

(8-10% solar energy conversion E)

Measured productivities:

Less than $25 \text{ g DW m}^{-2} \text{ d}^{-1}$

(3-4% solar energy conversion E)

