Maximizing Photosynthetic Efficiencies and Hydrogen Production in Microalgal Cultures

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May 24, 2004

This presentation does not contain any proprietary or confidential information

Objectives and Approach

General Objective: Minimize the chlorophyll antenna size of photosynthesis to maximize light energy conversion efficiency in green algae.

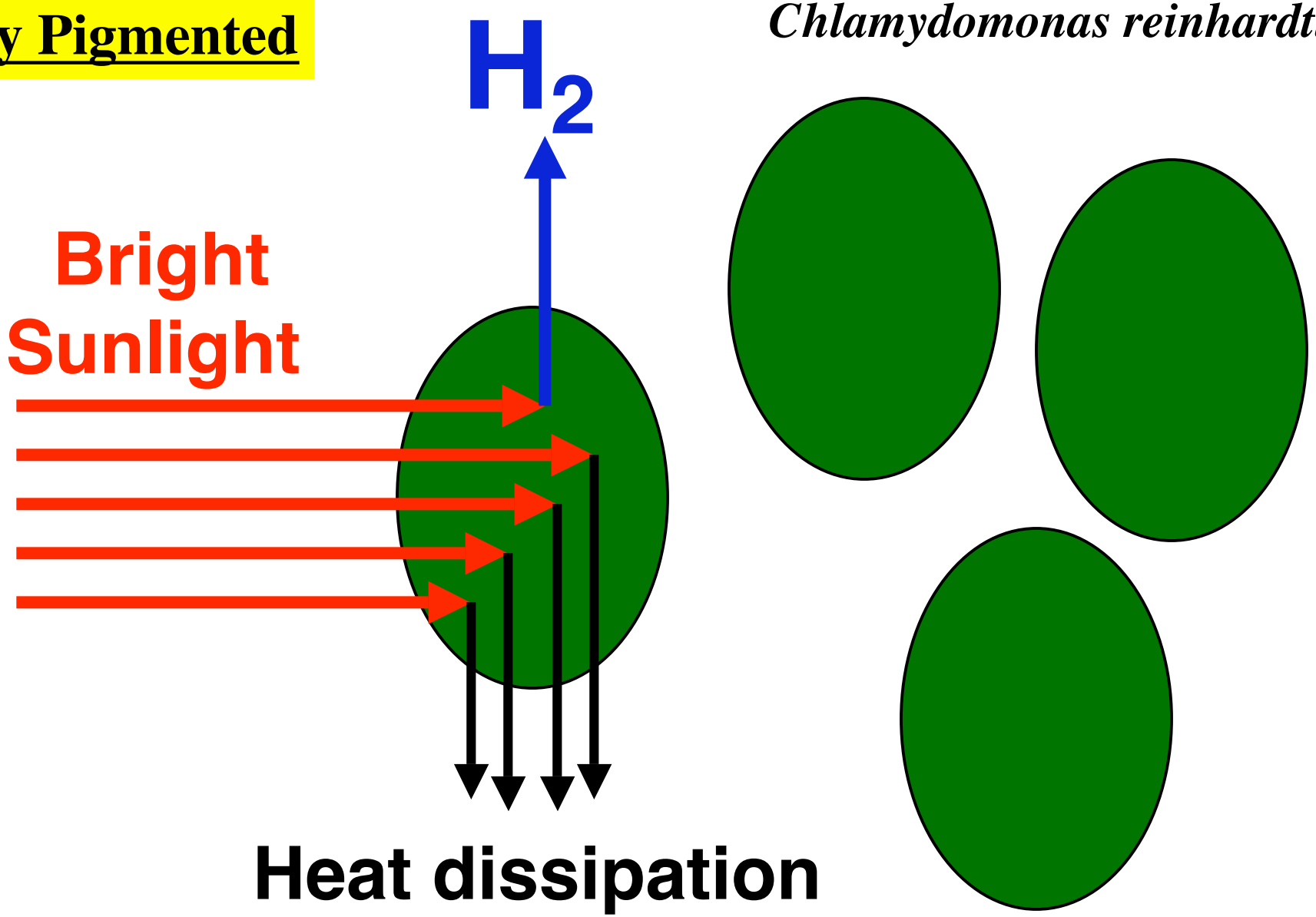
Approach: Employ DNA insertional mutagenesis and high-throughput screening methods to select tagged green algae with a smaller Chl antenna size.

Ancillary Objective: Identify and characterize genes that regulate the Chl antenna size in *Chlamydomonas reinhardtii.*

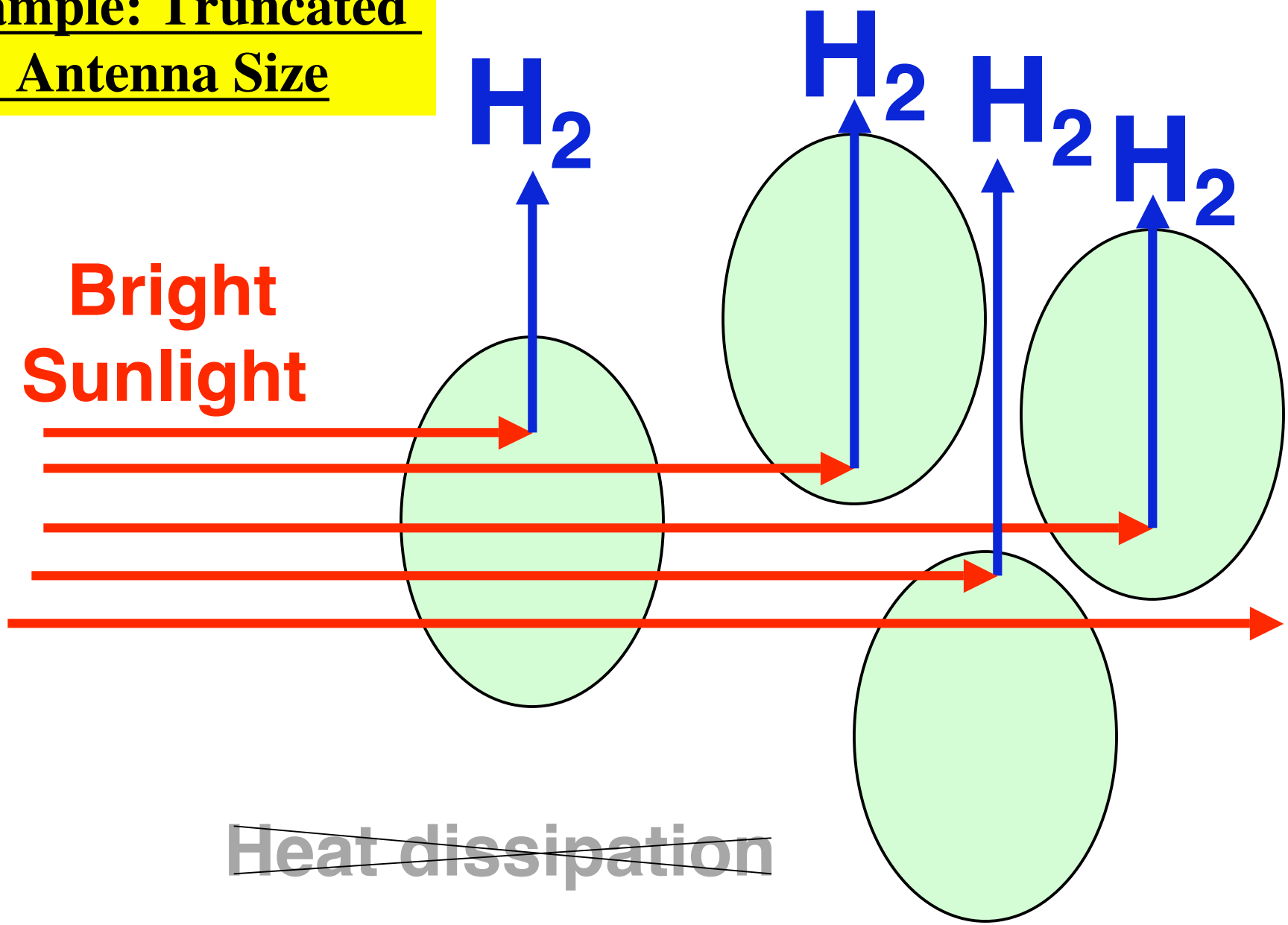
2004 Target: Achieve a 7.5% Utilization Efficiency of Absorbed Light Energy in green algal photosynthesis.

Example:
Fully Pigmented

The green algae
Chlamydomonas reinhardtii



Example: Truncated Chl Antenna Size



Benefits from this Project

Reducing the Chl antenna size of photosynthesis is needed for any effective use of microalgae in:

- **H_2 production,**
- **carbon sequestration,**
- **biomass accumulation,**
- **waste water treatment,**
- **other bio-fuels generation.**

Budget - FY 2004

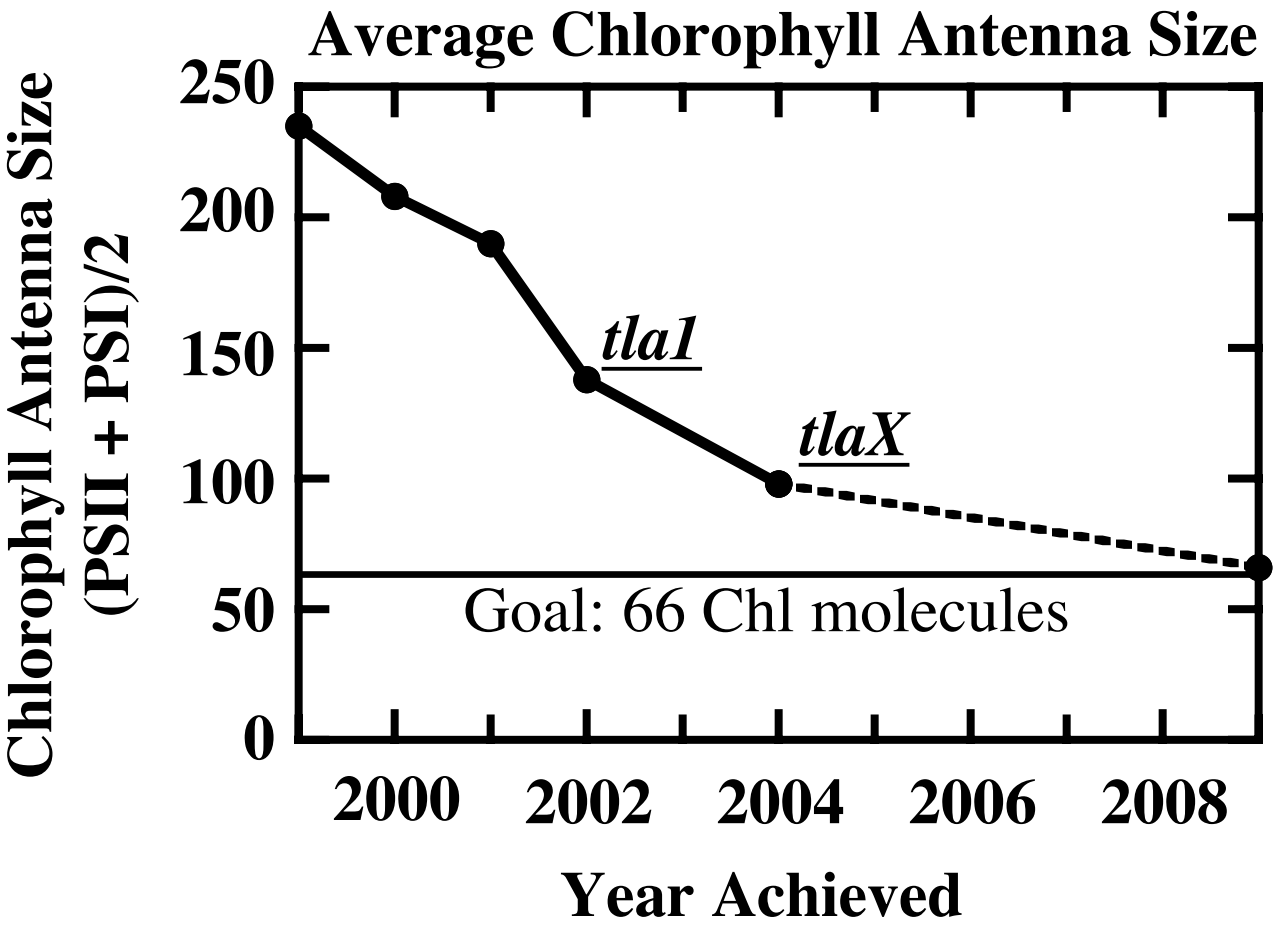
- **Total DOE: $ 200,000**
- **Direct: $ 131,200**
- **Indirect: $ 68,800 (Overhead)**

- **Cost Share (UC Berkeley): $ 50,000**

Technical Barriers and Targets

- **Barrier: Low Light Utilization Efficiency in Photobiological Hydrogen Production due to a Large Photosystem Chlorophyll Antenna Size (Barrier I).**
- **Topic: Topic 2 (Photolytic Processes), Sub-Topic 2B (Photobiological processes), Light Utilization Efficiency problem.**
- **Target for 2004: Reach a 7.5% Utilization Efficiency of Absorbed Light Energy.**

Project Timeline



Technical Accomplishments

Utilization Efficiency of Absorbed Light Energy

Target for 2004: 7.5%

- **Wild type antenna size = 235 Chl molecules (100%)**
  (PSII=230; PSI=240)
  Photon use efficiency of WT photosynthesis = ~10%
  Utilization Efficiency of Absorbed Light Energy by WT: ~5%

- ***tla1* antenna size = 138 Chl molecules (59% of control)**
  (PSII=115; PSI=160)
  Photon use efficiency of *tla1* photosynthesis = ~20%
  Utilization Efficiency of Absorbed Light Energy by *tla1*: ~10%

2004 Year Accomplishment

- ***tlaX* antenna size = 98 Chl molecules (42% of control)**
  (PSII=80; PSI=115)
  Photon use efficiency of *tlaX* photosynthesis = ~30%
  Utilization Efficiency of Absorbed Light Energy by *tlaX*: ~15%

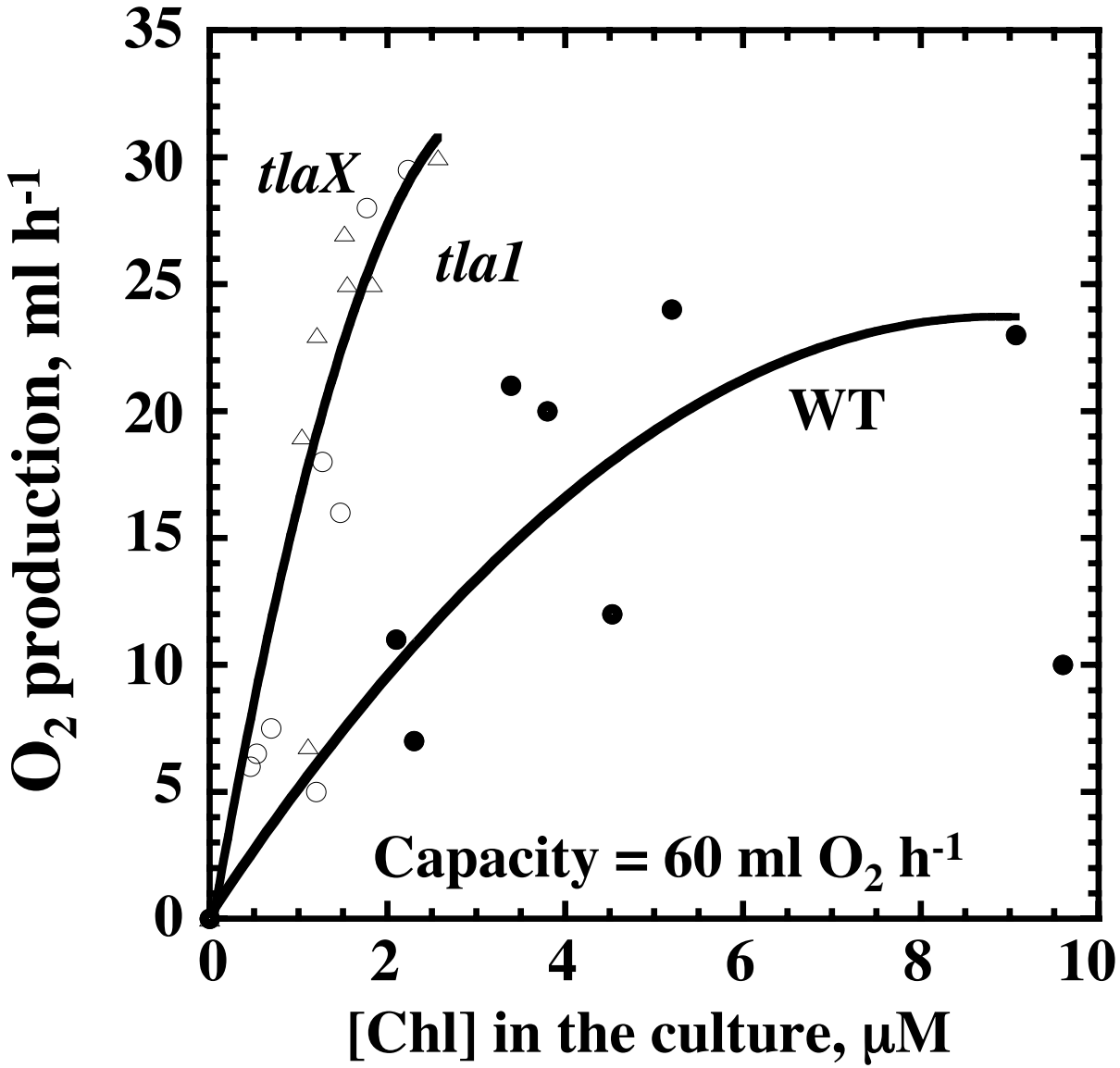
- **Long-term goal: 66 Chl molecules (28% of control)**
  (PSII=37; PSI=95)
  Photon use efficiency of photosynthesis *goal* = ~60%
  Utilization Efficiency of Absorbed Light Energy *goal*: ~30%

Measurement in Scale-up Cultures

WT

tla1

Productivity in Scale-up Cultures



Current State of the Art

Significant progress and ahead-of-schedule timeline in terms of acquiring "truncated Chl antenna size" mutants. *This demonstrates feasibility and suitability of the approach.*

Have completed characterization of the role of *Lhcb* and *CAO* gene expression in the regulation of the Chl antenna size.

Have not yet completed characterization of the *Tla1* and *TlaX* genes, neither do we know the mode by which these novel genes function in the regulation of the Chl antenna size in photosynthetic organisms.

Interactions and Collaborations

- Collaboration with NREL and ORNL

  (Made available to NREL and ORNL the *tlaX* truncated Chl antenna mutant for use in their Photobiological Hydrogen Production project.)

- Interactions with the Chrysler Corporation

  (Recipient of a Chrysler "University Research Opportunity Award". Advising the Technical Affairs division of DaimlerChrysler on matters of Hydrogen Biotechnology.)

Responses to Previous Year Reviewers Comments

- ***Is automated lab equipment available that would be of significant help in moving project forward?***

  My lab is well provided with automated equipment for the **Chl antenna size analyses** (**sole source**), as well as for the conduct of biochemistry, biophysics and molecular genetics RD&D. Moreover, UC Berkeley operates specialized facilities (**automated DNA sequencing, polyclonal antibody generation, microscopic imaging, greenhouses** etc.). These subsidized facilities serve to support research efforts on campus. In addition, this project in my lab further benefits from the recent sequencing of the *Chlamydomonas reinhardtii* genome by the **DOE's Joint Genome Institute** in nearby Walnut Creek, CA.

- ***Is cost and effectiveness easily justified?***

  In addition to the direct cost sharing, this project is further supported by the University in the form of **relatively low overhead and subsidized facilities**. This is possible because of the **instructional and training mission** of this public institution. As a result, progress is achieved at a fraction of the cost that would be required by government laboratories or industry.

Future Work

Remainder of FY 2004

1. **Advance the biochemical and molecular characterization of the *tlaX* strain. Publish *tla1*- and *tlaX*-related analyses.**

FY 2005 and Beyond

1. **Functionally characterize the corresponding *tla1* and *tlaX* genes (how do they work?)**
2. **Establish transformation (sense and antisense) protocols with *Tla*-type genes to further down-regulate the Chl antenna size in *Chlamydomonas reinhardtii.***
3. **Perform comparative green-alga light utilization efficiency and photosynthetic (H_2) productivity measurements under mass culture conditions in wild type and *Tla*-type mutants.**
4. **Perform genetic crosses to combine different *tla*-type properties.**

Safety Aspects

- **Identification and discussion of safety vulnerability techniques used in the analysis of the design and operation of equipment for this project**: Pressurized cylinders with hydrogen, helium and argon that are employed in the conduct of this work are safely anchored in appropriately designed berth spaces.

- **Identification of management of change process used for the project**: Training in general, and specific aspects of safety for this project, is mandatory for all employees in this department. The small amounts of H_2 involved in this work do not entail any special precautions.

- **Other safety-related insights benefiting the project and/or of potential application to other projects, e.g. experiences with management of change (MOC) procedures**: None