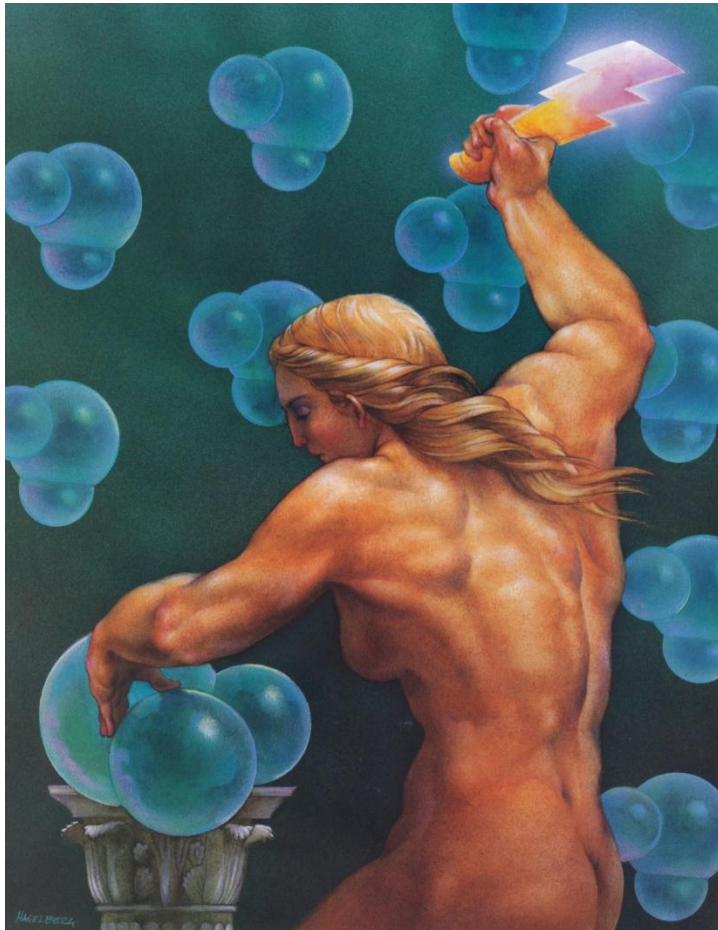


# Solar Fuels from Artificial Photosynthesis



michael.hagelberg@gmail.com

**Devens Gust**  
*Department of Chemistry  
and Biochemistry  
Arizona State University  
Tempe, AZ 85287-1604 USA*

**ASU Center for Bio-Inspired  
Solar Fuel Production**

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# Why do we need new energy sources?

- **Almost all our energy comes from burning fossil fuels.**
- **Why is this a problem?**
  - **Fossil fuel deposits are generally not located where the fuel is used, leading to geopolitical problems.**
  - **Combustion generates CO<sub>2</sub>, a greenhouse gas that contributes to climate change, and other pollutants.**
  - **Burning fossil fuels is not sustainable: eventually, we will run out.**

# What are the alternatives?

- **The size of the problem limits possible solutions**
  - Current human energy usage: ~14 Terawatts
  - 1 TW =  $10^{12}$  W = 10 billion hundred-watt light bulbs, all burning at once
- **The only practical solution - solar energy**
  - Rate of delivery of solar energy to earth is 12,000 TW
  - USA usage = ~3 TW
  - World requirement in 2050 = ~28 TW



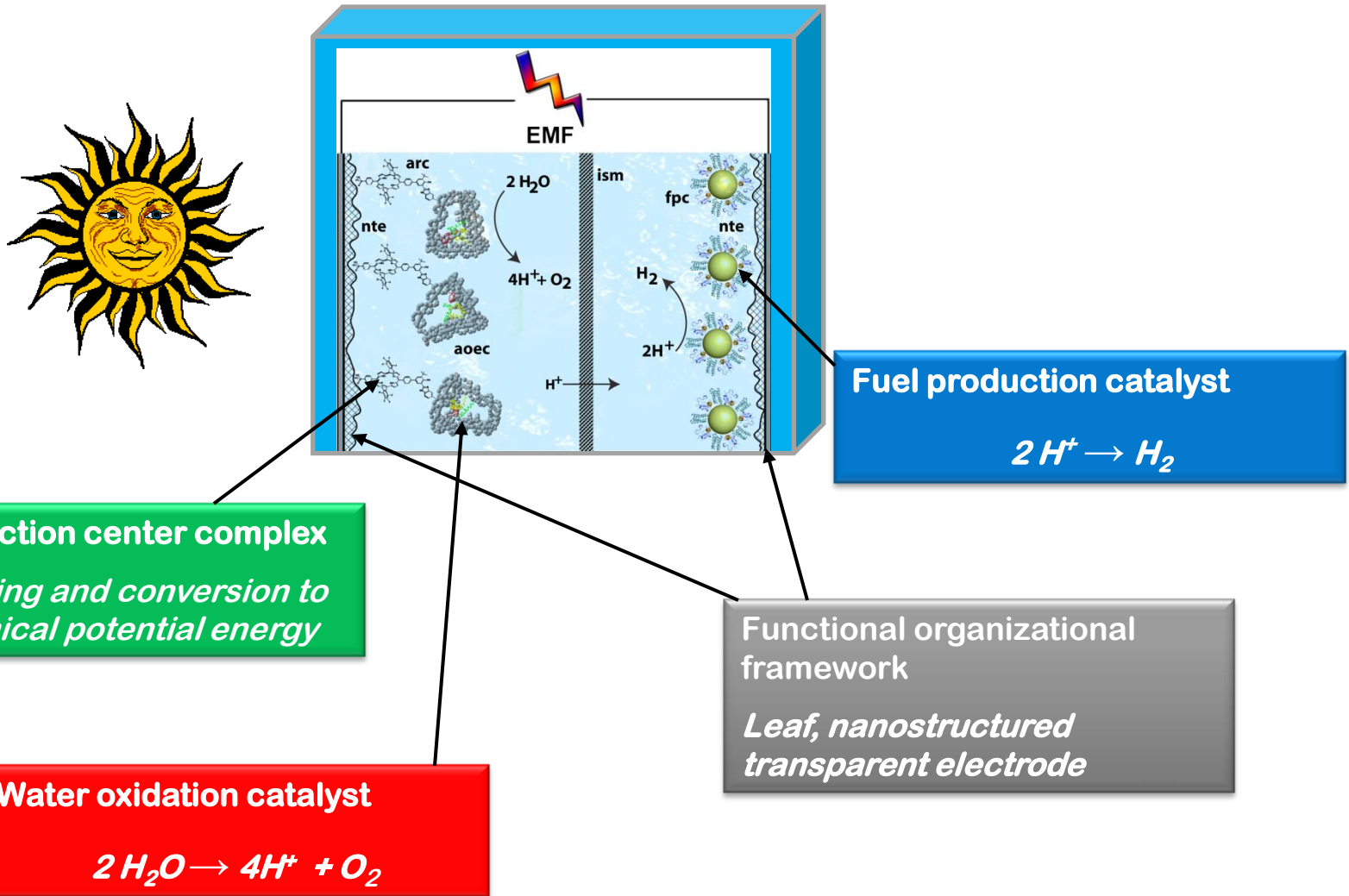
# Why solar fuels?

- Technology for solar electricity exists (but is expensive).
- We also need fuel because
  - Energy storage is necessary
  - Solar energy is diffuse
    - Light weight, energy dense fuels are needed for transportation
- In addition to sunlight, fuel production requires electrons and material to reduce to fuel
  - Water is the best source
- Best bets for solar fuel
  - Hydrogen gas
    - Easier
    - No carbon emissions when used
    - New infrastructure required
    - Dense storage required for transportation
  - Liquid fuels from CO<sub>2</sub> reduction
    - Harder
    - Carbon emissions when used
    - Easily adapted to current distribution system

# Pathways to solar fuels

- **Biofuels**
- **Artificial photosynthesis**
  - Exploiting the physics and chemistry underlying photosynthesis for technological purposes
  - This is the approach of the ASU Center for Bio-Inspired Solar Fuel Production
    - A fundamental research project – still basic science

# Components of a solar fuel production system (natural or artificial)

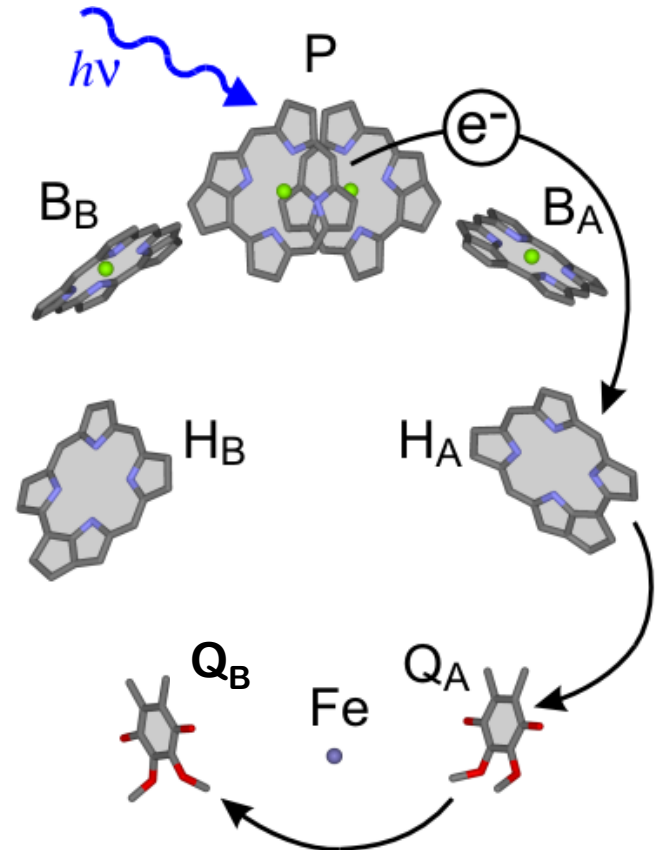


# An example: reaction center – the heart of photosynthesis

Reaction center from a  
photosynthetic bacterium

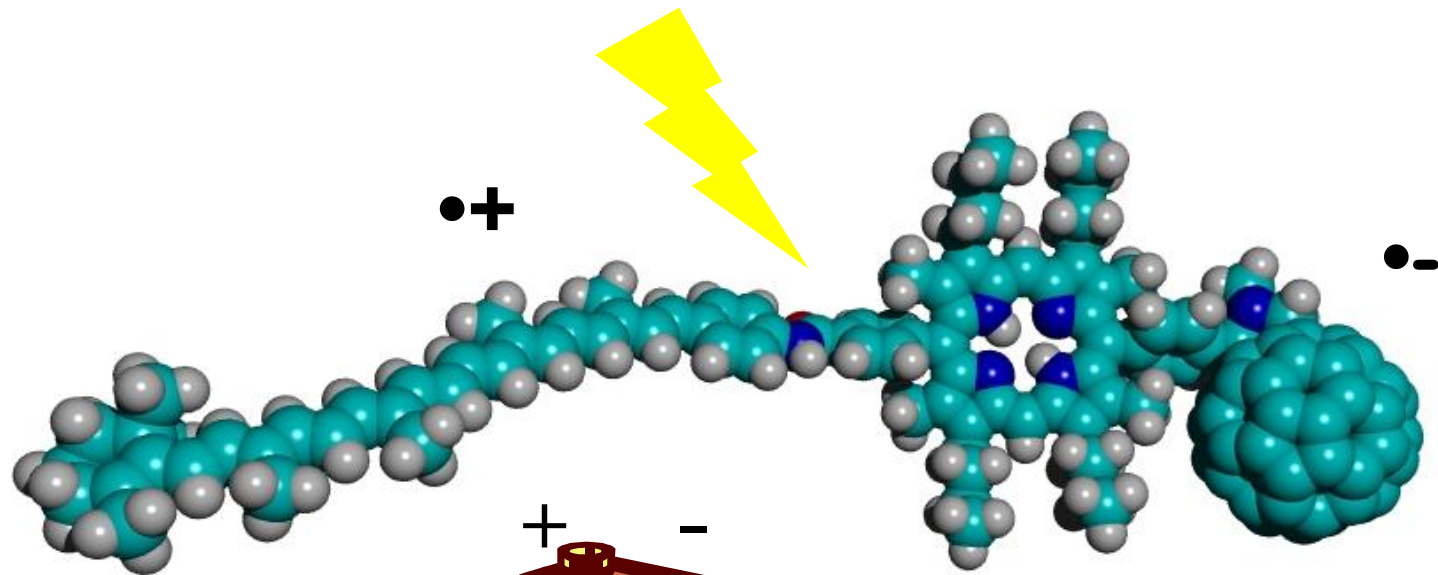


N. Woodbury, Department of Chemistry and  
Biochemistry, Arizona State University

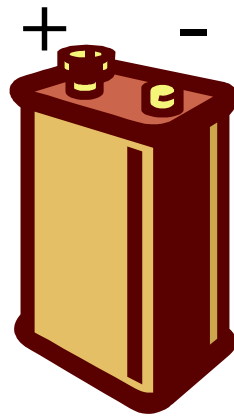


<http://www.fuchs-research.net>

# Artificial reaction centers



Molecular photovoltaic

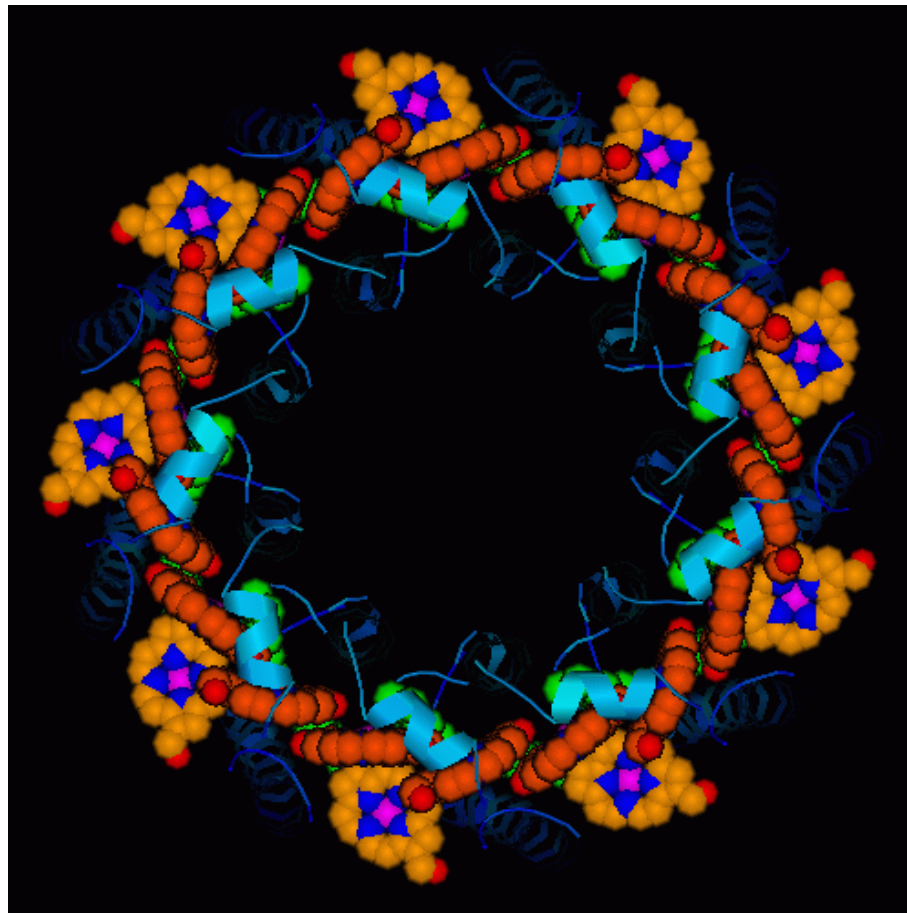




# Antenna systems

## LH2 Photosynthetic antenna

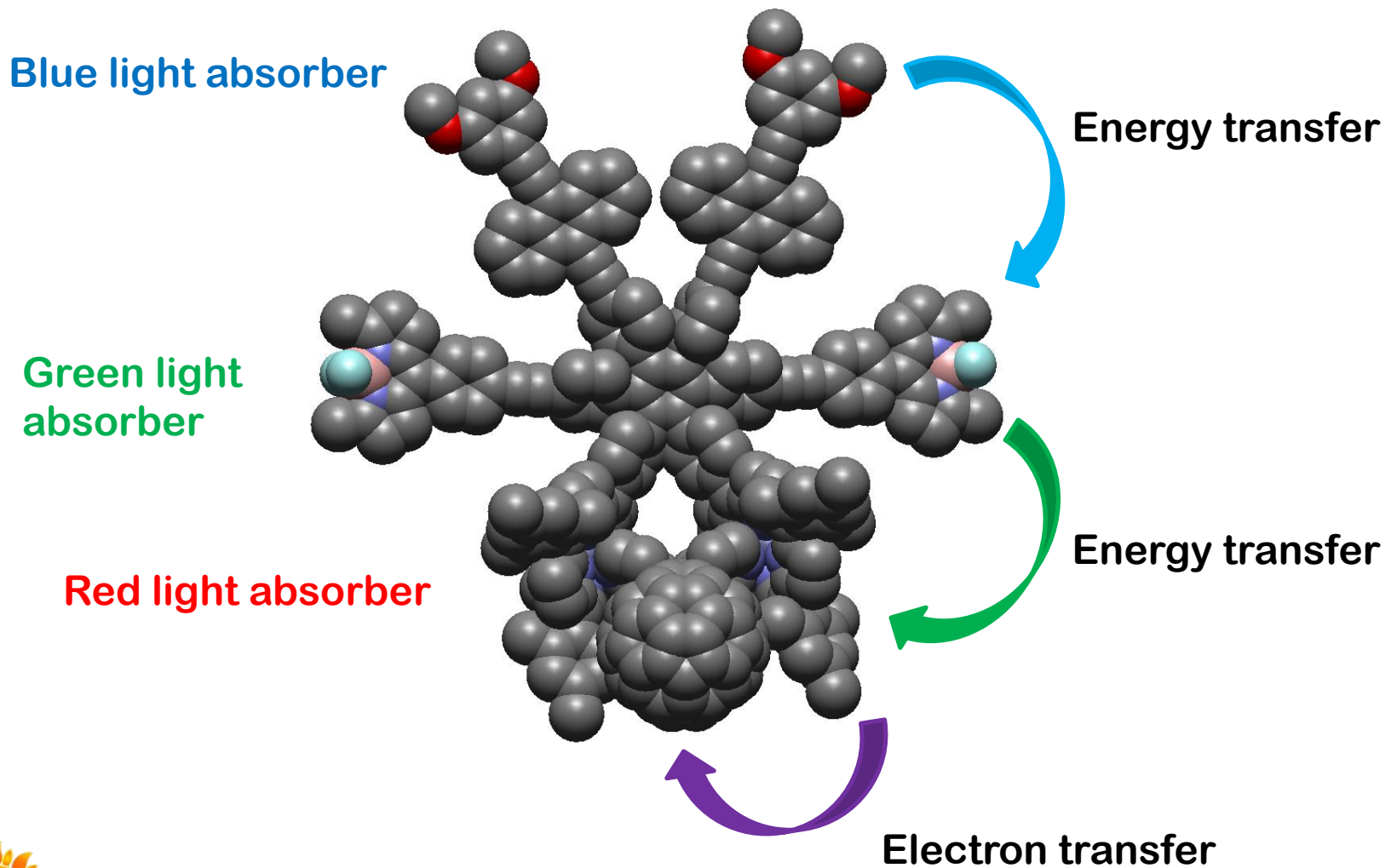
*Rhodospseudomonas acidophila*



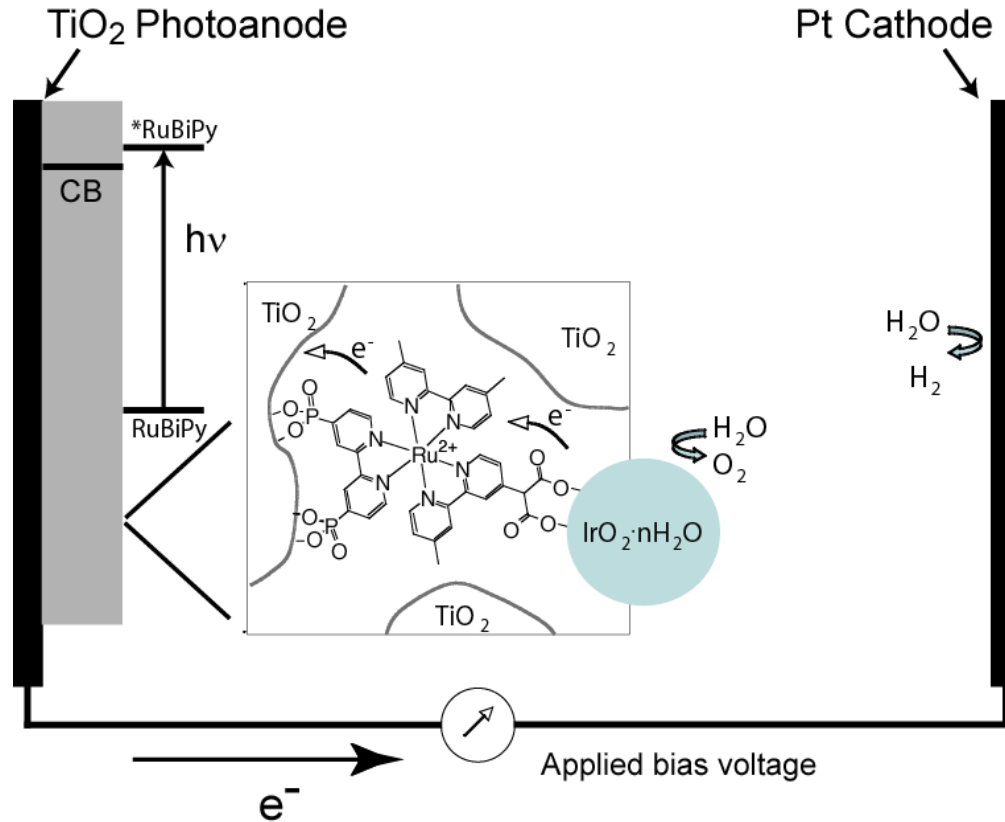
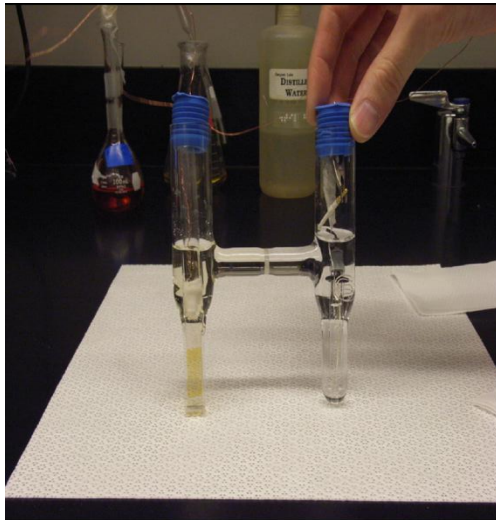
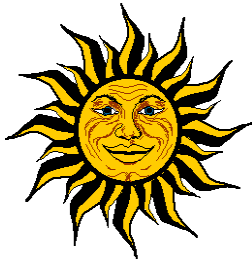
R. Cogdell

N. Isaacs

# Artificial antenna – RC complex



# An artificial photosynthetic solar hydrogen production system



W. J. Youngblood, S.-H. A. Lee, Y. Kobayashi, E. A. Hernandez-Pagan, P. G. Hoertz, T. A. Moore, A. L. Moore, D. Gust, T. E. Mallouk, *J. Am. Chem. Soc.*, 2009, 131, 926-927

**Φ ~ 0.9 %, additional potential needed, uses rare element, not particularly stable**

# Current status of artificial photosynthesis

- In principle, advantages are
  - Greater efficiency than photosynthesis
  - Inexpensive components
  - No requirement for arable land
  - Little water usage, except as electron and proton source
  - No greenhouse gas emissions (cyclic for CO<sub>2</sub> reduction)
  - Essentially inexhaustible, large capacity
- But – still a basic research problem