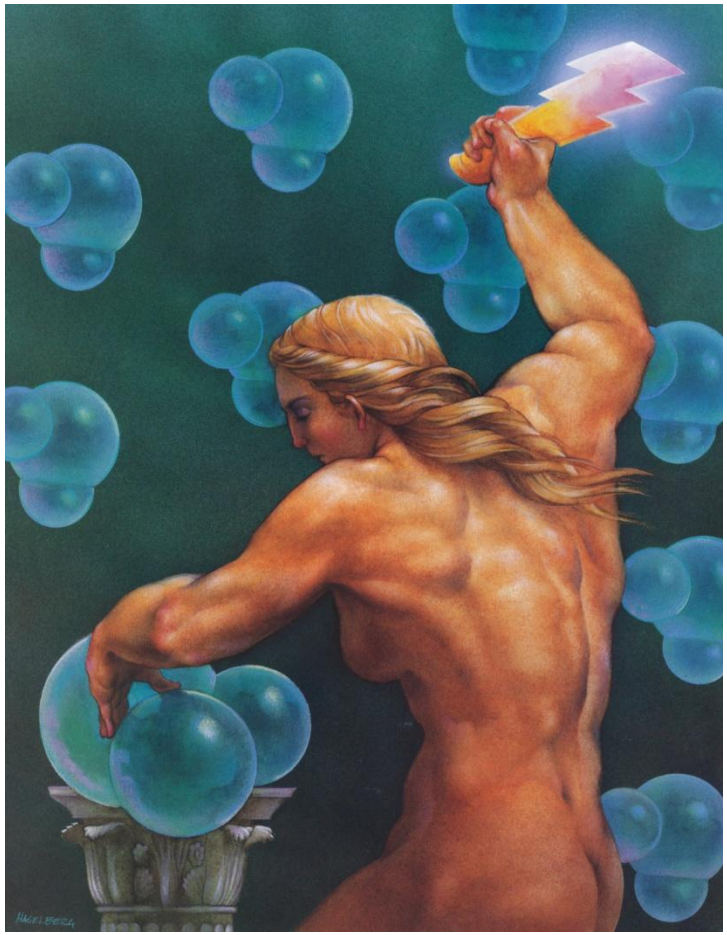
Solar Fuels from Artificial Photosynthesis



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ASU Center for Bio-Inspired Solar Fuel Production

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BISfuel

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_2, a greenhouse gas that contributes to climate change, and other pollutants.
  - Burning fossil fuels is not sustainable: eventually, we will run out.

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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

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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_2 reduction
    - Harder
    - Carbon emissions when used
    - Easily adapted to current distribution system

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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

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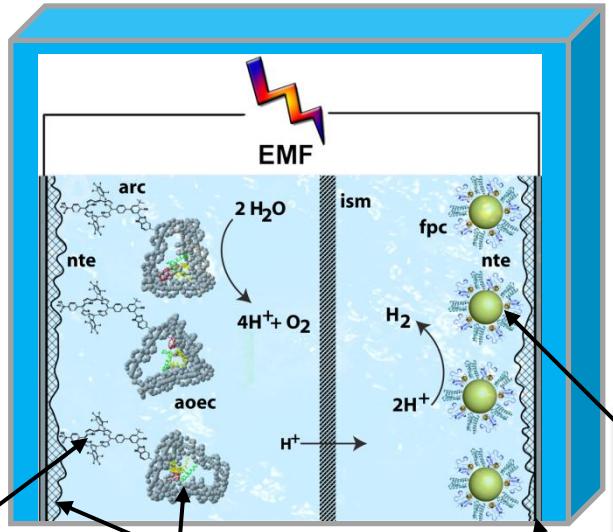
Components of a solar fuel production system (natural or artificial)



Fuel production catalyst

$2H^+ \rightarrow H_2$

Antenna-reaction center complex

Light gathering and conversion to electrochemical potential energy

Functional organizational framework

Leaf, nanostructured transparent electrode

Water oxidation catalyst

$2H_2O \rightarrow 4H^+ + O_2$

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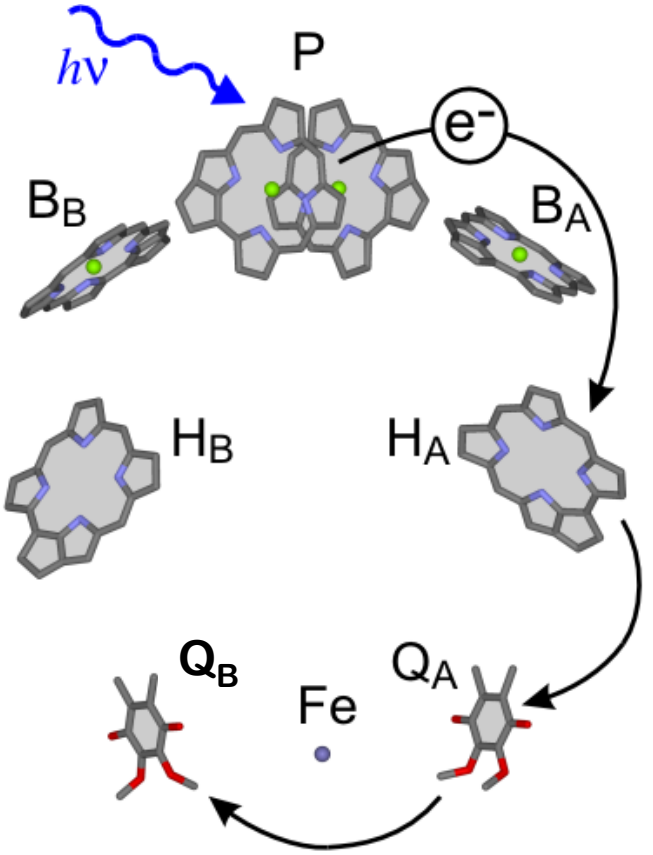
An example: reaction center – the heart of photosynthesis

Reaction center from a photosynthetic bacterium

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



http://www.fuchs-research.net

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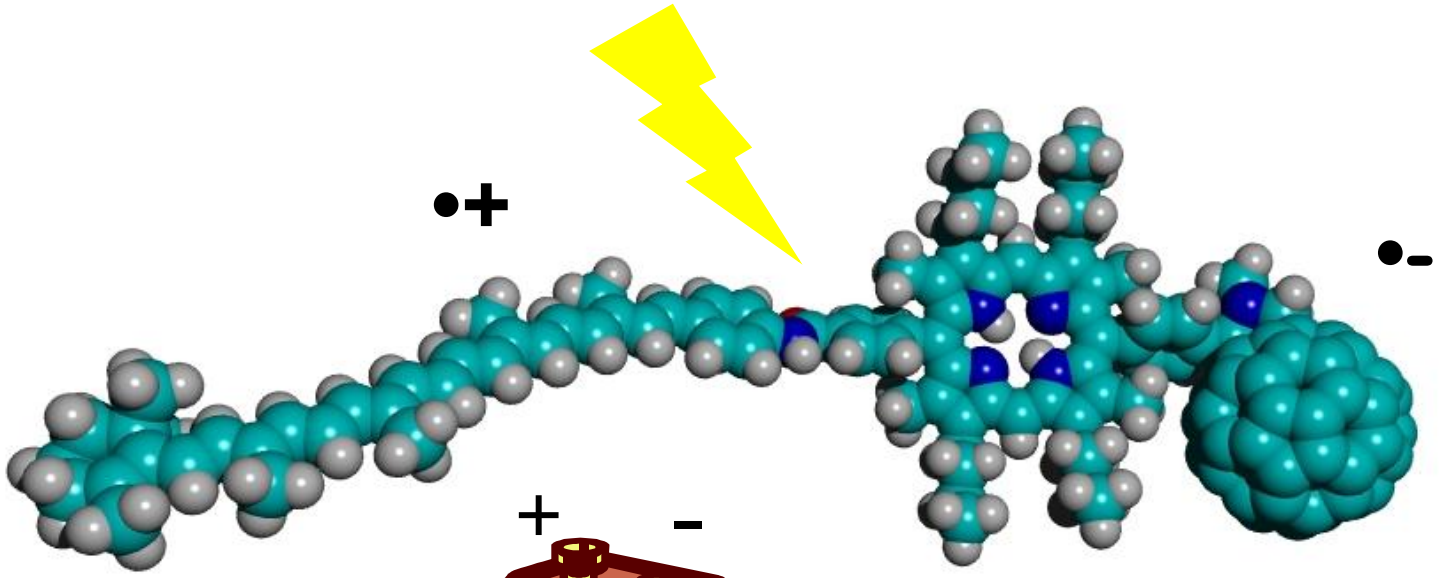
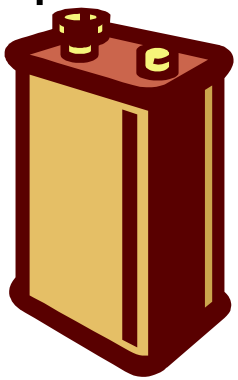
Artificial reaction centers





Molecular photovoltaic

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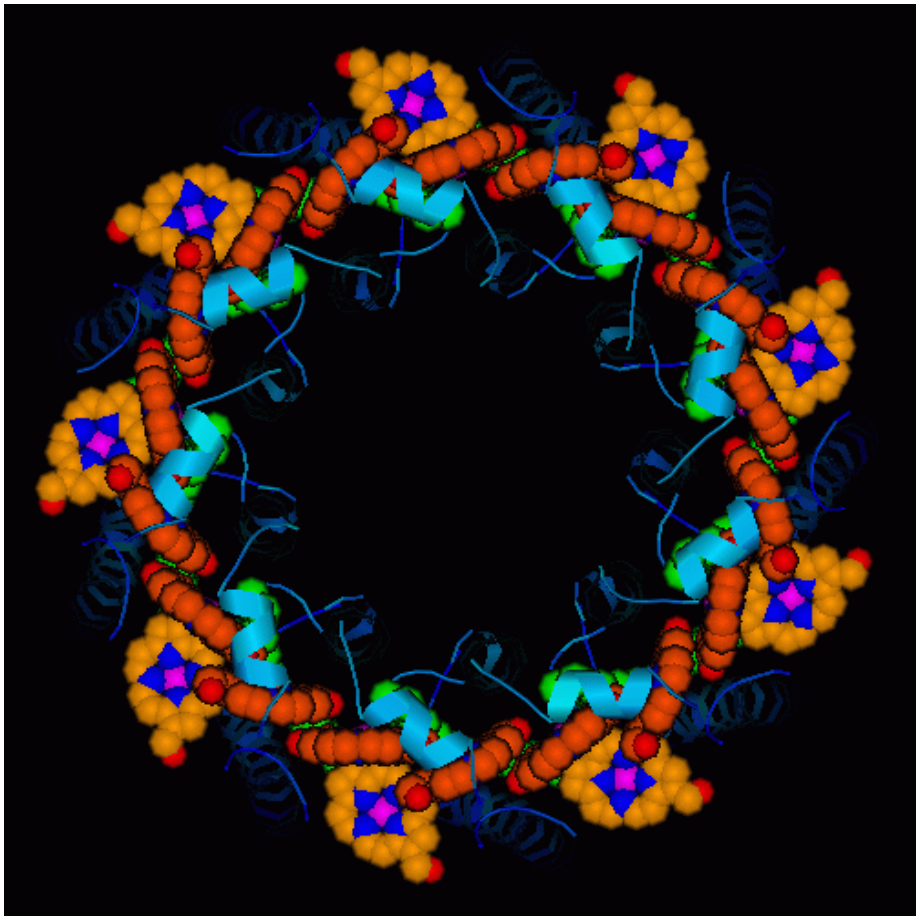
Antenna systems

LH2 Photosynthetic antenna

Rhodopseudomonas acidophila



R. Cogdell

N. Isaacs

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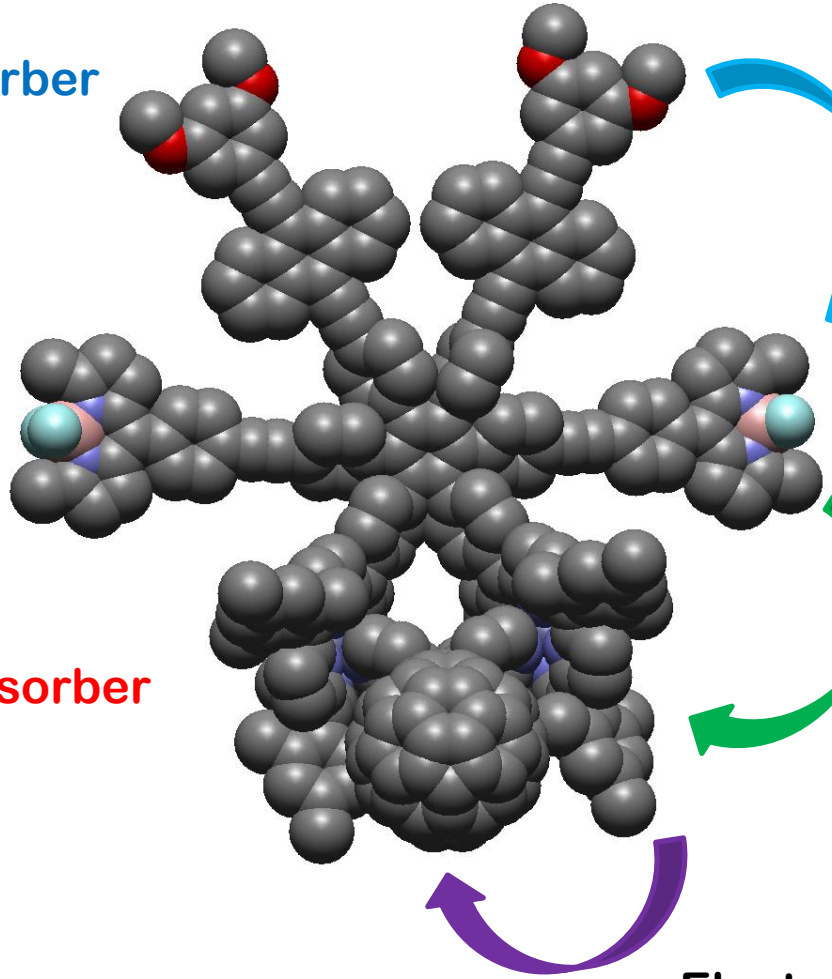
Artificial antenna – RC complex



Blue light absorber

Green light absorber

Red light absorber

Energy transfer

Energy transfer

Electron transfer

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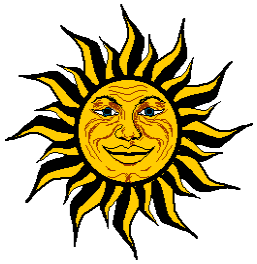
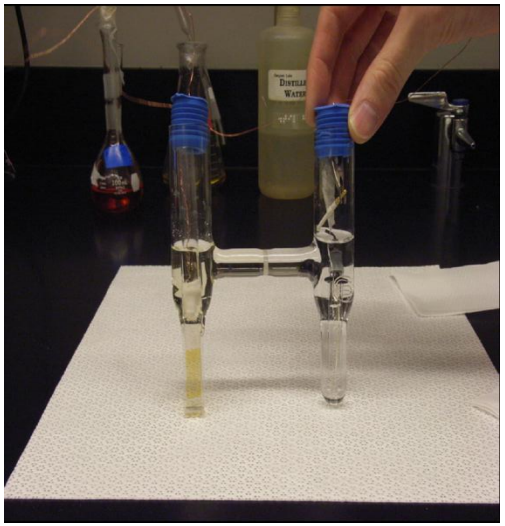
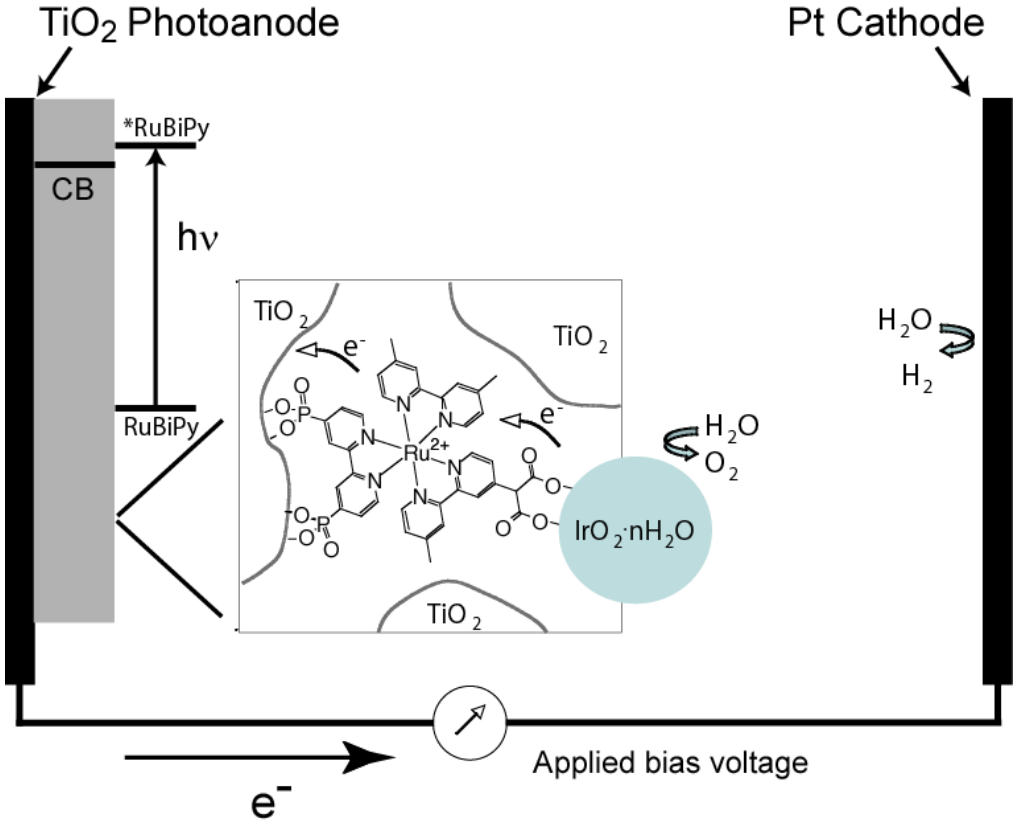
An artificial photosynthetic solar hydrogen production system







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

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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_2 reduction)
  - Essentially inexhaustible, large capacity
- But – still a basic research problem

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