# The Helios Project

by

Elaine Chandler

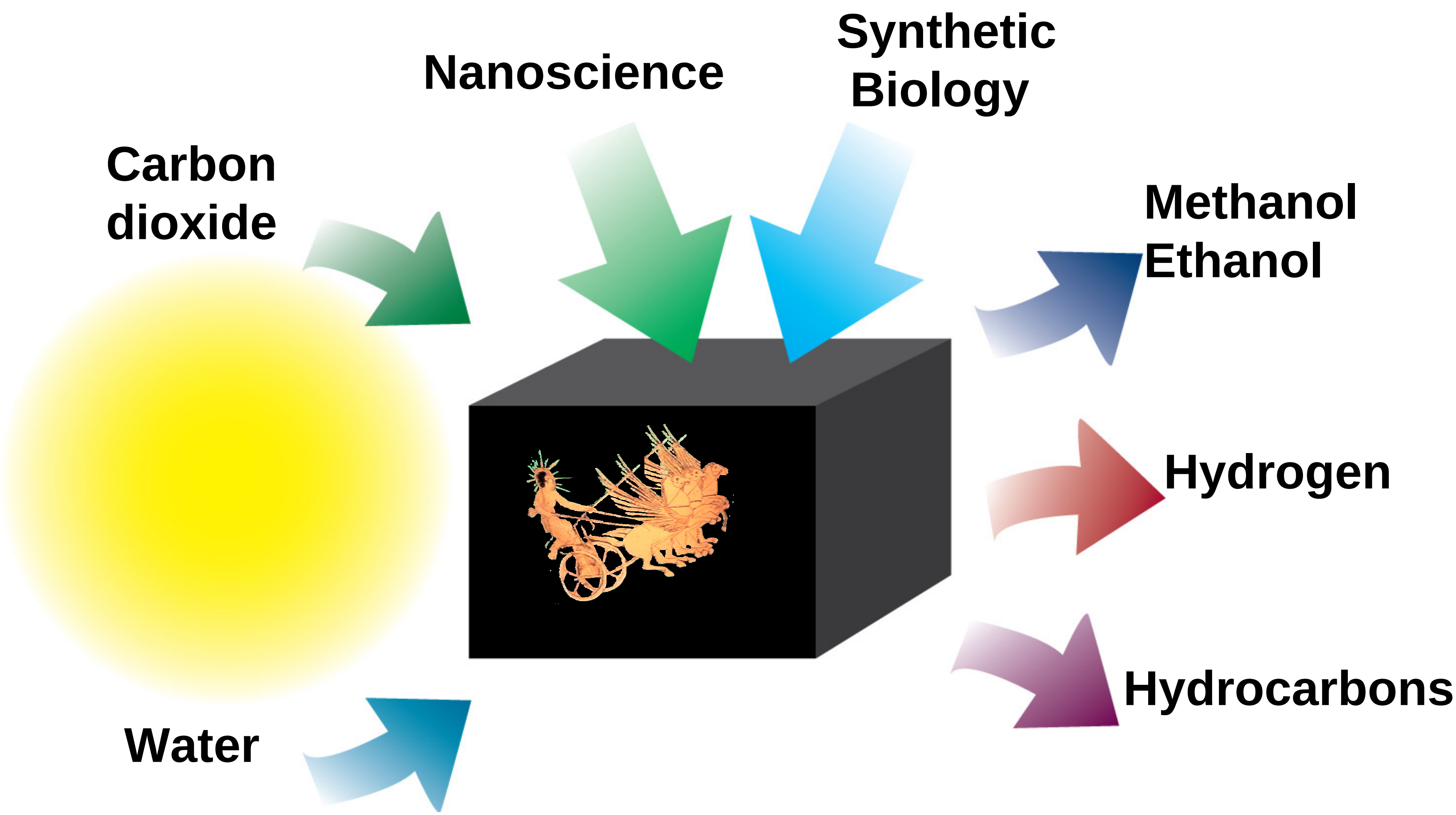
Lawrence Berkeley National Laboratory

To

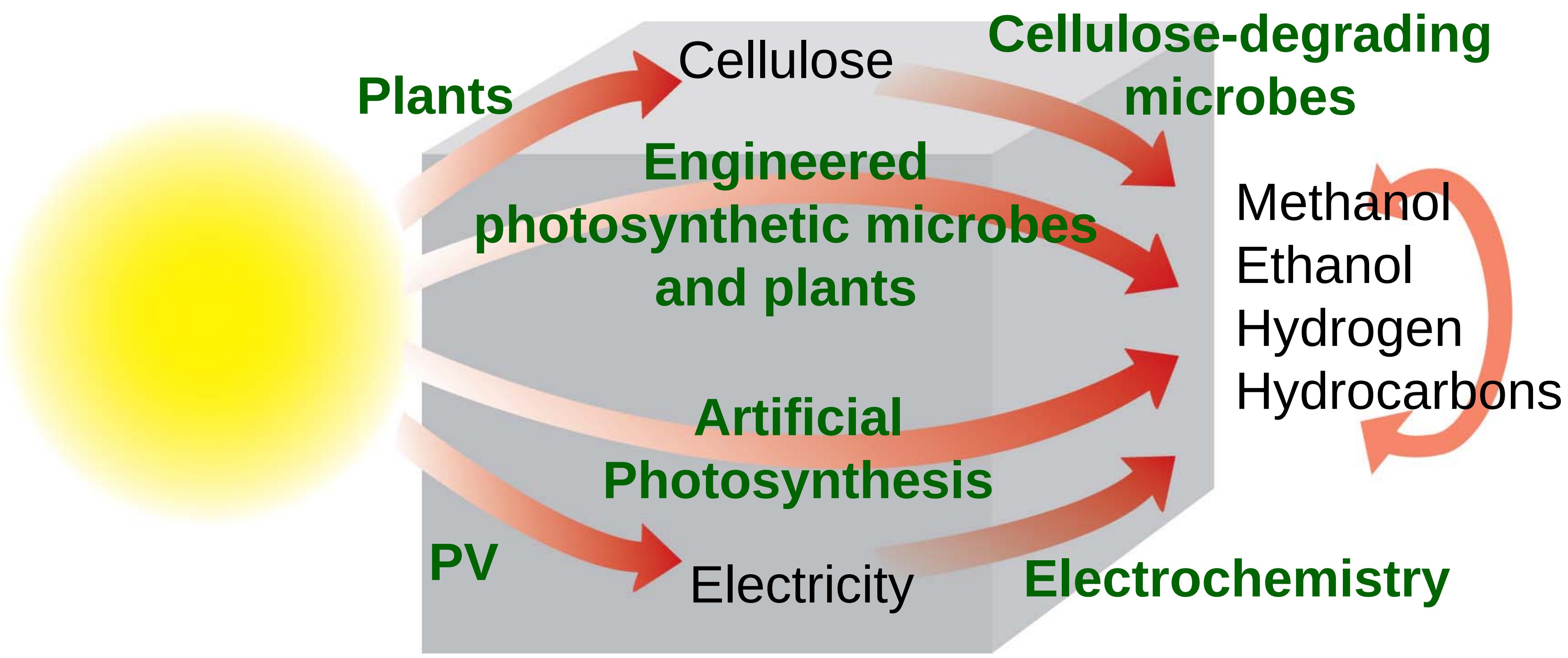
Guests from Innovation Center Denmark

February 1, 2007

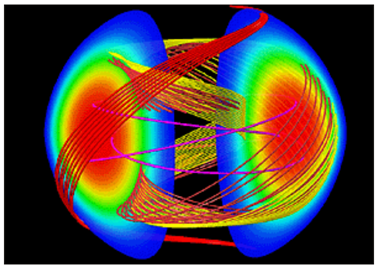
# Helios


Nanoscience
Synthetic
Biology
Carbon
dioxide
Methanol
Ethanol
Hydrogen
Hydrocarbons
Water

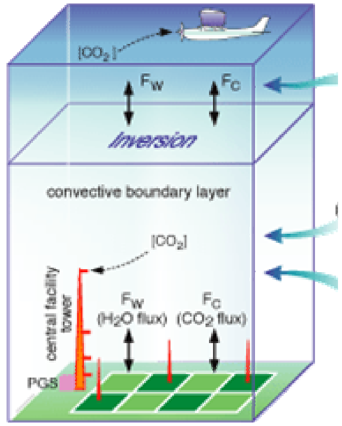
# Helios project overview: The four paths



# Berkeley Lab

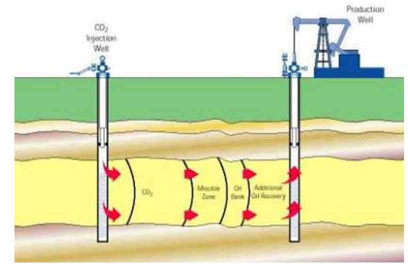


Fusion




Atmospheric studies

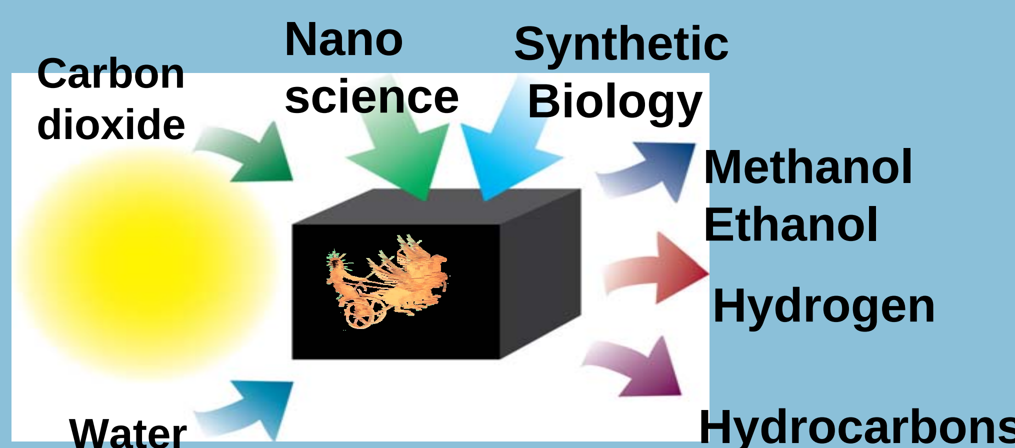
Geothermal



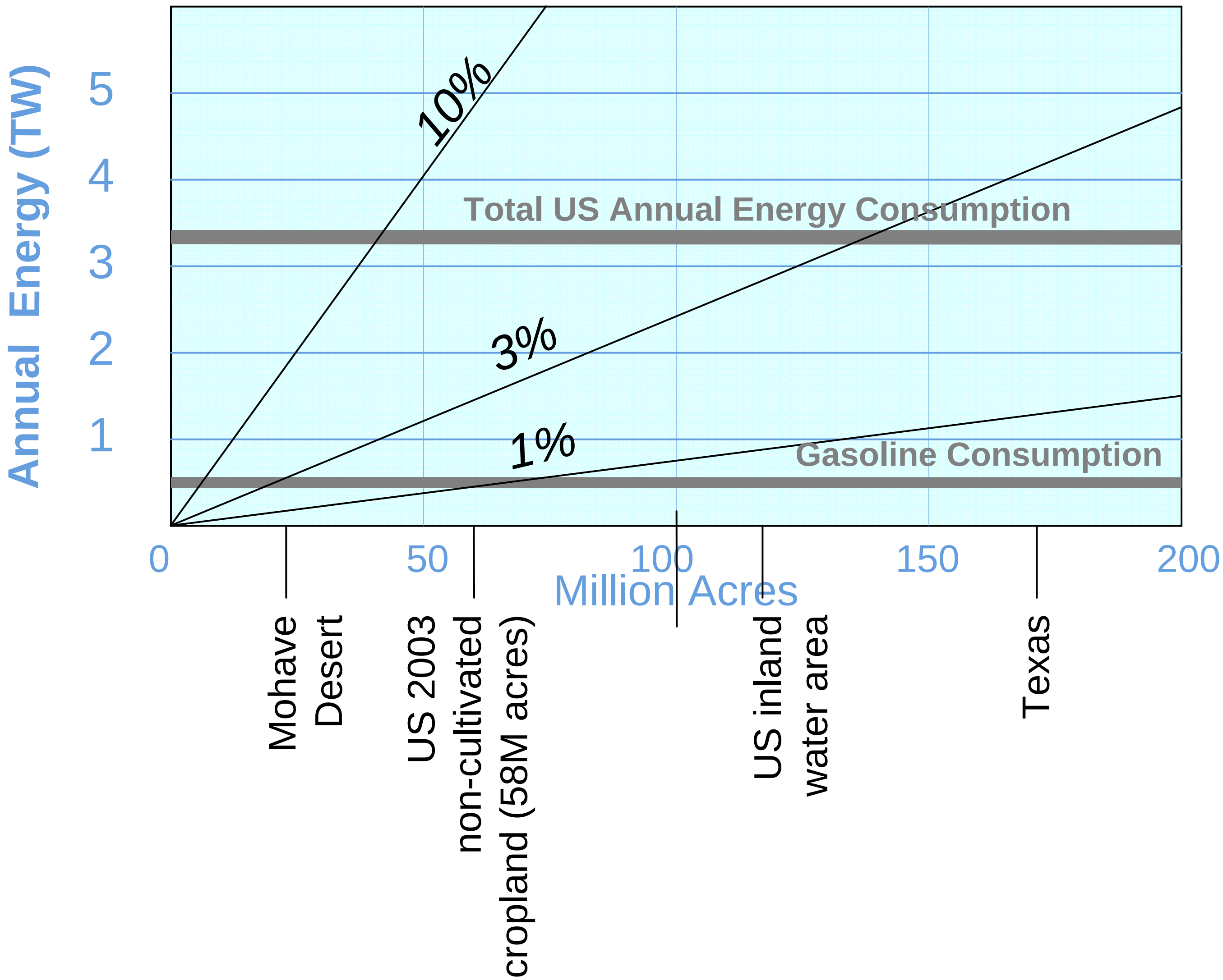
Fossil recovery & carbon sequestration

Building, Lighting, Home Appliance Standards

## Helios



# Solar efficiency and land usage

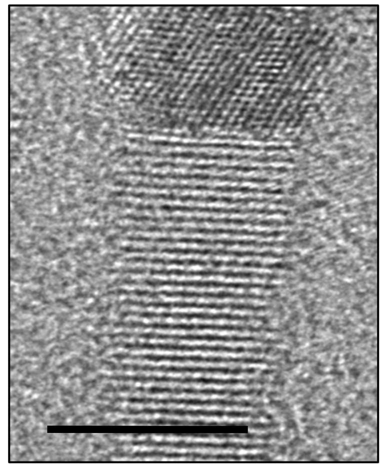



Total land area in contiguous US is 2,248 million acres

# There are significant benefits to going small

From the de Beers educational web site:


"Big diamonds are much rarer, so a diamond of double the weight costs around 4 times more. "




- Perfect building blocks at low cost
- Atomic level observation and control of essential interfaces
- Control of microscopic phenomena,
  e.g. scattering, energy dissipation, e-fields…

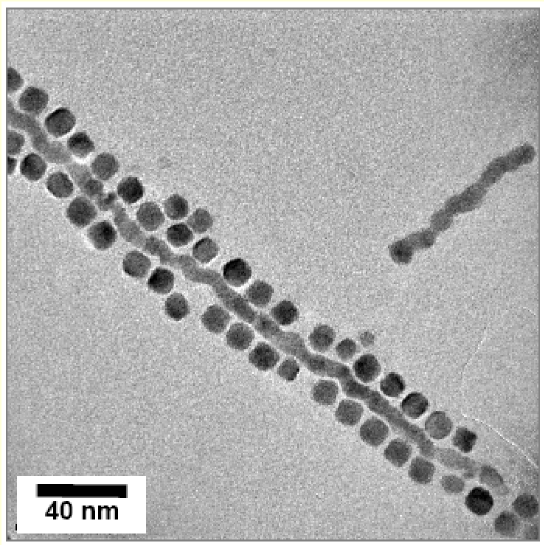
# Photovoltaics

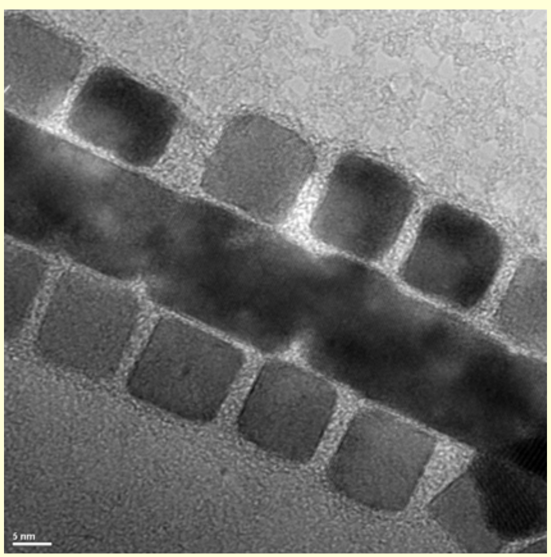


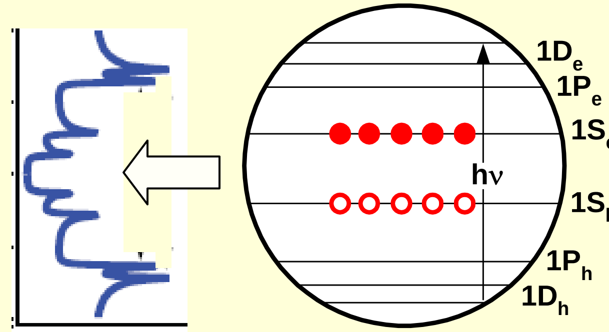
## New physical phenomena in nanoscale PVs

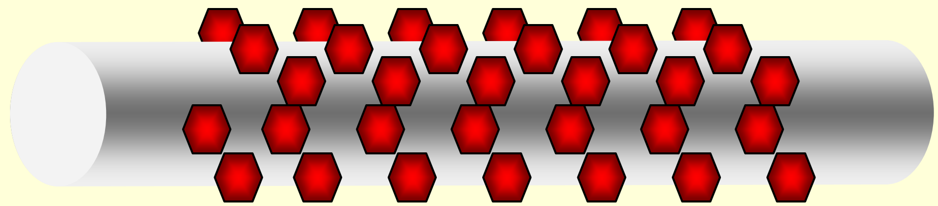
- Control of dissipation on the nanoscale
- Multi-exciton, hot electron, intermediate band gap concepts
- Novel quantum confinement and proximity based light absorbers- red absorption from large gaps
- Control of electrical transport within and between components
- Atomically defined and selective contacts
- Plasmonic enhancement of light absorption
- Photonic manipulation of light

# *An example of using new physical processes*: Coupling of Quantum dots to 1D nanostructures





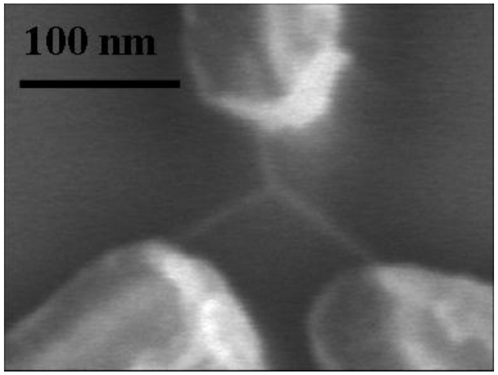
**Open questions:**

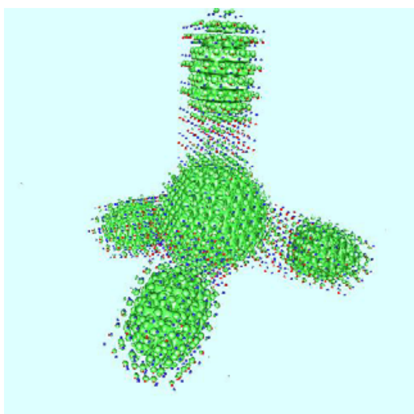
- how to make these structures?
- efficiency of carrier multiplication
- how to separate carriers?
- what are the materials requirements?

HELIOS

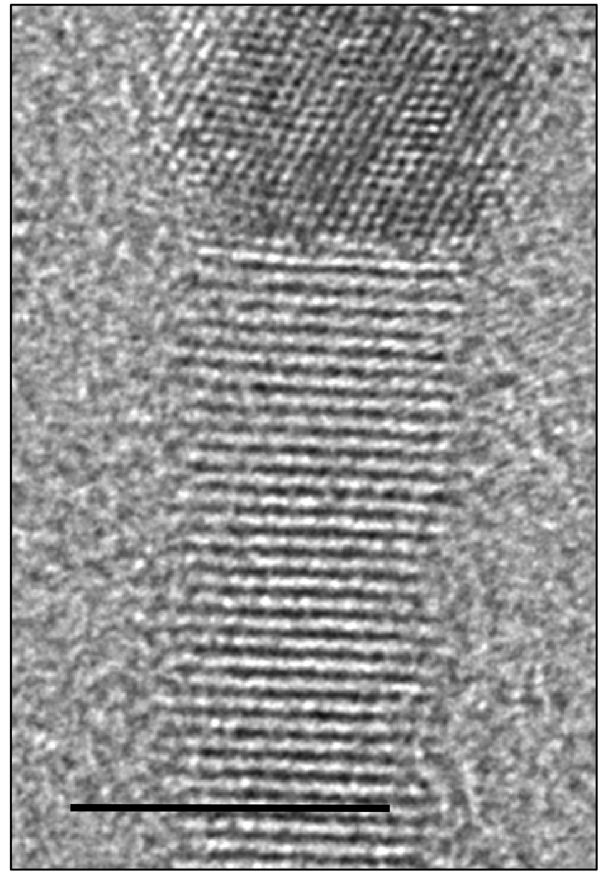
Unprecedented control

# Electrical contacts defined at the atomic level



Molecular-scale contact



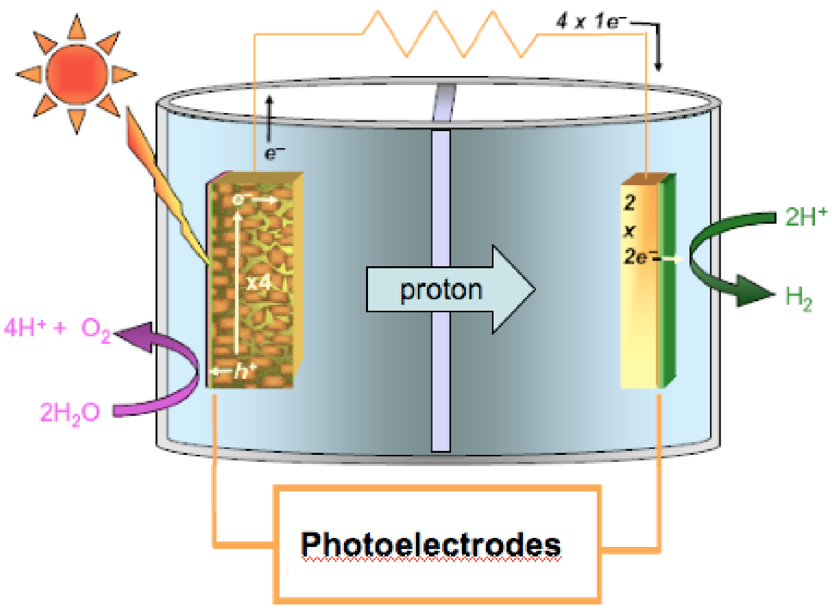
Contacts control the performance of microelectronics

# HELIOS Water splitting in a single unit

## Proof of principle

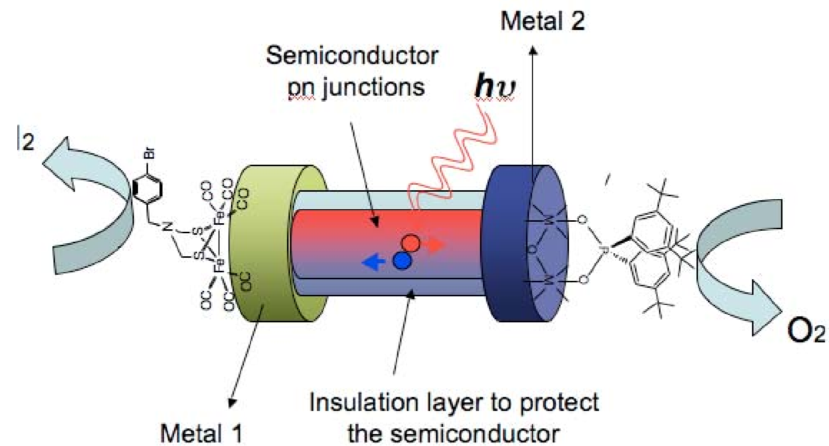
11 % efficiency

## Splitting



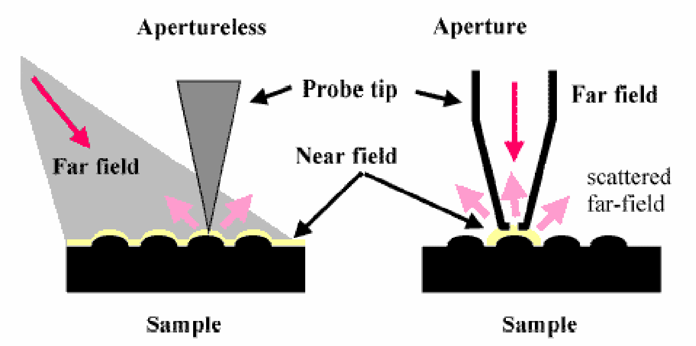

## Nano version

H

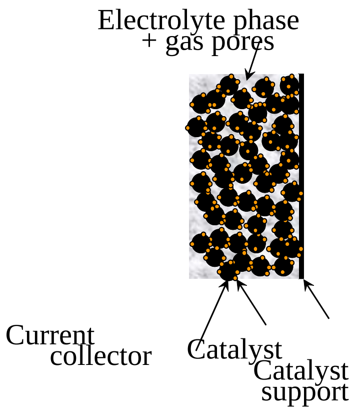



Will need double junctions.

# Photo-electrochemistry

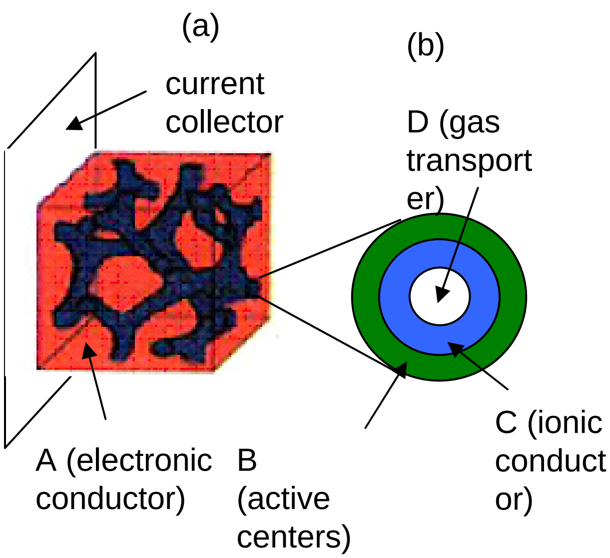



– Spectroscopic studies of electrode reactions




– Design of electrocatalysts

--Theoretical studies of electrocatalysts



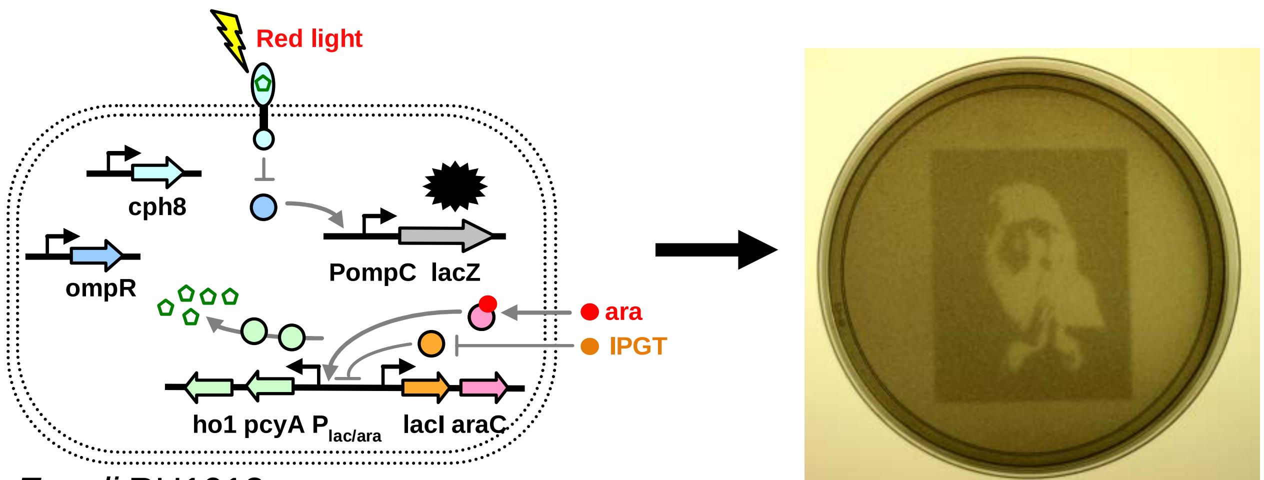

- High-surface area electrodes supporting highly efficient catalysts

# Reverse engineering of natural photosynthesis

- Understand the design principles of natural photosynthesis and how photosynthetic pigments, proteins, and other cofactors are assembled into functional complexes
- Proof: ability to generate a simplified, engineerable photosystem in a native host.

## Toolbox for engineering photosynthetic bacteria

- *Modular parts can be combined to build ‘systems.’ Example:*

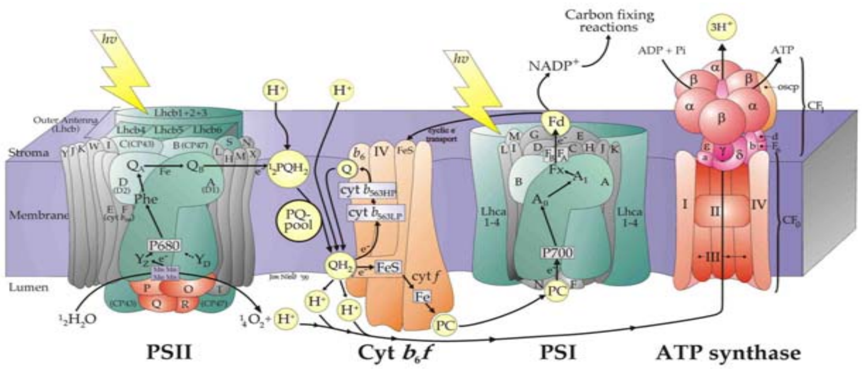



*E. coli* RU1012

# Integrated systems

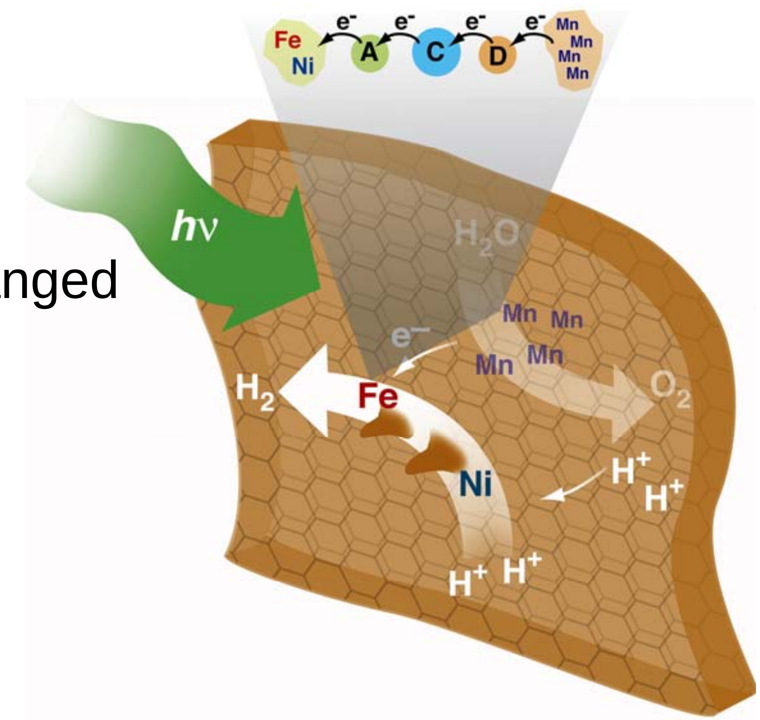


## Natural photosynthesis – proof of concept for solar to fuel in single integrated system




**Efficient for sustaining life - not efficient for making fuel**

Artificial system for sunlight to fuel molecules using elements of natural photosynthetic systems




- photoactive/catalytic assemblies arranged in one direction
- membrane separates fuel from $O_2$
- membrane $H^+$ permeable

# Photosynthesis: Challenges and Goals

- **Challenge:** To understand the assembly, function, regulation, and maintenance of the photosynthetic apparatus.
- **Goals**
  - To achieve a complete understanding of biological photosynthesis
  - To compile a complete parts list for oxygenic photosynthesis
  - To extract the design principles involved in natural photosynthesis for design of biomimetic or hybrid assemblies

# The Cellulosic Route

## Key Challenges and Opportunities in Cellulosic Pathway

Microbes secreting enzymes

Sunlight → (Plants) → Cellulose → (Enzymes) → Sugar → (Microbes) → Fuels

Increasing accessible cellulose and hemicellulose

Deconstructing feedstocks to sugars

Sugars to fuels

**Enzymes: Gut of termites**
**Microbes on the forest floor**

# Helios projects and crosscutting areas

**Projects:**

- Cellulose degrading microbes
- Plants
- Oleomics & Other microbes
- Reversed Engineering of Photosynthetic systems
- Bio-inorganic photosynthetic systems
- Photo-electrochemical cells
- Electrochemical cells
- Photovoltaics

**Crosscutting areas:**

- Theory
- Catalysis
- Transport & Separations
- Manufacuture & Sustainability