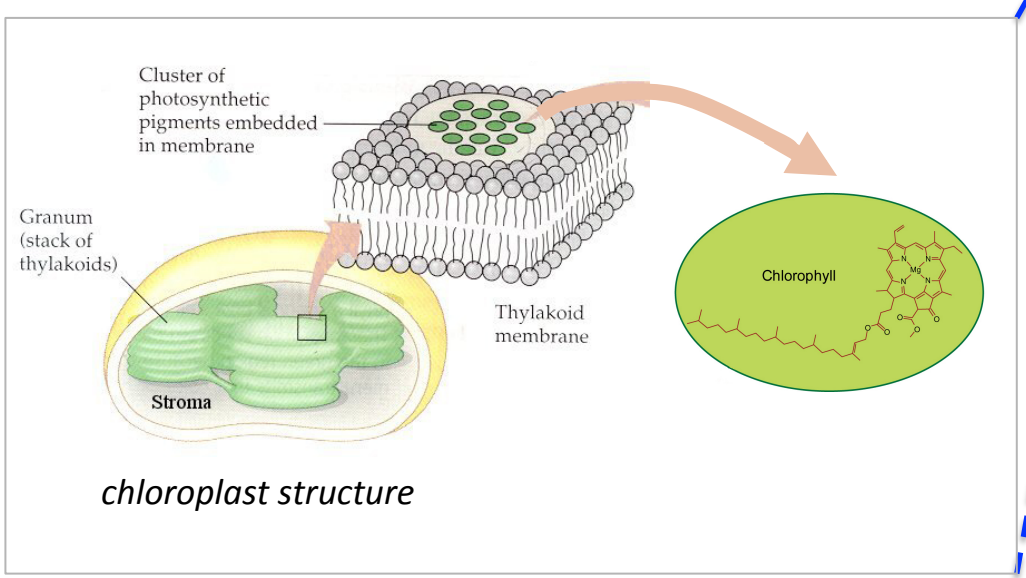
Photosynthesis and Dye-Sensitized Solar Cells

Photosynthesis

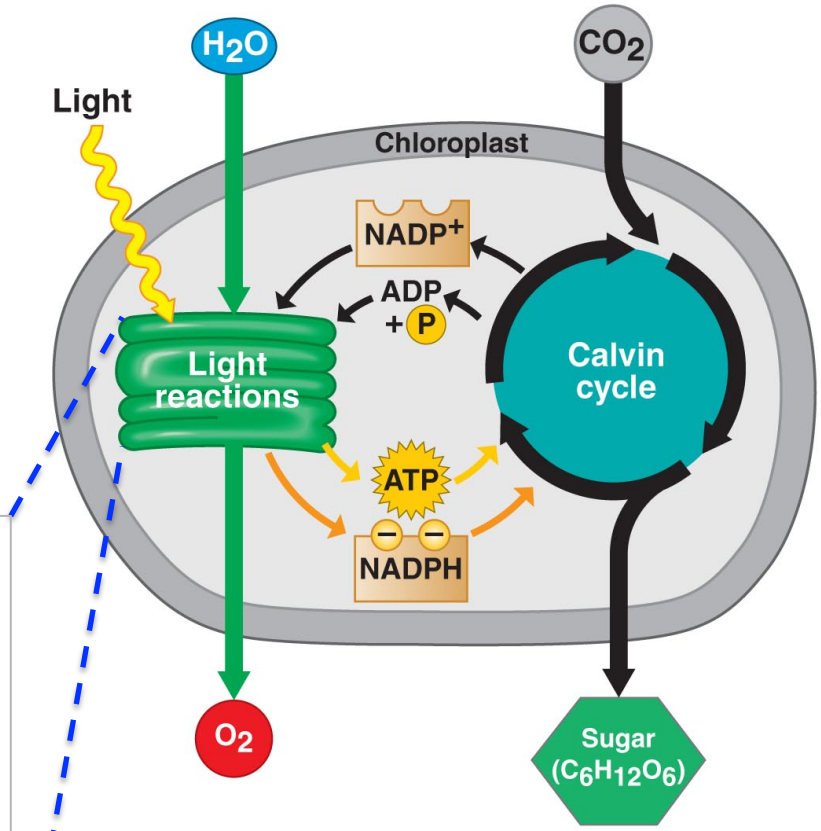
Photosynthesis uses sunlight to convert water and carbon dioxide into oxygen and sugar

Photosynthesis is critical for plants and also for animals that require oxygen to live

Chlorophyll pigments in the chloroplasts absorb sunlight, which is a critical part of photosynthesis

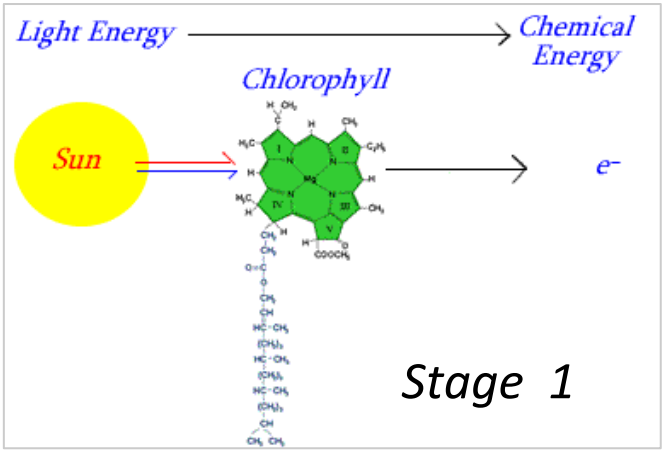


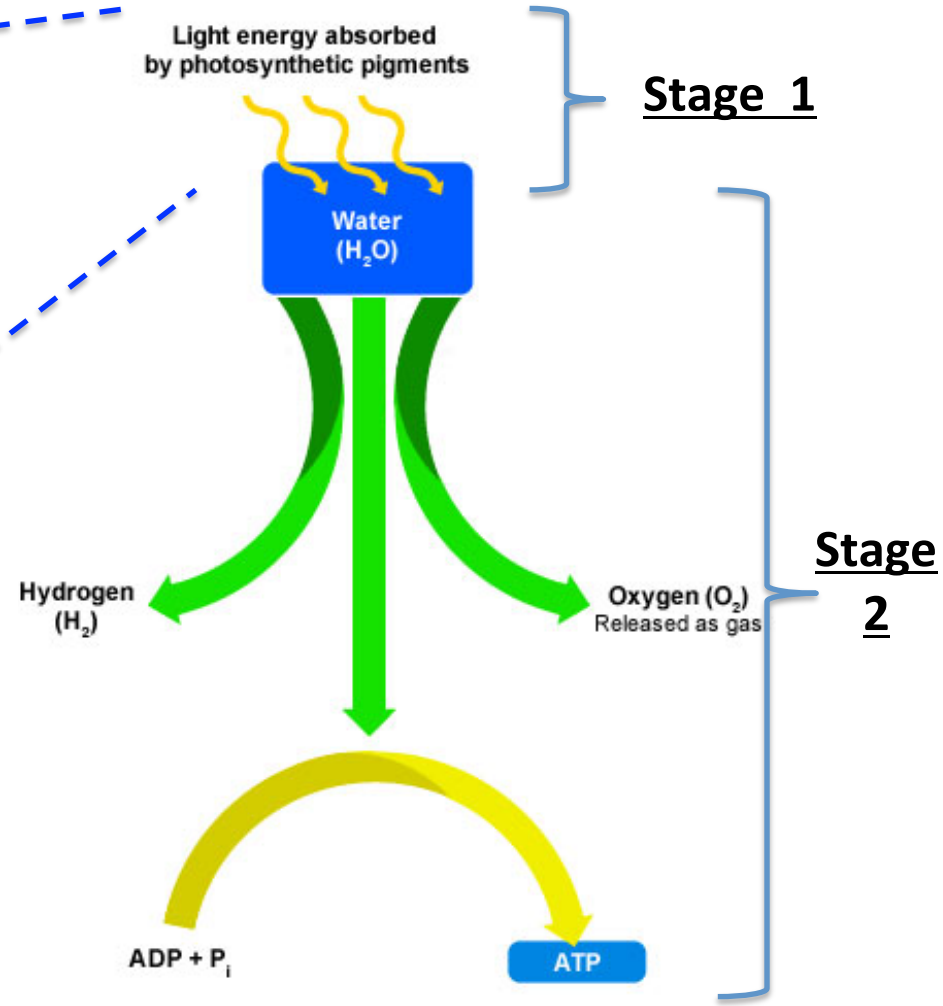
chloroplast structure



S. Hao *et al.*, *Solar Energy* 2006
http://www.ck12.org/ck12/images?id=311027
http://olearybio.blogspot.com/2010_12_01_archive.html
http://photosynthesis-hydrogenfuel.wikispaces.com/

Photosynthesis



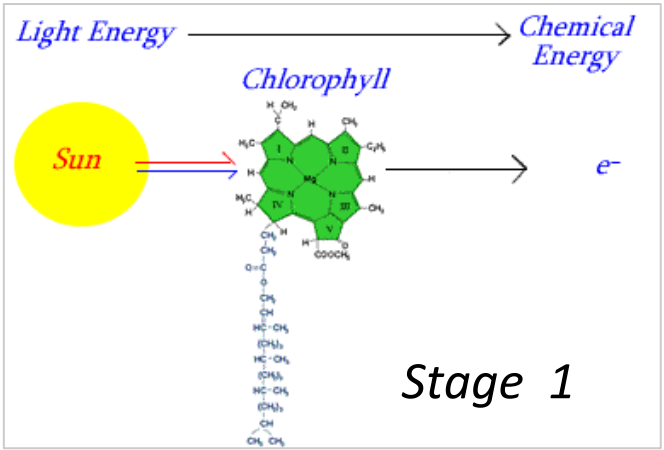


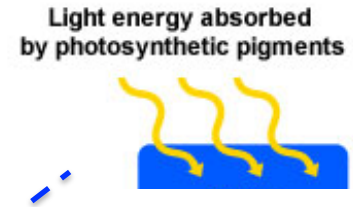
Photosynthesis is a two stage process

1. Chlorophyll absorbs light energy from the sun and converts it into chemical energy (electrons)
2. This chemical energy is used to produce ATP and split water into hydrogen and oxygen

http://click4biology.info/c4b/3/chem3.8.htm
http://www.bbc.co.uk/scotland/learning/bitesize/higher/biology/cell_biology/photosynthesis_rev2.shtml

Artificial Photosynthesis





Stage 1

What if we could capture the light energy (stage 1), but use it for something else, like powering light bulbs or cars?

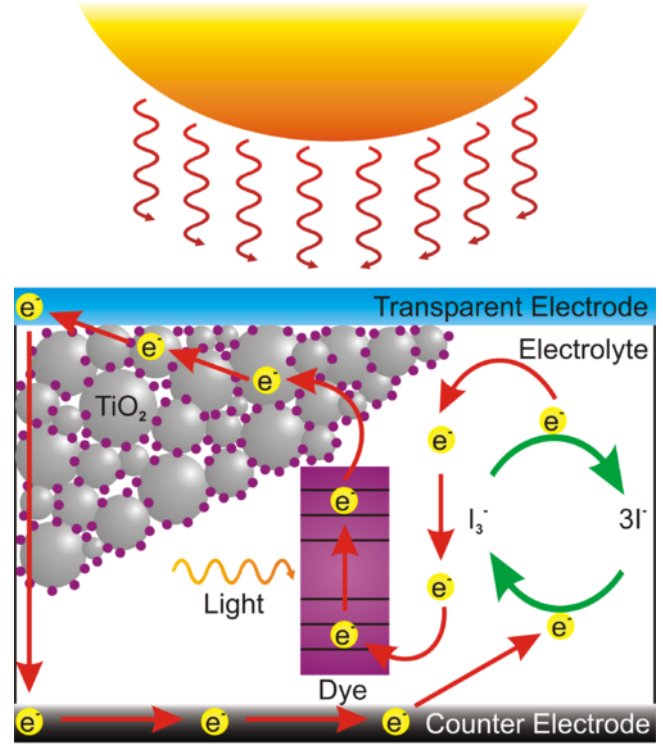
This is the goal of *artificial photosynthesis*

Stage 2 ?

http://click4biology.info/c4b/3/chem3.8.htm
http://www.bbc.co.uk/scotland/learning/bitesize/higher/biology/cell_biology/photosynthesis_rev2.shtml

Dye-Sensitized Solar Cell

This schematic illustrates one artificial photosynthesis method, dye-sensitized solar cells
Dye-sensitized solar cells use dyes or natural pigments to capture light energy
This light energy excites electrons, which can then flow toward the electrode



Stage 1

This electron flow can then be used to power other devices, like light bulbs or cars

Stage 2

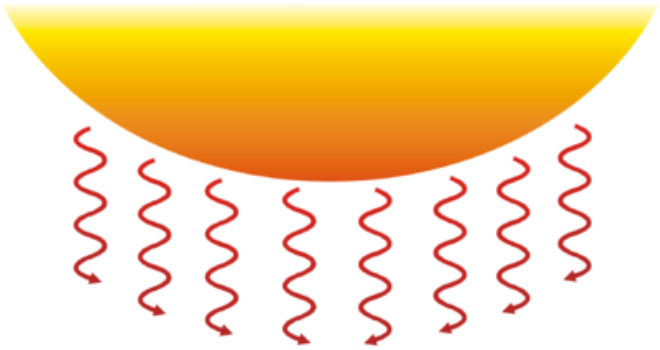
http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/plants/plants1.shtml

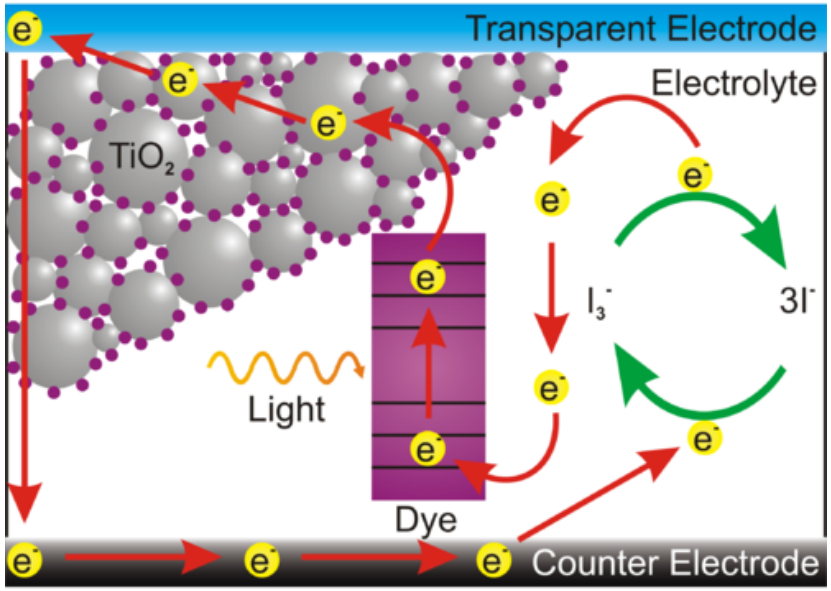
http://www.energyer.com/Know_How/dye-sensitized-solar-cell.html

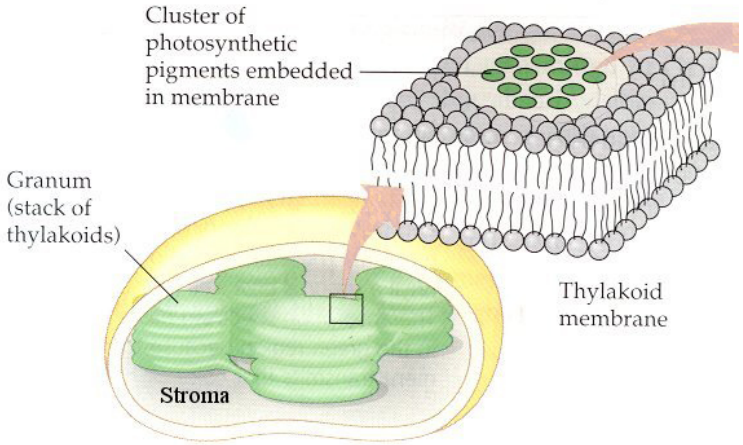
Dye-Sensitized Solar Cell

What's the purpose of the nanocrystalline TiO_2?

Due to the nanometer sized particles of TiO_2, the annealed surface is extremely rough at the nanoscale. The porous TiO_2 is analogous to the chloroplast in leaves, in that it increases the amount of pigment molecules per volume, allowing more light to be absorbed.







chloroplast structure

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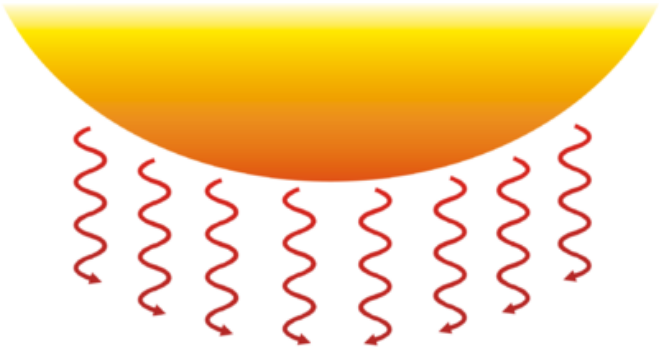
Dye-Sensitized Solar Cell

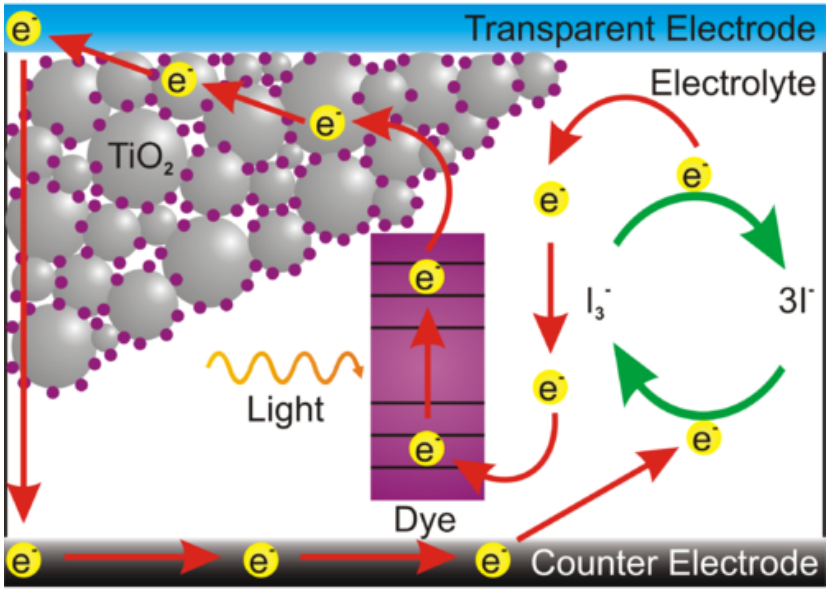
What's the purpose of the electrolyte I_2/I_3^- ?

After a dye molecule transfers an electron to the TiO_2, it is positively charged and needs an electron to become neutral

However most of the dye molecules are not in physical contact with the counter electrode

To solve this problem we use tri-iodide, which can "ferry" electrons between the counter electrode and the dye molecules





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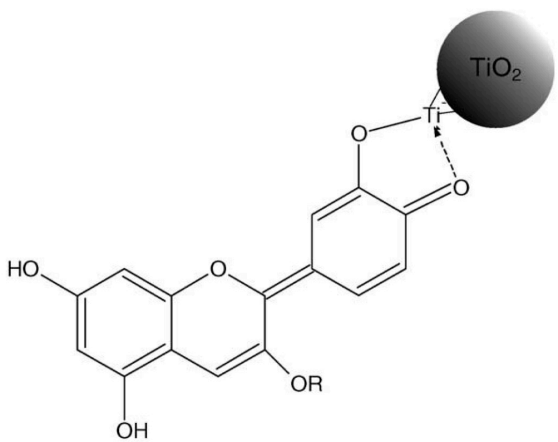
Dye-Sensitized Solar Cell

What kinds of dyes do scientists use?

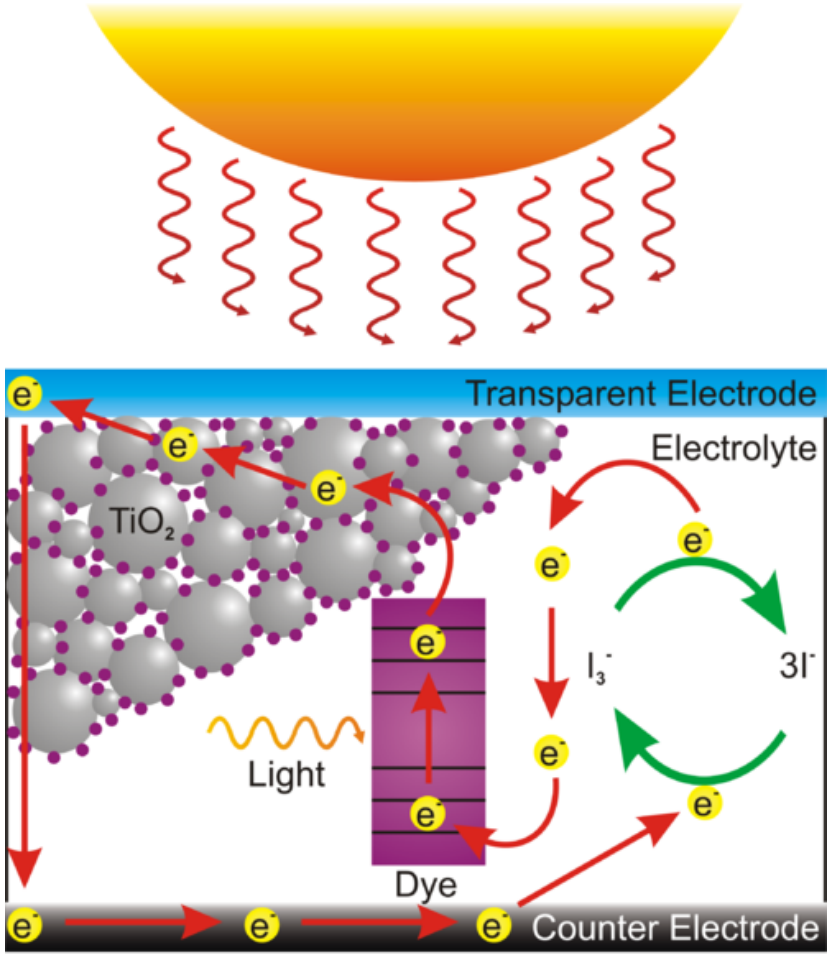
Scientists use synthetic dyes and natural pigments, like anthocyanins

Anthocyanins are a class of pigments found in many berries and other plants

Anthocyanins have higher efficiency than chlorophyll because of how anthocyanins bind to TiO_2



anthocyanin bound to TiO_2



S. Hao *et al.*, *Solar Energy* 2006
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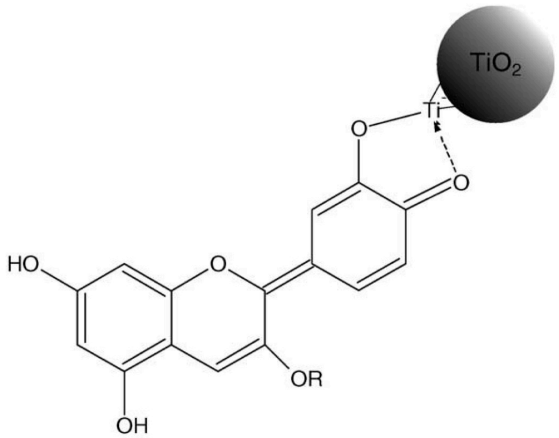
Dye-Sensitized Solar Cell

Want to know more about anthocyanins?

The color of anthocyanin pigments depends on the pH and varies from red to blue to purple

In nature, anthocyanins are thought to have many roles, including attracting pollinators/animals and providing protection from excess sunlight



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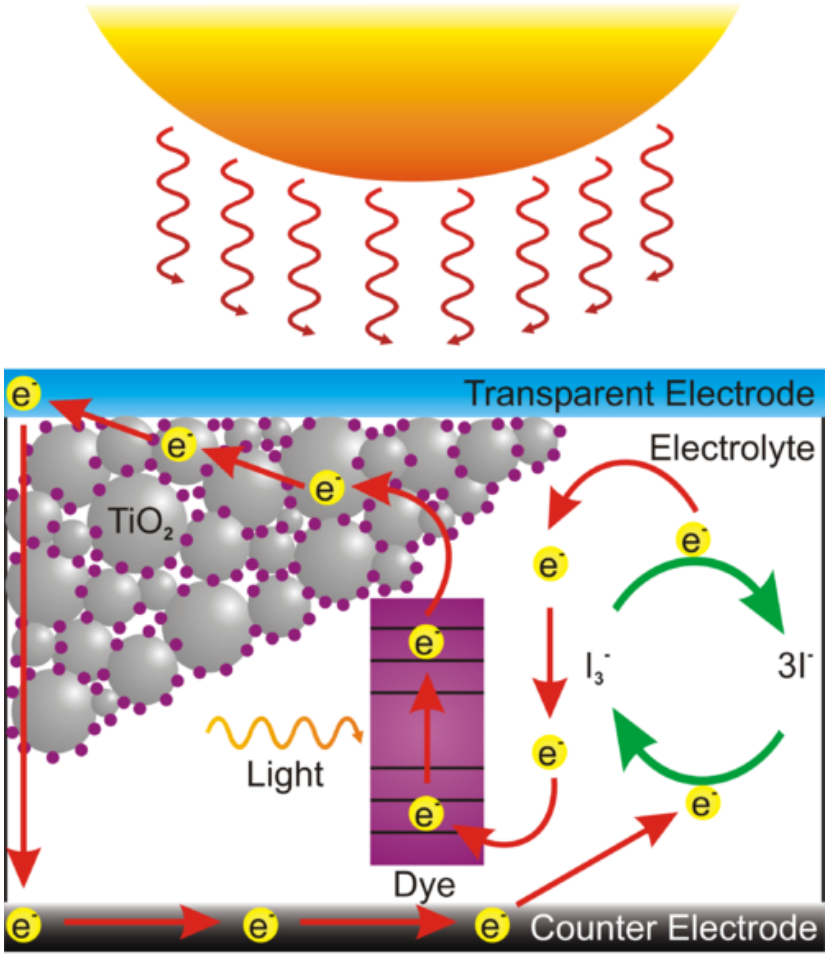

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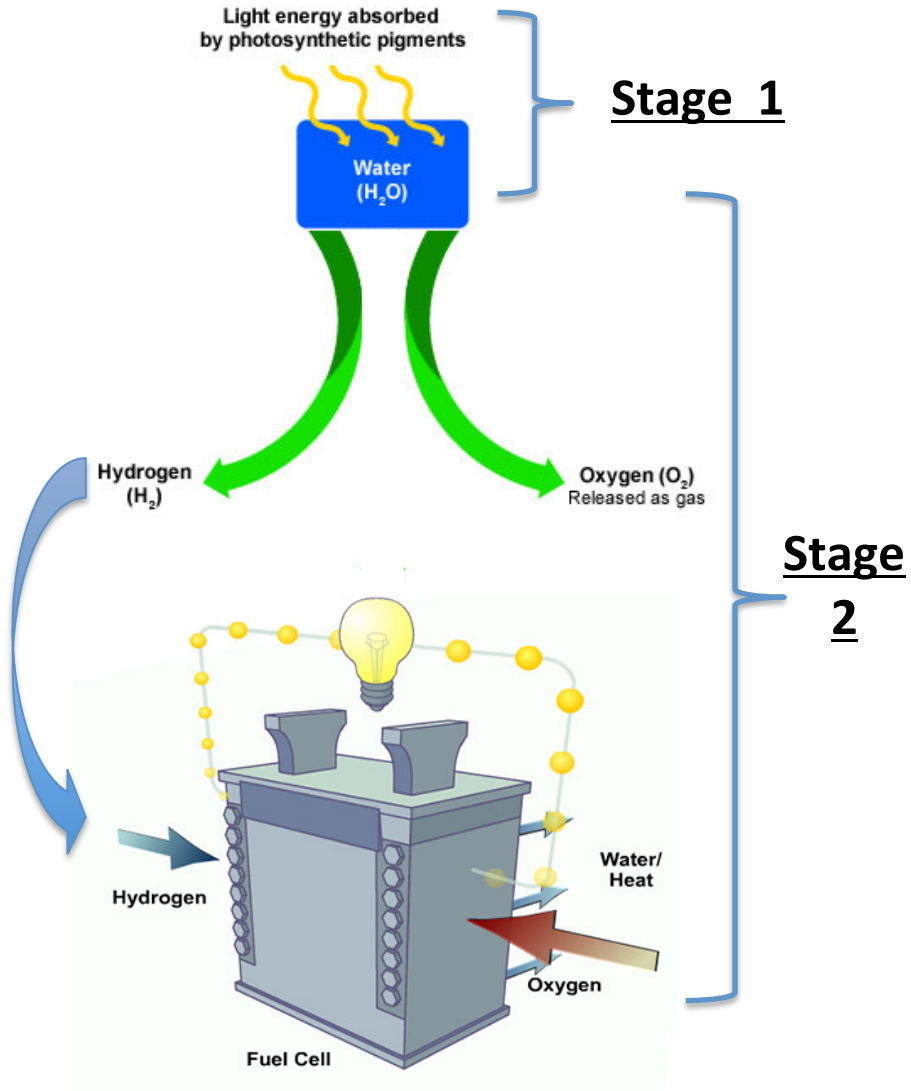
Artificial Photosynthesis

Instead of just using stage 1 of photosynthesis, we can utilize both stages 1 and 2

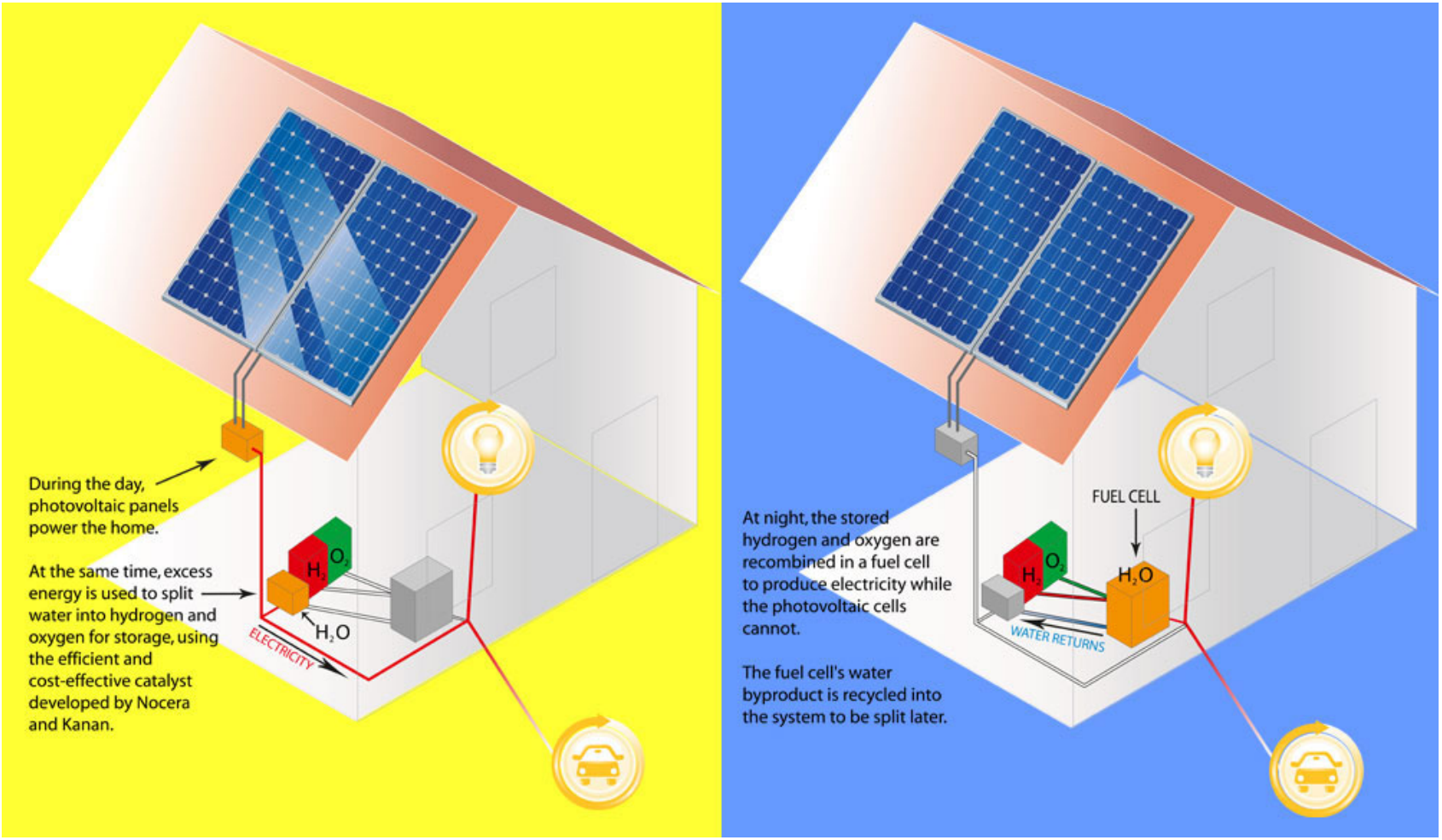
We can collect light energy and then use this energy to split water into hydrogen and oxygen

For example, we can use solar cells to produce H_2 and O_2, and then recombine the H_2 and O_2 in a fuel cell to produce electricity



http://www.afdc.energy.gov/afdc/vehicles/fuel_cell_what_is.html
http://click4biology.info/c4b/3/chem3.8.htm
http://www.bbc.co.uk/scotland/learning/bitesize/higher/biology/cell_biology/photosynthesis_rev2.shtml

Potential Scenario for Household Use



http://web.mit.edu/newsoffice/2008/oxygen-graphic-1.jpg