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.

S. Hao et al., Solar Energy 2006
http://www.ck12.org/ck12/images?id=311027
http://photosynthesis-hydrogenfuel.wikispaces.com/
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.
Artificial Photosynthesis

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
Dye-Sensitised Solar Cell

This schematic illustrates one artificial photosynthesis method, dye-sensitised solar cells. Dye-sensitised solar cells use dyes or natural pigments to capture light energy. This light energy excites electrons, which can then flow toward the electrode. This electron flow can then be used to power other devices, like light bulbs or cars.

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

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.

http://photosynthesis-hydrogenfuel.wikispaces.com

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.
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 TiO₂.
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.

anthocyanin bound to TiO₂

S. Hao et al., Solar Energy 2006
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 H₂ and O₂, and then recombine the H₂ and O₂ 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
Potential Scenario for Household Use

During the day, photovoltaic panels power the home.
At the same time, excess energy is used to split water into hydrogen and oxygen for storage, using the efficient and cost-effective catalyst developed by Nocera and Kaner.

At night, the stored hydrogen and oxygen are recombined in a fuel cell to produce electricity while the photovoltaic cells cannot.
The fuel cell's water byproduct is recycled into the system to be split later.

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