Photosynthesis

As you know well from biology, all energy in biological systems ultimately comes from the sun. You know that "photosynthesis converts light energy into chemical energy", but what does that actually mean? We've spent plenty of time in this course unpacking what we mean by "chemical energy", and now you're going to investigate how light affects chemical energy and the other way around.

Photosynthesis is a complex process with many steps, but we're just going to focus on the first part: a photon (with a wavelength around 680 nm) is absorbed by a chlorophyll molecule in Photosystem II, and an electron is ejected from the photosystem (specifically from P680, a special chlorophyll molecule at the center of the photosystem). This electron goes to to another molecule which is the primary electron acceptor (and they're still debating exactly which molecule that is, but we won't worry about that here). That's as far as we'll go today. (After this, a whole lot of chemistry happens.)

1) First of all, just to review, what do we mean by "chemical energy"? Based on what you've done in this class, can "chemical energy" be explained in terms of other forms of energy? What does it mean for a system to have "more" or "less" chemical energy?

2) What is a possible explanation for why photons with wavelengths around 680 nm (red light) will get this process going, and other photons won't?

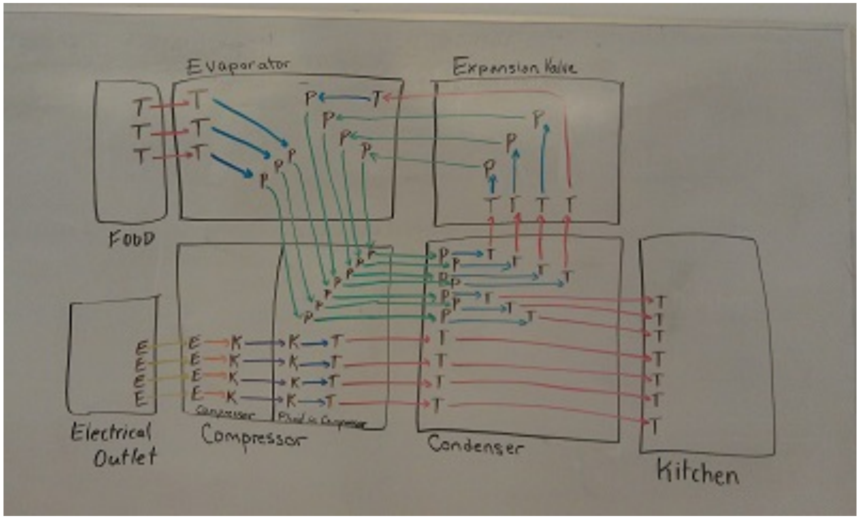
3) When a photon is absorbed by a chlorophyll molecule, an electron in the chlorophyll is excited, and then there are three possible things that could happen next:

- **Fluorescence:** The chlorophyll emits another photon.
- **Resonance transfer:** The chlorophyll excites an electron in a neighboring chlorophyll molecule. (How?)
- **Photochemistry:** The electron is ejected, and accepted by the primary electron acceptor.

As a group, draw diagrams illustrating each of these processes, to help visualize what's going on.

4) Let's start with just one of the processes: photochemistry. Draw energy bar charts for each step of the process. This requires defining your system and deciding on the number of steps and which forms of energy are relevant. (Note that in the How a Kinesin Walks activity you were given the steps as the "frames" of the "movie"; here you'll have to decide for yourselves what steps are worth representing.) Is the total energy conserved? (How can you tell?) Is there anything that can't be represented on the bar chart?

5) For the same process, draw an energy tracking diagram. Here's how an energy tracking diagram works: Each object in your system is represented by a box (or other shape). Each "chunk" of energy is represented by a letter standing for the form of energy. Energy transfers and transformations are represented by arrows. All arrows have a letter at the head and at the tail. If the arrow goes from one object to another, that means the energy is transferred. If the arrow has a different letter at the head and at the tail, that means the energy is transformed. (Below is an example of an energy tracking diagram, showing the operation of a refrigerator. Don't be spooked - this is just here to show what an energy tracking diagram looks like, and is probably much more complicated than the energy tracking diagram that you'll draw for the first step of photosynthesis.) After you've drawn your energy tracking diagram for the beginning of photosynthesis, ask yourself the same questions again: This time, is the total energy conserved? (How can you tell?) Is there anything that can't be represented on the energy tracking diagram?



6) Now, for the same process, draw a "reverse" energy tracking diagram. Here's how that works: Instead of having the objects in the system being the "locations" in your diagram, and the energy being the "stuff" moving from object to object, you're going to have the **energy** be the "location" (e.g. there can be "high energy" and "low energy" on the diagram), and the **objects** be the "stuff" moving from energy to energy (e.g. moving from high energy to low energy). If you want, you can use the template below, and draw in your objects. This time, is the total energy conserved? (How can you tell?) Is there anything that can't be represented on the reverse energy tracking diagram?

High energy ____

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____

____

Low energy ____

7) You've now drawn a whole bunch of diagrams! Which (if any) is most helpful to you in answering the original question - what does it mean to say that photosynthesis converts light energy into chemical energy?

8) Based on what you've done, can you tell whether photosynthesis is perfectly efficient in converting light energy into chemical energy? (Of course, you should find that the **total** energy is conserved, as always. But does the entire energy of the photon end up as "chemical energy", or does something else happen too?) Why or why not?

9) If you have time, pick the energy representation that you find most useful (either one of the ones from questions 4-6 or another one that you've seen before or that you're inventing on the spot) and create this energy representation for the other two processes (resonance transfer and fluorescence).

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