The light reactions convert solar energy to the chemical energy of ATP and NADPH: *a closer look*

- The thylakoids convert light energy (in the form of wavelengths of light) into the chemical energy of ATP and NADPH.
- The most important segment of the electromagnetic spectrum for life is a narrow band between 380 to 750 nm, visible light.
- While light travels as a wave, many of its properties are those of a discrete particle, the photon.
    - A photon is a fixed quantity of light energy
    - The amount of energy packaged in a photon is *inversely* related to its wavelength .
    - Photons with shorter wavelengths pack more energy.
- When light meets matter, it may be reflected, transmitted, or absorbed.
- Different pigments absorb photons of different wavelengths
- A leaf looks green because chlorophyll, the dominant pigment, absorbs red and blue light, while transmitting and reflecting green light.
- The light reaction of photosynthesis can perform work with those wavelengths of light that are absorbed.
- In the thylakoid are several pigments that differ in their absorption spectrum.
- Chlorophyll *a*, the dominant pigment, absorbs best in the red and blue wavelengths, and least in the green.
- Other pigments with different structures have different absorption spectra.
- Only chlorophyll *a* participates directly in the light reactions but accessory photosynthetic pigments absorb light and transfer energy to chlorophyll a.
- Chlorophyll *b*, with a slightly different structure than chlorophyll *a*, has a slightly different absorption spectrum and transfers the energy from these wavelengths to chlorophyll *a*.
- Carotenoids can transfer the energy from other wavelengths to chlorophyll *a* and also participate in *photoprotection* against excessive light.
- They absorb and scatter excessive light energy that would otherwise damage chlorophyll

- When a molecule absorbs a photon, one of that molecule's electrons is elevated to an orbital with more potential energy.
- Photons are absorbed by clusters of pigment molecules in the thylakoid membranes.
- The energy of the photon is converted to the potential energy of an electron raised from its ground state to an excited state.
- In the thylakoid membrane, chlorophyll is organized along with proteins and smaller organic molecules into photosystems.
- A photosystem acts like a light-gathering "antenna complex" consisting of a few hundred chlorophyll *a*, chlorophyll *b*, and carotenoid molecules.
- When any antenna molecule absorbs a photon, it is transmitted from molecule to molecule until it reaches a particular chlorophyll *a* molecule, the reaction center.
- At the reaction center is a primary electron acceptor which removes an excited electron from the reaction center chlorophyll a.
    - This starts the light reactions.
- Each photosystem - (reaction-center chlorophyll and primary electron acceptor surrounded by an antenna complex) - functions in the chloroplast as a light-harvesting unit.
- There are two types of photosystems.
- Photosystem I has a reaction center chlorophyll, the P700 center, that has an absorption peak at 700nm.
- Photosystem II has a reaction center with a peak at 680nm.
    - The differences between these reaction centers (and their absorption spectra) lie not in the chlorophyll molecules, but in the proteins associated with each reaction center.
- These two photosystems work together to use light energy to generate ATP and NADPH.

- During the light reactions, there are two possible routes for electron flow: cyclic and noncyclic.

- **Noncyclic electron flow**, the predominant route, produces both ATP and NADPH.

  1. When photosystem II absorbs light, an excited electron is captured by the primary electron acceptor, leaving the reaction center oxidized.

  2. An enzyme extracts electrons from water and supplies them to the oxidized reaction center.

     - This reaction splits water into two hydrogen ions and an oxygen atom which combines with another to form O_2.

  3. Photoexcited electrons pass along an electron transport chain before ending up at an oxidized photosystem I reaction center.

  4. As these electrons pass along the transport chain, their energy is harnessed to produce ATP.

     - The mechanism of **noncyclic photophosphorylation** is similar to the process of oxidative phosphorylation.

  5. At the bottom of this electron transport chain, the electrons fill an electron “hole” in an oxidized P700 center.

  6. This hole is created when photons excite electrons on the photosystem I complex.

     - The excited electrons are captured by a second primary electron acceptor which transmits them to a second electron transport chain.

     - Ultimately, these electrons are passed from the transport chain to $NADP^+$, creating NADPH.

       - NADPH will carry the reducing power of these high-energy electrons to the Calvin cycle.

- The light reactions use the solar power of photons absorbed by both photosystem I and photosystem II to provide chemical energy in the form of ATP and reducing power in the form of the electrons carried by NADPH.

- Chloroplasts and mitochondria generate ATP by the same mechanism: chemiosmosis.
  - An electron transport chain pumps protons across a membrane as electrons are passed along a series of more electronegative carriers.
  - This builds the proton-motive force in the form of an H^+ gradient across the membrane.
  - ATP synthase molecules harness the proton-motive force to generate ATP as H^+ diffuses back across the membrane.
- Mitochondria transfer chemical energy from food molecules to ATP and chloroplasts transform light energy into the chemical energy of ATP.
- The proton gradient, or pH gradient, across the thylakoid membrane is substantial.
  - When illuminated, the pH in the thylakoid space drops to about 5 and the pH in the stroma increases to about 8, a thousand-fold different in H+ concentration *(so what does this mean?)*
- The light-reaction "machinery" produces ATP and NADPH on the *stroma* side of the thylakoid (*WHY the stroma side?????)*
- Noncyclic electron flow pushes electrons from water, where they are at low potential energy, to NADPH, where they have high potential energy.
  - This process also produces ATP.
  - Oxygen is a byproduct.