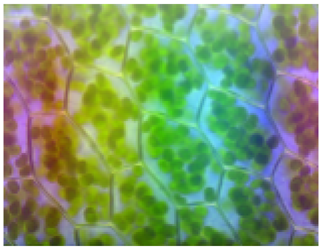
Name : ____ Period: ____

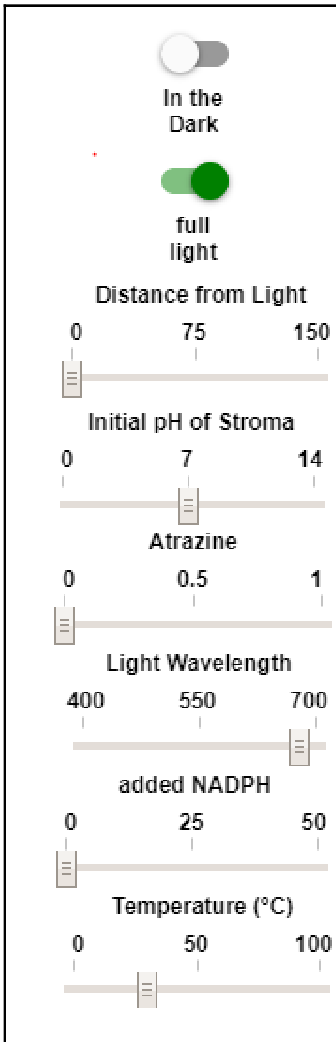


Photosynthesis Model and Simulation

Pre-Lab: Define the following terms:

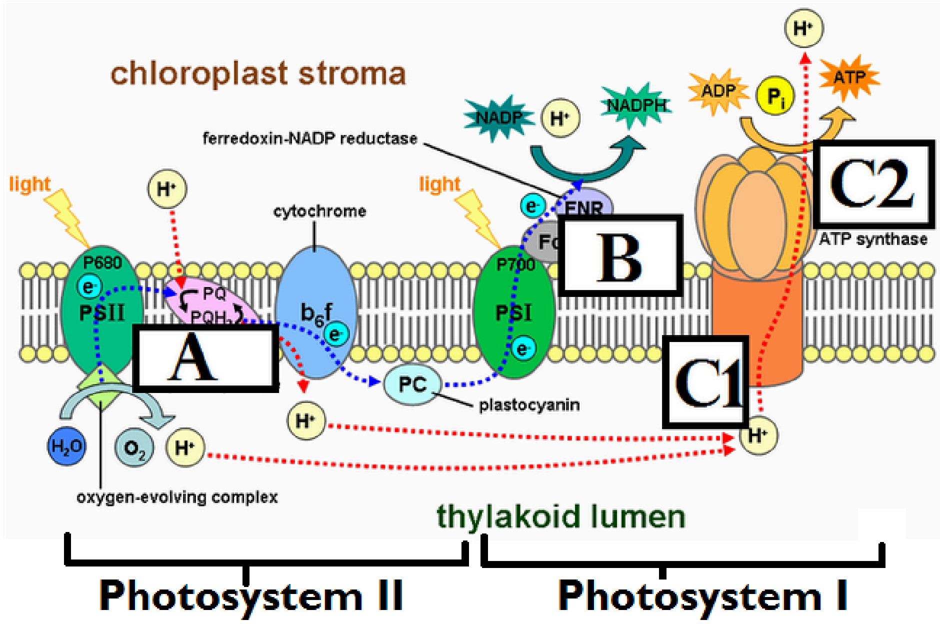
- ➔ chlorophyll
- ➔ light reaction (light-dependent reaction)
- ➔ dark reaction (light-independent reaction)
- ➔ thylakoid
- ➔ stroma
- ➔ ATP synthase
- ➔ hydrolysis
- ➔ reduction
- ➔ oxidation
- ➔ electron transport chain
- ➔ electrochemical gradient
- ➔ NADPH
- ➔ carbon fixation
- ➔ rubisco
- ➔ NADP+
- ➔ G3P

Variables Explained

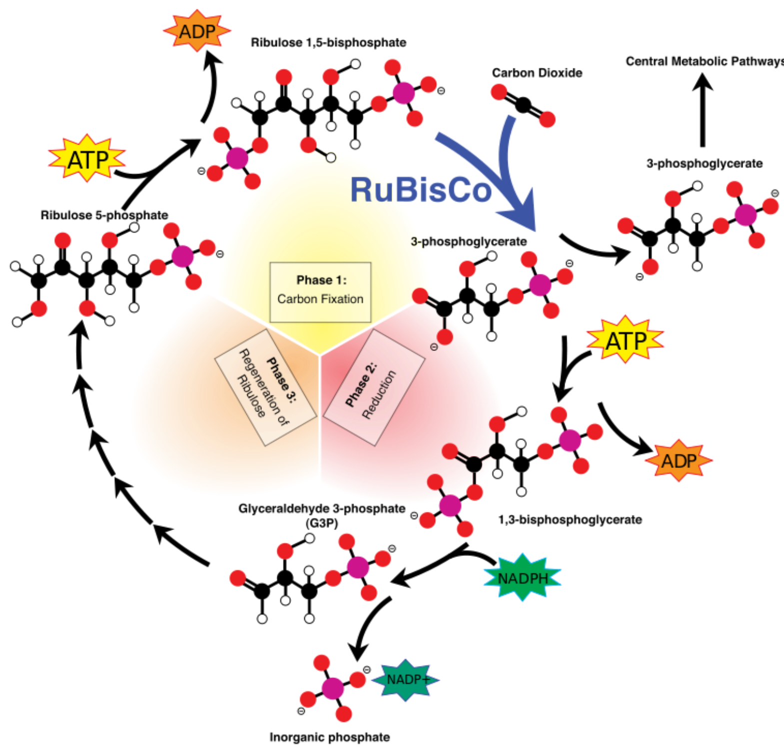


If "**In the Dark**" is ON (green), then the entire experiment is without light. If "In the Dark" is OFF (grey), then the experiment will vary by the type and amount of light.
If "**full light**" is ON (green), then it DOES NOT MATTER what the "Light Wavelength" is set to because "Full Light" = All Wavelengths. If "full light" is OFF (grey), then the experiment will receive the "Light Wavelength" only. Therefore, if you want to test a particular wavelength, turn "Light Wavelength" OFF.
The "**Distant from Light**" (the distance the plant experimental group is from the light source) is in centimeters.
The "**Initial pH of Stroma**" is the starting pH of the stroma in the plant experimental group. The stroma is the fluid space between the chloroplast membrane and the thylakoids.
Atrazine is one of the most widely used herbicides used to control weeds in agriculture. The "Atrazine" slider controls the *relative* amount atrazine added to the plant experimental group.
The "**Light Wavelength**" is the wavelength of light from the light source in nanometers. To manipulate the "Light Wavelength" the "full light" must be OFF (grey).
NADPH can be synthesized during photosynthesis. "added NADPH" includes an addition of NADPH concentration (μm/gram) to the plant experimental group at the start of the experiment.
Temperature (degrees Celcius) is the environmental conditions of the experiment.

The Light-dependent Reaction Model



The Light-independent ("Dark") Reaction Model



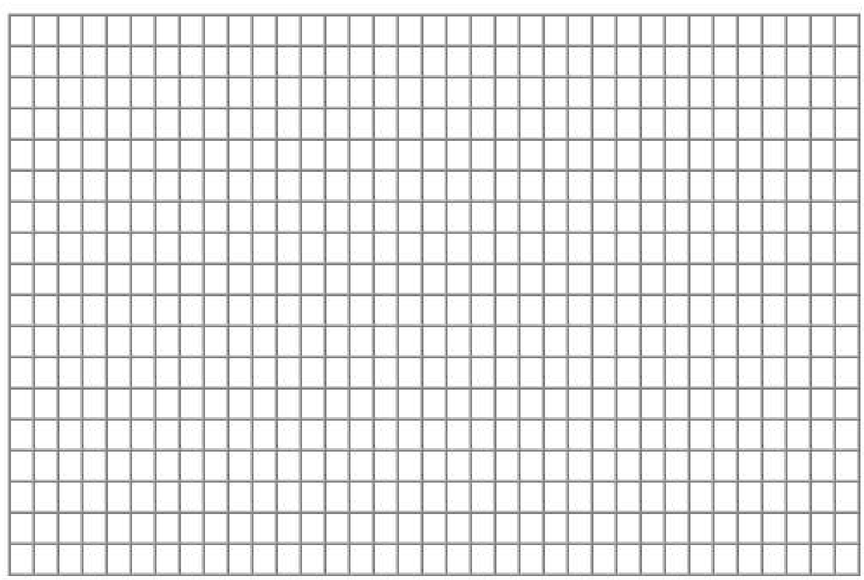
Modified from the assignment by Jon Darkow, 2015. *Simulation at* *https://sites.google.com/site/biologydarkow/photosynthesis-model*

Option A: Hydrolysis

For the reactions labeled "A" in the Light Reaction Model, use the simulation to test this idea.

1. **One of the major claims being made surrounding "A" of the light reaction model is that light energy is absorbed by chlorophyll and used for the hydrolysis of water and to create a concentration gradient of hydrogen ions? How could you test the idea that *solar energy is required for the hydrolysis of water during photosynthesis*?**

2. **Create a graph of the results testing the idea that *solar energy is required for the hydrolysis of water during photosynthesis*. Be sure to graph the independent and dependent variables.**



3. Is this idea that *solar energy is required for the hydrolysis of water during photosynthesis* supported by the simulation? *Justify* your response with evidence from the simulation.

4. Why is the hydrolysis of water required for photosynthesis?

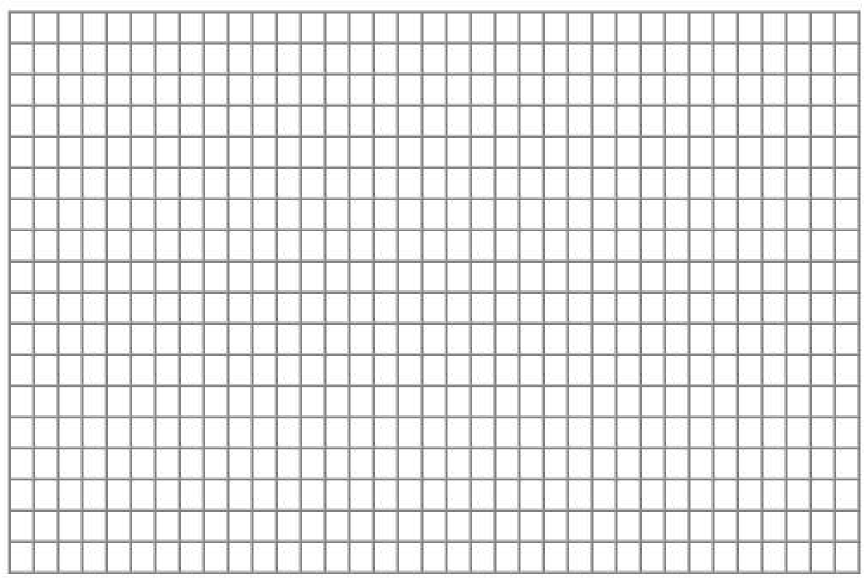
Modified from the assignment by Jon Darkow, 2015. Simulation at https://sites.google.com/site/biologydarkow/photosynthesis-model

Option B: Reduction of NADP+

For the reactions labeled “B” in the Light Reaction Model, use the simulation to test this idea.

1. **One of the major claims being made surrounding “B” (Photosystem II of the light reaction) is *solar energy is required for the reduction of NADP+ to NADPH*. How could you test this idea?**

2. Create a graph of the results testing the idea that *solar energy is required for the reduction of NADP+ to NADPH*. Be sure to graph the independent and dependent variables.



3. Is this idea that *solar energy is required for the reduction of NADP+ to NADPH* supported by the simulation? *Justify* your response with evidence from the simulation.

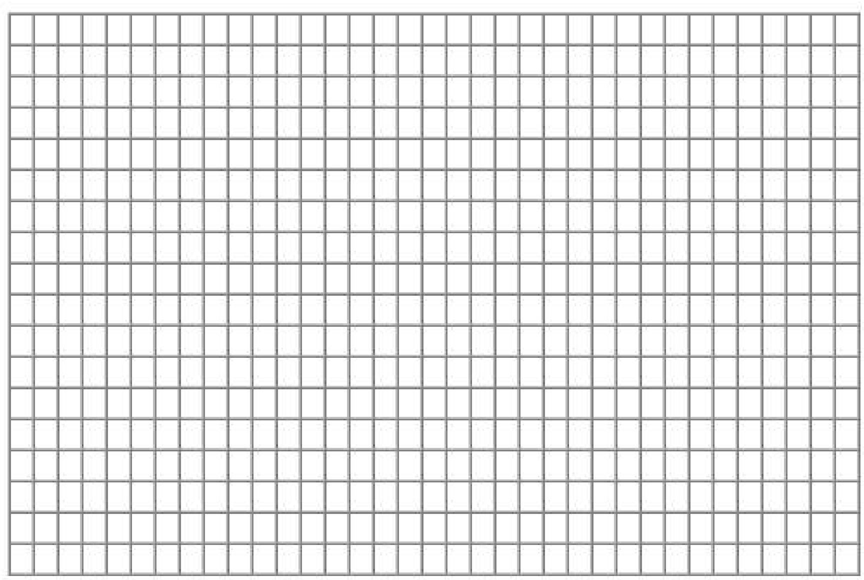
4. Why is NADPH required for photosynthesis?

Option C: Proton-Motive Force

A major aspect of the reactions labeled "C" ("C1" and "C2") in the Light Reaction Model is the production of ATP. Use the simulation to test this idea.

1. **The major claim of the reactions labeled "C1" and "C2" is that *the energy source for phosphorylation of ADP to make ATP, comes from the electrochemical gradient of hydrogen ions (proton-motive force).* How could you test this idea?**

2. Create a graph of the results testing the idea that *the energy source for phosphorylation of ADP to make ATP, comes from the electrochemical gradient of hydrogen ions (proton-motive force).* Be sure to graph the independent and dependent variables.



3. Is this idea that *the energy source for phosphorylation of ADP to make ATP, comes from the electrochemical gradient of hydrogen ions (proton-motive force)*, supported by the simulation? *Justify* your response with evidence from the simulation.

4. Why is ATP needed for photosynthesis?

Option D: Atrazine and the Electron Transport Chain

Atrazine is one of the most widely used agricultural pesticides. Atrazine kills plants by binding to a component of the electron transport chain on the thylakoid membrane on Photosystem II. Atrazine prevents electrons from passing along the electron transport chain causing all downstream electron carriers to stay in an oxidized form (Lodish, 2004.)

1. **The major claim of atrazine is that *atrazine prevents electron flow in Photosystem II.* How could you test this idea that atrazine affects electron flow in the Photosystems and not the Calvin cycle?**

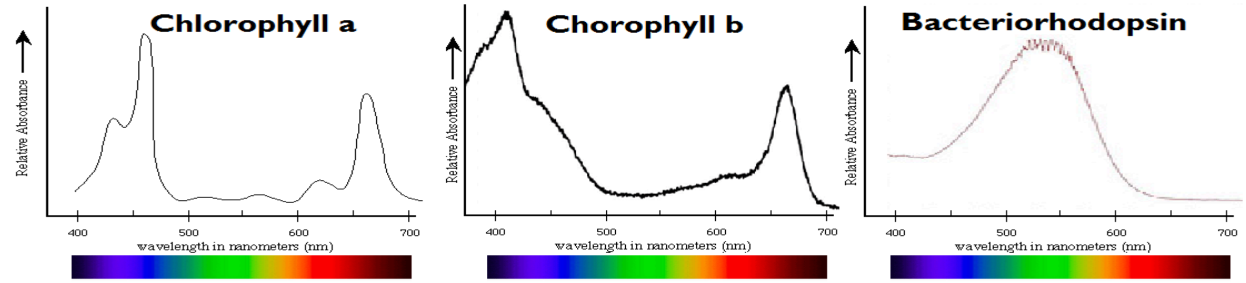
2. Create a graph of the results testing the idea that *atrazine affects the Photosystems, not the Calvin cycle.* Be sure to graph the independent and dependent variables.

3. Is the idea that *atrazine affects the Photosystems and not the Calvin cycle* supported by the simulation? *Justify* your response with evidence from the simulation.

4. Why is the movement of electrons necessary for photosynthesis?

Option E: Chlorophyll and Photophosphorylation

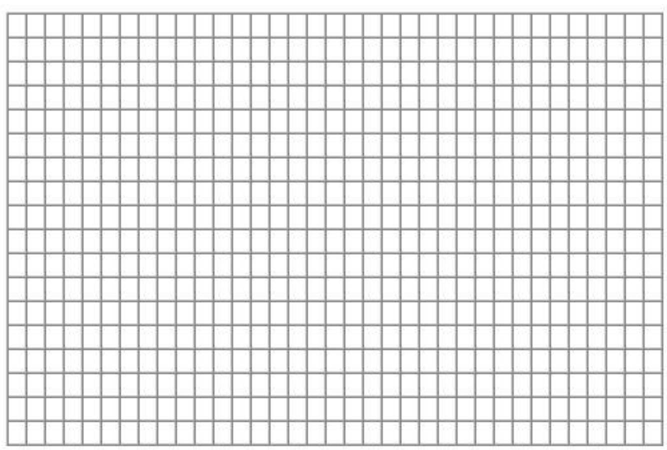
Chlorophyll a, ***chlorophyll B***, **and *bacteriorhodopsin* are the main pigments that absorb solar energy to excite electrons for photophosphorylation. Below are the absorbance spectra of those light-absorbing pigments. Chlorophyll a and b are found in plant chloroplasts. Bacteriorhodopsin are found in archaebacteria. Does the simulation assume that photophosphorylation is initiated by chlorophyll a, chlorophyll b, or bacteriorhodopsin.**



***HINT: For this experiment, be sure to turn the "Full Light" OFF (grey). This will ensure that the experimental group is exposed to only a specific wavelength of light.**

1. **Make a claim about which pigment above is being modeled in the simulation.**

2. Create a graph of the results testing your claim. Be sure to graph the independent and dependent variables.



3. Is your claim about which pigment is being modeled in the simulation supported by the evidence. *Justify* your response with evidence from the simulation.

4. Explain the color each pigment would appear?

5. Assuming that bacteriorhodopsin-based photosynthesis of archaebacteria evolved first, propose an explanation why the most prevalent method of photosynthesis today is chlorophyll-based.

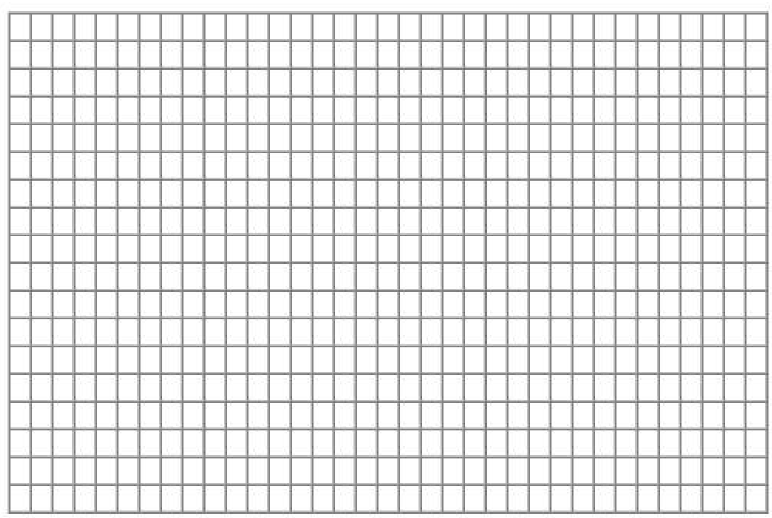
Modified from the assignment by Jon Darkow, 2015. Simulation at https://sites.google.com/site/biologydarkow/photosynthesis-model

Option F: Carbon Fixation in the Dark

According to the Dark Reaction Model above, the dark reaction does not have to occur when it is dark. Rather, it can occur whether it is dark or light. It operates in the stroma of chloroplasts independently of the solar energy. The major purpose of the dark reaction is carbon fixation.

1. **The major claim of the dark reaction model is that *light is not needed for carbon fixation.* How could you test this idea that *light is not needed for carbon fixation*?**

2. Create a graph of the results testing your claim. Be sure to graph the independent and dependent variables.



3. Is your claim that *solar energy is not needed for carbon fixation* justified based on the evidence of the simulation?

4. Why are ATP and NADPH both necessary for carbon fixation?

Modified from the assignment by Jon Darkow, 2015. Simulation at https://sites.google.com/site/biologydarkow/photosynthesis-model

Option G: Oxidation of ATP and NADPH

ATP and NADPH store free energy in their chemical bonds.

1. **One claim of the dark reaction model above is that *to make 1 gram/mol. of glucose during the dark reaction requires the oxidation of at least 18 grams/mol of ATP and the oxidation of 12 grams/mol of NADPH*. How could you test this hypothesis.**

2. Create a graph of the results testing the idea that *to make 1 gram/mol. of glucose during the dark reaction requires the oxidation of at least 12 grams/mol of ATP and the oxidation of 6 grams/mol of NADPH*. Be sure to graph the independent and dependent variables.

3. Is this idea that *to make 1 gram/mol. of glucose during the dark reaction requires the oxidation of at least 12 grams/mol of ATP and the oxidation of 6 grams/mol of NADPH* supported by the simulation? *Justify* your response with evidence from the simulation.

4. Why does carbon fixation require an input of energy from ATP and NADPH?

Option H: Optimal Temperature

Different plant species have different tolerance curves to different temperatures. Different species of plants have optimal temperatures for photosynthesis. Is there an optimal temperature for photosynthesis for the plant simulation?

1. **How can you test the optimal temperature for photosynthesis for the plant simulation?**

2. Create a graph of the results testing the optimal rate of photosynthesis. Be sure to graph the independent and dependent variables.

3. Is there an optimal temperature for photosynthesis in the plant simulation? *Justify* your response with evidence from the simulation.

4. *Explain* why temperature decreases the rate of photosynthesis at either temperature extreme?

Modified from the assignment by Jon Darkow, 2015. Simulation at https://sites.google.com/site/biologydarkow/photosynthesis-model

Teacher Notes:

1. **Print pages 1-2 for all students.**
2. **There are 8 options for students. I have my students complete at least 2 different options. For a class of 24 students, print 6 copies of pages 3-10. Have students select 2 options from the 8 choices. Students complete the 2 experiments/choices.**

A. **Hydrolysis**
B. **Reduction of NADP+**
C. **Proton Motive Force**
D. **Atrazine and the Electron Transport Chain**
E. **Chlorophyll and Photophosphorylation**
F. **Carbon Fixation in the Dark**
G. **Oxidation of ATP and NADPH**
H. **Optimal Temperature**

3. **I ask that they share with me "...how they will test" their experiment using the simulation, before going on to collecting data and graphing their results.**

After students complete their first option/experiment, I have my students share with the class the results. I will project the simulation on the overhead, so students see the results of the experiment. ***The great part of simulations is it does not take much longer to redo a student's experiment in front of the whole class.***

Notes on graphs: Each option has students graph the independent and dependent variable(s). Because the simulation plots the dependent variables over time students often will graph time as the independent variable. Make sure students are graphing the manipulated variable as the independent variable.

Works Cited

Lodish, H. (2004). 8.5 Molecular Analysis of Photosystems. In *Molecular cell biology* (5th ed.). New York: W.H. Freeman.