

Light Dependent Activity - Role Play Teacher Edition

Overview:

Photosynthesis is a complex process that converts light energy into chemical energy in the form of carbohydrates and/or other compounds in plants and other photosynthetic organisms. Photosynthesis occurs in two stages: light dependent and light independent reactions (Calvin Cycle).

Light dependent processes occur only in the presence of light energy. This activity is designed to engage students in the process that creates ATP and NADPH. These two products provide the energy that drives the next stage of photosynthesis, the Calvin Cycle. It is important to emphasize that ATP and NADPH are the main products of the light dependent reactions, while oxygen (O₂) is a by-product. The activity is linear in design, although many of the events happen simultaneously. After the students become familiar with the overall process, have the students run Photosystem II and Photosystem I with all the parts moving at the same time. Students will NOT read the script/cards out loud.

Resources:

Biology, Eighth Edition. Neil Campbell, et.al. San Francisco: Pearson 2008.

Biology. Kenneth Miller, & Joseph Levine. Upper Saddle River: Pearson 2006.

Framework SLE: *MC.3.B.4- Describe and model the conversion of light energy to chemical energy by photosynthetic organisms:*

- *Light dependent reactions*
- *Light independent reactions/Calvin cycle*

Time required: 1-2 Class periods

Materials: (Provided)

- 15 Tennis size balls – (photons of light, i.e. energy)
- 5 muffin pans- 6 cup-(electrons)
- 1 green shower curtain or green butcher paper- (photosystems I and II)
- 1 red balloon– (labeled oxygen)
- 2 white balloons – (labeled H for hydrogen ions (Note: Hydrogen ions are protons))
- 1 purple or different colored balloon-(NADP+)
- Sheet protectors – optional-(used for student signs)
- Template handouts- see Appendix A, B, C

Materials: (Supplied by the teacher)

- **Required:** 3 containers such as a box one foot wide, or plastic buckets – labeled as: water, ADP+, NADP+
- **Optional:** 2 plastic chains, each 1 meter long (electron transport chain).

Teacher Preparation

Student Role	Number of Students (Min. 13, Max. 22)
Narrator	1 - 2
Chlorophyll Reaction Center - P680	1
Chlorophyll Reaction Center - P700	1
Antenna Pigments	2-6 (1-3 per Photosystem)
Primary Electron Acceptor	2 (1 per Photosystem)
Electron Transport Chain	2-6 (1-3 per chain)
ATPase Enzyme	1
Sun - Photon Source	1
Reductase Enzyme - NADP+	1
Water Enzyme	1

Template Construction

- Print templates from Appendix A, B, C
- Appendix A- fold and insert each into a sheet protector.
- Appendix B- Cut out and place in ADP bucket.
- Appendix C- Make overhead or use with document camera
- Attach string to the holes in the protectors so they can be hung around the necks of students.

Script Preparation- If the teacher opts to use a script for each participant instead of the templates

- Print enough scripts for each student role
- Highlight on each script the speaking and action part that is specific for each student role. For example, the narrator script will only have the "Narrator Speaks" and "Narrator Action" highlighted throughout the script.

Electron Model- Muffin Pans- Three total

- Place three tennis balls into each of the three muffin trays.
- Place one pan at the Water Enzyme, one pan at the P680 Chlorophyll Reaction Center and one at the P700 Chlorophyll Reaction Center.

Water Model - Red and White Balloons in Container

- Place a muffin tray containing 3 tennis balls into the Water Enzyme box or bucket. Additionally, add 2 white balloons and 1 red balloon in the same box or bucket container. You may stick the balloons together to represent a single water molecule.
- Label the red balloon with an "O-".
- Label the white balloons with an "H+" on one side and an "H" on the other side. (One will be used for the NADPH molecule.)
- Label the container: "Water".

Photosystems in the Thylakoids - Green Shower Curtain/Green Butcher Paper

- Two pieces of green butcher paper, approximately 3' x 6'; or substitute one green shower curtain cut in half.
- Label the pieces: "Photosystem I" and "Photosystem II"

NADP+ Container

- Label a container "NADP+".
- Place the purple or different colored balloon with NADP+ written on it into the bucket.

ADP+ Container

- Label a container "ADP+".
- Make signs with "P" and "ADP+", student will hold these until he/she reads reaction process n script and then places them into the container. Appendix B.
- Make a sign with ATP and place it into the container. Appendix B.

Role Play set up- See Appendix C**Procedure**

1. Assign students the various roles, have them prepare for their role, and give each student the appropriate sign from the templates in Appendix B.
2. Make sure materials are in the appropriate places according to the diagram in Appendix C.
3. If you have more than one person for the electron transport chain, inform the students that each person will read the card as the electron is passed along to them.
4. If you have more than one person acting as antenna pigments, designate one to be the reader. The last person will pass the photon (tennis ball) to the Chlorophyll Reaction Center.
5. The Narrator will begin the activity by reading the "Narrator Speaks" part. It is encouraged, but not necessary, for teachers to read out loud the "Overview" found on the Teacher's Edition to provide a complete picture of the process.
6. As the Narrator describes each step of the process, the designated person will read the card or designated part of the script with the information that describes the action.
7. Perform the activity and then repeat the process by substituting students or rearranging responsibilities.
8. Teacher will debrief and ask students to define the most important steps and the products of the reaction.

Discussion/Closure questions

1. What products are created by the Light Dependent reactions?

Answer: ATP and NADPH, Oxygen is also accepted if designated as a waste or by-product

2. Why is water used in this process and describe its importance?

Answer: Water is used to replace the lost electron in the P680 of photosystem II. It is important because its byproduct is Oxygen (O₂) is essential for life and respiration. Also, water, when split replaces the lost electron in the P680.

3. Describe what happens to all the elements of water (H₂O) in photosynthesis?

**Answer: H₂O is split into 2 hydrogen, 2 electrons and 1 oxygen.
Electrons- supplied one to the P680+ pair
Oxygen- As a single it pairs with another Oxygen and is released as waste
Hydrogen- It moves into the Thylakoid space increasing/maintaining the high H⁺ concentration which drives the proton pump to create ATP.**

4. What happens in the first Electron Chain Transport that creates ATP that does not happen in the second Electron Chain Transport?

Answer: While going through the Electron Transport Chain (ETC), the electron passes through the cytochrome complex. Using the redox reactions to create a "proton-motive force", the H⁺ diffuses from the higher gradient to a lower gradient via ATP synthase. The ATP synthase affixes a phosphate to an ADP⁺ to make ATP in phosphorylation, thus lowering the energy level of the electron. The cytochrome complex is not found in the second ETC and therefore does not have the ability to create ATP.

5. How important is light frequency in the process of photosynthesis?

Answer: Light frequency is a very important part of photosynthesis. Light is a series of electromagnetic waves on various frequencies. Visible light, which ranges from 380 to 750 nm, contains the appropriate energy frequencies for antennae pigments to absorb for photosynthesis. Chlorophyll a, Chlorophyll b, and carotenoids (accessory pigments), absorb light frequencies between violet, red and red spectrum frequencies. Green, the color of most photosynthetic plants, is mostly, but not totally reflected, therefore creating a green color for the leaf.

Extension:

Using what you have learned, draw and label a diagram showing Photosystem I and Photosystem II and the processes that occur during the light dependent reactions.

Appendix A

No other information is on this page.

(I Sd)

ANTENNA PIGMENT

Back

Read in its entirety the first time.

“I am chlorophyll. As an Antenna Pigment, my job is to absorb light. I work like an antenna to absorb a photon from the Sun and transfer the energy it contains to another pigment in Photosystem I.”

Action: Accept the photon from the Sun and pass it along to another Antenna Pigment (if one is present), or to the Chlorophyll Reaction Center.

LAST ANTENNA PIGMENT PERSON PASSES BALL TO CHLOROPHYLL REACTION CENTER.

You will pass a total of three balls. Read only the underlined part when you pass the two remaining photons (tennis balls).

(PS II)

ANTENNA PIGMENT

Back

Read in its entirety the first time.

“I am chlorophyll. As an Antenna Pigment, my job is to absorb light.
I work like an antenna to absorb a photon from the Sun and transfer the energy it contains to another pigment in Photosystem II.”

Action: Accept the photon from the Sun and pass it along to another Antenna Pigment (if one is present), or to the Chlorophyll Reaction Center.

LAST ANTENNA PIGMENT PERSON PASSES BALL TO CHLOROPHYLL REACTION CENTER.

You will pass a total of three balls. Read only the underlined part when you pass the two remaining photons (tennis balls).

(P680) Primary Electron Acceptor

Back

“I have received the excited electron from the Chlorophyll Reaction Center in Photosystem II. The excited electron will be passed along to the Electron Transport Chain in Photosystem II.

Action: Pass the electron (muffin pan) to the first student in the electron transport chain in Photosystem II.

Primary Electron Acceptor (P700)

Back

“I received the excited electron from the Chlorophyll Reaction Center in Photosystem I. The excited electron will be passed from here to a molecule in the Electron Transport Chain in Photosystem I.”

Action: Pass the electron (muffin pan) to the first student in the electron transport chain.

(from P680)

Electron Transport Chain

Back

Photosystem II

“As the Electron Transport Chain, I connect the two Photosystems. The excited electron will lose energy as it is passed from molecule to molecule down the chain. The energy will be used to form an ATP molecule.”

Action: If more than one, each student will pass the muffin pan and place a tennis ball into the ATP bucket until there are three balls in the bucket. The last student in the chain will hold the muffin tin until it is time to pass it to the Reaction Center in Photosystem I.

Take cues from Narrator

Photosystem I

“If you’ll remember, the electron lost energy that was used to produce ATP in Photosystem II. I will now pass the electron to the Chlorophyll Reaction Center in Photosystem I to replace its lost electron.”

Action: The last person will pass muffin pan to the Chlorophyll Reaction Center P700.

Front

Electron Transport Chain (in P700)

Back

“I represent the Electron Transport Chain in Photosystem I. I received an excited electron from the Primary Electron Acceptor. The electron and all its energy is transported to NADP+. This provides energy so that an enzyme can create NADPH.”

Action: Put the entire muffin pan into the NADP+ container.

Enzyme

NADP+ Reductase

Back

“I am the Reductase enzyme. I received the electron from the Electron Transport Chain in Photosystem I. I am the last stop in the light dependent reactions. The electron provides energy so that I can create NADPH using hydrogen ions from water. NADPH will provide energy for the next stage of photosynthesis, the light independent reactions.”

Action: Combine the purple (or other color balloon) with the Hydrogen ion (white balloon) to create a NADPH molecule model.

Enzyme ATPase

Back

“I am an enzyme called ATPase. As an electron moves along the Electron Transport Chain in Photosystem II it loses energy. I use the energy to add a Phosphate to ADP to create an energy rich ATP molecule. The ATP molecule provides energy needed in the second stage of photosynthesis, the light independent reactions.”

Action: Place the “P” and “ADP+” signs into the ADP+ container and pull out the ATP sign.

Chlorophyll Reaction Center (P680)

Back

“I represent a special pair of chlorophyll molecules in Photosystem II that receives energy from the Antenna Pigments. As energy builds up, electrons become “excited” and will be transferred to the Primary Electron Acceptor. I now have to wait until water is split to replace my lost electron.”

Action: Accept the photons (tennis balls) from the antenna pigment student.

Once the tray is filled, turn and give it to the Primary Electron Acceptor.

Chlorophyll Reaction Center (P700)

ack

“I represent a special pair of chlorophyll molecules in Photosystem I that receives energy from the Antenna Pigments. As energy builds up, electrons become “excited” and will be transferred to the Primary Electron Acceptor. I now have to wait until the Electron Transport Chain in Photosystem II replaces my lost electron.”

Action: Accept the photons (tennis balls) from the antenna pigment student. Once the tray is filled, turn, and give it to the Primary Electron Acceptor.

(Look for Cues/Signal from Narrator)

After the Electron Transport Chain reads their part, accept the electron (muffin tray).

Photons of Light

The Sun

Back

Photosystem II: (Read this in its entirety the first time.)

“I am the Sun. I send out energy in the form of photons of light. This energy helps to drive the Light Dependent Reactions of Photosynthesis.”

Action: Hand a tennis ball (photon) to the antenna pigment student, listen to the Pigment antenna, read only the underlined sentence for the remaining two tennis balls, and pass a tennis ball.

Take cues (signals) from the Narrator

Photosystem I: (Read this in its entirety the first time.)

“Here I am, the Sun again! I’m sending down my photons to supply energy to another phase of the light dependent reactions”

Action: Hand a tennis ball (photon) to the antenna pigment student, listen to the Pigment antenna, read only the underlined sentence for the remaining two tennis balls, and pass a tennis ball.

Enzyme That Splits Water

Back

“I represent the enzyme that splits water. I break the bonds between the hydrogen and the oxygen in a water molecule. Electrons are released. One electron is transferred immediately to the Chlorophyll Reaction Center P680 to replace the one it has lost. The oxygen from the water forms oxygen gas that is released to the atmosphere. The molecule releases hydrogen ions that are needed later in the light reactions. “

Action: Remove the muffin pan from the Water Enzyme Container and pass it to the Chlorophyll Reaction Center. Remove the oxygen balloon(s) and lay it (them) aside. Remove and hold the hydrogen ions balloons. Move to a position next to the NADP+ Reductase enzyme. (LATER IN THE ROLE PLAY, these hydrogen ions balloons will be used in Photosystem I. When NADP+ Reductase Enzyme is speaking, take the hydrogen ions balloons and place them in the NADP+ container.)

Appendix B

No other information is on this page.

ADP +

P

ATP

Appendix C

No other information is on this page.

Light Dependent Reactions – Role Play

