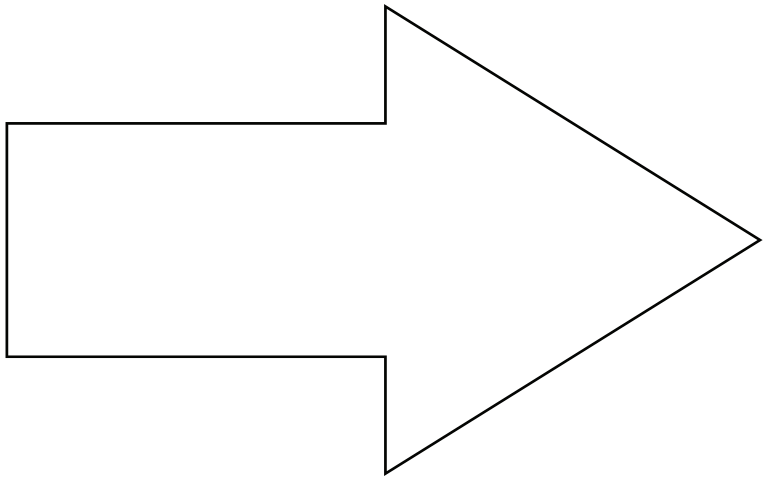
Leading Documents

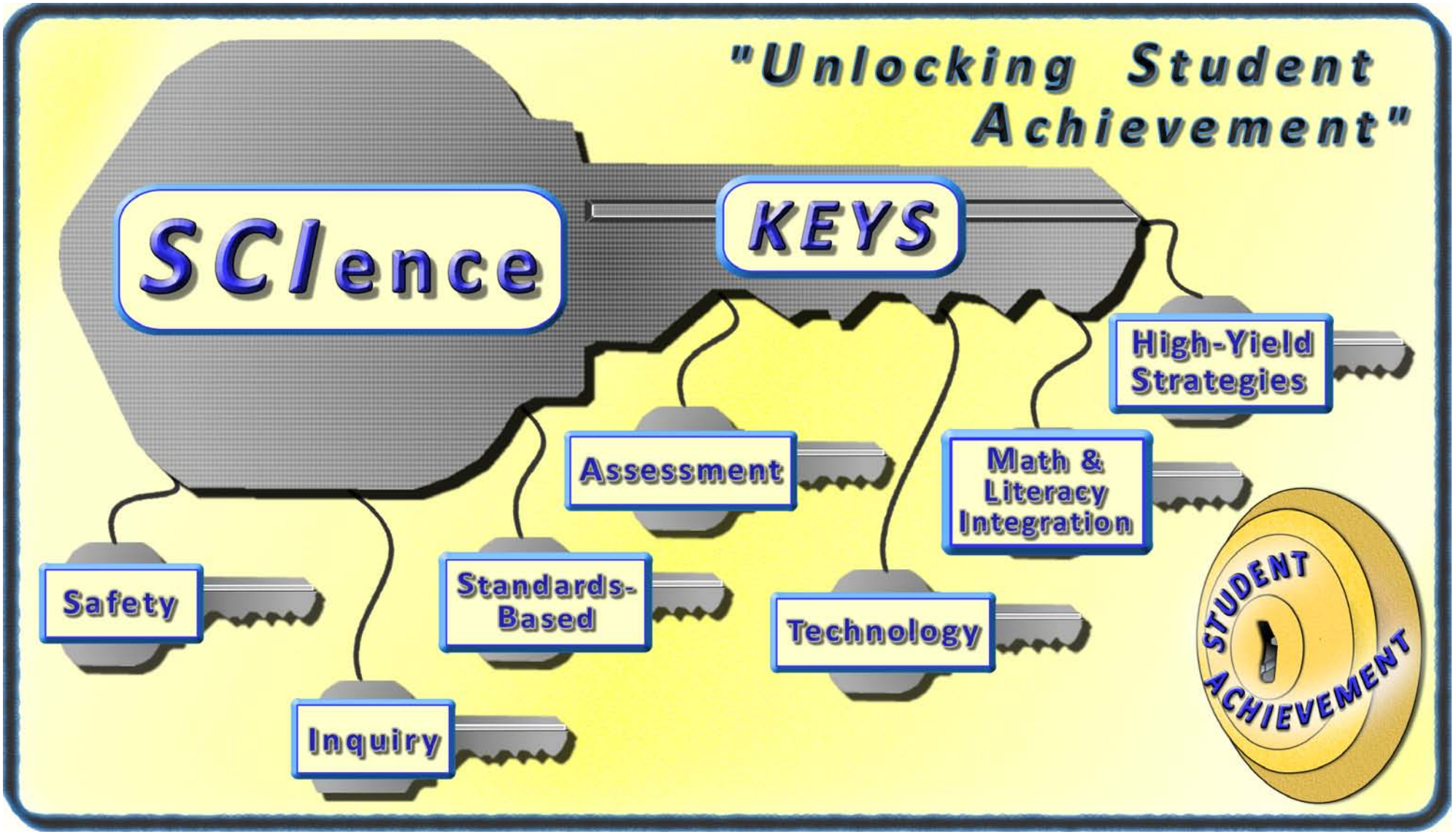


Section 1

The documents in this section are introductory to the Module. Some documents include the agenda, unit summary, and summative post test.

Biology Modules
Properties of Water & Photosynthesis

Participants will investigate the properties of water and its significance to life. Additionally, photosynthesis, including the light dependent and light independent reactions, will be explored**.** Materials will be provided for teacher use in the classroom. This module is part of a series of integrated, authentic inquiry-based modules aligned to the Arkansas Science Standards. All materials are provided free of charge. Instructional facilitation will also be provided for the teacher upon completion of this professional learning.


"Unlocking Student Achievement"
SCIence
KEYS
High-Yield Strategies
Assessment
Math & Literacy Integration
Safety
Standards-Based
Technology
Inquiry
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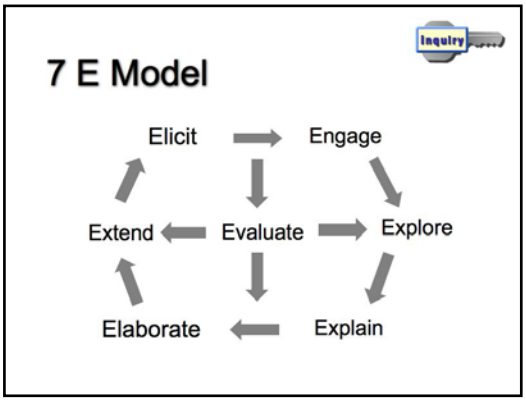
The 7-E's Learning Cycle



Phase 1: *Elicit*

Determining prior knowledge: "What do you know about..?"

Phase 2: *Engage*

Arouse student interest by using a discrepant event, telling a story, giving a demonstration, or by showing an object, picture, or brief video. Motivate and capture student interest.

Phase 3: *Explore*

Have students work with manipulative (e.g., natural objects, models) to make observations, investigate a question or phenomenon. Have students make predictions, develop hypotheses, design experiments, collect data, draw conclusions, and so forth. Teacher role is to provide support and scaffolding. Student role is to construct understanding through active experience.

Phase 4: *Explain*

Students report findings and discoveries to the class. Teacher allows opportunities to verbalize and clarify the concept; introduces concepts and terms and summarizes the results of the exploration phase. Teacher explanations, texts, and media are used to guide learning.

Phase 5: *Elaborate*

Have students apply the newly learned concepts to new contexts. Pose a different (but similar) question and have students explore it using the concept.

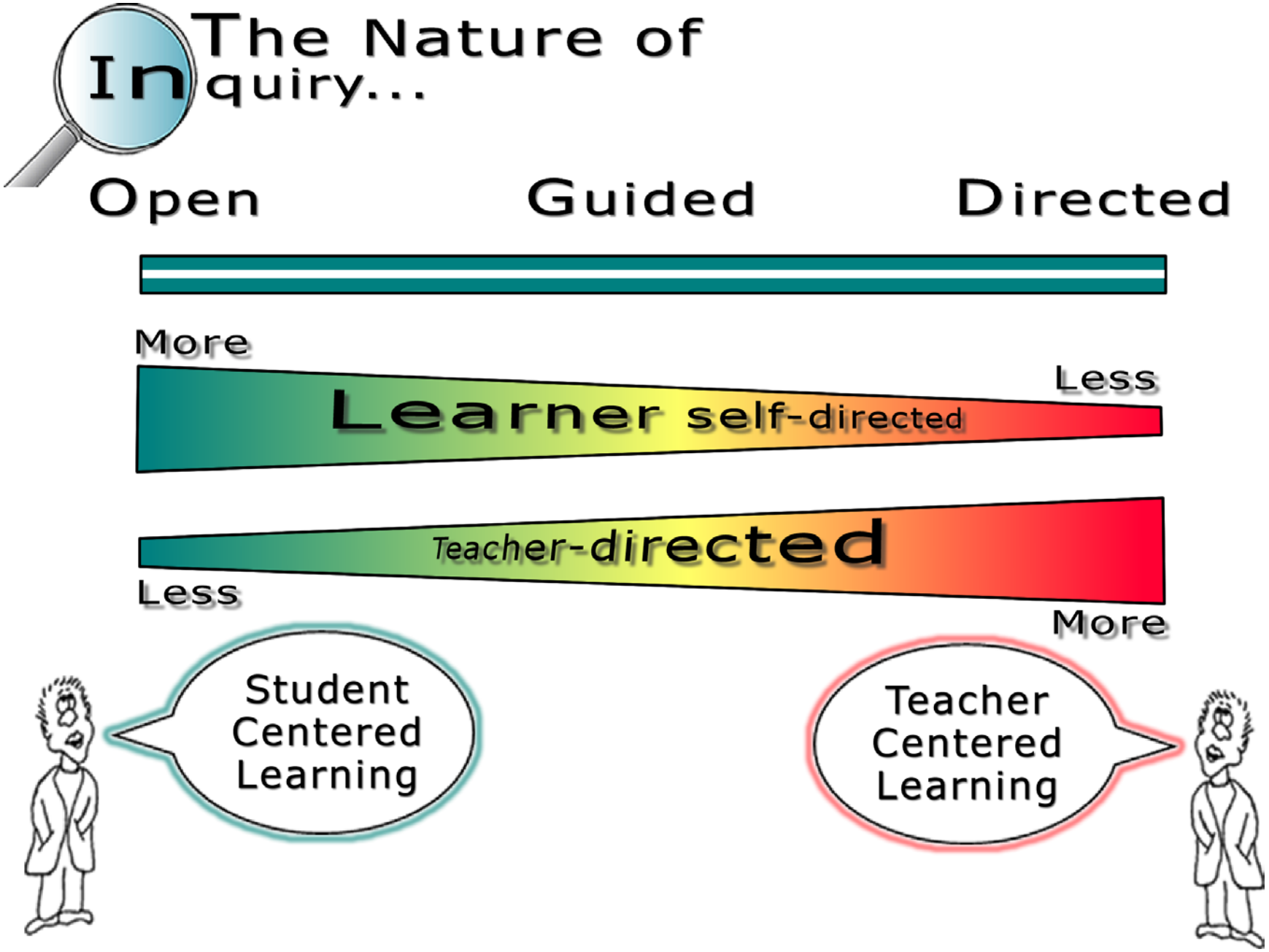
Phase 6: *Evaluate*

Use the formative assessment from Elicit Phase and assess: for example, the design of the investigation, the interpretation of the data, or follow-through on questions, looking for student growth. Growth is the desired change in the students' understanding of key concepts, principles, and skills in a differentiated classroom. Expectations vary according to the student's beginning point. Summative assessment may be used here to measure achievement and assign a grade.

Phase 7: *Extend*

Lead students to connect the concept to different contexts, transfer new learning.

"Teaching Constructivist Science K-8" by Bentley, Ebert, and Ebert; Corwin Press, 2007, pg. 117-119.


The Nature of Inquiry...
Open
Guided
Directed
More
Less
Learner self-directed
Teacher-directed
Less
More
Student Centered Learning
Teacher Centered Learning

Workshop Agenda

DAY 1 - Biology Module 1		
	KEY Event	**Notes/Questions**
	Introduction and Pre Test	
	**Safety KEY**	
	**Content KEY #1** – Properties of Water **Elicit:** Questions for notebooking	
	Engage: Demo "Balloney" **Explore:** Water Station Labs	
	Explain: Groups REPORT out	
	**Debrief and Standards KEY**	
	**Content KEY #2** – Photosynthesis BASICS	
	Elicit: Questions for notebooking	
	Engage: Kinesthetic walk through of photosynthesis	
	Explore: Diagram of leaf and chloroplast	
	Model Building Activities	
	Debrief and Standards KEY	
	Evaluate: Summarizing	
	Discuss assessments, extensions, bell ringers, integrations	
	**Assessment KEY-** Formative Assessment Complete and take up Reflection Cards	

DAY 2 - Biology Module 1		
	**Assessment KEY**	
	Explore: Photosynthesis Leaf Disk LAB	
	Explain	
	Explore: Leaf Stomata	
	Explain	
	Debrief and Standards KEY	
	High-yield Strategies	
	**Content KEY #3**– Photosynthesis DETAILS	
	ROLE PLAY: Light Dependent activity	
	**Debrief and Standards KEY**	
	Build Models: Light Independent/Calvin Cycle activity	
	Debrief and Standards KEY	
	**Technology KEY**	
	**Evaluation Key:** Post Test	

Water/Photosynthesis Comprehensive Learning Guide

Unit Overview

Unit Title: Water/Photosynthesis Module

Unit Summary: Chemistry is essential to understanding the life process. The structure and function of cells determines the foundation for all living things.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

- MC.1.B.3 Investigate the properties and importance of water and its significance for life: surface tension, adhesion, cohesion, polarity, and pH.
- MC.3.B.1 - Compare and contrast the structure and function of mitochondria and chloroplasts. (We will only address the chloroplast in this SLE.)
- MC.3.B.4 - Describe and model the conversion of light energy to chemical energy by photosynthetic organisms: light dependent reaction, light independent reaction.
- MC.3.B.5 - Compare and contrast cellular respiration and photosynthesis as energy conversion pathways. (We will only address the photosynthesis portion of this SLE.)
- CDL.7.B.17 - Describe the structure and function of the major parts of a plant: roots, stems, leaves, flowers. (We will only address the leaf in this SLE.)

Math Integration

- Data collection and analysis.

Literacy Integration

- Integrate grade level/student level appropriate reading books about water, utilize library skills by having students research properties of water or utilize exploration skills on the internet.

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details: NSES Content Standards for Grades 9-12:

- Standard B - Physical Science B1: Structure of Atoms; B2: Structure and Properties of Matter.
- Standard C: Develop an understanding of the cell.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Water:
  1. Sketch or construct a molecule of water demonstrating polarity and hydrogen bonding.
  2. Compare and contrast cohesion/adhesion.

3. Give examples of life processes related to the properties (adhesion, cohesion, surface tension) and importance of water.

- Photosynthesis:
  1. State/write the chemical equation of photosynthesis.
  2. Identify the major events involved in the light dependent and light independent reactions (Calvin Cycle)
  3. Identify the structure of a chloroplast.
  4. Identify the role of a chloroplast in photosynthesis.

Focus Question: How do the properties of water affect life?
How do cells obtain and utilize energy?

Prerequisites / Background Information:

- Lab safety
- Lab procedures

Timeline: Unit could take 1-2 weeks depending on class schedule.

Preparation:
Elicit/Engage:
Explore:
Explain:
Cleanup:

Teacher Preparation:

- Properties of Water Labs:
  1. Engage Activity-the science specialists chose the "Ballooney" activity as a demonstration. However, the teacher may choose any one of the lab activities to do as a demonstration.
  2. Explore Activity-students will rotate through the remainder of the activities.
- Other performance tasks:
  1. Sketch or construct a molecule of water demonstrating polarity and hydrogen bonding.
  2. Compare and contrast cohesion/adhesion.
  3. Give examples of life processes related to the properties (adhesion, cohesion, surface tension) and importance of water.
- Photosynthesis Labs and Activities:
  1. Kinesthetic Walkthrough
  2. Leaf/Chloroplast Model building
  3. Leaf Disc lab
  4. Lt Dependent Role Play
  5. Lt Independent Bead Activity

Materials:

- Materials for labs are included in each Teachers Guide

Technology – Hardware: (Click boxes of all equipment needed)

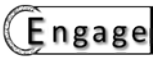
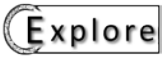
☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☒ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☒ Multimedia	☐ Other:
☒ Internet Web Browser	☐ Word Processing	

Internet Resources:

Cytoplasm Elodea Streaming - YouTube
Cytoplasm Streaming in the Water Lily - YouTube
The Futures Channel - Fish Farming
The Futures Channel - Water Supply
The Futures Channel - Water Tanks
Slow Frozen People – Web Research

Procedures:	**Teacher's Notes:**
 • No eating or drinking in the lab • Follow written & oral instructions • No horse play • Wear appropriate safety gear (goggles, apron, gloves)	
 • Water: In groups of two or three, have students discuss and write in science notebooks and illustrate what they know about the structure and properties of water. Share responses on the board or chart paper so that students can add to their own science notebook entries any ideas they did not already have. • Photosynthesis: Discuss the impact of clear cutting in the forest and explain the ramifications of losing the trees. Have students explain why the loss of trees can influence humans and ask students to identify what part(s) of the tree we most rely upon.	• Vocabulary: 1. Water: Adhesion, cohesion, polarity, surface tension, pH, capillary action, acid, base, hydrogen bonding, solvent. 2. Photosynthesis: ATP, electron transport chain, glucose, carbon dioxide, oxygen, chloroplasts, light dependent, light independent, photosynthesis.
 • Properties of Water Lab- the science specialists chose the "Ballooney" activity as a demonstration. However, the teacher may choose any one of the lab activities to do as a demonstration. • Photosynthesis: streaming video of Elodea, light dependent activity, students collect leaves from trees.	
 • Water: Properties of Water Lab -students will rotate through the remainder of the activities. • Photosynthesis: Leaf disk lab, counting stomata, kinesthetic activity, light dependent role play, chloroplast/leaf model building, light independent bead activity.	

Explain

- Teacher should review the Properties of Water and Explanation of the Lab documents prior to the lesson.
- Teacher will review properties of water with students and discuss why these properties are important for living things (water's significance for life).
- Teacher will ask questions about lab, such as:
  1. Which properties of water are being demonstrated at this station?
  2. How is this property important for living things?
  3. What are some other properties of water not covered in the lab and how are they important for living things?
- Photosynthesis PPT can be used.

Misconceptions:

- Water:
  1. Adhesion is the same as cohesion.
  2. Water dissolves everything.
  3. Water atoms expand or change when ice melts.
  4. A film on the surface of water does nothing to the water.
  5. Liquids rise in a straw because of "suction".
- Photosynthesis:
  1. Photosynthesis is a simple reaction.
  2. Photosynthesis occurs only in plants.
  3. Photosynthesis occurs only on land.
  4. Leaves reflect all green light and do not use green light in photosynthesis.
  5. Plants photosynthesize during the day and conduct cellular respiration only at night.
  6. Photosynthetic carbon fixation (dark reactions) occurs at night.
  7. Bubble formation on leaves submerged in water is always caused by photosynthesis.

Elaborate

- Any of the chemistry lab activities not previously done, or students may design experiments to test the questions they generated during the lab.
- Each photosynthesis lab/activity can be expanded to further student knowledge.

Evaluate

- Ex: Make a "foldable" whereby students compare adhesion/ cohesion, list 5 properties of water and/or write an application for each of the properties of water to life.

Formative Assessment:

1. Water Formative Assessment
2. Questions from self-assessment
3. Notebook entries from beginning of lesson
4. Photosynthesis Pre/Post test
5. OR Questions

Summative Assessment:

- End of unit assessment provided.

Environment Movie - Water Supply Lesson - Web

Cross-Curricular

- Water:
  1. Water samples from various sources could be tested with pH probes.
  2. Water scavenger hunts via internet are another way for students to interact with the learning.
- Photosynthesis:
  1. Students can record on video the photosynthesis process correctly and post it for review.
  2. Students can record an incorrect version of the process and have students identify what was wrong and explain the correct process.
  3. Students can build an electronic presentation of the photosynthesis reaction.

Notes:

- Modifications:
  1. Place students in mixed ability groups or mixed learning style groups. Other modifications may be made as determined by an individual IEP.
- Interventions:
  1. Water: Address misconceptions by explaining the difference in adhesion and cohesion. Discuss the reason water is known as the "Universal Solvent" even though it does not dissolve everything.
  2. Photosynthesis: Address misconceptions by explaining the difference in light dependent and independent reactions. Discuss the importance of photosynthesis for both the plant and animals.
- Gifted and Talented:
  1. GT students can research and present other activities that demonstrate the properties of water or research ways these properties are associated with living things. GT students can research and present other activities that demonstrate the process of photosynthesis.
- Parental Involvement:
  1. Water and its importance to living things could be an excellent theme for a family science night. Stations with water activities and mini lessons could be set up. Invite guest speakers from universities or greenhouses, coordinate field trips for students to explore how businesses and universities need to understand photosynthesis.

Water/Photosynthesis Unit

1. Rate your understanding of best practices and how it relates to teaching science.
    a. Poor
    b. Fair
    c. Adequate
    d. Good
    e. Excellent

2. I am adequately prepared to deliver instruction from this training to my students.
    a. Poor
    b. Fair
    c. Adequate
    d. Good
    e. Excellent

3. Rate your understanding of the 7E model.
    a. Poor
    b. Fair
    c. Adequate
    d. Good
    e. Excellent

4. Rate your ability to apply the 7E model to science instruction.
    a. Poor
    b. Fair
    c. Adequate
    d. Good
    e. Excellent

5. Rate your understanding of inquiry-based science instruction.
    a. Poor
    b. Fair
    c. Adequate
    d. Good
    e. Excellent

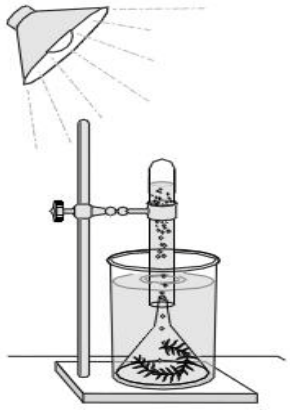
6. How are photosynthesis and cellular respiration similar?
    a. They occur in animal cells.
    b. They take place in the same organelle.
    c. They involve the conversion of energy.
    d. They produce the same complex carbohydrate.

7. What is formed during photosynthesis and broken down during cellular respiration?
    a. Water
    b. Glucose
    c. Lactic acid
    d. Carbon dioxide

8. Which process occurs in the chloroplasts of plant cells?
    a. Reproduction
    b. Photosynthesis
    c. Protein synthesis
    d. Cellular respiration

9. Which of the following is needed to transfer and release energy?
    a. Nitrate
    b. Calcium
    c. Potassium
    d. Phosphate

10. Where does the light independent reaction occur?
    a. Stroma
    b. Granum
    c. Thylakoid membrane
    d. Chloroplast membrane

11. 

In the experiment above, which factor was most responsible for the production of oxygen by *Elodea*?

a. Sugar was present in the liquid.
b. The presence of light stimulated photosynthesis.
c. The plant contained a large number of mitochondria.
d. The liquid contained enough oxygen for the plant to absorb.

12. During photosynthesis, energy from the sun is trapped in –

a. Enzymes.
b. Golgi bodies.
c. Chemical bonds.
d. The nuclei of atoms.

13. The glucose produced during photosynthesis is an example of a –

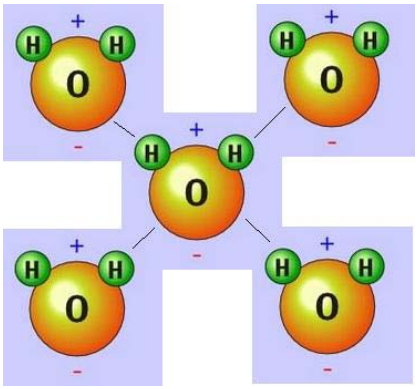
a. Lipid.
b. Protein.
c. Nucleic acid.
d. Carbohydrate.

14. Which of the following is produced during a light dependent reaction?

a. O_2
b. ATP.
c. NADPH
d. All of the above

15. In the basic process of photosynthesis, light energy is converted to

a. Thermal energy
b. Electrical energy
c. Chemical energy
d. Mechanical energy



16. Which property of water is shown above?

a. pH
b. Polarity
c. Adhesion
d. Solubility

17. A person fills a drinking glass with water until the water is bulging slightly above the rim of the glass. Which property of water is most accurately demonstrated by this?

a. pH
b. Osmosis
c. Cohesion
d. Solubility

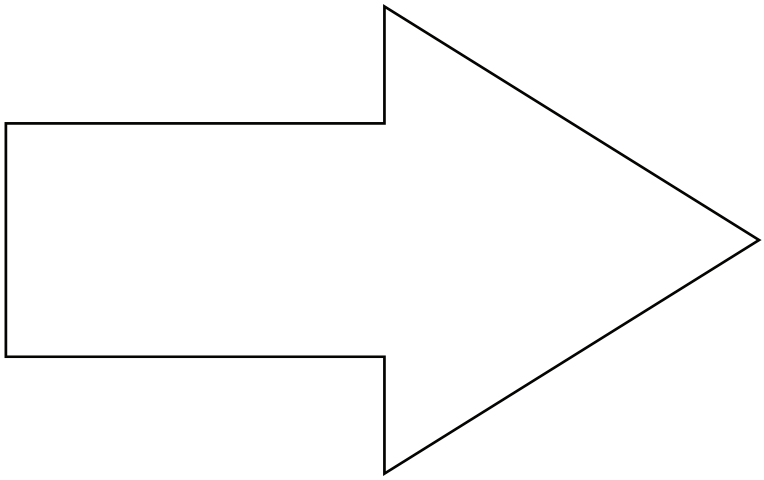
18. Which of the following statements are true?

a. Adhesion is similar molecules clinging together
b. Cohesion is similar molecules clinging together
c. Adhesion and cohesion are the same thing.
d. Water dissolves everything.

Biology Module 1 Summative
Pre/Post Test

1. Opinion
2. Opinion
3. Opinion
4. Opinion
5. Opinion
6. C
7. B
8. B
9. D
10. A
11. B
12. C
13. D
14. D
15. C
16. B
17. C
18. B

Properties of Water



Section 2

The section contains the Properties of water documents.

Including lessons and assessments.

Properties of Water Lesson Guide

Unit Overview

Unit Title: Properties of Water

Lesson Summary: Chemistry is essential to understanding the life process.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

- MC.1.B.3 Investigate the properties and importance of water and its significance for life: surface tension, adhesion, cohesion, polarity, and pH.

- Graph the number of drops of water with detergent vs. the number of drops of water without detergent that stay on the coin.

- Integrate reading books about water, utilize library skills by having students research properties of water or utilize exploration skills on the internet. Journal entries, lab reports. http://www.sciencedaily.com/releases/2006/06/060620171022.htm

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details: NSES Content Standards for Grades 9-12:

- Standard B - Physical Science B1: Structure of Atoms; B2: Structure and Properties of Matter.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:
- Sketch or construct a molecule of water demonstrating polarity and hydrogen bonding.
- Compare and contrast cohesion/adhesion.
- Give examples of life processes related to the properties (adhesion, cohesion, surface tension) and importance of water.

Focus Question:
- How do the properties of water affect life?

Prerequisites / Background Information:
- Document: Properties of Water Background Information

Timeline: 1-2 Class periods depending on instruction time

Preparation:	• 1 Hour
Elicit/Engage:	• 10 min
Explore:	• 1 Hour
Explain:	• 20 min
Cleanup:	• 30 min

Teacher Preparation:

- Teacher lesson plan, water information, lab set up and student response sheets are included in the link next to the engage instructions.
  Modifications: Place students in mixed ability groups or mixed learning style groups. Other modifications may be made as determined by an individual IEP.
- Interventions: Address misconceptions by explaining the difference in adhesion and cohesion. Discuss the reason water is known as the "Universal Solvent" even though it does not dissolve everything.
- Intellectual Challenges: GT students can research and present other activities that demonstrate the properties of water or research ways these properties are associated with living things.

Materials:

- Document: Properties of Water Lab Materials

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☒ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☒ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• No eating or drinking in the lab • Follow written & oral instructions • No horse play • Wear appropriate safety gear (goggles, apron, gloves)	

Elicit

- In groups of two or three, have students discuss and write in science notebooks, illustrate what they know about the structure and properties of water.
- Share responses on the board or chart paper so that students can add to their own science notebook entries any ideas they did not already have.
- Writing Prompts:
  1. Is water really the universal solvent?
  2. Can you give an example of something that does not dissolve in water?

Engage

- Water:
  "Ballooney" is the engagement; however, the teacher may choose any of the lab stations for a demonstration.

Explore

- Chemistry-Properties of Water Lab --teacher will choose as many as possible of the activities out of the remaining activities.

Explain

- Review the Properties of Water and Explanation of the Lab documents prior to the lesson.
- Review properties of water with students and discuss why these properties are important for living things (water's significance for life).
- Ask questions about lab, such as:
  1. Which properties of water are being demonstrated at this station?
  2. How is this property important for living things?
  3. What are some other properties of water not covered in the lab and how are they important for living things?
- Possible Misconceptions:
  1. Adhesion is the same as cohesion.
  2. Water dissolves everything.
  3. Water atoms expand or change when ice melts.
  4. A film on the surface of water does nothing to the water.
  5. Liquids rise in a straw because of "suction".
  6. See additional misconceptions below in the provided web links.

- Vocabulary
  Adhesion, cohesion, polarity, surface tension, pH, capillary action, acid, base, hydrogen bonding, solvent.

Elaborate

- The student may complete any of the chemistry lab activities not previously completed, or may design experiments to test the questions they generated during the lab.

Evaluate

Formative Assessment

- Water formative assessments
- Make a "foldable" whereby students compare adhesion/ cohesion, list 5 properties of water and/or write an application for each of the properties of water to life.
- Questions for Reflection:
  1. Two things I learned about water that I did not know.
  2. One thing I am unclear about.

Summative Assessment

- Unit Summative Assessment

Extend

- Environment Movie - Water Supply Lesson - Web
- Frozen People

- http://www.thefutureschannel.com/dockets/hands-on_math/water_supply/
- http://www.sciencedaily.com/releases/2006/06/060620171022.htm

Cross-Curricular

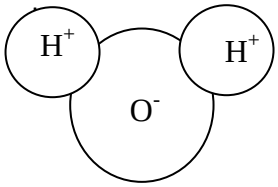
- Document: Properties Of Water Cross Curriculum
- Technology:
  1. Water samples from various sources can pH probes.
  2. Water scavenger hunts via internet are another way for students to interact with the learning.

Notes:

- 21st Century Skills: Teaming, Collaboration, Inventive thinking.

The Properties of Water

If you could see molecules of water and how they act, you would notice that each water molecule electrically attracts neighboring molecules. Each molecule has two hydrogen atoms and one oxygen atom, H_20. A simple diagram of the asymmetrical shape of a water molecule resembles a “Mickey Mouse” head.



The “stickiness” of water is due to the two hydrogen atoms which are arranged on one side of the molecule and are attracted to the oxygen atoms of other nearby water molecules in a state known as **"hydrogen bonding."** (If the molecules of a liquid did not attract one another, then the constant thermal agitation of the molecules would cause the liquid to instantly boil or evaporate.) See the “Explain the Lab” page for a diagram of hydrogen bonding.

The hydrogen atom has one valence electron and an electronegativity value of 2.2. Oxygen has six valence electrons with an electronegativity value of 3.44. Electronegativity is the tendency an element has to attract electrons. The higher the electronegativity of an atom, the greater its tendency is to attract electrons in a shared pair. This means that oxygen has a greater tendency to attract electrons. Therefore, the valence electron on each hydrogen atom tends to be pulled toward the oxygen atom, leaving an uneven distribution of electrons called polarity.

Since opposite charges attract, it is no surprise that the hydrogen atoms of a water molecule like to point toward the oxygen atom of other molecules. Of course, in the liquid state, the molecules have too much energy to become locked into a fixed pattern; nevertheless, the numerous temporary "hydrogen bonds" between molecules make water an extraordinarily sticky fluid.

Cohesion and Adhesion

The property that causes water molecules to be attracted to other water molecules is called **cohesion.** When water is attracted to molecules of other materials it is referred to as **adhesion**. Because of the unequal charge distribution, the hydrogen of one water molecule is attracted to the oxygen of other molecules. This gives water its cohesive and adhesive properties. These two properties of water can help explain how water can bulge upward from the rim of a glass filled with water. **Surface tension** is the name given to this phenomenon.

Adhesion and cohesion explain what happens when you dip one end of a piece of paper towel into a glass of water. The water will climb up the fibers of the paper, getting it wet above the level of the water in the glass. We know gravity is pulling down on the water, so why is the water moving up? The water molecules' positive and negative charges are attracted to the positive and negative charges in the cellulose molecules in the paper. The water molecules also "stick" to each other, causing an upward movement.

Surface Tension

Within a body of water, every molecule is engaged in a tug of war with its neighbors on every side. For every "up" pull there is a "down" pull, and for every "left" pull there is a "right" pull, and so on, so that any given molecule feels no net force at all.

At the surface things are different. There is no up pull for every down pull, since of course there is no liquid above the surface; thus the surface molecules tend to be pulled back into the liquid. It takes work to pull a molecule up to the surface. If the surface is stretched - as when you blow a bubble - it becomes larger in area, and more molecules are dragged from within the liquid to become part of this increased area. This "stretchy skin" effect is called **surface tension**. Surface tension plays an important role in the way liquids behave. If you fill a glass with water, you will be able to add water above the rim of the glass because of surface tension. Try this and you will notice the water “piling up” above the rim of the glass.

There are many simple experiments that can be performed with surface tension, and many real world examples that can be used to illustrate its effects. A water strider can “scoot” rapidly across the surface of a pond without breaking the surface tension. You will notice a dimpling of the water’s surface where each leg touches the surface.

You can float a paper clip or a sewing needle on the surface of water. Place the paper clip on a fork (or another paper clip that is unfolded) and lower it slowly onto the water’s surface. The paper clip is supported by the surface-tension “skin” of the water.

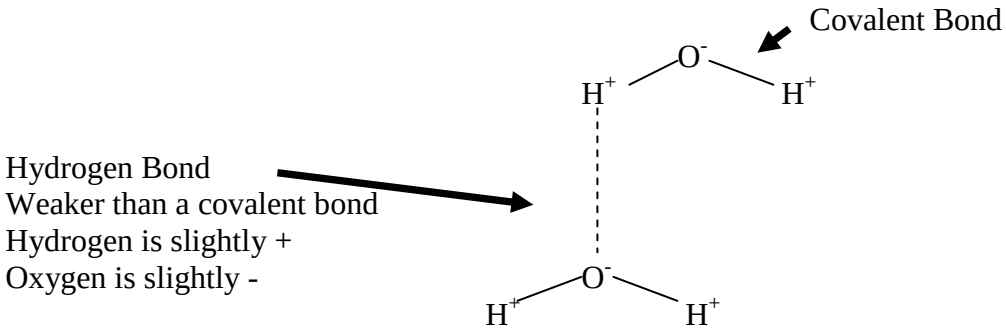
Surfactants and Surface Tension

Soaps and detergents have a polar “head” to which water is attracted, known as the hydrophilic end. It also has a non-polar “tail” that is hydrophobic or water fearing (repelling). When these substances are added to water, they weaken the strength of the surface tension by interfering with hydrogen bonding between water molecules. At the surface the non-polar tails stick out away from the water reducing the surface tension.

To illustrate this, sprinkle grains of black pepper over the surface of a bowl of water. Dip a swab in detergent and touch it to the middle of the water’s surface. The pepper grains will rapidly move to the side of the bowl when the detergent “breaks down” the surface tension. This effect can also be simulated by a group performing a tug of water with a rope. As long as tension is equal in both directions nothing happens; but if the rope is cut, both groups will suddenly fall down.

Explanation of Chemistry
The Properties of Water Lab

Water is unique; it does not follow the predicted trends that many other chemical compounds follow. The polarity and hydrogen bonding allow for interesting properties that make life possible.
This polarity and subsequent hydrogen bonding allows for the properties of water such as high boiling point, high heat of vaporization, high specific heat, high heat of fusion, low vapor pressure, ice floating, and high cohesive forces.
Water is composed of two hydrogen atoms covalently bonded to one oxygen atom. Water molecules are attracted to one another through much weaker bonds called hydrogen bonds, where the hydrogen of one water molecule forms a weak bond (the hydrogen bond) with the oxygen of another water molecule.



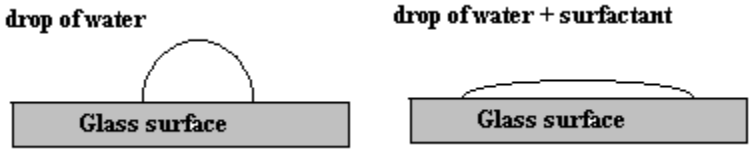
These are good sources of information about water:
http://www.physicalgeography.net/fundamentals/8a.html
http://ga.water.usgs.gov/edu/waterproperties.html Has an online quiz
http://en.wikipedia.org/wiki/Water_(molecule)
http://www.edinformatics.com/math_science/water_ice.htm
http://www.johnkyrk.com/H2O.html Great animations
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page3.html
http://www.youtube.com/watch?v=TdMIsCF_7p0&NR=1 slow motion video that demonstrates the adhesion, cohesion, and surface tension properties of water. REALLY COOL!

Station 1-Water expands as it freezes, and becomes less dense. In liquid water, as molecules slip and slide past each other, hydrogen bonds form, break, and reform. By the time water has cooled to 4°C, the energy in the molecules is so low that the molecules are very close together, and each water molecule forms additional hydrogen bonds. At this temperature water reaches its maximum density, making it denser than water at room temperature. However, between the temperature of 4°C and 0°C the molecules line up in a crystalline lattice, which is an open hexagonal shape so as to achieve the maximum distance between the electron-rich oxygen atoms (like charges repel one another). The water molecules are held rigidly apart, unlike the molecules in liquid water. This means more empty space between the molecules and it occupies more space, and is subsequently less dense. Recall that density is defined as mass per unit volume.

Station 2 part 1-Water has a high surface tension. In other words, water is cohesive, adhesive, and elastic, and tends to aggregate in drops rather than spread over a surface as a thin film. This phenomenon also causes water to stick to the sides of vertical structures despite gravity's downward pull. Water's high surface tension allows for the formation of water droplets and waves, allows plants to move water (and dissolved nutrients) from their roots to their leaves, and the movement of blood through tiny vessels in the bodies of some animals. Pidwirny, M. (2006). "Physical Properties of Water". *Fundamentals of Physical Geography, 2nd Edition*. December 30, 2008. http://www.physicalgeography.net/fundamentals/8a.html Surface tension is the result of the strong cohesive forces of water.

Unlike water molecules in the interior of the liquid, which are bonded equally in all directions, water molecules at the surface are drawn to each other in fewer directions (horizontally and various angles downward) because air molecules lie above the water surface. With fewer total bonds, each surface water molecule bonds more strongly with those water molecules that surround it to the sides and below, almost forming a "skin" on the water surface.
http://www.kids.union.edu/pepperRun.htm

Station 2 part 2-Detergents contain surfactants (**s**urface **act**ing age**nts**) which reduce the surface tension of water by adsorption at the liquid-gas, liquid-solid, or liquid-liquid interfaces, which means that the presence of the surfactant in the water allows a film of gas molecules to adhere to the surface of the water thereby reducing the interfacial tension causing the droplet to spread out. A **detergent** is a material intended to assist cleaning.
http://en.wikipedia.org/wiki/Surfactant
A surfactant is briefly defined as a material that can greatly reduce the surface tension of water when used in very low concentrations.
http://www.chemistry.co.nz/surfactants.htm



Station 3-Adhesion and cohesion- **Adhesion** is the tendency of certain **dissimilar molecules** to cling together due to attractive forces. http://en.wikipedia.org/wiki/Adhesion
Cohesion (chemistry): the intermolecular attraction between **like-molecules**.
http://en.wikipedia.org/wiki/Cohesive

The water adheres to the glass stirring rod because the charges of the water and the glass attract each other. Cohesion (relates back to hydrogen bonding) of the water molecules keep it on the stirring rod. Water does not adhere to the plastic because the charges on the water molecules and the plastic do not attract each other.

Station 4 part 1-Adhesion, cohesion, and surface tension (see station 2 part 1 and station 3). The water adheres to the dime and the cohesion of the water molecules and the strong surface tension keep them bound together. At some point, the force of gravity on the water bulging over the sides is greater than the cohesive and surface tension forces.

Station 4 part 2-The detergent acts as a surfactant and lowers the surface tension of the water (see station 2 part 2)

Station 5-Adhesion, cohesion, and surface tension (see above). Alcohol has lower adhesion, cohesion and surface tension than water.

Station 6-Water molecules are polar; they have an electron rich end (partially negative) and an electron poor end (partially positive). When you rub a balloon on a paper towel (or your hair) you give the balloon a static charge (in this case, a negative charge). When the balloon is brought close to the water stream, the water is polarized by the presence of the electric field from the balloon, attracting the partially positive ends of the water molecules thereby bending the water stream.

Station 7-Water molecules adhere to the paper, and the cohesive forces keep the column of water together. The water should move until the adhesive and cohesive forces are equal to the force of gravity. This is an example of capillary action.

Station 8-The adhesive forces of water and glass are strong, the adhesive forces of water and plastic are not as strong, so you see a meniscus in the glass cylinder but not one in the plastic cylinder. Compare the alcohol to the water. Does alcohol have strong adhesive forces to glass or alcohol? If a meniscus forms, the answer is yes.

Station 9-The high surface tension of water allows the pepper to float randomly on the surface. The addition of detergent disrupts the surface tension where the detergent is placed and the water molecules and pepper on top move to the sides. This is similar to what happens when a rope being pulled on both ends equally is suddenly cut in the middle. Here is one explanation: http://drholly.typepad.com/ask_me_a_chemistry_questi/2006/01/pepper_and_soap.html

Station 10-The pH of pure water is 7 because when water ionizes, the concentration of the hydronium ion (H_3O^+) is equal to the concentration of the hydroxide ion (OH^-). If the concentration of H_3O^+ is greater than the concentration of OH^-, the solution is acidic (pH lower than 7). If the concentration of OH^- is greater than the concentration of H^+, then the solution is basic (pH greater than 7).

Most of the water we drink is close to a pH of 7, depending upon the materials naturally found in it, therefore, all of the drinking water tested should be around 7. If the pH is higher or lower, something in the water is causing it to be more acidic or basic. The other liquids will have different pH values. http://ga.water.usgs.gov/edu/phdiagram.html

Station 11- Capillary action occurs because water is sticky -- water molecules stick to each other (cohesion) and to other substances (adhesion), such as glass, cloth, organic tissues, and soil.

Plants and trees could not thrive without capillary action. Plants put down roots into the soil which are capable of carrying water from the soil up into the plant. Water, which contains dissolved nutrients, moves into the roots and up the plant tissue. As a water molecule begins climbing, it pulls a nearby water molecule with it, and so on.

Think of the tiniest blood vessels in your body -- your capillaries. Your blood is mostly water, and capillary action assists the pumping action of your heart to help keep blood moving in your blood vessels.
http://dwb4.unl.edu/Chem/CHEM869A/CHEM869ALinks/ga.water.usgs.gov/edu/capillaryaction.html

Water climbs up a thin glass tube because of the strong hydrogen-bonding interactions between the water and the oxygens (and terminal hydrogens) at the surface of the glass (SiO_2; surface oxygens are typically bonded to hydrogen). The energetic gain from the new intermolecular interactions must be balanced against gravity, which attempts to pull the liquid back down. Therefore, the narrower the tube, the higher the liquid will climb, because a narrow column of liquid weighs less than a thick one. http://www.madsci.org/posts/archives/1998-02/887637827.Ch.r.html

Water will not move between the two slides rubber banded together because there is not enough space between them. Water will move up the slides separated with the toothpick, however, the side without the toothpick has the best movement. Capillary action occurs best in small spaces and the side with the toothpick has a larger space.

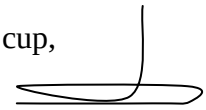
Properties of Water Lab
Materials List

Station #1: Freeze
Materials: one ½ pint plastic water bottle filled to the rim with water and frozen (NO lid), one ½ pint plastic water bottle filled to the rim with water and left at room temperature, container filled with water (large enough for the bottles to fit), Parafilm, and paper towels to cover the bottles. Coloring water may make the ice more visible. You will only need one room temperature bottle and you will need to freeze several water bottles to have enough that stay frozen for each class.

Station #2 Part 1: Dish and Clips
Materials: paper clips, tweezers, water in a bowl or large cup, paper towels. You may use a bent paper clip instead of tweezers

Bent Paper Clip

Station #2 Part 2: Clean Dish and Clips
Materials: paper clips, tweezers, water mixed with several drops of detergent in a bowl or large cup, paper towels. You may use a bent paper clip instead of tweezers



Bent Paper Clip

Station #3: Stir it Up
Materials: glass stirring rod, plastic coffee stirrer (or plastic straw),
2 clear plastic cups, paper towels, and colored water.

Station #4 Part 1: Stop on a Dime
Materials: dropper, dime, cup of water, paper towels

Station # 4 Part 2: A Clean Dime
Materials: dropper, dime, cup of water with several drops of detergent mixed in, paper towels

Station #5: Wax on, Wax off
Materials: sheet of folded wax paper (or Styrofoam tray), dropper, water in cup, rubbing alcohol in cup, and paper towels, food coloring optional

Station #6: Ballooney
Materials: paper towels, balloons, water in buret, buret stand, cup of colored water and dish pan. If you don't have burets, use a **very** thin stream of water from a faucet. If not used as the "Engage", leave the water running from the faucet so the stream of water stays consistent.

Station #7: Anti-Gravity
Materials: paper towels, shallow dish or Petri dish, stapler, cup of colored water, metric ruler, marker

Station 8: Look Very Carefully!
Materials: 2 plastic 10ml graduated cylinders (or small plastic test tubes), 2 glass 10 ml graduated cylinders, (or small glass test tubes) Label 1 plastic cylinder **rubbing alcohol** and one **water**. Label one glass cylinder **rubbing alcohol** and one **water**. Add equal amounts of water or rubbing alcohol to the appropriately labeled cylinder. Coloring water may make difference more visible.

Station # 9: Pepper Anyone?
Materials: shallow round container or Petri dish, pepper, toothpicks or cotton swabs, detergent in a small container, cup of water

Station #10: What's the difference? Choose the number of liquids you have time for!
Materials: water from different sources (tap, bottled, distilled, spring, pond, etc.), plus any other liquids such as lemon juice, perfume, cola, eye drops, milk, etc that you have available.
Large scale (pH 0-14) pH paper (or pH probes), small containers for each of the liquids

Station #11: Sliding through ACC (Adhesion, Cohesion and Capillary action)
Materials: 4 glass slides, 1 toothpick, 2 rubber bands, and shallow dish with colored water

Station #12: Models
Materials: Water magnet models

Properties of Water Lab

Stations have been set up around the room. At each station, your group will perform the experiment indicated. The experiments can be done in any order. When you arrive at each station:

1. Read and follow procedures.
2. Record answers in the table provided.
3. If required, **PREDICT** before observing.
4. Record your observations.
5. Write a possible explanation for your observations.

Station #1: Freeze

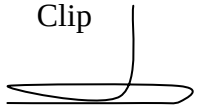
Materials: one ½ pint plastic water bottle filled to the rim with water and frozen (NO lid), one ½ pint plastic water bottle filled to the rim with water and left at room temperature, container filled with water (large enough for the bottles to fit), Parafilm, and paper towels to cover the bottles.

Procedure:

1. **PREDICT** what the frozen water bottle will look like. How will it compare to the bottle that was not frozen? **PREDICT** what will happen when you place bottles in a container of water.
2. Uncover the bottles and record your observations.
3. Cover both bottle openings tightly with Parafilm or plastic wrap.
4. Place both bottles in the pan of water and record your observations.
5. Remove and dry the bottles, remove the Parafilm or plastic wrap and cover the bottles for the next group.

Station #1: Freeze		
Prediction	**Observation**	**Explanation**
Frozen		
Room temperature		
What do you still want to know?		

Station #2 Part 1: Dish and clips



Materials: paper clips, tweezers or bent paper clip, water in a bowl or large cup, paper towels.

Procedure:

1. **PREDICT** what will happen when you **gently** place a paperclip on the surface of water.
2. Make sure the paperclip is dry, use the tweezers or bent paper clip to **gently** put the paperclip **on** the surface of the water and observe. Can you put more than one paperclip on the surface of the water?
3. When finished, refill the cup if necessary; dry the paper clip, and place it on a paper towel for the next group.

#2 Part: Dish and Clips		
Prediction	Observation	Explanation
What do you still want to know?		

Station #2 Part 2: Clean Dish and Clips

Materials: paper clips, tweezers or bent paper clip, water mixed with several drops of detergent in a bowl or large cup, paper towels.

Procedure:

1. **PREDICT** what will happen when you place a paperclip on the surface of the water-detergent mixture.
2. Make sure the paper clip is dry, use the tweezers or bent paper clip to **gently** place the paperclip **on** the surface of the water and observe. Can you put more than one paperclip on the surface?
3. When finished, refill the cup if necessary; dry the paper clip and place it on a paper towel for the next group.

#2 Part 2: Clean Dish and Clips		
Prediction	Observation	Explanation
What do you still want to know?		

Station #3: Stir it Up

Materials: glass stirring rod, plastic coffee stirrer (or plastic straw),
2 clear plastic cups, paper towels,

Procedure:

1. Make sure the glass rod and coffee stirrer are dry.
2. Fill one cup with water.
3. Hold the glass stirring rod at a 45^0 angle over the center of the empty cup.
4. Slowly pour all water from the first cup on to the top end of the stirring rod into the empty cup.
5. Record your observations.
6. Repeat Steps 1-5 using a plastic coffee stirrer (or plastic straw).

#3 Stir it Up	
Observation: glass rod	Explanation
Observation: coffee stirrer	Explanation
What do you still want to know?	

Station #4 Part 1: Stop on a Dime
Materials: dropper, dime, cup of water, paper towels
Procedure:

1. **PREDICT** how many drops of water will fit on the dime before it spills over the edge.
2. Hold the dropper vertically. Count the drops as you carefully add water to the surface of the dime. **Stop** when water spills over the edge.
3. Record your observations.
4. Dry the dime and refill the cup for the next group, if necessary..

#4 Part 1-Stop on a Dime		
Prediction	Observation	Explanation
What do you still want to know?		

Station # 4 Part 2: A Clean Dime
Materials: dropper, dime, cup of water with several drops of detergent mixed in, paper towels
Procedure:

1. **PREDICT** how many drops of water with detergent will fit on the dime before it spills over the edge.
2. Hold the dropper vertically. Count the drops as you carefully add water to the surface of the dime. **Stop** when water spills over the edge.
3. Record your observations.
4. Dry the dime and refill the cup for the next group, if necessary.

#4 Part 2- A Clean Dime		
Prediction	Observation	Explanation
What do you still want to know?		

Station #5: Wax on, Wax off

Materials: sheet of wax paper (or Styrofoam tray), dropper, water in cup, rubbing alcohol in cup, paper towels

Procedure:

1. Holding the dropper vertically, form a circle of water about the size of a nickel on the wax paper.
2. Place the tip of the dropper in the center of the circle and slowly drag the circle of water around.
3. Record your observations.
4. **PREDICT** what will happen when rubbing alcohol is used instead of water.
5. Dry the wax paper and repeat steps 1-3 with rubbing alcohol.
6. When finished, dry the wax paper for the next group.

#5 Wax on, Wax off		
Observation-water	Explanation-water	
Prediction-rubbing alcohol	Observation-Rubbing alcohol	Explanation-rubbing alcohol
What do you still want to know?		

Station #6: Ballooney

Materials: paper towels, balloons, water in buret, buret stand, cup of water. If you don't have burets, use a **very** thin stream of water from a faucet. Leave the water from the faucet running to maintain a consistent stream.

Procedure:

1. Blow up a balloon. Tie a knot in it.
2. **PREDICT** what will happen when the balloon gets close to a stream of water.
3. Fill the buret and make a stream of water flow from it into the cup (or turn on a very small stream from a faucet)
4. Place the balloon near, but not touching, the stream of water.
5. Record your observations.
6. **PREDICT** what will happen when a balloon rubbed with a paper towel is held close to a stream of water.
7. Rub the balloon with a paper towel.
8. Bring the balloon near, but not touching, the stream of water.
9. Record your observations.
10. Clean up any spilled water and throw the balloon away to get ready for the next group.

#6 Ballooney		
Prediction #1	Observation	Explanation
Prediction #2 Rubbed balloon	Observation	Explanation
What do you still want to know?		

Station #7: Anti-Gravity
Materials: paper towels, shallow dish, stapler, cup of colored water, metric ruler, marker
Procedure:

1. Fill the dish ½ full of colored water.
2. Fold a paper towel in half, then roll it into a tube which has a diameter smaller than the dish and staple it together.
3. Stand the rolled paper towel in the water and observe until the water stops moving.
4. Record your observations.
5. When the water movement has stopped, remove the paper towel tube and mark the point where the water stopped.
6. Measure and record (in centimeters) the distance the colored water traveled up the paper towel.
7. Empty and dry the dish to get ready for next group. Throw the paper towel away.

#7 Anti-Gravity	
Observation Distance water traveled in cm _____	Explanation
What do you still want to know?	

Station 8: Look Very Carefully!
Materials: 2 plastic 10ml graduated cylinders (or small plastic test tubes), 2 glass 10 ml graduated cylinders, (or small glass test tubes) Label 1 plastic cylinder **rubbing alcohol** and one **water**. Label one glass cylinder **rubbing alcohol** and one **water**. Add equal amounts of water or rubbing alcohol to the appropriately labeled cylinder.
Procedure:

1. **Leave the cylinder on the table and carefully** look through the side of the graduated cylinder at the surface of the liquid.
2. **Sketch** and label what you see.

#8 Look Very Carefully!		
Sketch and label what you see		Explain
Water in glass	Rubbing alcohol in glass	
Water in plastic	Rubbing alcohol in plastic	
What else would you like to know?		

Station # 9: Pepper Anyone?

Materials: shallow round container, pepper, toothpicks or cotton swabs, detergent in a small container, cup of water

Procedure:

1. Fill the shallow container ½ full of water.
2. Sprinkle pepper on the water and record your observations.
3. Carefully touch the surface of water in the middle of the container with the toothpick or swab and record your observations.
4. Dip the tip of a toothpick or cotton swab into the detergent.
5. Carefully touch the surface of water in the middle of the container with the detergent toothpick or swab.
6. Record your observations.
7. Discard the contents of the container, and rinse it well to prepare for the next group.

#9 Pepper Anyone?		
Sketch the pepper and water	Sketch again after touching with toothpick or describe what happened	Explanation
Sketch the pepper and water	Sketch again after touching with detergent toothpick or describe what happened.	Explanation
What else would you like to know?		

Station #10: What's the difference?

Materials: water from different sources (tap, bottled, distilled, spring, pond, etc.), plus any other liquids such as lemon juice, perfume, cola, eye drops, milk, etc that you have available. Choose the number of liquids you have time for. Large scale (pH 0-14) pH paper (or pH probes), small containers for each of the liquids

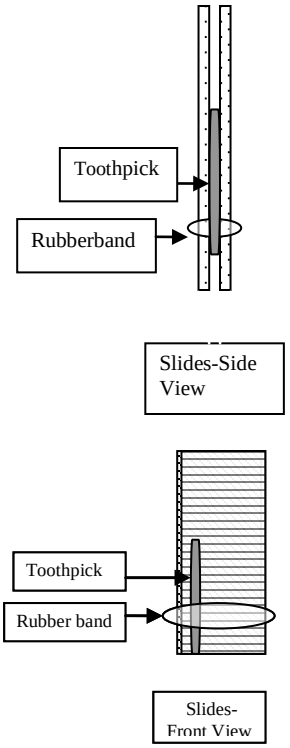
Procedure:

1. Place equal amounts of each liquid in the containers and label. Your teacher may have done this for you.
2. Record all water from different sources first, followed by the rest of the liquids.
3. **PREDICT** the pH of each liquid.
4. Dip a piece of pH paper into each type of water and the other liquids.
5. Record the pH.
6. Dispose of the pH paper and liquids according to your teacher's instructions.

Station #10 - What's the difference?			
Substance	Predicted pH	Observed pH	Explanation
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
What else would you like to know?			

Station #11: Sliding through ACC (Adhesion, Cohesion and Capillary action)
Materials: 4 glass slides, 1 toothpick, 2 rubber bands, and shallow dish with water
Procedure:

1. Place 2 slides together.
2. Put a rubber band around them to hold them together. This will be the control.
3. Place 2 more slides together, with a toothpick between them.
4. Put a rubber band around them to hold them together.
5. **PREDICT** what will happen when the short end of the slides are placed in the shallow dish of water.
6. Record your predictions
7. Place the short end of both slides into the dish of water.
8. Record your observations.
9. Dispose of the slides according to your teacher's instructions.



Prediction	Observation	Explanation
Slide to slide		
Slides with toothpick		

Station #12: Water Magnet Model

Materials: Water magnet models

Procedure:

1. Manipulate the models
2. Answer the questions.

1. Pull the pieces apart until there are 4 models, each containing one red and two white parts. What does each of these four models represent?

2. What does the red part represent? The white part?

3. Put the 4 water molecules close together again until they connect. Sketch and explain what happens.

4. What happens when you put two white parts together? Two red parts?

5. What type of force is attracting the models to each other? What type of force attracts actual water molecules to each other?

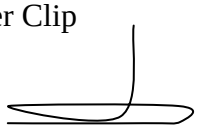
6. What holds the oxygen to the hydrogen in an actual water molecule?

Properties of Water Lab
Station Instructions Sheet

Station #1: Freeze
Materials: one ½ pint plastic water bottle filled to the rim with water and frozen (NO lid), one ½ pint plastic water bottle filled to the rim with water and left at room temperature, container filled with water (large enough for the bottles to fit), Parafilm, and paper towels to cover the bottles.
Procedure:

1. **PREDICT** what the frozen water bottle will look like. How will it compare to the bottle that was not frozen? **PREDICT** what will happen when you place bottles in a container of water.
2. Uncover the bottles and record your observations.
3. Cover both bottle openings tightly with Parafilm or plastic wrap.
4. Place both bottles in the pan of water and record your observations.
5. Remove and dry the bottles, remove the Parafilm or plastic wrap and cover the bottles for the next group.

Bent Paper Clip



Station #2 Part 1: Dish and clips
Materials: paper clips, tweezers or bent paper clip, water in a bowl or large cup, paper towels.
Procedure:

1. **PREDICT** what will happen when you **gently** place a paperclip on the surface of water.
2. Make sure the paperclip is dry, use the tweezers or bent paper clip to **gently** put the paperclip **on** the surface of the water and observe. Can you put more than one paperclip on the surface of the water?
3. When finished, refill the cup if necessary; dry the paper clip, and place it on a paper towel for the next group.

Bent Paper Clip

Station #2 Part 2: Clean Dish and Clips

Materials: paper clips, tweezers or bent paper clip, water mixed with several drops of detergent in a bowl or large cup, paper towels.

Procedure:

1. **PREDICT** what will happen when you place a paperclip on the surface of the water-detergent mixture.
2. Make sure the paper clip is dry, use the tweezers or bent paper clip to **gently** place the paper clip **on** the surface of the water and observe. Can you put more than one paper clip on the surface?
4. When finished, refill the cup if necessary; dry the paper clip and place it on a paper towel for the next group.

Station #3: Stir it Up

Materials: glass stirring rod, plastic coffee stirrer (or plastic straw), 2 clear plastic cups, paper towels, colored water

Procedure:

1. Make sure the glass rod and coffee stirrer are dry.
2. Fill one cup with water.
3. Hold the glass stirring rod at a 45^0 angle over the center of the empty cup.
4. Slowly pour all water from the first cup on to the top end of the stirring rod into the empty cup.
5. Record your observations.
6. Repeat Steps 1-5 using a plastic coffee stirrer (or plastic straw).

Station #4 Part 1: Stop on a Dime
Materials: dropper, dime, cup of water, paper towels
Procedure:

1. **PREDICT** how many drops of water will fit on the dime before it spills over the edge.
2. Hold the dropper vertically. Count the drops as you carefully add water to the surface of the dime. **Stop** when water spills over the edge.
3. Record your observations.
4. Dry the dime and refill the cup for the next group, if necessary,

Station # 4 Part 2: A Clean Dime
Materials: dropper, dime, cup of water with several drops of detergent mixed in, paper towels
Procedure:

1. **PREDICT** how many drops of water with detergent will fit on the dime before it spills over the edge.
2. Hold the dropper vertically. Count the drops as you carefully add water to the surface of the dime. **Stop** when water spills over the edge.
3. Record your observations.
4. Dry the dime and refill the cup for the next group, if necessary.

Station #5: Wax on, Wax off

Materials: sheet of wax paper (or Styrofoam tray), dropper, water in cup, rubbing alcohol in cup, paper towels

Procedure:

1. Holding the dropper vertically, form a circle of water about the size of a nickel on the wax paper.
2. Place the tip of the dropper in the center of the circle and slowly drag the circle of water around.
3. Record your observations.
4. **PREDICT** what will happen when rubbing alcohol is used instead of water.
5. Dry the wax paper and repeat steps 1-3 with rubbing alcohol.
6. When finished, dry the wax paper for the next group.

Station #6: Ballooney

Materials: paper towels, balloons, water in buret, buret stand, cup of colored water. If you don't have burets, use a **very** thin stream of water from a faucet. Leave the water from the faucet running to maintain a consistent stream.

Procedure:

1. Blow up a balloon. Tie a knot in it.
2. Predict what will happen when the balloon gets close to a stream of water.
3. Fill the buret and make a stream of water flow from it into the cup (or turn on a very small stream from a faucet)
4. Place the balloon near, but not touching, the stream of water.
5. Record your observations.
6. Predict what will happen when a balloon rubbed with a paper towel is held close to a stream of water.
7. Rub the balloon with a paper towel.
8. Bring the balloon near, but not touching, the stream of water.
9. Record your observations.
10. Clean up any spilled water and throw the balloon away to get ready for the next group.

Station #7: Anti-Gravity
Materials: paper towels, shallow dish, stapler, cup of colored water, metric ruler, marker
Procedure:

1. Fill the dish ½ full of colored water.
2. Fold a paper towel in half, then roll it into a tube which has a diameter smaller than the dish and staple it together.
3. Stand the rolled paper towel in the water and observe until the water stops moving.
4. Record your observations.
5. When the water movement has stopped, remove the paper towel tube and mark the point where the water stopped.
6. Measure and record (in centimeters) the distance the colored water traveled up the paper towel.
7. Empty and dry the dish to get ready for next group. Throw the paper towel away.

Station 8: Look Very Carefully!
Materials: 2 plastic 10ml graduated cylinders (or small plastic test tubes), 2 glass 10 ml graduated cylinders, (or small glass test tubes) Label 1 plastic cylinder **rubbing alcohol** and one **water**. Label one glass cylinder **rubbing alcohol** and one **water**. Add equal amounts of colored water or colored rubbing alcohol to the appropriately labeled cylinder.
Procedure:

1. **Leave the cylinder on the table and carefully** look through the side of the graduated cylinder at the surface of the liquid.
2. **Sketch** and label what you see.

Station # 9: Pepper Anyone?
Materials: shallow round container, pepper, toothpicks or cotton swabs, detergent in a small container, cup of water
Procedure:

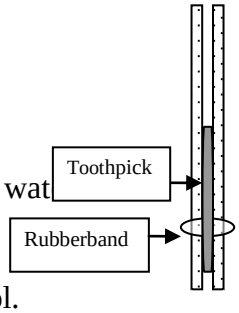
1. Fill the shallow container and fill it ½ full of water.
2. Sprinkle pepper on the water and record your observations.
3. Carefully touch the surface of water in the middle of the container with the toothpick or swab and record your observations.
4. Dip the tip of a toothpick or cotton swab into the detergent.
5. Carefully touch the surface of water in the middle of the container with the detergent toothpick or swab.
6. Record your observations.
7. Discard the contents of the container, and rinse it well to prepare for the next group.

Station #10: What's the difference?
Materials: water from different sources (tap, bottled, distilled, spring, pond, etc.), plus any other liquids such as lemon juice, perfume, cola, eye drops, milk, etc that you have available.. Choose the number of liquids you have time for. Large scale (pH 0-14) pH paper (or pH probes), small containers for each of the liquids
Procedure:

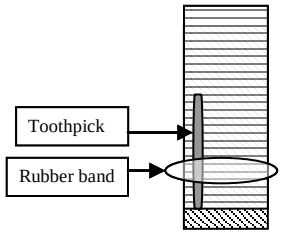
1. Place equal amounts of each liquid in the containers and label. Your teacher may have done this for you.
2. Record all water from different sources first, followed by the rest of the liquids.
3. Predict the pH of each liquid.
4. Dip a piece of pH paper into each type of water and the other liquids.
5. Record the pH.
6. Dispose of the pH paper and the liquids according to your teacher's instructions.

Station #11: Sliding through ACC (Adhesion, Cohesion and Capillary action)
Materials: 4 glass slides, 1 toothpick, 2 rubber bands, and shallow dish with colored wat
Procedure:

1. Place 2 slides together.
2. Put a rubber band around them to hold them together. This will be the control.
3. Place 2 more slides together, with a toothpick between them.
4. Put a rubber band around them to hold them together.
5. **PREDICT** what will happen when the short end of the slides are placed in the shallow dish of water.
6. Record your predictions
7. Place the short end of both slides into the dish of water.
8. Record your observations.
9. Dispose of the slides according to your teacher's instructions.



Slides-Side View



Slides-Front View

Station #12: Water Magnet Model
Materials: Water magnet models
Procedure:

1. Manipulate the models
2. Answer the questions.

1. Pull the pieces apart until there are 4 models, each containing one red and two white parts. What does each of these four models represent?
2. What does the red part represent? The white part?
3. Put the 4 water molecules close together again until they connect. Sketch and explain what happens.
4. What happens when you put two white parts together? Two red parts?
5. What type of force is attracting the models to each other? What type of force attracts actual water molecules to each other?
6. What holds the oxygen to the hydrogen in an actual water molecule?

Properties of Water Lab
Student Data Sheets

Stations have been set up around the room. At each station, your group will perform the experiment indicated. The experiments can be done in any order. When you arrive at each station:

1. Read and follow procedures.
2. Record answers in the table provided.
3. If required, predict before observing.
4. Record your observations.
5. Write a possible explanation for your observations.

Station #1 - Freeze		
Prediction	**Observation**	**Explanation**
Frozen		
Room temperature		
What do you still want to know?		

Station #2 Part 1 - Dish and Clips		
Prediction	Observation	Explanation
What do you still want to know?		

Station #2 Part 2 - Clean Dish and Clips		
Prediction	Observation	Explanation
What do you still want to know?		

Station #3 - Stir it Up	
Observation: glass rod	Explanation
Observation: coffee stirrer	Explanation
What do you still want to know?	

Station #4 Part 1 - Stop on a Dime		
Prediction	Observation	Explanation
What do you still want to know?		

Station #4 Part 2 - A Clean Dime		
Prediction	Observation	Explanation
What do you still want to know?		

Station #5 - Wax on, Wax off		
Observation-water	Explanation-water	
Prediction-alcohol	Observation-Alcohol	Explanation-alcohol
What do you still want to know?		

Station #6 - Ballooney		
Prediction #1	Observation	Explanation
Prediction #2 Rubbed balloon	Observation	Explanation
What do you still want to know?		

Station #7 - Anti-Gravity	
Observation Distance water traveled in cm _____	Explanation
What do you still want to know?	

Station #8 - Look Very Carefully!		
Sketch and label what you see		Explain
Water in glass	Alcohol in glass	
Water in plastic	Alcohol in plastic	
What else would you like to know?		

Station #9 - Pepper Anyone?		
Sketch the pepper and water	Sketch again after touching with toothpick or describe what happened	Explanation
Sketch the pepper and water	Sketch again after touching with detergent toothpick or describe what happened.	Explanation
What else would you like to know?		

Station #10 - What's the Difference?			
Substance	Predicted pH	Observed pH	Explanation
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
What else would you like to know?			

Station #11 – Sliding Through ACC		
Prediction	Observation	Explanation
Slide to slide		
Slides with toothpick		

Station #12-Models
Manipulate the models and answer the following questions.

1. Pull the pieces apart until there are 4 models, each containing one red and two white parts. What does each of these four models represent?

2. What does the red part represent? The white part?

3. Put the 4 water molecules close together again until they connect. Sketch and explain what happens.

4. What happens when you put two white parts together? Two red parts?

5. What type of force is attracting the models to each other? What type of force attracts actual water molecules to each other?

6. What holds the oxygen to the hydrogen in an actual water molecule?

Properties of Water
Open Response

Objective: Properties of Water

Water is a polar molecule. The hydrogen side is slightly positive while the oxygen is slightly negative in charge.

A. List three properties of water related to polarity.

B. Choose one of these three properties and discuss two ways it is important for living things.

Properties of Water
Open Response-Teacher Rubric

Objective: Properties of Water

Water is a polar molecule. The hydrogen side is slightly positive while the oxygen is slightly negative in charge.

A. List three properties of water related to polarity.
B. Choose one of these three properties and discuss two ways it is important for living things.

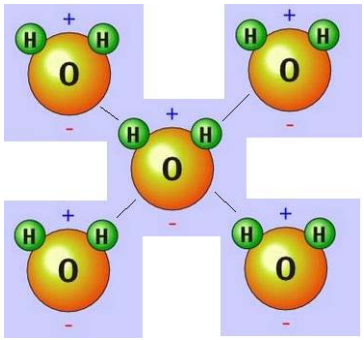
Content Scoring Guide

Part A	2 points	Student correctly lists 3 properties of water related to polarity. Example: adhesion, cohesion, surface tension, capillary action, hydrogen bonding, high boiling point, high specific heat, ice less dense than water, high heat of vaporization, high heat of fusion, good solvent for many materials but not all	
	1 point	Student correctly lists 1 or 2 properties of water related to polarity	
	0 points	Incorrect or no answer	
Part B	2 points	Student restates 1 of the 3 properties of water and correctly discusses 2 ways it is important for living things. Example: Adhesion and/or Cohesion-plants get water through xylem against gravity, Adhesion and/or cohesion allows for capillary action which helps transport materials in living things, good solvent: many materials in living things dissolve in water, floats when frozen (ice is less dense than water)-allows living things to survive in cold climates by insulating the water, high specific heat-stabilizes air temperature and/or keeps large bodies of water from changing temperature rapidly, because it does not dissolve everything (only dissolves polar things)it will not dissolve cell membranes, etc.	
	1 point	Student restates 1 of the 3 properties of water and correctly discusses 1 way it is important for living things	
	0 points	Incorrect or no answer	

(This question was and rubric were modified from http://mpweb1.jefferson.k12.ar.us/OpenResponseBank)

Properties of Water
Formative Assessment

1. Which property of water is shown below?



A. pH
B. Polarity
C. Adhesion
D. Solubility

2. A person fills a drinking glass with water until the water is bulging slightly over the glass rim. Which property of water is most accurately demonstrated by this?

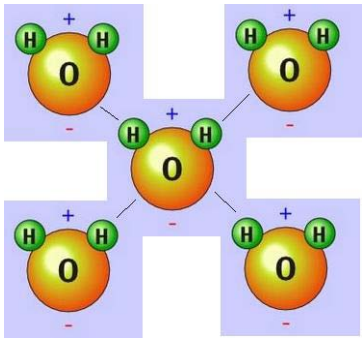
A. pH
B. Osmosis
C. Cohesion
D. Solubility

3. Which of the following statements is true?

A. Water dissolves everything.
B. Adhesion and cohesion are the same thing.
C. Adhesion is similar molecules clinging together
D. Cohesion is similar molecules clinging together

Properties of Water
Formative Assessment – KEY

1. Which property of water is shown below?



A. pH
B. Polarity
C. Adhesion
D. Solubility

2. A person fills a drinking glass with water until the water is bulging slightly over the glass rim. Which property of water is most accurately demonstrated by this?

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C. Cohesion
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3. Which of the following statements is true?

A. Water dissolves everything.
B. Adhesion and cohesion are the same thing.
C. Adhesion is similar molecules clinging together
D. Cohesion is similar molecules clinging together

Properties of Water
Summative Assessment

1. Water is composed of
   a. 2 hydrogen and 1 oxygen atom
   b. 1 hydrogen and 1 oxygen atom
   c. 2 hydrogen and 2 oxygen atoms
   d. 1 hydrogen and 2 oxygen atoms

2. Water molecules are attracted to other water molecules. This property of water is called:
   a. Polarity
   b. Adhesion
   c. Cohesion
   d. Capillarity

3. Liquid water moving through spaces such as small tubes, soil, or paper towels is called:
   a. Adhesion
   b. Cohesion
   c. Capillary action
   d. Surface tension

4. The pH of pure water is:
   a. 1
   b. 7
   c. 10
   d. 14

5. Which property of water allows a water strider to walk on water or a paper clip to float on water?
   a. Polarity
   b. Adhesion
   c. Surface tension
   d. Capillary Action

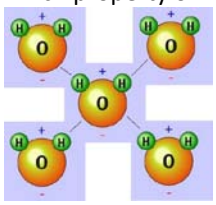
6. In a water molecule, the hydrogen atoms have a partial positive charge and the oxygen atoms have a partial negative charge. This makes the water molecule:
   a. Polar
   b. Static
   c. Liquid
   d. Non-polar

7. A meniscus on the surface of water in a small diameter glass cylinder is primarily the result of:
   a. Adhesion
   b. Cohesion
   c. Surface tension
   d. Capillary Action

8. The density of water is greatest when water is:
   a. A solid
   b. A liquid
   c. A gas
   d. Plasma

9. What property of water is most important for living organisms?
   a. It is odorless
   b. It is tasteless
   c. It does not conduct electricity
   d. It is liquid at most temperatures on Earth

10. Which property of water is shown below?



   a. pH
   b. Polarity
   c. Adhesion
   d. Solubility

11. A person fills a drinking glass with water until the water is bulging slightly over the glass rim. The property of water that prevents the water from spilling is
   a. pH
   b. Osmosis
   c. Cohesion
   d. Solubility

Properties of Water - KEY
Summative Assessment

1. Water is composed of
   a. 2 hydrogen and 1 oxygen atom
   b. 1 hydrogen and 1 oxygen atom
   c. 2 hydrogen and 2 oxygen atoms
   d. 1 hydrogen and 2 oxygen atoms

2. Water molecules are attracted to other water molecules. This property of water is called:
   a. Polarity
   b. Adhesion
   c. Cohesion
   d. Capillarity

3. Liquid water moving through spaces such as small tubes, soil, or paper towels is called:
   a. Cohesion
   b. Adhesion
   c. Capillarity action
   d. Surface tension

4. The pH of pure water is:
   a. 1
   b. 7
   c. 10
   d. 14

5. Which property of water allows a water strider to walk on water or a paper clip to float on water?
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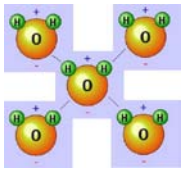
    d. Solubility



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    e. pH
    f. Osmosis
    g. Cohesion
    h. Solubility

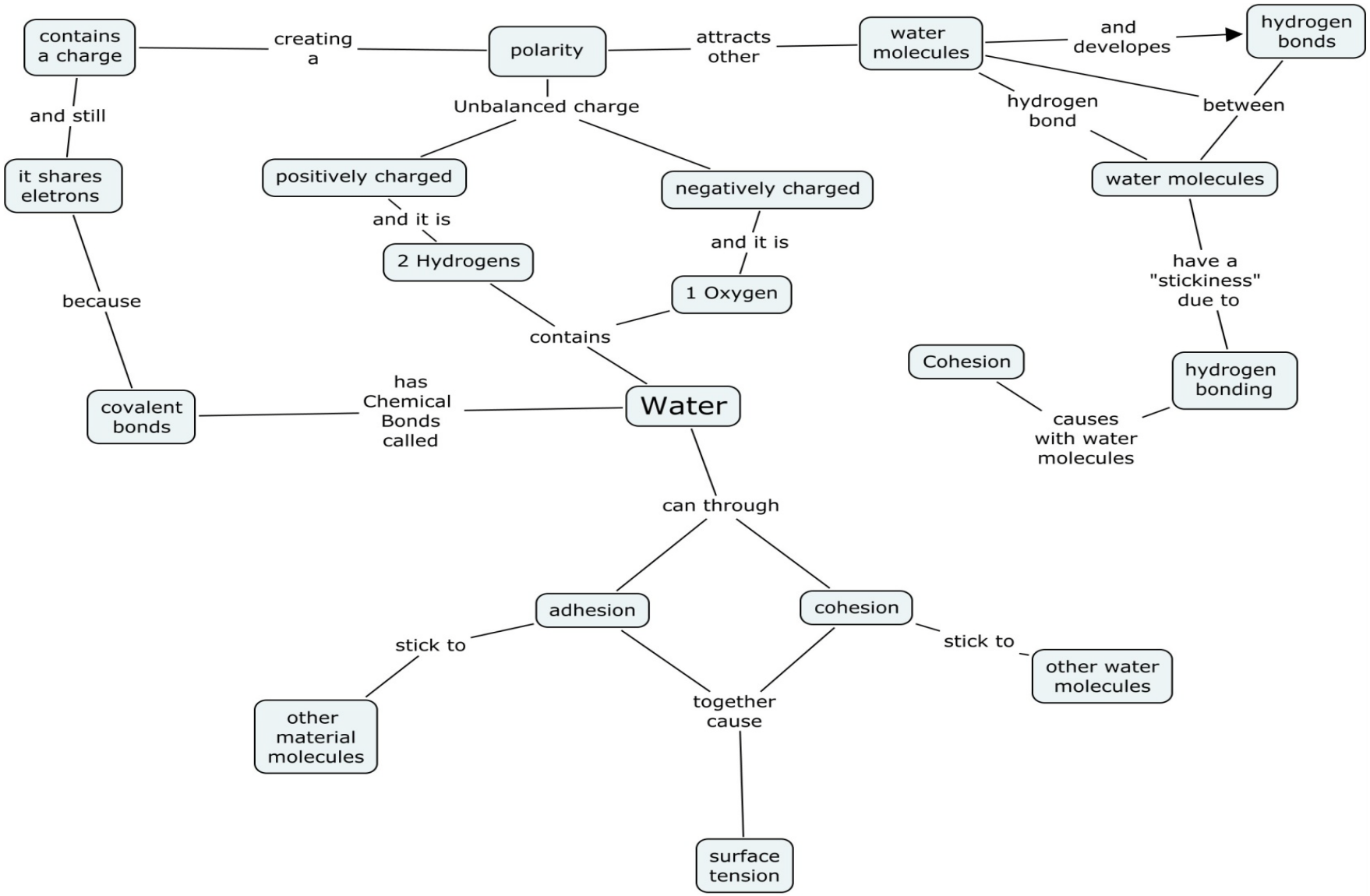
References:

1. ARDOE EOC Biology Released Items Booklet http://arkansased.org/testing/pdf/rib_bio_spr08.pdf
2. http://www.doe.state.de.us/infosuites/staff/sci_assess/files/POM%20Assessment%20Test%20Final%20Copy8-11-04.pdf
   http://www.studystack.com/studytable-23075

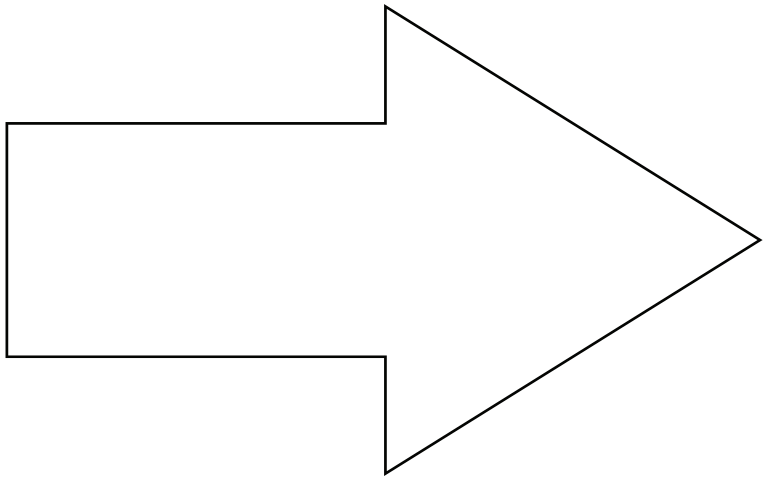
Properties of Water Lab

Cross Curriculum Application

****Cross Curriculum**	Family Consumer Science	Cosmetology: Duty F (Explain the pH scale) describe the pH scale and values associated with water, Family and Consumer Science: Measure liquid supplies (1.4.16), Practice and distinguish situations that require immediate hand washing when working with food (2.3)1.4.14), Food and Nutrition: Describe effect of nutrition on health and body mass (water content) (1.414).
	Agriculture	Agriculture Science: Explain the importance of soil and water conservation (Science Skill)(6.3), List Natural resources and describe their importance (6.2), Aquaculture Biology: Name and describe body systems of aquatic species (habitat, nutrition, adaptation to environment)(2.4), Circulatory/Respiratory (water quality)(2.6), water importance in aquaculture (4.2.1), Describe water cycle (4.3.1), Quality of water (4.4.1, 4.4.2), Water quality factors (4.10.1, 4.10.2), Impact of oxygen, temperature, pH, and hardness on water (4.11.1, 4.11.2, 4.11,3), Factors that affect dissolved oxygen (4.12.1, 4.12.2, 4.12.3), Water Quality: Water quality characteristics (5.2), Physical/Biological characteristics of H2O (5.3).
	Health	Understand the part water plays in maintaining a healthy body both internally and externally. Understand the importance of appropriate hydration in maintaining health. (N.7.HW.5), Identify ways diseases are transmitted (water-borne) (DP.2.HW.3), Water quality and its influence on the health of the community (CHP.3HW.6).
	PE	Engage in health-enhancing activities that promote improvement in body composition (water) (HRF.2.PEL.2)
	Media	Students can research real world water issues in newspapers and magazines.
		The Futures Channel - Water Tanks
		The Futures Channel - Fish Farming
		The Futures Channel - Water Supply
	History	Arkansas History (7-8) G.1.AH.7-8.2 Identify and map the major rivers of Arkansas. G.1.AH.7-8.3 Describe factors contributing to the settlement of Arkansas (climate, water). GD.8.AH.7-8.1 Describe the economic and social effects of the 1927 flood on Arkansas using primary and secondary resources
		Arkansas History (9-12) GD.8.AH.9-12.1
		Contemporary U.S. History E.7.CH.1 Examine the influence of the following on the environmental Movement: - The Novel Silent *Spring,* -Environmental Protection Agency, -Green Peace, -Earth Day, E.7.CH.2 Investigate the consequences of environmental disasters. E.7.CH.3 Discuss contemporary environmental issues.
		World Geography PR.2.WG.4 Research physical characteristics of regions floodplain, coastal Flood zone, river crossing). PS.3.WG.1 Features of the hydrosphere and biosphere. ES.7.WG.1 Research Floods. ES.7.WG.8 Examine human impact on the depletion of oceans and coastal resources


contains a charge
creating a
polarity
attracts other
water molecules
and developes
hydrogen bonds
and still
Unbalanced charge
hydrogen bond
between
it shares eletrons
positively charged
negatively charged
water molecules
and it is
and it is
2 Hydrogens
1 Oxygen
have a "stickiness" due to
because
contains
Cohesion
hydrogen bonding
has Chemical Bonds called
covalent bonds
Water
causes with water molecules
can through
adhesion
cohesion
stick to
stick to
other water molecules
other material molecules
together cause
surface tension

Photosynthesis



Section 3

The section contains the Photosynthesis documents, including lessons and assessments.

Photosynthesis Unit Guide

Unit Overview

Unit Title: Photosynthesis

Lesson Summary: The structure and function of cells determines the foundation for all living things

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

- MC.3.B.1 - Compare and contrast the structure and function of mitochondria and chloroplasts. (Only the chloroplast portion is addressed in this SLE.)
- MC.3.B.4 - Describe and model the conversion of light energy to chemical energy by photosynthetic organisms: light dependant reaction, light independent reaction.
- MC.3.B.5 - Compare and contrast cellular respiration and photosynthesis as energy conversion pathways. (Only the photosynthesis portion is addressed in this SLE.)

- Equations, symmetry, graphing

- Find real world application of photosynthesis in magazines, newspapers or other non-fiction text.
- RAFT Writing Prompts
- Solar Powered Sea Slug video:
http://www.newscientist.com/article/dn16124-solarpowered-sea-slug-harnesses-stolen-plant-genes-.html

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: Develop an understanding of the cell.
- Standard G: Historical perspectives.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Kinesthetic Walk-Through:
  1. Recognize the photosynthesis equation.
  2. Write the equations for photosynthesis with coefficients and subscripts.

- Leaf Models:
  1. Create/Examine a leaf model.
  2. Know the basic structure of a leaf.
  3. Relate the structure to the function of a leaf during photosynthesis.
- Chloroplast:
  1. Design and create a model of the internal structure of a chloroplast.
  2. Know the names of the parts of the chloroplast.
  3. Relate the internal structure of a chloroplast to its function.
  4. Write a fact-based account of a journey through a chloroplast from the viewpoint of a molecule or photon.
- Leaf Disk Lab:
  1. Describe the reactants and products of photosynthesis and the source of reactants from the environment.
  2. Explain the relationship of photosynthesis to the observations made during the experiment.
  3. Identify another variable that might affect photosynthesis and design an experiment that uses leaf disks to test ideas.
  4. Create hypotheses about the effects of environmental variables on the rate of photosynthesis.
- Light Dependent Role Play:
  1. Describe and model conversion of light energy to chemical energy.
  2. Model light dependent reactions.
- Light Independent Bead Activity:
  1. Construct and modify models of carbon compounds involved in the light independent reactions of photosynthesis.
  2. Know the role of carbon dioxide in photosynthesis.
  3. Calculate the amount of energy (ATP) needed in/provided by the light independent reactions.
  4. Relate the energy sources for the light independent reactions to their formation.
  5. Understand that manufacturing glucose is a complex process.

Focus Question:

- How do cells obtain and utilize energy?

Prerequisites / Background Information:

- Photosynthesis is the process of converting light energy to chemical energy and storing it in the chemical bonds of sugar.

Timeline: 1 -2 weeks depending on schedule

Preparation: See individual lessons.
Elicit/Engage:
Explore:
Explain:
Cleanup:

Teacher Preparation:

- Teacher prep, possible misconceptions, lab information can be found in the individual lesson documents.

Materials:

- Lab materials are included in individual lessons.

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☒ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

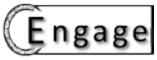
☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☒ Internet Web Browser	☐ Word Processing	

Internet Resources:

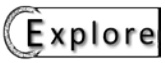
Procedures:	**Teacher's Notes:**

- No eating or drinking in the lab
- Follow written & oral instructions
- No horse play
- Wear appropriate safety gear (goggles, apron, gloves)

- General Elicit: Discuss the impact of clear cutting in the forest and explain the ramifications of losing the trees. Have students explain why the loss of trees can influence humans. Ask students to identify what part(s) of the tree we most rely upon.
- Kinesthetic Walk-through: Review equations and balancing from physical science by writing the equation for photosynthesis on the board and have students tell what they already know.
- Leaf Models: Have sample real leaves on student's desks. Have students quickly draw the leaf and label the parts.

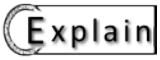


- Suggested Engage: Elodea Video, Kinesthetic Walk-thru, Conduct light dependant activity, have students collect leaves from trees.
- Kinesthetic Walk-Thru: This activity can be done as whole group with students actively moving about to create the photosynthesis equation or it can be done as table groups.
- Leaf Models: Unfold the large leaf model and flip through the layers. Students will be excited to create their own smaller version.



- Leaf Models: The large leaf model is best be used as a teachers aid. The small leaf model is designed for each student to be able to make and take their own leaf model with them.

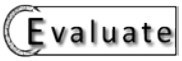
- Chloroplast Model: Students will design and construct a model of a plant chloroplast using textbooks or diagrams as reference. If studying respiration, the class may be divided, and half of the students assigned models of mitochondria. The models can also be retained and used for comparison to mitochondria in future chapters.
- Light Dependant Role Play: 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 the scenario with all the parts moving at the same time.
- Light Independent Bead Activity: In this activity, students will construct models of the basic compounds involved in the Calvin Cycle, focusing on the role of carbon and the amount of energy utilized during the process.



- Use of Photosynthesis PowerPoint.

- Vocabulary:
  ATP, electron transport chain, glucose, carbon dioxide, oxygen, chloroplasts, light dependent, light dependent, photosynthesis

- Suggestions:
  1. Lab reports
  2. Written tests



- Suggested Evaluations: Photosynthesis Formative Assessment, student questions with lessons, light Independent writing prompt, RAFT writing activity.

Formative Assessment:

- Photosynthesis Pre/Post Tests
- Photosynthesis Standards Based Formative Assessment
- Leaf Models: Students build a small leaf model and use it to identify the layers of a leaf.
- Chloroplast Model: Student models are evaluated for accuracy of parts and labels.
- Light Independent Bead Activity: Students will construct a concept map to illustrate the Calvin Cycle as they conduct the bead activity.

Summative Assessment:

- Water/Photosynthesis Unit Summative Assessment

- Extend Suggestions: With any of the lessons and labs in this unit, there are no limits to what a class can do. Explore models, repeat role play, etc.
- Kinesthetic Walk-through: This activity provides a good transition into the study of acids and bases, chemical bonding, study of nutrients, and the way that cells and the bodies of animals use energy.
- Leaf Models: The small leaf model is a great integration of the leaves of Arkansas. This offers students a chance to explore and model that content as well.
- Chloroplast Model: Write a fact-based account of a journey through a chloroplast from the viewpoint of a molecule or photon.
- Light Dependant Role Play: 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.
- Light Independent Bead Activity: This lesson requires students to work with partners, follow directions, and work through the process in a collaborative effort.

Cross-Curricular

- See Cross Curriculum document
- Technology:
  1. Kinesthetic Walk-through: Glucose & humans: Conduct research or discussions to explore the physiology of diabetes. Students love to sing. Challenge students to include basic concepts about photosynthesis in a song, poem or rap.
  2. Leaf Models: Student conduct internet or library research of the native leaves of Arkansas and their structure.
  3. Chloroplast Model: students research various diagrams and pictures of chloroplast.

Vernier Lesson: Photosynthesis With Probes - included

Notes:

- Kinesthetic Walk-through: Modified from an activity by: Eva Carswell, Westside High School, Macon, GA and Ananda Weerasuriya, PhD, Mercer University School of Medicine.
- Large Leaf Model: Adapted from an article, Building Leaves and an Understanding of Photosynthesis, Patty Littlejohn, The Science Scope, p. 22-25, April/May, 2007.
- Chloroplast Model: Helpsavetheclimate.com/photosynthesisBiodidac.bio.uottawa.ca
- Light Dependant Role Play: Biology, Eighth Edition. Neil Campbell, et.al. San Francisco: Pearson 2008. Biology. Kenneth Miller, & Joseph Levine. Upper Saddle River: Pearson 2006.

Photosynthesis Background

All life is based on the element ***carbon***. Carbon is the major chemical constituent of most organic matter, from fossil fuels to the complex molecules (DNA and RNA) that control genetic reproduction in organisms.

Ecosystems gain most of their carbon dioxide from the atmosphere. A number of autotrophic organisms have specialized mechanisms that allow for absorption of this gas into their cells. With the addition of water and energy from solar radiation, these organisms use **photosynthesis** to chemically convert the carbon dioxide to carbon-based sugar molecules. These molecules can then be chemically modified by these organisms through the metabolic addition of other elements to produce more complex compounds like proteins, cellulose, and amino acids. Some of the organic matter produced in plants is passed down to heterotrophic animals through consumption.

Carbon is released from ecosystems as carbon dioxide gas by the process of **respiration**. Respiration takes place in both plants and animals and involves the breakdown of carbon-based organic molecules into carbon dioxide gas and some other compound by-products. The detritus food chain (decomposers) contains a number of organisms whose primary ecological role is the decomposition of organic matter into its abiotic components.

Pidwirny, M. (2006). "The Carbon Cycle". *Fundamentals of Physical Geography, 2nd Edition*. 1/4/09. http://www.physicalgeography.net/fundamentals/9r.html

Carbon is the backbone of the organic world. It is found in most everything and almost everywhere. The chemical composition of carbon makes it a very durable and flexible element. Carbon can bond in many ways because of the presence of four bonding electrons; it can form single, double, and triple bonds that can bond with many other atoms as well as with carbon itself. Carbon compounds can exist in linear or ring forms. Because of its design, most of our fuels, such as coal, oil, and natural gas, are carbon based. Coal, oil, and natural gas are collectively known as fossil fuels.

Carbon, in various forms and combinations, moves between the atmosphere, soil, the ocean, and many living things, as seen in the Carbon Cycle. It is also found in dead organisms and fossil fuels. It exists primarily as a gas, carbon dioxide (CO_2), in the atmosphere and as the solid organic form in living and dead organisms. Atmospheric carbon is constantly recycled. Many organisms release carbon, in the form of CO_2, as a waste by-product, which is quickly absorbed mostly by green plants and algae creating oxygen in the process.

Organisms, like green plants and algae containing chlorophyll, use photosynthesis to store the sun's energy in the bonds of carbohydrates (compounds containing carbon, hydrogen, and oxygen) for future use, both by the organisms themselves and by other organisms. One such energy usage and transformation occurs in the process of photosynthesis.

Photosynthesis is the process of converting light energy to chemical energy and storing it in the bonds of sugar. A simplified version of this reaction is:

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} [CH_2O] + O_2$$

Carbon dioxide + water + light energy + chlorophyll yields carbohydrate + oxygen

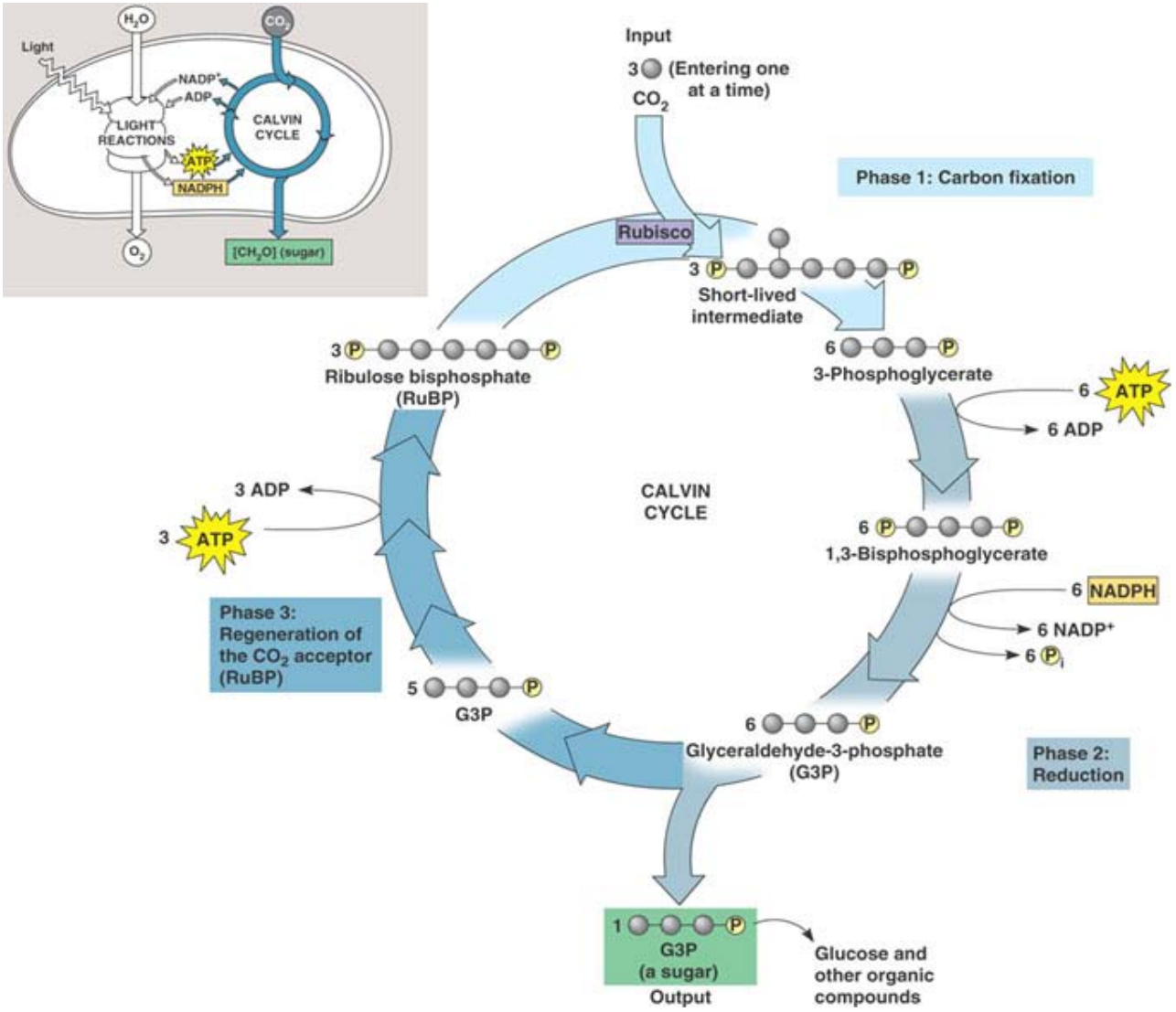
This process occurs in plants and some algae (Kingdom Protista). Plants need only light energy, CO_2, and H_2O to make sugar. The process of photosynthesis takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis.

Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems, etc. The parts of a typical leaf include the **upper and lower** epidermis, the mesophyll, the **vascular bundle(s)** (veins), and the stomates. The upper and lower epidermal cells do not have chloroplasts, thus photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The stomates are holes which occur primarily in the lower epidermis and are for air exchange: they let CO_2 in and O_2 out. ttp://biology.clc.uc.edu/Courses/bio104/photosyn.htm)

There are two parts to photosynthesis: light dependent and light independent. In the light dependent phase, light as energy is taken and converted to chemical energy. This first process requires direct energy of light to make energy carrier molecules that are used in the second process called light independent. Oxygen, removed from water, is released back into the atmosphere as a waste product, whereas the hydrogen and released energy are used to combine with NADP+ to form NADPH. The light independent phase can occur with or without light and combines water with carbon dioxide to form a carbohydrate. Water is used in both phases, but carbon is "fixed" (used) only in the light independent phase. Therefore, "in the light dependent processes light strikes chlorophyll in such a way as to excite electrons to a higher energy state. In a series of reactions the energy is converted (along an electron transport process) into ATP and NADPH. Water is split in the process, releasing oxygen as a by-product of the reaction. The ATP and NADPH are used to make C-C bonds in the Light Independent Process" (http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookPS.html).

Light independent process is also called the Calvin Cycle. The energy stored in ATP and NADPH in the light dependent reactions will now be used in the Calvin cycle. This cycle continually produces and uses a five-carbon sugar called ribulose disphosphate (RuDP), also called ribulose biphosphate (RuBP). The cycle begins when a carbon dioxide molecule bonds with a RuDP molecule. The resulting molecule, which has six carbon atoms, splits into two three-carbon atoms. These three-carbon molecules are called phosphoglycerates (PGA). The PGA molecules undergo additional reactions, outlined below, which allows for the regeneration of the RuDP molecule and the production of a three-carbon molecule called glyceraldehyde phosphate (PGAL). Notice how the NADPH molecule produced during noncyclical electron flow is necessary for the Calvin cycle. (http://kvhs.nbed.nb.ca/gallant/biology/calvin_cycle.jpg)

After many turns of the Calvin cycle, PGAL molecules can be bonded together to form glucose (which can be used as food) or other more complex sugars like sucrose. In addition, PGAL can also be used in the formation of lipids and proteins. (Information for Calvin Cycle found primarily in library.thinkquest.org/.../calvin_cycle)



Investigating Photosynthesis through Kinesthetics

Lesson Overview

Unit Title: Photosynthesis

Lesson Summary: Recognize the photosynthesis equation. Engage Activity for Photosynthesis-should be taught before MC.3.B.4

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

- MC.3.B.4 Describe and model the conversion of light energy to chemical energy by photosynthetic organisms:
  1. light dependent reactions
  2. light independent reactions

Math Integration

- Balancing Equations

Literacy Integration

- Read non-fiction articles and construct benchmark style questions.
- Solar Powered Sea Slug video: http://www.newscientist.com/article/dn16124-solarpowered-sea-slug-harnesses-stolen-plant-genes-.html

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: develop an understanding of the cell

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:
- Recognize the photosynthesis equation.
- Write the equations for photosynthesis with coefficients and subscripts (study time may be required).
- Realize that the same carbon atoms that make up carbon dioxide make up the backbone for the glucose (carbohydrates) molecule.

Focus Question:
- How do cells obtain and utilize energy?

Prerequisites / Background Information:

- Document Included: Photosynthesis Background Information

Timeline: This activity can be completed in 15-30 minutes depending on the size of your class and their familiarity with the concepts presented.

Preparation: • Prep will take 1 hour the first time, then materials are reusable.
Elicit/Engage: • 15 min – 30 min
Explore:
Explain:
Cleanup: • 5 Min

Teacher Preparation:

- Copy templates and prepare cards.

Materials:

- 43 pieces of card stock or laminated cards. 1 poster board is optional.

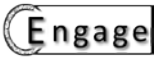
Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☐ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☒ Internet Connection	☐ Other:

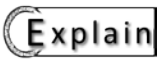
Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☒ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	Teacher's Notes:
	
• No horseplay in the lab. No special safety equipment is necessary.	
	
• Give students the following warm-up activity: 1. Write the equation for photosynthesis. 2. Define atom, element, molecule and compound.	
	
• This is the engage activity for the lessons on photosynthesis. • This activity can be done as whole group with students actively moving about to create the photosynthesis equation or it can be done as table groups.	

- The science specialists prefer the table groups doing the activity.



Formative Assessment

- Non-paper assessments such as verbal acknowledgment of equation, proper placement of elements in equation.

Summative Assessment

- This activity provides a good transition into the study of acids and bases, chemical bonding, study of nutrients, and the way that cells and the bodies of animals use energy.

Cross-Curricular

- Document included:
  1. Photosynthesis Cross-curricular Connections
- Other:
  1. Glucose & humans: Research or discussions could also be conducted to explore the physiology of diabetes.
  2. Students love to sing. Challenge students to include basic concepts about photosynthesis in a song, poem or rap.

Notes:

- Modified from an activity by: Eva Carswell, Westside High School, Macon, GA and Ananda Weerasuriya, PhD, Mercer University School of Medicine
- Photosynthesis Equation for the poster included.

Investigating Photosynthesis through Kinesthetics

Modified from an activity by: Eva Carswell, Westside High School, Macon, GA and Ananda Weerasuriya, PhD, Mercer University School of Medicine

Grade Level: Middle-High School

Photosynthesis Equation

$$6CO_2 + 6H_2O \xrightarrow{\text{SUN}} C_6H_{12}O_6 + 6O_2$$

(Carbon Dioxide) (Water) (Glucose) (Oxygen)
(Carbohydrate)
(Reactants) (Products)

Purpose:
To provide middle or high school students with an activity in which they can explore photosynthesis.

Objectives:
Students will be able to:

- Recognize the photosynthesis equation.
- Realize that the carbon dioxide molecules that heterotrophs breathe out are the same carbon dioxide molecules that make up the backbone of the glucose (carbohydrates) molecule.
- Write the equations for photosynthesis with coefficients and subscripts (study time may be required).
- Infer that humans breathe out carbon dioxide and plants take in carbon dioxide and give off oxygen (during the light reactions).

Materials:

1. Six cards with C (Carbon) – (Use template)
2. Twelve cards with H (Hydrogen) – (Use template)
3. Eighteen cards with O (Oxygen) – (Use template)
4. One card that says "Sun" – (Use template)
5. One card with a "+" on it – (Use template)
6. One card with an arrow to represent the yields sign in the equation – (Use template)
7. Poster board with the equation for photosynthesis (to be held up so students know where to position cards)
8. One card that reads "carbon dioxide" – (Use template)
9. One card that reads "water" – (Use template)
10. One card that reads "glucose" – (Use template)
11. One card that reads "oxygen" – (Use template)

Preparation (teacher):
Copy templates
Give students the following warm-up activity:

1. Write the equation for photosynthesis.
2. Define atom, element, molecule and compound.

This activity can be completed in 15-25 minutes depending on the size of your class and their familiarity with the concepts presented.

Procedure:
Variation 1
Each student is given the role of a molecule of carbon, hydrogen, or oxygen. Depending on the size of your class, some students may need to be assigned the same role. For example you may need to give one student two "H's" instead of one "H". If you have a large open area in your classroom, you can conduct this part of the activity inside. Otherwise, you will need to plan to go outdoors or into the hall.

Once you arrive at your destination, hold up the poster board with the equation for Photosynthesis. First, instruct the students to position themselves so that they represent the reactants of the equation. Remember to assign a student to the role of "sun", "+", and "yields".) Once students have gotten into the correct positions give each group of molecules the name of the substance that they represent (carbon dioxide or water). Next, have the students' position themselves so that they represent the products of the photosynthesis equation. Once the students have positioned themselves correctly give each group of molecules the name of the substance they represent (glucose or oxygen). The idea is that students will realize that the same carbon atoms that make up carbon dioxide make up the backbone for the glucose (carbohydrates) molecule.

Variation 2:
Make enough cards to give to individual students, pairs, or teams so that the students can work at their tables under the teacher's guided instruction.

Safety:
No special safety equipment is necessary.

Q**uestions to Ask:**

- How many molecules of carbon dioxide and how many molecules of water are needed for green plants to synthesize one molecule of glucose and six molecules of oxygen?
- What type of nutrient is glucose (carbohydrate, protein, nucleic acid or lipid)?
- What are other sources of carbon dioxide (besides animals exhaling)?
- What gas do plants release?

Extensions:
This activity provides a good transition into the study of acids and bases, chemical bonding, study of nutrients, and the way that cells and the bodies of animals use energy.
Glucose & humans: Research or discussions could also be conducted to explore the physiology of diabetes. Students love to sing. Challenge students to include basic concepts about photosynthesis in a song, poem or rap.

TEMPLATES

- Run off 6 carbon **per group** on blue paper
- Run off 12 hydrogen **per group** on red paper
- Run off 18 oxygen **per group** on green paper
- Run off one set of words and symbols **per group** on any other color

C C

C C

C C

H H

H H

H H

O O

O O

O O

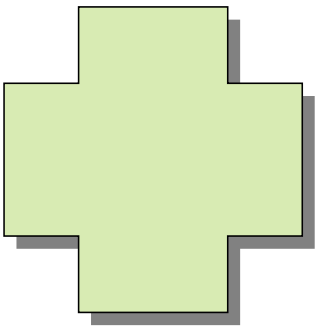
SUN

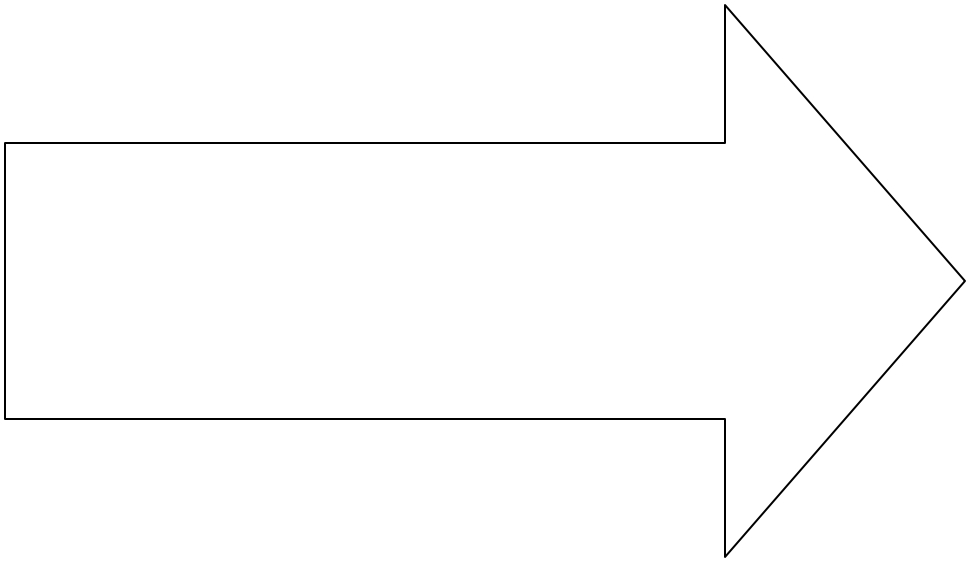
CARBON DIOXIDE

WATER

OXYGEN

GLUCOSE
(CARBOHYDRATE)





PHOTOSYNTHESIS

Sunlight

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Reactants Products

Making Large and Small Leaf Model

Lesson Overview

Unit Title: Photosynthesis

Lesson Summary: This is a hands-on activity designed to investigate the structure of the leaf.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

- CDL.7.B.17 Describe the structure and function of the major parts of a plant: roots, stems, leaves, flowers. (Only addressing leaves)

Math Integration

- Measurement, symmetry, shapes

Literacy Integration

- Journal writing: Write a summary of the relationship of the structure of plant tissue to its function as it relates to photosynthesis.

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: Develop an understanding of the cell.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Students will know the structure and function of parts of the leaf.
  1. Create/Examine a leaf model.
  2. Know the basic structure of a leaf.
  3. Relate the structure to the function of a leaf as it relates to photosynthesis.

Focus Question:

- How do cells obtain and use energy?

Prerequisites / Background Information:

- Vocabulary
  1. Petiole: Stalk of a leaf that attaches the blade to the stem.
  2. Leaf blade: Broad, expanded part of a leaf that serves to capture light.
  3. Axillary buds: Buds located where a leaf joins a stem.

4. Vein: Vascular bundles which consist of xylem and phloem tissue give support to the leaf and also transport food and water.
5. Upper Epidermis: Translucent tissue that allows light to pass through it to reach the mesophyll; also protects the internal tissues.
6. Palisade Mesophyll: Contains the majority of the chloroplasts, therefore most photosynthesis occurs here.
7. Spongy Mesophyll: Provides space for the exchange of gases during photosynthesis.
8. Lower Epidermis: Contains most of the stomata (thousands per square centimeter).
9. Guard Cells: Regulate the opening and closing of the stomata, therefore they control the exchange of gases between the leaf and the surrounding atmosphere.

- Provide students with an introduction and explanation of leaf structure and tissue before they begin. Same leaf parts and descriptions apply as with the large leaf model.

Timeline: 1-2 class periods to make models, answer questions and explore further.

Preparation: • 15 min to gather materials.
Elicit/Engage:
Explore: • 30 minutes
Explain: • 15-20 minutes
Cleanup: • 5 minutes

Teacher Preparation:

- Two variations of the leaf model are provided. A large leaf that could be done in groups or small leaf which each student can do and take home.
- Small Leaf Notes: Have various texts available for students to use as reference sources. The internet can also be used for reference. It is a good idea to have a sample small leaf model made in advance.
- Large Leaf: The class size model of the leaf helps the students to visualize where photosynthesis occurs in the leaf. This model is a very simple representation. It is important that the students know and understand the reactants and products of photosynthesis and what role each part of the leaf plays in the process.
- Small Leaf: In this assignment, students will construct a model of a leaf using textbooks or diagrams as a reference.

Materials:

- Large Leaf Model: per group
  1. 2 pieces green butcher paper or 1 green shower curtain.
  2. 2 sheets of clear plastic sheeting
  3. permanent green marker
  4. 5-6 brass fasteners
  5. scissors
  6. clear tape
  7. clear plastic tubing or cording
  8. colored construction paper
  9. permanent black marker
- Small Leaf Model: per student
  1. 2 green sheets (any type paper)
  2. 2 sheets clear
  3. 1 clear straw
- Shared Materials:
  1. permanent green markers
  2. stapler

3. scissors
4. clear tape

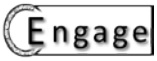
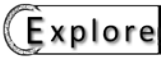
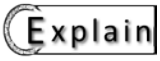
Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☐ Computer(s)	☐ Digital Camera
☐ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☐ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• Appropriate classroom behavior required. No specific safety equipment is required.	• Students will be using scissors, caution is advised.
	
• Have samples of real leaves on student's desks. Have students quickly draw the leaf and label the parts.	
	
• If you have made a large leaf model, unfold the large leaf model and flip through the layers.	• Students will be excited to create their own smaller version.
	
• The large leaf model would best be used as a teacher's aid. • The small leaf model lesson is designed for each student to be able to make and take their own leaf model with them.	
	
  	

Formative Assessment

- Have the students manipulate the reactants and products and explain what is happening in the leaf using the large leaf model.
- Student questions may be found at the end of this lesson.

Summative Assessment

- An examination and classification of Arkansas trees by using their leaves.
- Compare and contrast of different leaves from trees native to Arkansas.

Cross-Curricular

- Agri/Forestry with the leaves of Arkansas.
- Technology: Student could conduct internet or library research of the native trees of Arkansas and their leaf structure.

Notes:

- Resources:
  1. Large Leaf Model: Adapted from an article, Building Leaves and an Understanding of Photosynthesis, Patty Littlejohn, The Science Scope, p. 22-25, April/May, 2007.

Making a Large Leaf Model
Teacher Preparation

The class size model of the leaf helps the students to visualize where photosynthesis occurs in the leaf. This model is a very simple representation. It is important that the students know and understand the reactants and products of photosynthesis and what role each part of the leaf plays in the process.

CDL.7.B.17 Describe the structure and function of the major parts of a plant: roots, stems, leaves, flowers (This lesson involves leaves only)
CDL.7.B.18 Relate the structure of plant tissue to its function: epidermal, ground, and vascular

Objectives:

Students will:

- Examine a leaf model
- Know the basic structure of a leaf
- Relate the structure to the function of a leaf during photosynthesis
- Write a summary of the relationship of the structure of plant tissue to its function as it relates to photosynthesis

Materials per classroom

- 2 pieces of green butcher paper (1.3 m long) or 1 green shower curtain or vinyl tablecloth (or one sheet of green and one sheet of bubble wrap)
- 2 sheets of clear plastic sheeting (.91 m X 1.3 m long)
  (Plastic sheeting usually comes in 36" width which equals .91 m!)
- permanent green marker
- 8-10 brass fasteners
- scissors
- clear plastic tubing (1.3 m) or rope or cording (1.3 m)
- clear tape

Materials for Elements and compounds (for use with large leaf model)

- Colored paper---construction paper or copy paper, four different colors---laminate them for extended use!
- marker

Preparation Tips:

If using a vinyl shower curtain, it can be folded in half and cut.

The plastic sheeting usually comes in 36" (.91 m) width so that is convenient to use for the overall width of the leaf.

Procedure:

1. Layer the sheets on top of one another as follows:

Layer	Sheets	Represents
Top	Clear	Upper Epidermis
Second	Green	Palisade Layer
Third	Green or bubble wrap	Spongy mesophyll
Bottom	Clear	Lower epidermis

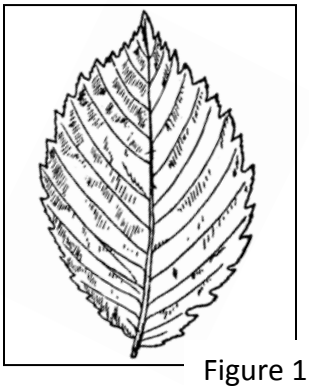
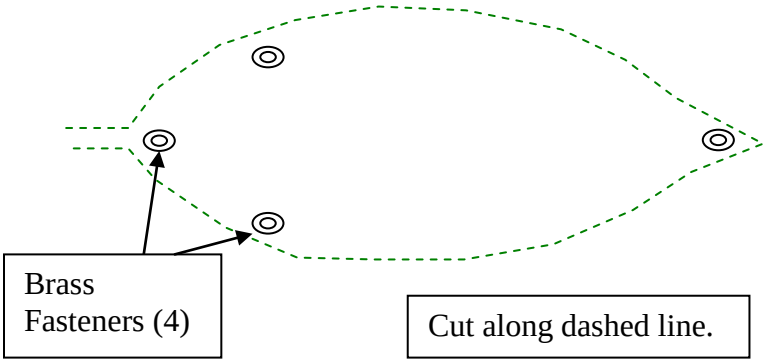


Figure 1

2. Use the marker to trace a leaf, including a petiole, on the top clear layer. The leaf shape should just fit inside the sheet. See Figure 1 above.

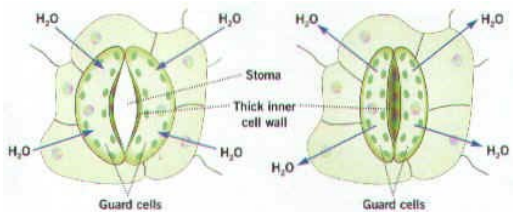
3. Insert the tubing or cord (vein) between the second and third layer of the leaf. Tape the other end of the tubing or cord to the third layer (green sheet or bubble wrap). Let the end of the tubing extend out of the petiole about 3 cm. Attach the layers using brass fasteners that are placed about 3-5 cm inside the leaf edge. Place fasteners at the petiole end approximately 20 cm apart. Put one fastener at the tip end. Use scissors to cut out the leaf shape**. See diagram below.**

Diagram for Cutting Large Leaf



4. Remove the fastener from the tip end of the leaf only. Label each layer with the names in Step 1.

5. On the lower epidermis, draw as many stomata as will fit on your leaf. Using the green permanent marker, trace the stomata on the bottom clear layer using the template provided.



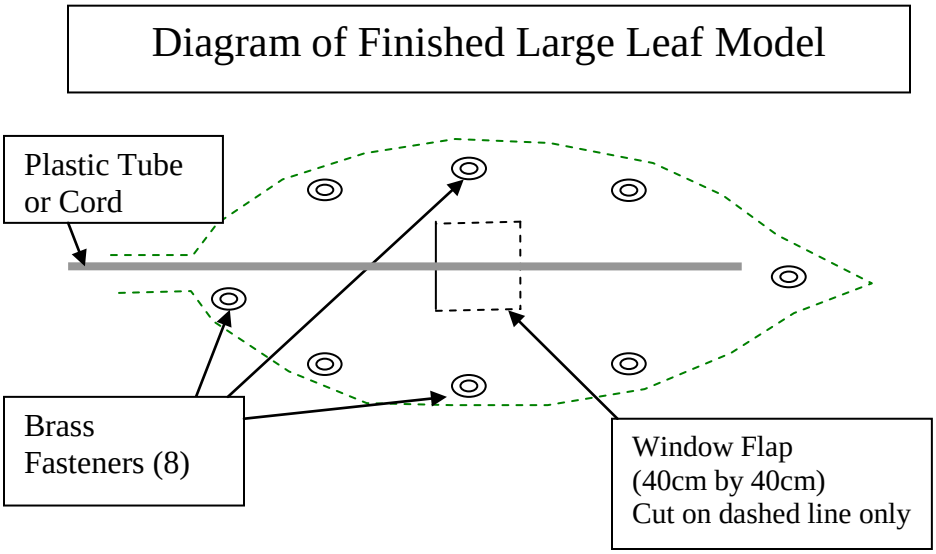
Graphic reference
http://www.biologyjunction.com/leaf_stomata_lab.htm

6. On the lower epidermis create open pores by cutting out the vinyl between the open guard cells. These openings allow for the exchange of gases.

7. Draw chloroplasts on the second layer (green sheet) with the green permanent marker. Trace as many chloroplasts as will fit on the sheet. Use the chloroplast template provided.

8. Cut a window flap about 40 cm x 40 cm in the clear upper epidermis layer so that students can lift up this layer to view the chloroplasts in the palisade layer.

9. Attach the layers using brass fasteners so that the layers will stay in place. **See diagram below.**



9. Make element and compound circles to use with leaf model. Cut out 8 circles with a diameter of 4 cm from colored paper. (White, yellow, red, and blue) Use the circle template provided.

4 cm diameter circles (Cut 2 circles of each)	Front side of circle	Back side of circle
white	oxygen	O_2
yellow	carbon dioxide	CO_2
red	glucose	$C_6 H_{12} O_6$
blue	water	H_2O

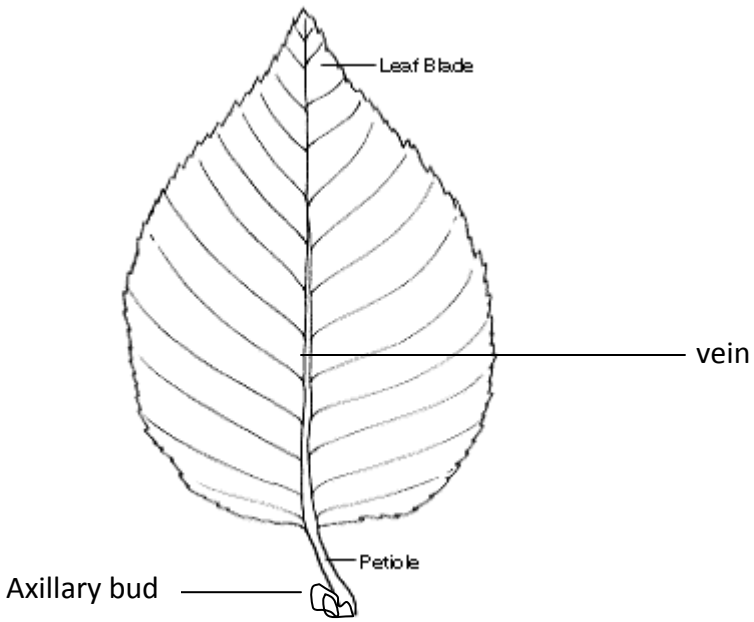
Laminate the circles for extended use!

10. Use the sheet "Teaching Strategies to Use with the Leaf Model".

Teacher Background Information to Use with the Leaf Model

CDL.7.B.17 Describe the structure and function of the major parts of a plant: roots, stems, leaves, flowers (*This lesson involves leaves only*)

A SIMPLE LEAF



Petiole: The stalk of a leaf that attaches the blade to the stem.

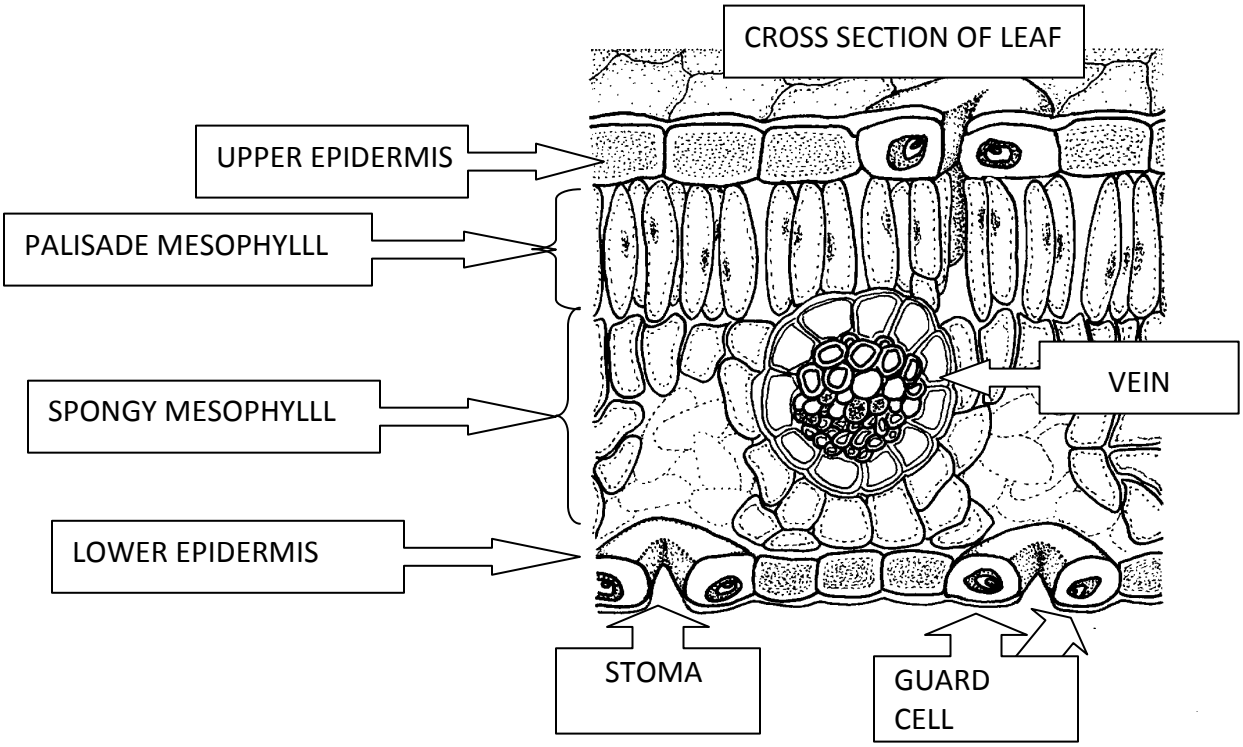
Leaf blade: The broad, expanded part of a leaf that serves to capture light.

Axillary buds: Buds located where a leaf joins a stem.

Vein: Vascular bundles which consist of xylem and phloem tissue give support to the leaf and also transport food and water.

CDL.7.B.18 Relate the structure of plant tissue to its function: epidermal, ground, and vascular

Plants are organized into tissue systems: epidermal, ground, and vascular. Leaves, as part of a plant, include these three tissue systems. The epidermal tissue is like the "skin" of the leaf because it consists of the outermost layer of cells. The vascular tissue is similar in function to the "bloodstream", transporting water and nutrients throughout the leaf in the veins. The ground tissue composes the remaining tissues of the leaf. The ground tissue is where most photosynthesis occurs (mesophyll) and some of it also functions to support the plant structure. Diagram from http://biodidac.bio.uottawa.ca/



Upper Epidermis: translucent tissue that allows light to pass through it to reach the mesophyll also protects the internal tissues.

Palisade Mesophyll: contains the majority of the chloroplasts so photosynthesis occurs here.

Spongy Mesophyll: provides space for the exchange of gases during photosynthesis.

Lower Epidermis: Most of the stomata (thousands per square centimeter) are located in the lower epidermis. Although most of the cells of the lower epidermis resemble those of the upper epidermis, each stoma is flanked by two sausage-shaped cells called **guard cells**. These differ from the other cells of the lower epidermis not only in their shape but also in having chloroplasts. The guard cells regulate the opening and closing of the stomata. Thus they control the exchange of gases between the leaf and the surrounding atmosphere

Teaching Strategies to Use with the Large Leaf Model

1. Peel back the upper epidermis (a layer of clear sheeting) to reveal the chloroplasts. Chloroplasts are mainly located in the palisade mesophyll and this is where most photosynthesis occurs.

2. Turn the leaf over to examine the stomata. Some stomata are open and some are closed.

3. Have the students pass CO_2 molecules (poster board circles) through the stomata.

4. Examine the vein (cording) that runs down the center of the leaf, delivering water to the leaf from the roots of the plant and moving the carbohydrates through the plant.

5. The water (more poster board circles) inside the leaf is released from the vein through osmosis.

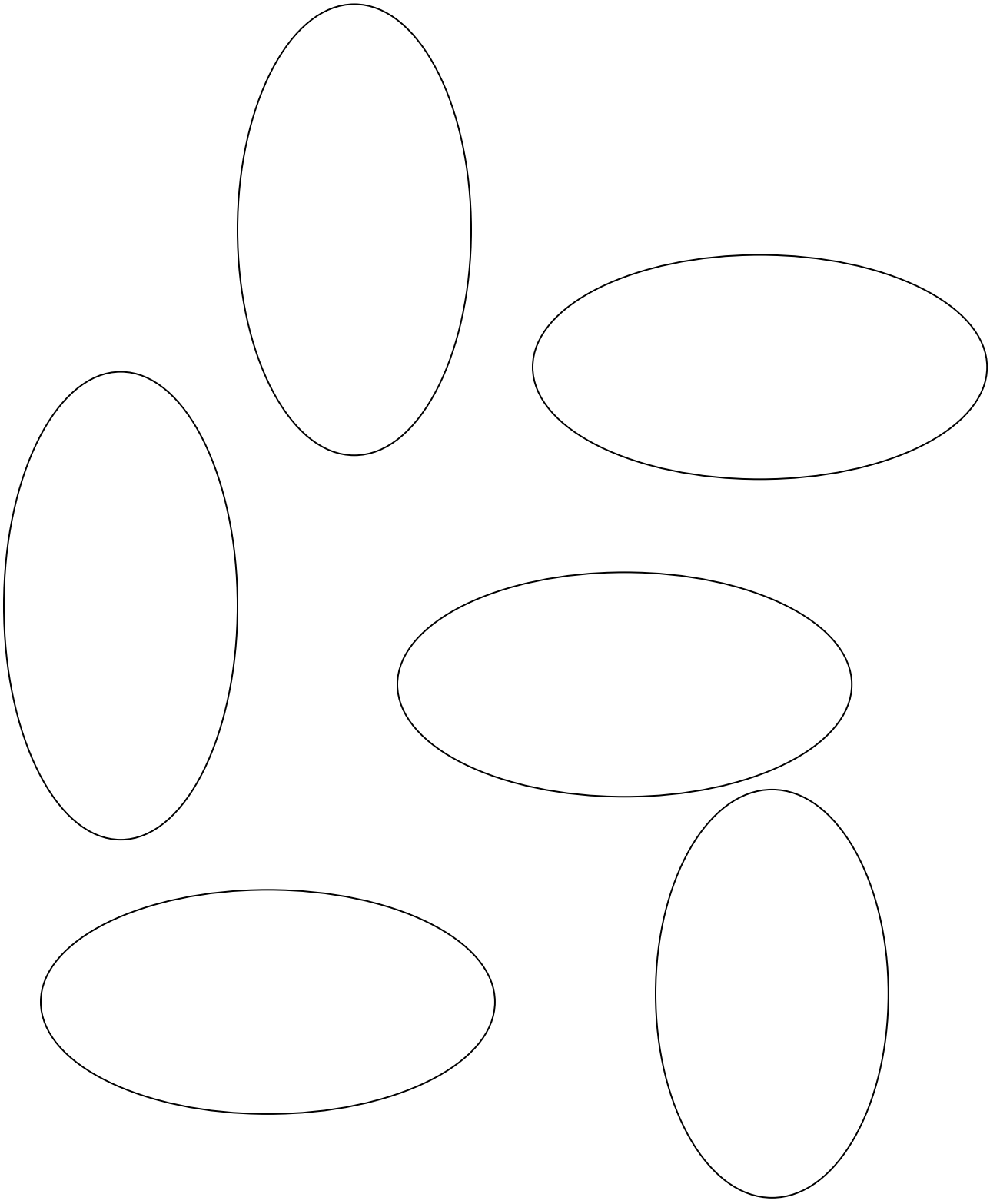
6. This initial examination demonstrates that the reactants of photosynthesis, water and carbon dioxide, along with chlorophyll, are available within the leaf.

7. Turn the leaf back over to the top side…where the process of photosynthesis takes place. Light energy shining on the leaf triggers a chemical reaction with the carbon dioxide, water, and chlorophyll. The carbon dioxide (which enters the leaf through the stomata) and water (which enters through the vein) are represented by poster board circles within the model, but the chlorophyll is just assumed to be present within the chloroplast. The interaction of the light energy, chlorophyll, water and carbon dioxide produces oxygen (O_2) and glucose ($C_6H_{12}O_6$), which are represented by poster board circles---the oxygen passes out of the leaf through the stomata and the glucose is stored within the leaf, stems, and roots.

8. A good assessment is to have the students manipulate the reactants and products and explain what is happening in the leaf.

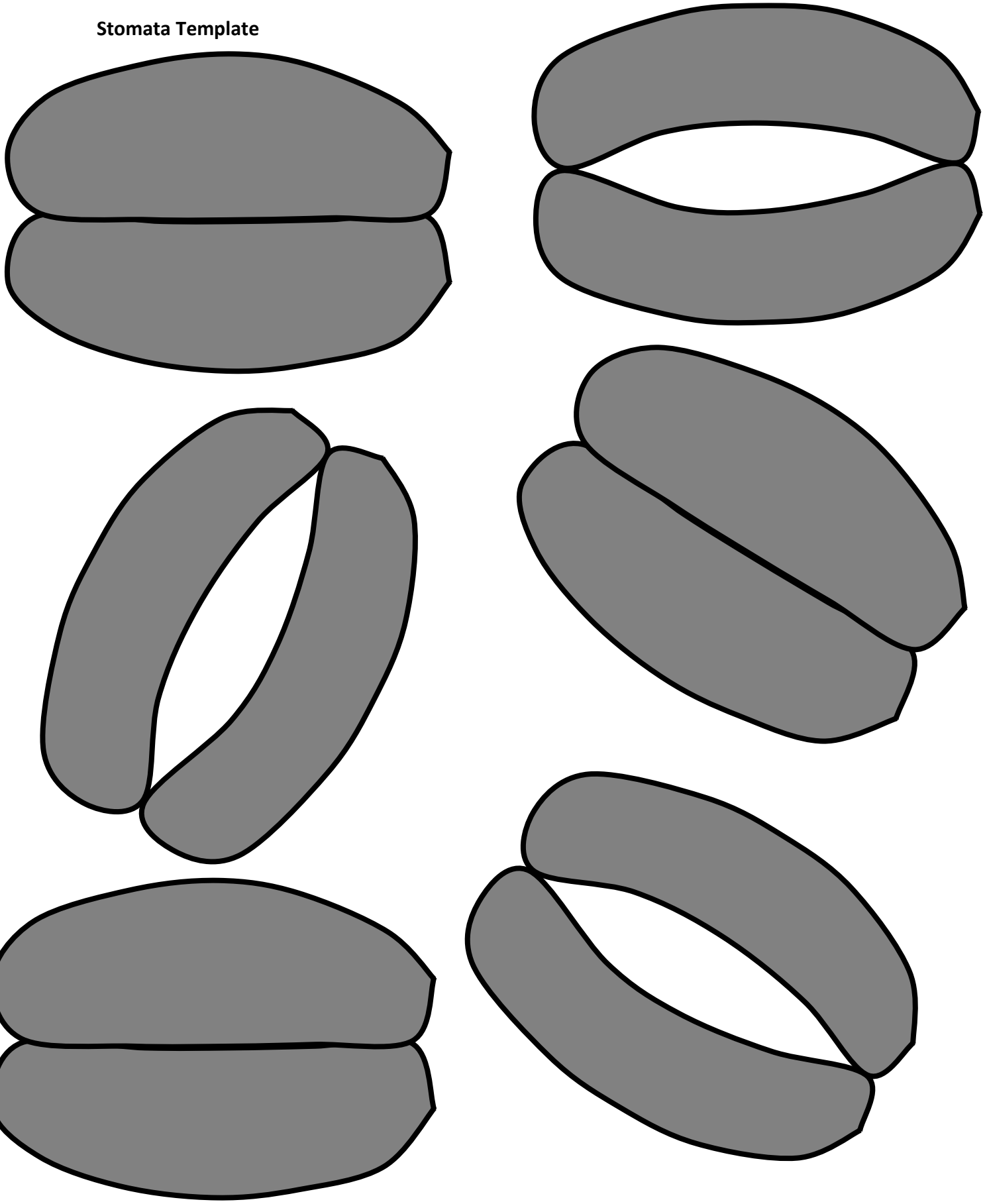
9. If you have the students build their own small model of the leaf, they can use it to explain the leaf layers and what role each plays in photosynthesis.

Adapted from an article, Building Leaves and an Understanding of Photosynthesis, Patty Littlejohn, The Science Scope, p. 22-25, April/May, 2007.



Chloroplast Template

Stomata Template



CARBON DIOXIDE	CO_2	CARBON DIOXIDE	CO_2
CARBON DIOXIDE	CO_2	CARBON DIOXIDE	CO_2
CARBON DIOXIDE	CO_2	CARBON DIOXIDE	CO_2
CARBON DIOXIDE	CO_2	CARBON DIOXIDE	CO_2

GLUCOSE $C_6 H_{12} O_6$

GLUCOSE $C_6 H_{12} O_6$

GLUCOSE $C_6 H_{12} O_6$

GLUCOSE $C_6 H_{12} O_6$

GLUCOSE $C_6 H_{12} O_6$

GLUCOSE $C_6 H_{12} O_6$

GLUCOSE $C_6 H_{12} O_6$

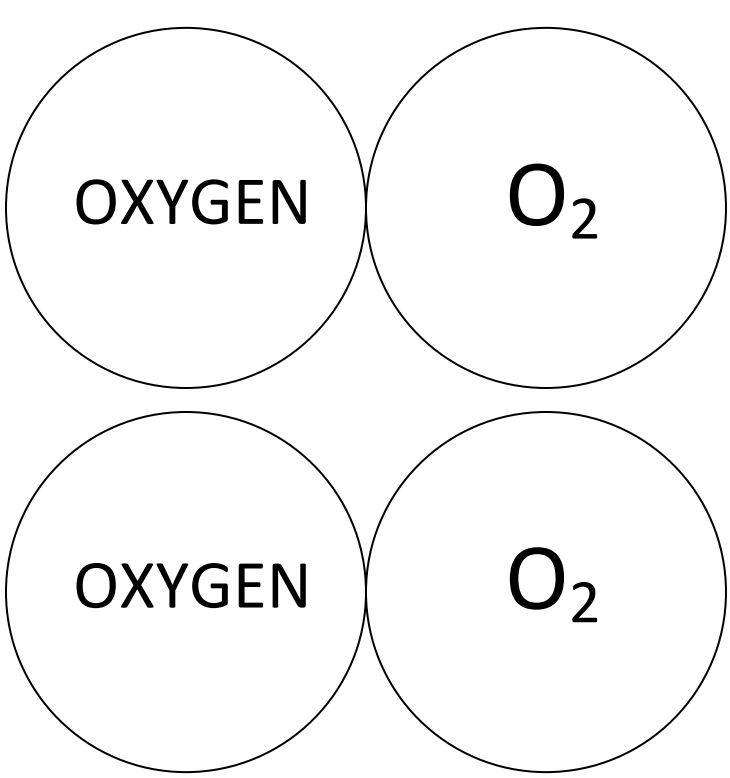
GLUCOSE $C_6 H_{12} O_6$

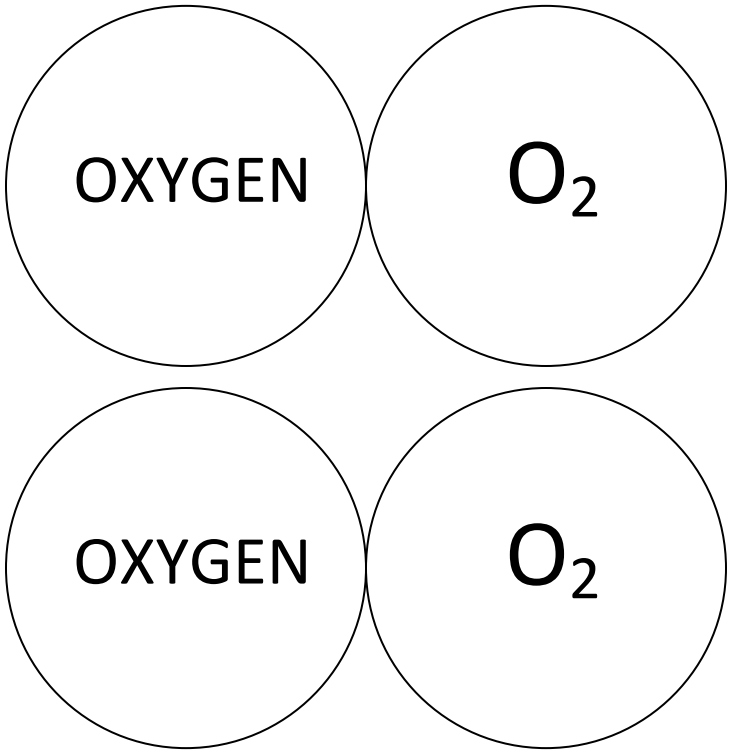
WATER H_2O WATER H_2O

WATER H_2O WATER H_2O

WATER H_2O WATER H_2O

WATER H_2O WATER H_2O


OXYGEN
O_2
OXYGEN
O_2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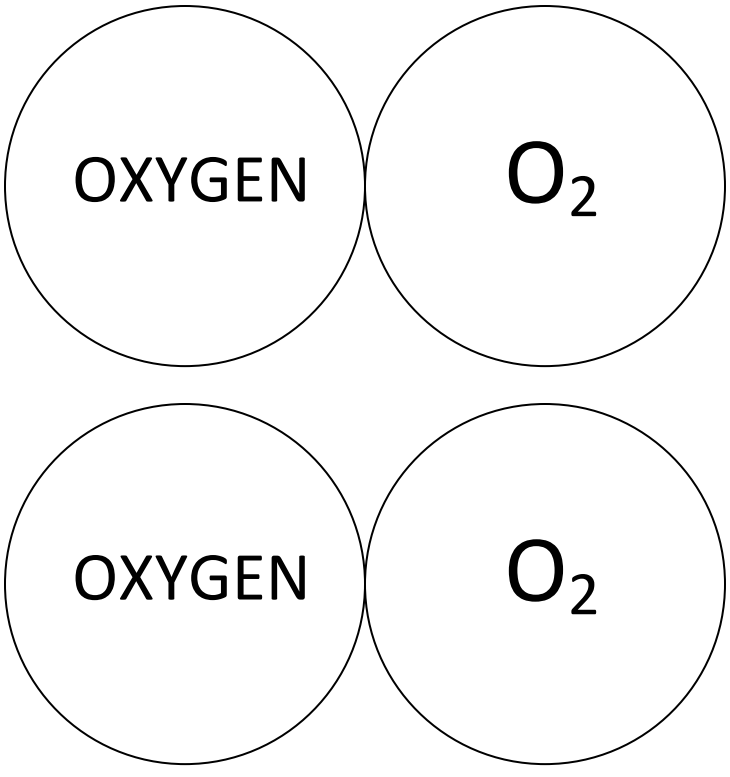
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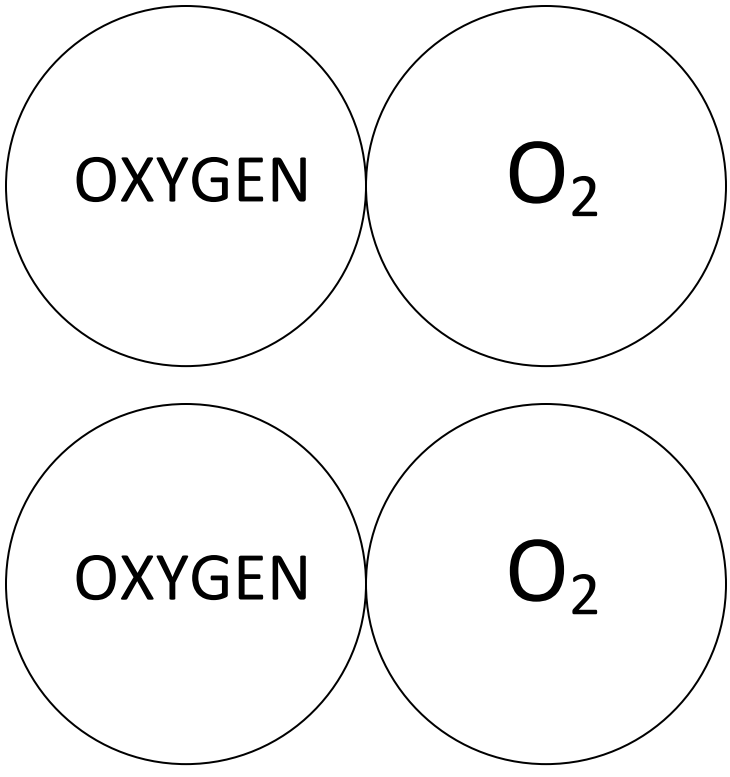

OXYGEN
O_2
OXYGEN
O_2

Making a Small Leaf Model
Teacher Preparation

In this assignment, students will construct a model of a leaf using textbooks or diagrams as a reference. The flip-book model can be constructed on any type of green paper. The clear plastic sheets can be recycled from laminate scraps, sheet protectors cut apart, or overhead transparency sheets. Provide students with an introduction and explanation of leaf structure and tissue before they begin. Use the "Teacher Background Information to use with the Leaf Model".

CDL.7.B.17 Describe the structure and function of the major parts of a plant: roots, stems, leaves, flowers (This lesson involves leaves only)
CDL.7.B.18 Relate the structure of plant tissue to its function: epidermal, ground, and vascular

Objectives:

Students will:

- Create a leaf model
- Know the basic structure of a leaf
- Relate the structure to the function of a leaf as it relates to photosynthesis
- Write a summary of the relationship of the structure of plant tissue to its function as it relates to photosynthesis

Materials per student:

- 2 green sheets (card stock, construction paper, foam sheets) (8 1/2 X 11 in.)or 1 green sheet and one sheet of bubble wrap
- 2 sheets of clear scrap laminate, acetate sheets for overheads, or sheet protectors (cut apart)
- 1 clear straw

Available for students to share in small group:

- permanent green or black marker
- stapler and regular staples
- scissors
- clear tape

Preparation Tips:

Have various texts available for students to use as reference sources. The internet can also be used for reference.

It is a good idea to have a sample small leaf model made in advance.

Making a Small Leaf Model- *TEACHER KEY*

Student Name_____ Date_____

Questions:

1. What is the role that each leaf layer plays in photosynthesis?

Upper Epidermis: translucent tissue that allows light to pass through it to reach the mesophyll also protects the internal tissues.
Palisade Mesophyll: contains the majority of the chloroplasts so photosynthesis occurs here.
Spongy Mesophyll: provides space for the exchange of gases during photosynthesis.
Lower Epidermis: Most of the stomata (thousands per square centimeter) are located in the lower epidermis. Although most of the cells of the lower epidermis resemble those of the upper epidermis, each stoma is flanked by two sausage-shaped cells called **guard cells**. These differ from the other cells of the lower epidermis not only in their shape but also in having chloroplasts. The guard cells regulate the opening and closing of the stomata. Thus they control the exchange of gases between the leaf and the surrounding atmosphere

2. How does the structure of the leaf allow it to carry out photosynthesis?

The structure of most leaves is broad and thin….this shape provides a large surface area to collect sunlight.
The epidermal layer is translucent, allowing light to pass through it.
Under the protective epidermal cells, the top layer of mesophyll cells (called the palisade layer) consists of tightly packed cells with many chloroplasts that collect the light and begin the reactions of photosynthesis.

3. Where does gas exchange occur in a leaf? How does this process occur?

The gas exchange occurs mainly on the lower surface of the leaf through the stoma.
The guard cells control the opening and closing of the stoma which allows for gas exchange in the leaf. Carbon dioxide enters the leaf and oxygen is released.

4. Describe the function of epidermal, vascular and ground tissue found in a leaf.

The epidermal tissue is like the “skin” of the leaf because it consists of the outermost layer of cells. The vascular tissue is similar in function to the “bloodstream”, transporting water and nutrients throughout the leaf in the veins. The ground tissue composes the remaining tissues of the leaf. The ground tissue is where most photosynthesis occurs (mesophyll) and some of it also functions to support the plant structure.

Making a Small Leaf Model

Student Name_____ Date_____

Introduction:

The leaves of a plant are the major location of photosynthesis. The structure of a leaf is designed so that it is an efficient location for photosynthesis to occur. Think about the reactants necessary for photosynthesis to occur and how the leaf is able to furnish those substances. When you complete this model, you will be able to complete that task easily!

Objectives:

- Create a leaf model
- Know the basic structure of a leaf
- Relate the structure to the function of a leaf as it relates to photosynthesis
- Write a summary of the relationship of the structure of plant tissue to its function as it relates to photosynthesis

Materials per student:

- 2 green sheets (card stock, construction paper, foam sheets) (8 1/2 X 11 in.) or one sheet of green and one sheet of bubble wrap
- 2 sheets of clear scrap laminate, acetate sheets for overheads, or sheet protectors (cut apart)
- 1 clear straw

  Available for students to share in small group:
- permanent green or black marker
- stapler and regular staples
- scissors
- clear tape

Figure 1

Procedure:

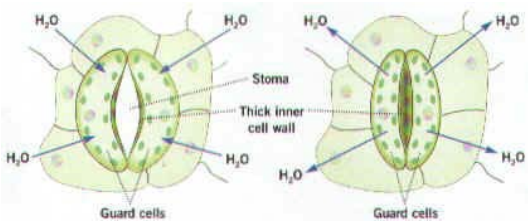
1. Layer the four sheets on top of one another as follows:

Layer	Sheets	Represents
Top	Clear	Upper epidermis
Second	Green	Palisade mesophyll
Third	Green or bubble wrap	Spongy mesophyll
Bottom	Clear	Lower epidermis

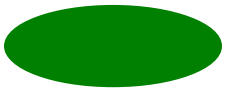
2. Use the marker to trace a leaf, including a petiole, on the top clear layer. The leaf shape should just fit inside the sheet. See Figure 1 above. You may use any leaf shape.

3. Insert the straw (vein) between the second and third layer of the leaf. Tape the other end of the straw to the second layer. Let the end of the straw extend out of the petiole. Staple the sheets together at the petiole to secure the straw and layers. Use scissors to cut out the leaf shape. Label each layer in the booklet with the appropriate name from Step 1.

4. On the bottom layer, draw as many stomata as will fit on the leaf. Make some guard cells open and some closed. The open stomata should resemble a pair of open lips and the closed stomata should resemble a pair of closed lips. See drawing below from http://www.biologyjunction.com/leaf_stomata_lab.htm.



5. Draw chloroplasts on the third layer (a clear sheet). Fill in with as many chloroplasts as possible on the sheet. See diagram.



6. In the leaf booklet, write a short summary of what happens in each leaf layer and how it relates to photosynthesis.

Making a Small Leaf Model

Student Name_____ Date_____

Questions:

1. What is the role that each leaf layer plays in photosynthesis?

2. How does the structure of the leaf allow it to carry out photosynthesis?

3. Where does gas exchange occur in a leaf? How does this process occur?

4. Describe the function of epidermal, vascular and ground tissue found in a leaf.

Modeling the Chloroplast

Lesson Overview

Unit Title: Photosynthesis

Lesson Summary: This is a hands-on activity designed to investigate the structure of the chloroplast.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

- MC.3.B.1 Compare and contrast the structure and function of mitochondria and chloroplasts. This lesson deals only with the structure of the chloroplast.

Math Integration

Literacy Integration

- Resource: RAFT Example

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: Develop an understanding of the cell.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Students will describe and illustrate the structure and function of parts of the chloroplast.
  1. Design and create a model of the internal structure of a chloroplast.
  2. Know the names of the parts of the chloroplast.
  3. Relate the internal structure of a chloroplast to its function.
  4. Write a fact-based account of a journey through a chloroplast from the viewpoint of a molecule or photon.

Focus Question:

- How do cells obtain and use energy?

Prerequisites / Background Information:

- See Photosynthesis background document.

Timeline: 1 class period

Preparation:	• 15 min
Elicit/Engage:	
Explore:	• 30 min
Explain:	• 10 min
Cleanup:	• 5 min

Teacher Preparation:

- The model should approximate the internal appearance as closely as possible with the materials provided. If studying respiration, the class may be divided, and half of the students assigned models of mitochondria. The models can also be retained and used for comparison to mitochondria in future chapters.

Materials:

- Paper plate or oval cardboard base, glue, scissors, green craft materials,
- Labels for internal structures, green markers,
- Diagrams of chloroplasts and text.

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☐ Computer(s)	☐ Digital Camera
☐ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☐ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• Appropriate classroom behavior required. • No specific safety equipment. • Use caution with scissors or hot-glue guns.	
	
	

Explore

- Students will design and construct a model of a plant chloroplast using textbooks or diagrams as reference. If studying respiration, the class may be divided, and half of the students assigned models of mitochondria.
- The models can also be retained and used for comparison to mitochondria in future chapters.

Explain

Elaborate

- Students can compare their own model to others and practice identifying the correct parts of the chloroplast.

Evaluate

Formative Assessment

- Students' models may be evaluated for accuracy.

Summative Assessment

- RAFT Writing Prompts:
  Write a fact-based account of a journey through a chloroplast from the viewpoint of a molecule or photon.

Extend

Cross-Curricular

- Art
- Literacy
- Technology

Notes:

Modeling the Chloroplast
Teacher Preparation

In this assignment, students will design and construct a model of a plant chloroplast using textbooks or diagrams as reference. The three-dimensional model can be constructed on paper plates or ovals cut from poster board. Provide students with some introduction and explanation of the structure before they begin. It will also be helpful if students have previously studied the structure of the plasma membrane and the basic process of photosynthesis. The model should approximate the internal appearance as closely as possible with the materials provided. If studying respiration, the class may be divided, and half of the students assigned models of mitochondria. The models can also be retained and used for comparison to mitochondria in future chapters.

MC.3.B.1- *Compare and contrast the structure and function of mitochondria and chloroplasts.*

Objectives:

Students will:

- Design and create a model of the internal structure of a chloroplast.
- Know the names of the parts of the chloroplast.
- Relate the internal structure of a chloroplast to its function.
- Write a fact-based account of a journey through a chloroplast from the viewpoint of a molecule or photon.

Materials:

- Paper plates (white or green)
- Hot glue guns/sticks or craft glue
- Scissors
- Printed labels or index cards, markers

Various green craft materials:
Sponges, felt, foam sheets, plastic beads, buttons, paper, chenille stems, cardstock, cotton swabs, ribbon, bubble wrap

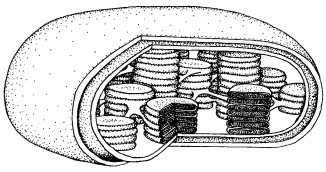
Preparation Tips:

- Collect various materials throughout the year so you have enough for the assignment.
- You may wish to ask students to provide their own green materials, or divide materials you have on hand into zipper bags to discourage waste.
- An interesting variation is to have an activity, such as a review game, during which students can “earn” points or money with which to buy the materials. Provide them with basics and then assign prices to additional materials so they have to determine what they can afford to buy and use.
- **Safety**- Caution students on the proper use of scissors and hot glue guns.

Student Name _____ Date_____

Modeling the Chloroplast

Introduction:



Photosynthesis occurs in organelles called chloroplasts found within the cells of plant leaves, or other organisms such as protists. A basic knowledge of the structure of a chloroplast is important in understanding where the phases of photosynthesis occur. In this assignment, you will design and create a three-dimensional model of a chloroplast using materials provided by the teacher. As you choose materials for the construction, try to simulate the appearance of an actual chloroplast as closely as possible using diagrams as reference.

Objectives:

- Design and create a model of the internal structure of a chloroplast.
- Know the names of the parts of the chloroplast.
- Relate the internal structure of a chloroplast to its function.
- Review the process of photosynthesis and write a fact-based account of a journey through a chloroplast from the viewpoint of a molecule or photon.

Materials:

- Paper plate or oval cardboard base
- Glue
- Scissors
- Green craft materials
- Labels for internal structures, green markers
- Diagrams of chloroplasts and text

Instructions:

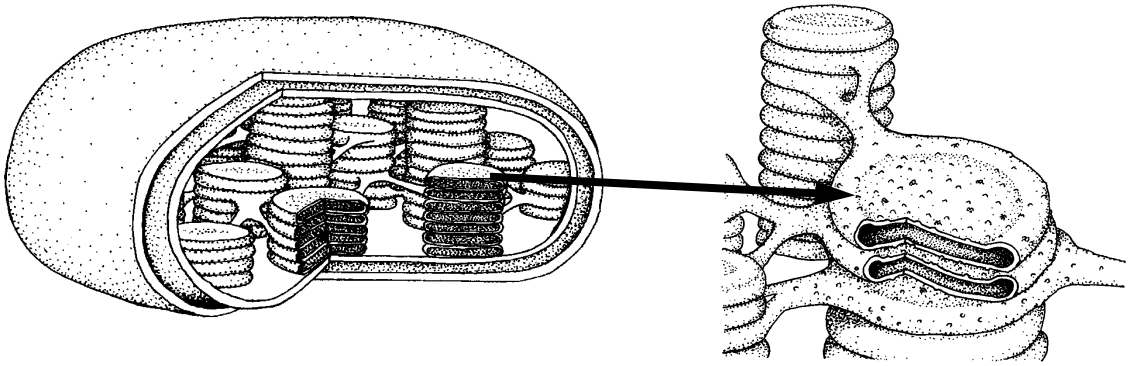
Safety: Use caution with scissors or hot-glue guns.

- Examine diagrams of the internal structure of a chloroplast in your text or other resources.
- Review the structure and function of all parts.

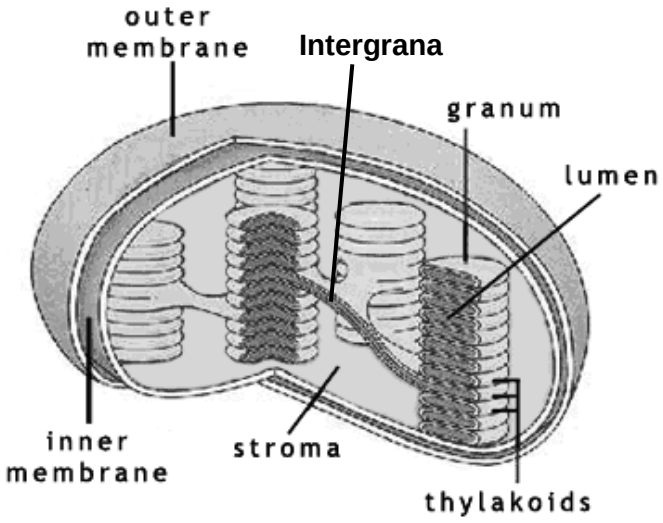
Instructions (continued)

- Assemble your materials and decide how to best represent the structure in a three-dimensional way.
- Cut out and arrange the materials on the paper plate base.
- When you are satisfied with the appearance begin to glue items to the base.
- Make labels for each structure in the chloroplast or use those provided by the teacher.
- Glue the labels next to each structure.

Chloroplast Diagrams



Use these diagrams as reference for structure. Label the inner structures as indicated by the teacher. You may also refer to your textbook.



Reference: Diagrams: Helpsavetheclimate.com/photosynthesisBiodidac.bio.uottawa.ca

Name _____ Date_____

Modeling the Chloroplast

Questions:

1. Where are the chlorophyll molecules and other pigment molecules located in the chloroplast? How are these pigment molecules arranged?

2. What is the difference between the granum and a thylakoid?

3. Photosynthesis can be divided into two distinct phases. What are they called and where does each occur?

4. Write a balanced equation for photosynthesis and indicate the products and reactants. During what phase of photosynthesis are each of the reactants used?

5. Why is it incorrect to refer to part of photosynthesis as the “Dark Reactions”?

Modeling the Chloroplast
Key to Questions

1. Where are the chlorophyll molecules and other pigment molecules located in the chloroplast? How are these pigment molecules arranged?

   They are arranged in photosystems within the thylakoid membranes.

2. What is the difference between the granum and a thylakoid?

   A thylakoid is a single membranous sack and a granum is a stack of several thylakoids.

3. Photosynthesis can be divided into two distinct phases. What are they called and where does each occur?

   The first phase of photosynthesis is the light dependent reactions and occurs in the thylakoid membrane. The second phase is the light independent reactions (Calvin Cycle) and occurs in the stroma of the chloroplast.

4. Write a balanced equation for photosynthesis and indicate the products and reactants. During what phase of photosynthesis is each of the reactants used?

   $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

   Water is split during the light dependent phase, and carbon dioxide is utilized during the light independent phase.

5. Why is it misleading to refer to part of photosynthesis as the "Dark Reactions"?

   The light independent reactions were at one time referred to as dark reactions because light is not required. Since they can occur during the day or at night it is misleading to call them the dark reactions.

Name _____ Date_____

RAFT Writing 1 - The Chloroplast

"RAFT" writing is a paper written from a viewpoint other than your own as a student, to someone other than your teacher. RAFT stands for Role, Audience, Format, and Topic.

- You will be writing about the structure of a chloroplast, from the viewpoint of a **photon of light** that has entered the chloroplast.
- Your audience will be other photons that have not yet entered the chloroplast.
- The format will be a descriptive trip through the chloroplast, relating what you as a photon "saw" and what happened to you or what you did.
- The paper should be creative and not a copy of source information. Include a title.
- Write it in your own words and be able to describe or explain the information using terminology you've learned.
- Review the process of photosynthesis before you begin.

Name _____ Date_____

RAFT Writing 2 - The Chloroplast

"RAFT" writing is a paper written from a viewpoint other than your own as a student, to someone other than your teacher. RAFT stands for Role, Audience, Format, and Topic.

- You will be writing about the structure of a chloroplast from the viewpoint of a **water molecule** that has entered the chloroplast.
- Your audience will be other water molecules that have not yet entered the chloroplast.
- The format will be a descriptive trip through the chloroplast, relating what you as a water molecule "saw" and what happened to you or what you did.
- The paper should be creative and not a copy of source information. Include a title.
- Write it in your own words and be able to describe or explain the information using terminology you've learned.
- Review the process of photosynthesis before you begin.

Photosynthesis in Leaf Disks

Lesson Overview

Unit Title: Photosynthesis

Lesson Summary: 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. This is a quick, easy, cheap and safe lab to demonstrate photosynthesis.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

- MC.3.B.4 Describe and model the conversion of light energy to chemical energy by photosynthetic organisms:
  1. light dependent reactions
  2. light independent reactions

Math Integration

- Graphing

Literacy Integration

- Constructed Responses

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: Develop an understanding of the cell.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Demonstrate laboratory techniques necessary to perform the experiment.
- Identify another variable that might affect photosynthesis and design an experiment that uses leaf disks to test the ideas.
- Design an inquiry to examine an appropriate variable in the experiment.
- Describe the reactants and products of photosynthesis and the source of reactants from the environment.
- Explain the relationship of photosynthesis to the observations made during the experiment.
- Create hypotheses about the effects of environmental variables on the rate of photosynthesis.

Focus Question:
- How do cells obtain and utilize energy?

Prerequisites / Background Information:
- Photosynthesis is a complex process that converts light energy into chemical energy in the form of carbohydrates and/or other compounds in photosynthetic organisms.
- Photosynthesis occurs in two stages: light dependent reactions and light independent reactions/Calvin cycle.
- In this experiment, the students will use a syringe to vacuum the air from the spaces in the spongy mesophyll of leaf disks (do not use thick leaves such as holly). The spaces will then be infiltrated with a sodium bicarbonate ($NaHCO_3$) solution, which contains a tiny amount of detergent to break down the waxy leaf coating (cuticle).
- The leaf disks are then exposed to light and observations are made as the cells undergo photosynthesis.

Timeline: 1 class period

Preparation:	• 30 min
Elicit/Engage:	
Explore:	• 25-30 min
Explain:	• 10 min
Cleanup:	• 5 min

Teacher Preparation:
- Gather leaves and other materials.

Materials:
- Baking soda, large cup or beaker (500 mL), 2 large cups or beakers (250 mL), hole punch, fresh leaves, light source (60 watt or higher), liquid detergent, plastic spoon or straw, eyedropper, timer, large plastic syringes (1 per group).

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☐ Computer(s)	☐ Digital Camera
☐ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☐ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• Goggles must be worn. The chemicals used are safe to use without gloves and the liquid may be disposed of down the sink. The leaf disks should be placed in a trash container as they may stop up a sink.	

- Caution the students to grasp the syringe firmly and keep one finger over the tip to prevent water from spraying out the opening.

Elicit

Engage

Explore

- This lab gives students an authentic "Lab" experience and addresses several NS skills.
- Students will follow directions, conduct the written lab, and they will get to design their own experiment.

Explain

Elaborate

- As an extension you may propose that the floating disks be placed in the dark to determine if the disks will sink after photosynthesis ceases.

Evaluate

Formative Assessment

- Observations of students as they conduct the lab

Summative Assessment

- Constructed responses to student handout
- Design of inquiry experiment

Extend

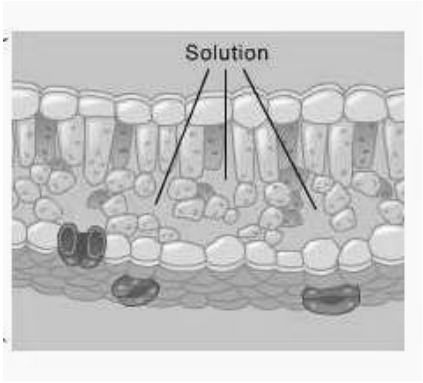
Cross-Curricular

Notes:

Photosynthesis in Leaf Disks
Teacher Preparation and Background Information

General Information: **Safety:** Goggles should be worn during the experiment. Solutions may be handled without gloves and may be disposed of in sink drains.

In this experiment, students will use a syringe to vacuum the air from the spaces in the spongy mesophyll of leaf disks (do not use thick leaves such as holly). The spaces will then be infiltrated with a sodium bicarbonate ($NaHCO_3$) solution, which contains a tiny amount of detergent to break down the waxy leaf coating (cuticle).
Note: The amount of sodium bicarbonate is approximate. You may wish to test this prior to the experiment, or measure it for the students. The sodium bicarbonate solution adds carbon dioxide to the solution to stimulate photosynthesis.



As solution enters the leaf spaces and forces the air out, the additional mass causes the disks to sink in the solution. The solution should be vacuumed through the leaf disks several times, shaking the syringe after each attempt.

Caution the students to grasp the syringe firmly and keep one finger over the tip to prevent water from spraying out the opening. If the disks do not sink add a little more detergent to the solution.

The leaf disks are then divided equally into 2 cups, the remaining solution is added equally to each. One cup is exposed to light while the other serves as the control, and is covered. As photosynthesis occurs, oxygen is produced which fills the intercellular spaces. The decrease in density causes the leaf discs to rise and float. Observations are made as the disk cells undergo photosynthesis and students will record the time it takes for leaf disks to rise to the surface.

As an extension you may propose that the floating disks be placed in the dark to determine if the disks will sink after photosynthesis ceases.

After mastering the basic techniques in the controlled lab, each pair of students will design and carry out an Experimental Lab with one variable introduced. You may need to provide suggestions and provide equipment: concentration of sodium bicarbonate solution, pH of solution, temperature of solution, intensity of light, color (wavelength) of light, distance from light, type of leaf, and presence of other chemicals such as herbicides that interfere with photosynthesis. (Use safety precautions with chemicals)

Materials: Per Group

Sodium bicarbonate (baking soda)
1 large plastic cup or beaker (app. 500 mL)
2 clear plastic cups or beakers (app. 250 mL)
Hole punch (can be shared by groups)
Fresh Leaves (spinach, ivy, pansy, other of your choosing)
Large plastic syringes (35-65 mL, 1 per group)
Light sources, 60 watt bulb or higher
Liquid detergent
Plastic spoon or straw
Eyedropper
Timers or a clock with second hand
(Other materials for experimental labs)

Photosynthesis in Leaf Disks

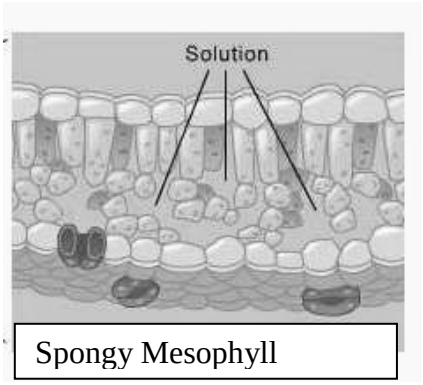
Name_____ Group_____ Date_____

Photosynthesis in Leaf Disk

Introduction:
Photosynthesis is a process in which plants convert light energy (sunlight) into usable chemical energy (carbohydrates). Photosynthesis involves two simultaneous processes: the light dependent reactions and the light independent reactions (Calvin Cycle). In the light dependent reactions, light energy is captured and converted to high energy ATP and NADPH molecules. In the light independent reactions these high-energy molecules are used to reduce CO_2 and eventually form carbohydrates such as glucose.

Overall reaction (unbalanced): $CO_2 + H_2O$ + light energy → Glucose + O_2

In this experiment, the spaces in the spongy mesophyll of leaf disks are filled with a sodium bicarbonate solution, which causes them to sink in the solution. The leaf disks are then exposed to light and observations are made as the cells undergo photosynthesis.



Spongy Mesophyll

Objectives:
By the end of this activity you should be able to:

- Describe the reactants and products of photosynthesis and the source of reactants from the environment.
- Explain the relationship of photosynthesis to the observations made during the experiment.
- Identify another variable that might affect photosynthesis and design an experiment that uses leaf disks to test your ideas.
- Create hypotheses about the effects of environmental variables on the rate of photosynthesis.

Materials:

- 1.5 g sodium bicarbonate (baking soda)
- Liquid dish soap
- Eyedropper
- Plastic syringe (20-65 mL)—no needle!
- Plastic spoon or straw (for stirring)
- Leaf material
- Hole punch
- 1 large beaker or plastic cup
- 2 small beakers or plastic cups
- Timer or clock with second hand
- Light source
- Paper towels

Photosynthesis in Leaf Discs

Procedure: **Solutions are safe to handle without gloves.** **Wear Goggles!**

1. Using a one-hole punch, cut 20 leaf disks from young actively growing leaves.

2. Prepare a 0.2% solution of sodium bicarbonate ($NaHCO_3$) and water in the large beaker or clear plastic cup, by adding approximately 1.5 g sodium bicarbonate to 300 mL of water. Stir until dissolved. Use an eyedropper to add about 2 drops of dish detergent to the solution and stir gently. There should be no bubbles afterward.

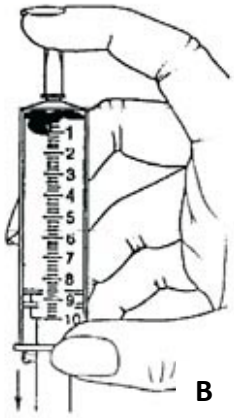
3. Remove the plunger from a large clean syringe (no needle). Place 20 leaf disks into the body of the syringe. Be sure the leaf disks are near the tip of the syringe as you re-insert the plunger so as not to damage the disks. **(A)**

4. Insert the tip of the syringe into a beaker of 0.2% sodium bicarbonate solution and draw 15-20 mL into the syringe. The leaf disks should be floating at this time. If your syringe is smaller than 60ml fill it about one third full.

A

5. Hold the syringe tip upward and expel the air by depressing the plunger carefully. **Stop** before solution comes out the tip.

6. Seal the tip of the syringe using the index finger of your left hand and hold tightly. Pull back on the plunger creating a partial vacuum within the syringe. If you have a good seal it should be hard to pull on the plunger and you should see bubbles coming from the edge of the leaf disks. Hold for a count of ten. **(B)**



B

7. Simultaneously, release your index finger and the plunger. Some of the leaf disks should start to sink. Tap the side of the tube or shake gently to break any bubbles on the edges of the disks.

8. Repeat steps 6 and 7 until all the disks sink. Do not overdo these steps!! You have been successful if the disks sink to the bottom. Don't repeat "just to be sure" as it is possible to damage the cells of the leaves.

9. Remove the plunger from the syringe and pour the solution containing the disks into 2 plastic cups or beakers and **add the remainder** of your solution equally to both beakers. There should be 10 disks per cup. Make sure they sink to the bottom.

10. Cover ONE of the beakers to block light from the leaf disks. Place the second beaker under a light source, approximately 6-8 inches below the light. The lights are best held in a clamp on a ring stand. Begin timing the experiment as soon as the light is turned on. Record your observations on page 4.

11. Notice what is happening to the leaf disks as photosynthesis proceeds. Continue to record your observations in the chart on page 4. After each time check, tap the side of the beaker to make sure the

disks are not "sticking" to the container walls. ***Note:*** *Check the covered beaker quickly to avoid light exposure. When instructed, clean the lab equipment and dispose of solutions in the sink drains.*

Photosynthesis in Leaf Disks **_____Name**

Data Table: Number of Leaf Disks Floating

Time (Minutes)	Number of Disks Floating (Light)	Number of Disks Floating (Dark)
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

(After 15 minutes consider the experiment over and that no more disks will rise.)

Lab Analysis and Questions:

1. Use the graphing grid on page 6 and graph the results from the light and dark treatments.

2. What is the variable in the experiment?

What problem/question did you answer in this experiment?

3. Why was detergent added to the solution?

Why was sodium bicarbonate ($NaHCO_3$) added to the solution?

Photosynthesis in Leaf Disks **_____Name**

4. Explain why it was important to keep one beaker covered during the experiment.

5. Describe and explain the relationship between the number of disks floating and time, as shown on the graph.

6. Did any leaf disks float in the dark treatment? If so, what may explain this result?

7. What process cannot occur in the dark treatment?

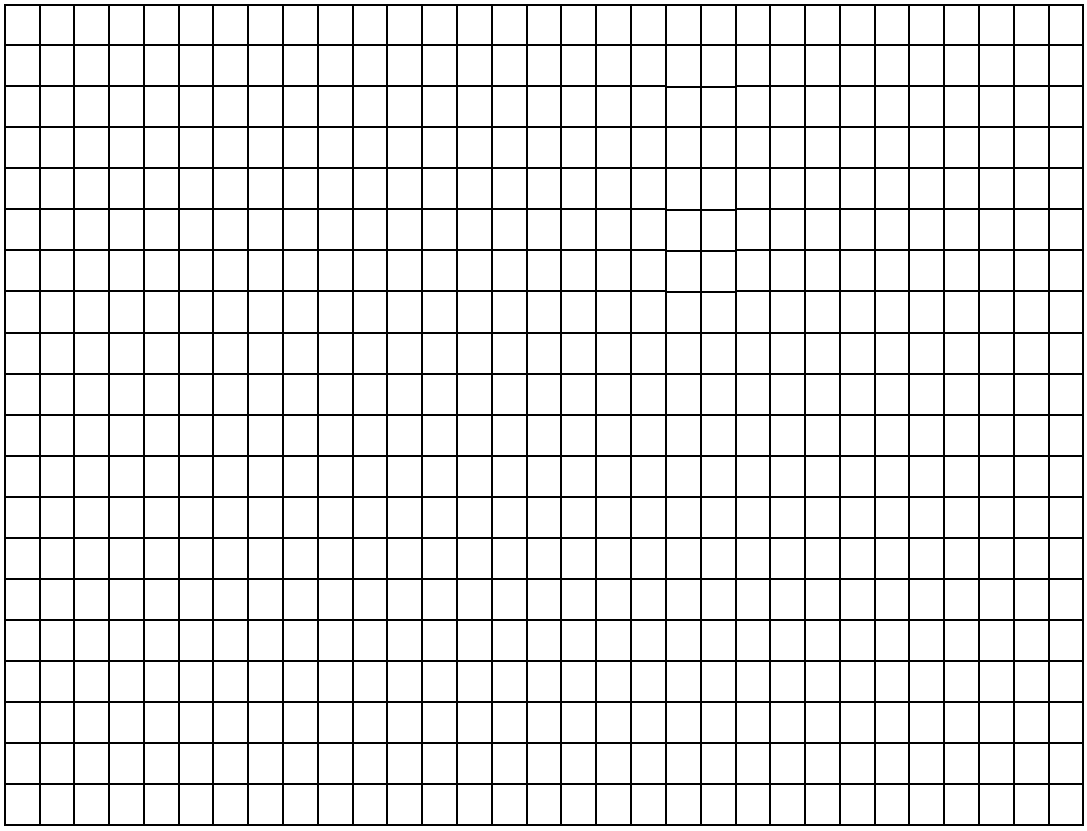
8. Explain the changes that occurred within the leaf tissue that allowed the leaf disks to rise to the surface.

9. You will now design and carry out an "Experimental Lab" using a variable that you select. Think about another factor you could test to determine its affect on photosynthesis. Set up a lab notebook page that lists your hypothesis, materials, procedures, data charts and conclusions. Ask your teacher for any extra materials you might need to be sure they are available. Be sure to follow all safety guidelines.

Photosynthesis in Leaf Disks _____Name

Question 1 –Graph

In the area below create a **double line graph** to display the results of the experiment. Provide a title, label the X and Y axis, and label each line appropriately or use a color key.



Light Dependent Role Play

Lesson Overview

Unit Title: Photosynthesis

Lesson Summary: Photosynthesis is a complex process that converts light energy into chemical energy in the form of carbohydrates and/or other compounds in photosynthetic organisms. Photosynthesis occurs in two stages: light dependent reactions and light independent reactions/Calvin Cycle. This kinesthetic activity takes students through the steps of the light dependent reactions.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

- MC.3.B.4 Describe and model the conversion of light energy to chemical energy by photosynthetic organisms:
  1. light dependent reactions
  2. light independent reactions

- Student constructed responses to reflection questions.

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: Develop an understanding of the cell.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:
- Model and Identify the major events involved in the light dependent reactions.
  1. Describe and model the conversion of light energy to chemical energy.

Focus Question:
- How do cells obtain and use energy?

Prerequisites / Background Information:

- Photosynthesis is a complex process that converts light energy into chemical energy in the form of carbohydrates and/or other compounds in photosynthetic organisms.
- Photosynthesis occurs in two stages: light dependent reactions and light independent reactions/Calvin Cycle.
- Reminder: It is important for the student to read his or her script/card as the process occurs. This will help the student understand the function of each component. Role play narration linked below.

Timeline: 1-2 class periods

Preparation:	• 1st time 1 hour, materials are reusable
Elicit/Engage:	
Explore:	• 40 min
Explain:	• 15-30 min
Cleanup:	• 5 min

Teacher Preparation:

- Gather materials and supplies
- Print and highlight scripts and cards

Materials:

- 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 blue 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
- Teacher supplied: 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)

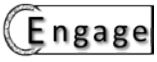
Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☐ Computer(s)	☐ Digital Camera
☐ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☐ Internet Web Browser	☐ Word Processing	

Internet Resources: List Resources Here or at End.

Procedures:	**Teacher's Notes:**
	
• Appropriate classroom behavior is required.	
	
	

Explore

- 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 the scenario with all the parts moving at the same time.

Explain

Elaborate

- Draw and label a diagram showing Photosystem I and Photosystem II and the processes that occur during the light dependent reactions.

Evaluate

Formative Assessment

- Student constructed responses to reflection questions.

Summative Assessment

- Photosynthesis graphic organizer

Extend

Cross-Curricular

- PE
- Technology

Notes:

- Biology, Eighth Edition. Neil Campbell, et.al. San Francisco: Pearson 2008.
- Biology. Kenneth Miller, & Joseph Levine. Upper Saddle River: Pearson 2006

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 (O_2) 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 (O_2) 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.

ANTENNA PIGMENT (PS I)

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).

ANTENNA PIGMENT (PS II)

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).

Primary Electron Acceptor (P680)

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.

Electron Transport Chain (from P680)

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).

The Sun

Photons of Light

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

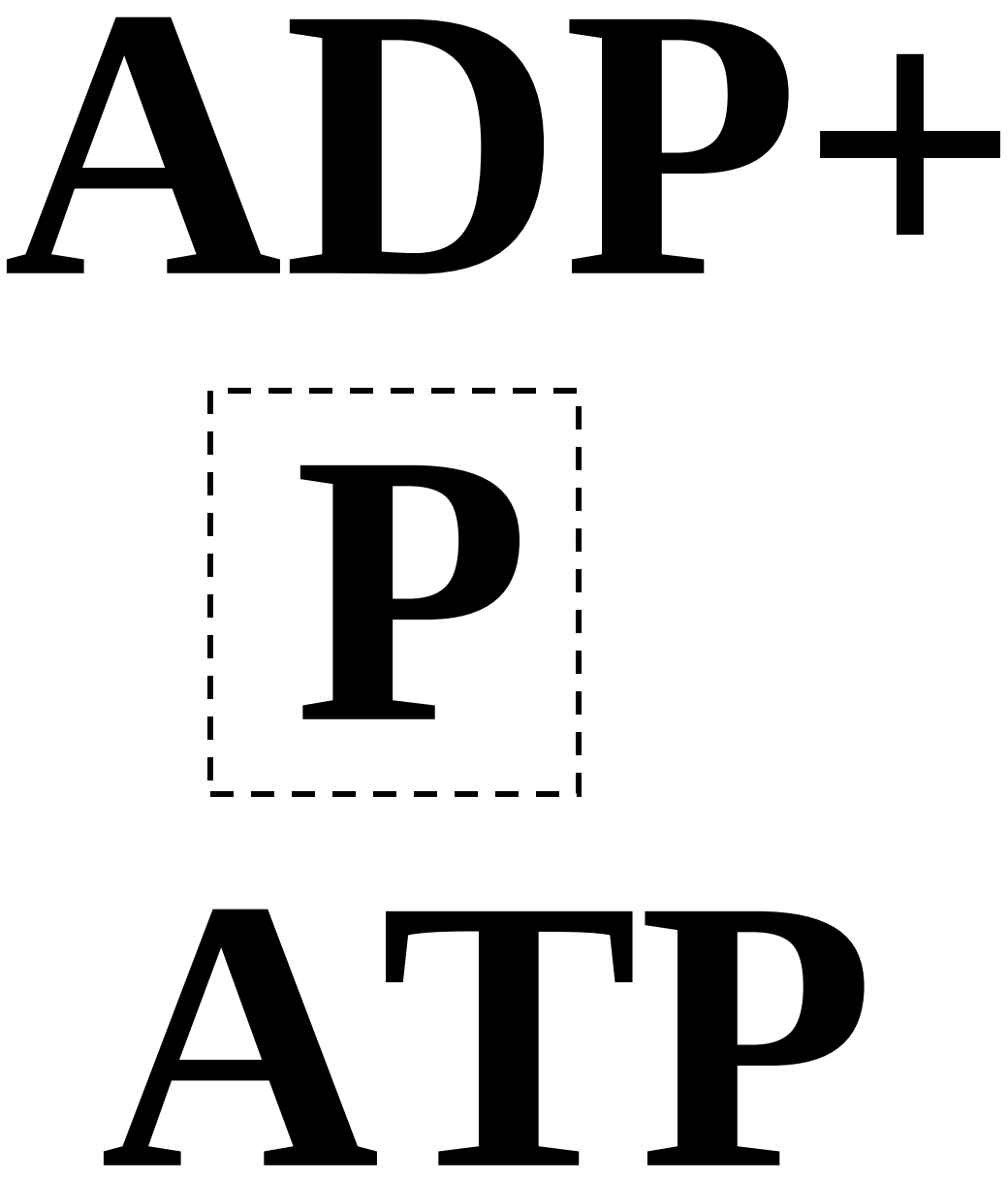
Back

"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

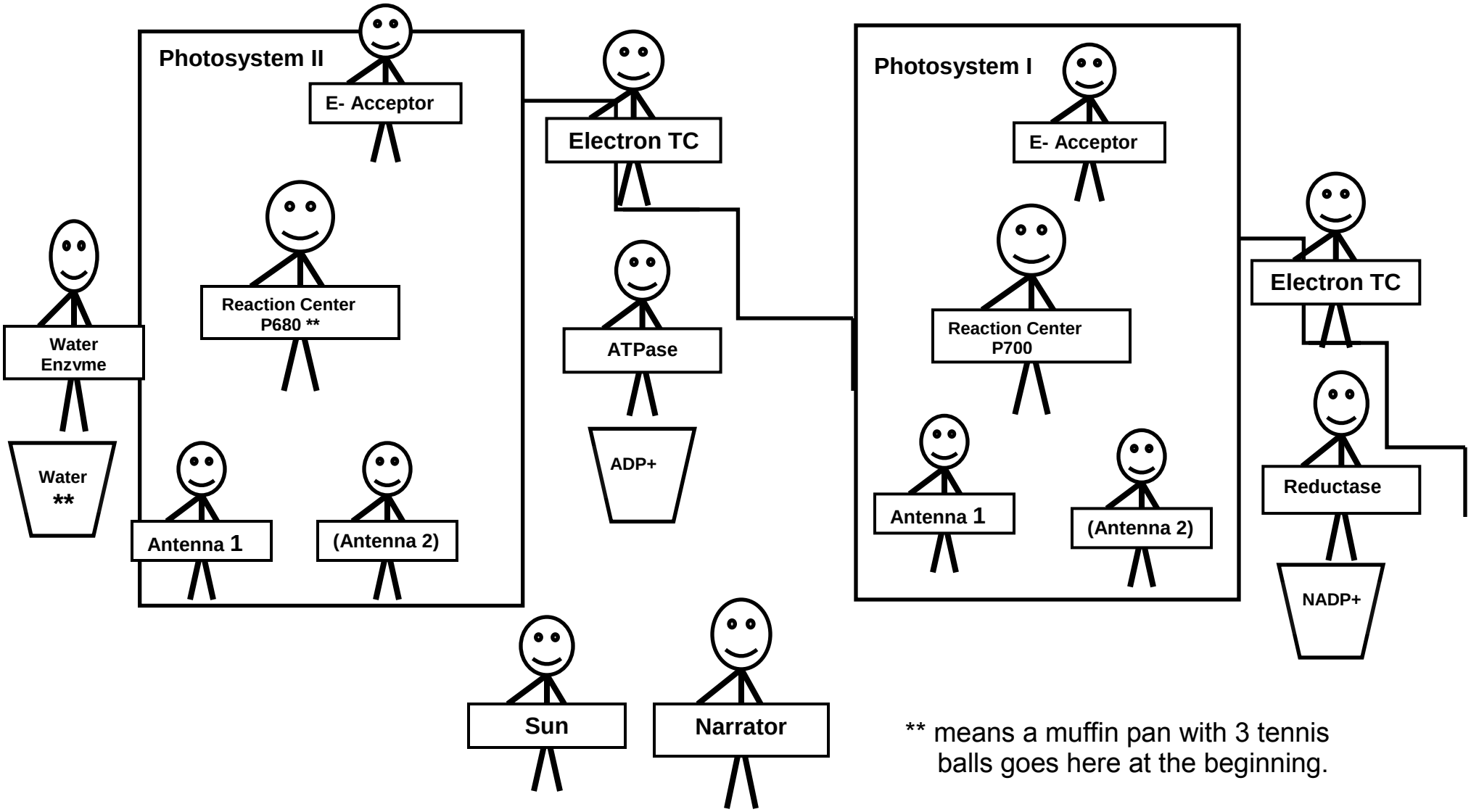
No other information is on this page.


ADP+
P
ATP

Appendix C

No other information is on this page.

Light Dependent Reactions – Role Play



** means a muffin pan with 3 tennis balls goes here at the beginning.

Front of Setup

Light Dependent Role Play
Script

Narrator Speaks:	**"The Sun, the greatest source of energy for our planet, is constantly sending down photons of light energy to Earth's surface. Plants will take this light energy and convert it to chemical energy. It all starts with just a few small photons."**
Narrator Action:	Point to Sun
Sun Speaks:	**"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."**
Sun Action:	Hand a tennis ball photon to the Antenna Pigment.
Antenna Pigment Photosystem II Speaks:	**"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."**
Antenna Pigment 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 PASSES BALL TO CHLOROPHYLL REACTION CENTER.
Chlorophyll Reaction Center (P680) Action:	Take 1 ball (photon) from Antenna Pigment and put in muffin pan (electron).
Sun Speaks:	**"I am the Sun. I send out energy in the form of photons of light. "**
Sun Action:	Hand a tennis ball photon to the Antenna Pigment.
Antenna Pigment Photosystem II Speaks:	**"I am chlorophyll. As an Antenna Pigment, my job is to absorb light.**
Antenna Pigment Photosystem II Action:	Accept the photon from the Sun and pass it to the Chlorophyll Reaction Center. (If no other Antenna Pigments are present.)
Chlorophyll Reaction Center (P680) Action:	Take 1 ball (photon) from Antenna Pigment and put in muffin pan (electron).
Sun Speaks:	**"I am the Sun. I send out energy in the form of photons of light."**
Sun Action:	Hand a tennis ball photon to the Antenna Pigment.
Antenna Pigment Photosystem II Speaks:	**"I am chlorophyll. As an Antenna Pigment, my job is to absorb light."**
Antenna Pigment Photosystem II Action:	Accept the photon from the Sun and pass it to the Chlorophyll Reaction Center. (If no other Antenna Pigments are present.)

Chlorophyll Reaction Center (P680) Action:	Take 1 ball (photon) from Antenna Pigment and put in muffin pan (electron).
Narrator Speaks:	**"When the Antenna Pigment has received enough energy from the photons, an electron is raised to an excited energy state and has to leave the molecule. Chlorophyll Reaction Center, can we hear from you?"**
Chlorophyll Reaction Center (P680) Speaks:	**"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."**
Chlorophyll Reaction Center (P680) Action:	Give full pan to Primary Electron Acceptor.
Narrator Speaks:	**It is here that we must examine what happens to the water molecule. Water Enzyme, tell us what happens.**
Narrator Action:	Point to Water Enzyme.
Water Enzyme Speaks:	**"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. "**
Water Enzyme Actions:	Remove the muffin pan from the Water Enzyme Container and pass it to the Chlorophyll Reaction Center. Remove the oxygen balloons and lay them aside. Remove and hold the hydrogen protons. Move and stand next to the NADP+ Reductase Enzyme. (LATER IN THE ROLE PLAY, these hydrogen protons will be used in Photosystem I. When NADP+ Reductase Enzyme is speaking, take the hydrogen protons and place them in the NADP+ container.)
Narrator Speaks:	**Now that the Chlorophyll Reaction Center has received an electron from the splitting of water, we will continue the action with the Primary Electron Acceptor in Photosystem II.**
Narrator Action:	Point to the Primary Electron Acceptor in Photosystem II.
Primary Electron Acceptor Photosystem II Speaks:	**I have received the excited electron from the Chlorophyll Reaction Center. The excited electron will be passed along to the Electron Transport Chain.**
Primary Electron Acceptor Photosystem II Action:	Pass muffin pan to Electron Transport Chain Photosystem II.

Electron Transport Chain Photosystem II Speaks:	**"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."**
Electron Transport Chain Photosystem II Action:	Place 3 tennis balls into the ATP bucket. Hold the muffin pan until it is time to pass it to the Chlorophyll Reaction Center in Photosystem I.
ATPase Enzyme Speaks:	**"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."**
ATPase Enzyme Action:	Place the phosphate sign into the ADP container and pull out the ATP sign.
Narrator Speaks:	**Now we will examine what happens in Photosystem I. A very similar process is occurring here. Keep in mind that both Photosystems are running at the same time. We now pick up the action with the Sun in Photosystem I.**
Narrator Action:	Point to Sun dramatically!
Sun Speaks:	**Here I am, the Sun again! I'm sending down my photons to supply energy to another phase of the light dependent reactions.**
Sun Action:	Hand a tennis ball photon to the Antenna Pigment.
Antenna Pigment Photosystem I Speaks:	**"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 the photosystem."**
Antenna Pigment 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 PASSES BALL TO CHLOROPHYLL REACTION CENTER.
Chlorophyll Reaction Center (P700) Action:	Take 1 ball (photon) from Antenna Pigment and put in muffin pan (electron).
Sun Speaks:	**"I am the Sun. I send out energy in the form of photons of light. "**
Sun Action:	Hand a tennis ball photon to the Antenna Pigment.
Antenna Pigment Photosystem I Speaks:	**"I am chlorophyll. As an Antenna Pigment, my job is to absorb light."**
Antenna Pigment Photosystem I Action:	Accept the photon from the Sun and pass it to the Chlorophyll Reaction Center. (If no other Antenna Pigments are present.)

Chlorophyll Reaction Center (P700) Action:	Take 1 ball (photon) from Antenna Pigment and put in muffin pan (electron).
Sun Speaks:	**"I am the Sun. I send out energy in the form of photons of light."**
Sun Action:	Hand a tennis ball photon to the Antenna Pigment.
Antenna Pigment Photosystem I Speaks:	**"I am chlorophyll. As an Antenna Pigment, my job is to absorb light."**
Antenna Pigment Photosystem I Action:	Accept the photon from the Sun and pass it to the Chlorophyll Reaction Center. (If no other Antenna Pigments are present.)
Chlorophyll Reaction Center (P700) Action:	Take 1 ball (photon) from Antenna Pigment and put in muffin pan (electron).
Chlorophyll Reaction Center (P700) Speaks:	**"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.**
Chlorophyll Reaction Center (P700) Action:	Hand pan to Primary Electron Acceptor.
Narrator Speaks:	**Let's observe what is happening in Photosystem I. The Chlorophyll Reaction Center has lost an electron. The electron will be replaced by an electron passing down the Electron Transport Chain from Photosystem II.**
Narrator Action:	Point to the Electron Transport Chain Photosystem II.
Electron Transport Chain Photosystem II Speaks:	**If you'll remember, the electron lost energy that was used to produce ATP in Photosystem II. The electron will now pass to the Chlorophyll Reaction Center in Photosystem I to replace its lost electron.**
Electron Transport Chain Photosystem II Action:	Pass muffin pan to the Chlorophyll Reaction Center P700.
Narrator Speaks:	**The chlorophyll molecule has regained an electron and is now stable. We will now resume the action at the Primary Electron Acceptor in Photosystem I.**
Primary Electron Acceptor Photosystem I Speaks:	**"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."**
Primary Electron Acceptor Photosystem I Action:	Pass the electron (muffin pan) to the Electron Transport Chain Photosystem I.

Electron Transport Chain Photosystem I Speaks:	**"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 NADPH Enzyme. This provides energy so that an enzyme can create NADPH."**
Electron Transport Chain Photosystem I Action:	Put the entire muffin pan into the NADPH Enzyme container.
NADP+ Reductase Enzyme Speaks:	**"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."**
Water Enzyme Action:	Take the hydrogen ion and place it in the NADPH Enzyme container.
NADP+ Reductase Enzyme Action:	Combine the purple (or other color balloon) with the Hydrogen ion (white balloon) to create a NADPH molecule model.
Narrator Speaks:	**The light dependent reactions are now complete. We have observed the movement of electrons as they gain and lose energy to produce two important compounds.** **ATP and NADPH come forward. You will now be used in the light independent reactions.**
ATPase Enzyme Action:	Come forward with ATP sign.
NADP+ Reductase Enzyme Action:	Come forward with NADPH sign.
ATPase Enzyme and NADP+ Reductase Enzyme Speak Together	**We are products of the light dependent reactions which are now complete. We will now be used in the light independent reactions, also known as the Calvin Cycle.**

Light Independent Activity

Lesson Overview

Unit Title: Photosynthesis

Lesson Summary: Photosynthesis is a complex process that converts light energy into chemical energy in the form of carbohydrates and/or other compounds in photosynthetic organisms. Photosynthesis occurs in two stages: light dependent reactions and light independent reactions/Calvin Cycle. This is a hands-on activity to demonstrate the steps in the light independent reactions/Calvin Cycle.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

- MC.3.B.4 Describe and model the conversion of light energy to chemical energy by photosynthetic organisms:
  1. light dependent reactions
  2. light independent reactions

- Constructed responses

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

- Standard C: Develop an understanding of the cell.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Identify the major events involved in the light independent reactions.
- Construct and modify models of carbon compounds involved in the light independent reactions of photosynthesis.
- Know the role of carbon dioxide in photosynthesis.
- Calculate the amount of energy (ATP) needed in the light independent reactions.
- Relate the energy sources for the light independent reactions to their formation.
- Understand that manufacturing glucose is a complex process.

Focus Question:

- How do cells obtain and use energy?

Prerequisites / Background Information:

- Photosynthesis is a complex process that converts light energy into chemical energy in the form of carbohydrates and/or other compounds in photosynthetic organisms.
- Photosynthesis occurs in two stages: light dependent reactions and light independent reactions/Calvin Cycle.
- The amounts listed in the materials section provide extra beads and checks so that students will have to keep track of what they use as the reaction proceeds. Have extra beads on hand in case any are lost. Determine the total numbers of beads and checks necessary according to the number of student groups in your class. The molecules constructed can be taken apart and used again in other classes, although you may need to replace chenille stems if they become misshapen.
- This lesson requires students to work with partners, follow directions, and work through the process in a collaborative effort.

Timeline: 1 class period

Preparation:	• 1st time 1 hour, materials will be reusable
Elicit/Engage:	
Explore:	• Model on overhead 10 min, Student construction of model 20 min
Explain:	• 10 min
Cleanup:	• 5 min

Teacher Preparation:

- Gather materials, photocopy templates and lab sheets, assemble bags of materials

Materials:

- 46 black "pony" beads, 26 yellow beads, 16 white beads, 24 ATP "checks", 16 NADPH "checks", 2 small zipper bags, 2 copies of the lab, text or descriptive information.

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☐ Computer(s)	☐ Digital Camera
☐ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other:
☐ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• appropriate classroom behavior required	

Elicit

Engage

Explore

- Prior to doing this assignment, they should already have completed a study of the structure of chloroplasts and the processes that produce energy carriers during the light dependent reactions.
- Students will construct models of the basic compounds involved in the Calvin Cycle, focusing on the role of carbon and the amount of energy utilized during the process.

Explain

Elaborate

Evaluate

Formative Assessment

- Students will construct a concept map to illustrate the Calvin Cycle as they conduct the bead activity.

Summative Assessment

Extend

Cross-Curricular

Notes:

Modeling the Light Independent Reactions
Teacher Preparation

The light independent reactions, also called the Calvin Cycle, are a series of complex molecular changes that occur as the final stage of photosynthesis. During this cycle, carbon dioxide is fixed into an organic compound that can be converted to glucose and other carbohydrates. In this activity, students will construct models of the basic compounds involved in the Calvin Cycle, focusing on the role of carbon and the amount of energy utilized during the process. Prior to doing this assignment, they should already have completed a study of the structure of chloroplasts and the processes that produce energy carriers during the light dependent reactions.

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

Student Objectives:

Students will:

- Construct and modify models of carbon compounds involved in the light independent reactions of photosynthesis.
- Know the role of carbon dioxide in photosynthesis.
- Calculate the amount of energy needed in the light independent reactions.
- Relate the energy sources for the light independent reactions to their formation.
- Understand that manufacturing glucose is a complex process.

Materials: Per Group of 2 Students

- 46 Black "Pony" beads — representing carbon atoms
- 26 Purple or Yellow beads — representing phosphates
- 16 White chenille stems — about 6" long
- 24 ATP use "checks" — representing ATP energy required
- 16 NADPH use "checks" — representing NADPH energy required
- 2 small zipper bags
- 2 copies of the lab
- Text or descriptive information

Modeling the Light Independent Reactions
Teacher Preparation

Preparation Tips:

- Print ATP (24/group of 2) and NADPH (16 /group of 2) checks and cut apart; print lab pages/blank diagrams for each student.
- Cut all of the chenille stems in half.
- Prepare two **zipper bags** for each **group of two students.**
    - Place 48 black beads, 16 chenille stems and 24 ATP energy checks into "Bag 1".
    - Place 26 yellow (or purple) beads and 16 NADPH energy checks into "Bag 2".

The amounts listed provide extra beads and checks so that students will have to keep track of what they use as the reaction proceeds. Have extra beads on hand in case any are lost. Determine the total numbers of beads and checks necessary according to the number of student groups in your class.
The molecules constructed can be taken apart and used again in other classes, although you may need to replace chenille stems if they become misshapen.

Prerequisite Knowledge and Pre-lab Discussion:

- Point out to students at the beginning of the activity that the molecules are much more complex than is indicated by the models they will build. The molecules contain other atoms in addition to the carbon and phosphate groups and have been simplified for the activity. You may wish to show students a structural model of RuBP (ribulose biphosphate) or glucose for clarification.
- The names of the molecules involved in the cycle have also been simplified in some cases. For example, the molecule name, 3-Phosphoglycerate, is shortened to 3-PG. The number "3" refers to a location on the molecule where a side branch (or atom) is found. You may want to explain this to students before you begin so that the numbers included in the names do not cause confusion, as they do not relate to the number of carbons present in the models being constructed.
- The students should understand the term "phosphorylation" and know that ATP contains high energy bonds between phosphate groups.
- Students should already have completed activities related to light dependent reactions.
- Be sure that students understand they will track only the carbon atoms and energy carriers (ATP, NADPH) during the reactions, and that the reactions have been simplified in this activity.

Procedures:

- At the beginning of the activity each student will construct three molecules of RuBP and then continue to modify these molecules throughout the cycle as they fill in their diagrams.
- **They must follow the directions carefully. If they become confused tell them to go back and begin again.**
- There are some parts of the activity in which students must calculate the number of beads to remove from the bag, or the number of ATP checks they need. If they are unsure how many they need, point out how that the number is determined by the molecules they are trying to modify.
- **When students finish, the lab partners will combine their information in the creation of a glucose molecule and may need to be reminded that only carbon is shown in their model.**
- If the students become confused they may repeat the activity.

ATP Energy Check **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**	**ATP Energy Check** **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**
ATP Energy Check **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**	**ATP Energy Check** **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**
ATP Energy Check **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**	**ATP Energy Check** **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**
ATP Energy Check **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**	**ATP Energy Check** **Value = Gain 1 Phosphate** **ATP phosphorylates a molecule.** **ATP – 1 Phosphate = ADP**

Student Name _____ Date _____

Modeling The Light Independent Reactions – Student Handout

The light independent reactions, also called the Calvin Cycle, are a series of complex molecular changes that occur as the final stage of photosynthesis. During this cycle, carbon dioxide is fixed into an organic compound that can be converted to glucose and other carbohydrates. In this activity, you and a partner will construct models of the basic compounds involved in the Calvin Cycle, focusing on the role of carbon and the amount of energy utilized during the process. At the end of the activity you and your partner will combine your information to generate the product of photosynthesis and answer questions related to the cycle.

Objectives:

- Construct and modify models of carbon compounds involved in the light independent reactions of photosynthesis.
- Know the role of carbon dioxide in photosynthesis.
- Calculate the amount of energy needed in the light independent reactions.
- Relate the energy sources for the light independent reactions to their formation.
- Understand that producing glucose requires complex chemical reactions.

Materials: For each group of two students.

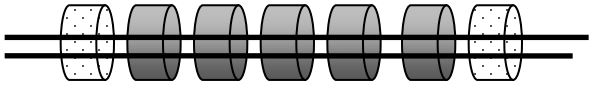
- Two zipper bags of pony beads and energy checks (materials are shared by the group)
    - **Black** –carbon atoms
    - **Purple or Yellow** –Phosphate groups
    - ATP energy use “checks”
    - NADPH energy use “checks”
    - White chenille stems
- Blank diagrams of the light Independent cycle, page 9.
- Textbook

Note: Two students will share the materials in the bags, but each student must construct their own models and fill in a diagram following the instructions on the next 2 pages. Leave materials in the bags until the instructions indicate they should be removed.

Model Construction: Follow each step carefully.

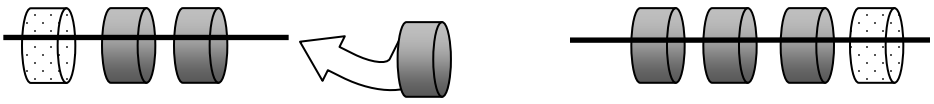
Step: 1- The cycle begins with ribulose biphosphate, RuBP.

- **Construct 3 models** of RuBP as shown in the diagram below. Hold two chenille stems together and slide five black carbon beads onto the stems. Add a phosphate bead to each end.
- **Draw one** of these molecules on your diagram in the box at "Step 1" and indicate you have made three of them by writing **"X 3"** (this means "times 3").
- **Shade** the carbon beads and leave the phosphates white as shown below.
- **Label it**: RuBP.



Step: 2- Carbon dioxide molecules enter the cycle and are "fixed" into each RuBP molecule. The new molecule is unstable and breaks apart.

- **Locate CO_2** entering the cycle on your diagram. Indicate that three molecules entered the cycle. (Write "X 3").
- **Remove** carbon beads from the bag to represent carbon dioxide entering the cycle.
- Carefully slide the two chenille stems apart keeping the three carbon beads and one phosphate bead on one stem, as shown below.
- "Fix" the CO_2 by adding a carbon bead to the other stem, so that each stem has three carbons, as shown below. Repeat the steps above with all molecules.
- **Draw one** of these molecules in the box at Step 2 and indicate how many you have.
- **Label it**: 3-PG (This is 3-Phosphoglycerate)



Step: 3- During Phosphorylation, one phosphate from ATP is added to **each** molecule of 3-Phosphoglycerate. (ATP – Phosphate = ADP)

- Use one "ATP Check" to "buy" each phosphate you will need. **Remove the "ATP Checks"** from the zipper bag and place them near your diagram.
- **Write** the number of ATP molecules required on the diagram near Step 3.
- **Remove** the phosphate beads you "bought" from the bag and add one phosphate bead to the end of **each** molecule stem.
- **Draw** the new molecule in the Step 3 box on your diagram and indicate how many you have by using an "X" and the number.
- **Label it**: 1-3-PG (1-3-Phosphoglycerate)

Step: 4- Phosphate will now be removed from each molecule. NADPH is used in this process, and is converted to NADP+

- Use one "NADPH Check" to buy each phosphate so that **one** can be **removed** from **each** molecule. Return the phosphate beads to the bag.
- Count and remove the "NADPH Checks" needed from the bag and place them near your diagram.
- **Write the number of NADPH** required on your diagram beside Step 4.
- **Draw** the new molecule in the Step 4 box on the diagram and indicate the number you have with an "X" and the number.
- **Label it**: G3P (Glyceraldehyde 3-phosphate)

Step: 5- One G3P will now leave the cycle and be available to generate glucose.

- **Set aside one G3P** molecule and save it for use later. This is the product of the Light Independent Reactions and will be used to create glucose.
- **Draw and label a G3P** molecule on your diagram in the Step 5 box. Draw an arrow to show it is leaving the cycle.

Step: 6- The remaining G3P will be used to regenerate **RuBP**. This requires energy and a phosphate from ATP.

- **Draw and label a G3P** molecule in the box at Step 6. Indicate the number **remaining** in the cycle.
- **Three ATP molecules are expended** during the rearrangement of G3P to recreate the RuBP that will continue the cycle.
- **Remove 3 "ATP Checks"** from the baggy and add them to your stack.
- **Draw an arrow** near Step 6 and label it to show that three ATP have been used.
- **Re-create RuBP** by rearranging the beads on your chenille stems. Remove the necessary phosphate beads and stems from the bag in order to make the RuBP molecules.
- **Refer to Step 1** for the structure if necessary. (RuBP is already on your diagram. Do not draw it on the diagram again.)

You and a partner will combine the information from your completed diagrams to answer the analysis questions on the next page.

You will use the G3P molecule models you set aside in step 5.

Do not replace any of the materials still on your desk until you answer all the questions.

Name _____ Date _____

Analysis and Questions: Light Independent Reactions – Student Handout

Your diagram should be finished at this point. You should have a stack of ATP and NADPH Checks that you accumulated during the activity. You will also have one G3P molecule and the newly created RuBP molecules that will continue the cycle.

Questions: Work with your partner to determine answers to the following questions. Remember to combine the information on both diagrams to arrive at your answers.

1. With your partner create a glucose model with the remaining G3P models made in the light independent cycle. Glucose is a 6-carbon sugar but does not contain any phosphate. What was removed from the molecule to form glucose?

2. Glucose contains other elements not shown in your model. What is the actual chemical formula of glucose?

3. How many total carbon dioxide molecules were required to generate one glucose molecule?

4. Calculate the total number of ATP molecules required to manufacture one glucose molecule?

5. How many NADPH molecules were required to make one glucose molecule?

6. What is the source of the ATP and NADPH molecules required in this cycle?

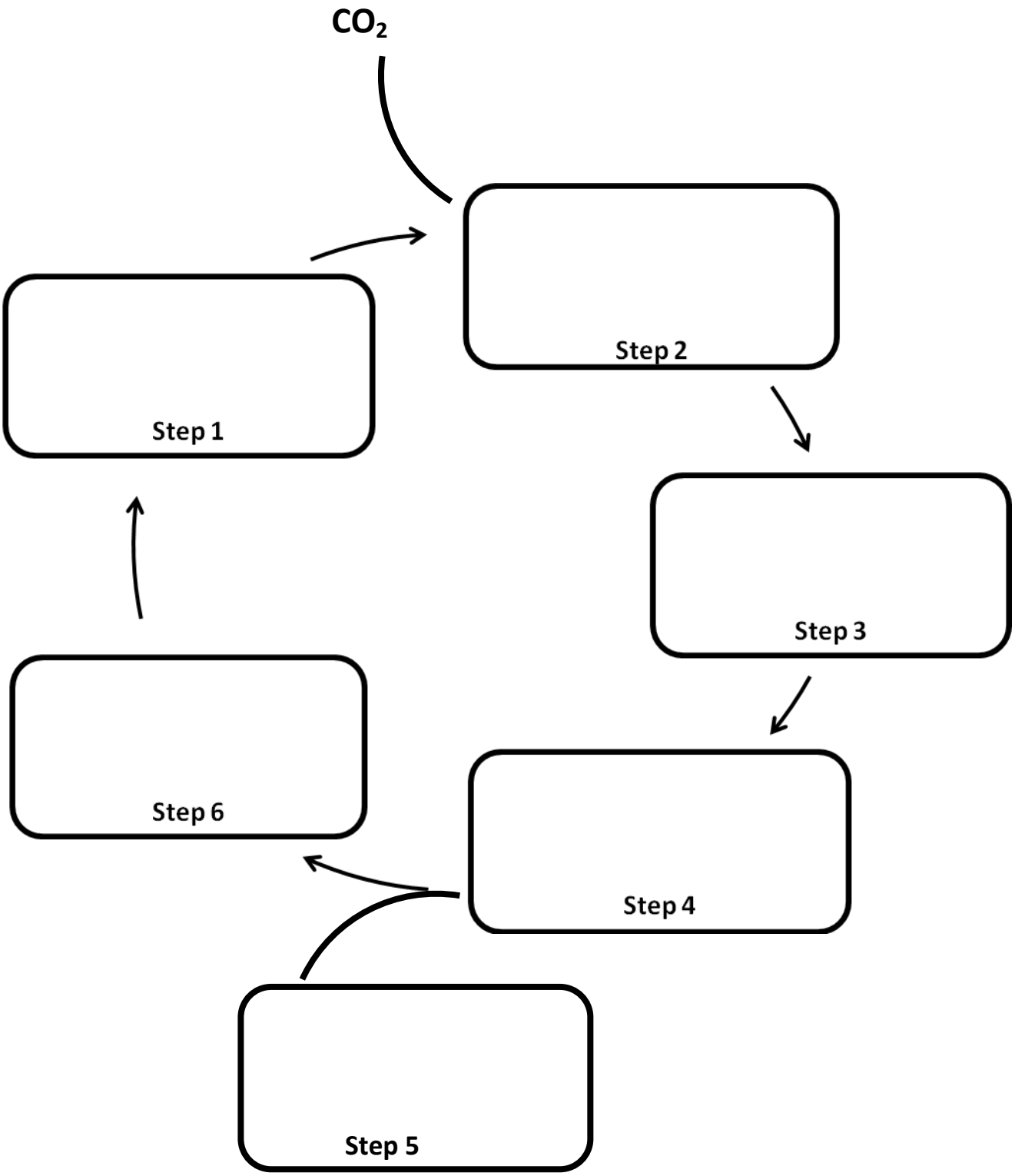
7. What happens to most of the carbon involved in the light independent cycle?

8. An enzyme called Rubisco is required to 'fix" carbon dioxide into RuBP. What does it mean to "fix" carbon into RuBP?

9. Is the creation of glucose as simple as the formula of photosynthesis makes it seem? Explain your reasoning.

Name _____ **Date _____**

Light Independent Reactions Diagram – Student Handout



Teacher Explanation: Light Independent Reaction Diagram

- At the beginning of the cycle, during carbon "fixation", RuBP combines with carbon dioxide. The carbon is added as a "branch" on the RuBP molecule. Afterward, RuBP breaks apart. It would be difficult to demonstrate this the way these molecules are constructed. Therefore, students broke the RuBP first and then added the carbon from carbon dioxide.
- Rubisco, an enzyme required to "fix" carbon into the RuBP molecule is one of the most abundant substances on the planet. Enzymes are compounds that catalyze reactions, such as the breaking apart of large molecules to form smaller ones. If students have not studied enzymes direct them to necessary text material.
- Every "turn" of the Calvin Cycle adds one more carbon dioxide into the cycle. So, every three turns makes a new three-carbon G3P (PGAL) molecule. This means that six turns through the cycle would give you enough carbon to make a glucose molecule! This is why groups of two students are able to combine their work and create one glucose molecule after the activity.
- For every G3P (PGAL) molecule made, it takes nine molecules of ATP and six NADPH. If students combine their work, it will require 18 ATP, and 12 NADPH to generate enough G3P to manufacture one glucose molecule.
- Sugar (glucose) is not made during photosynthesis, but the molecules necessary are (G3P). The G3P (GPGAL) molecules can be used to make other carbohydrate compounds the plant needs; glucose, starch, cellulose etc.
- Student Learning Goals: The students should note the reactions are very complex requiring many changes and the necessary enzymes. They should identify the sources of the materials required to complete the cycle, i.e. carbon dioxide, ATP and NADPH. They should know the basic structure of glucose.

Light Independent Reactions
Key to Analysis and Questions

1. Phosphate was removed.

2. The formula for glucose is $C_6H_{12}O_6$.

3. 6 molecules of carbon dioxide are required for generation of one glucose molecule.

4. 18 ATP molecules are required to generate one glucose molecule.

5. 12 molecules of NADPH are required to generate on glucose molecule.

6. The ATP and NADPH required in the light independent reactions is generated during the **light dependent reactions** of photosynthesis.

7. Most of the carbon involved in the light independent reaction cycle is used to regenerate the RuBP that continues the cycle.

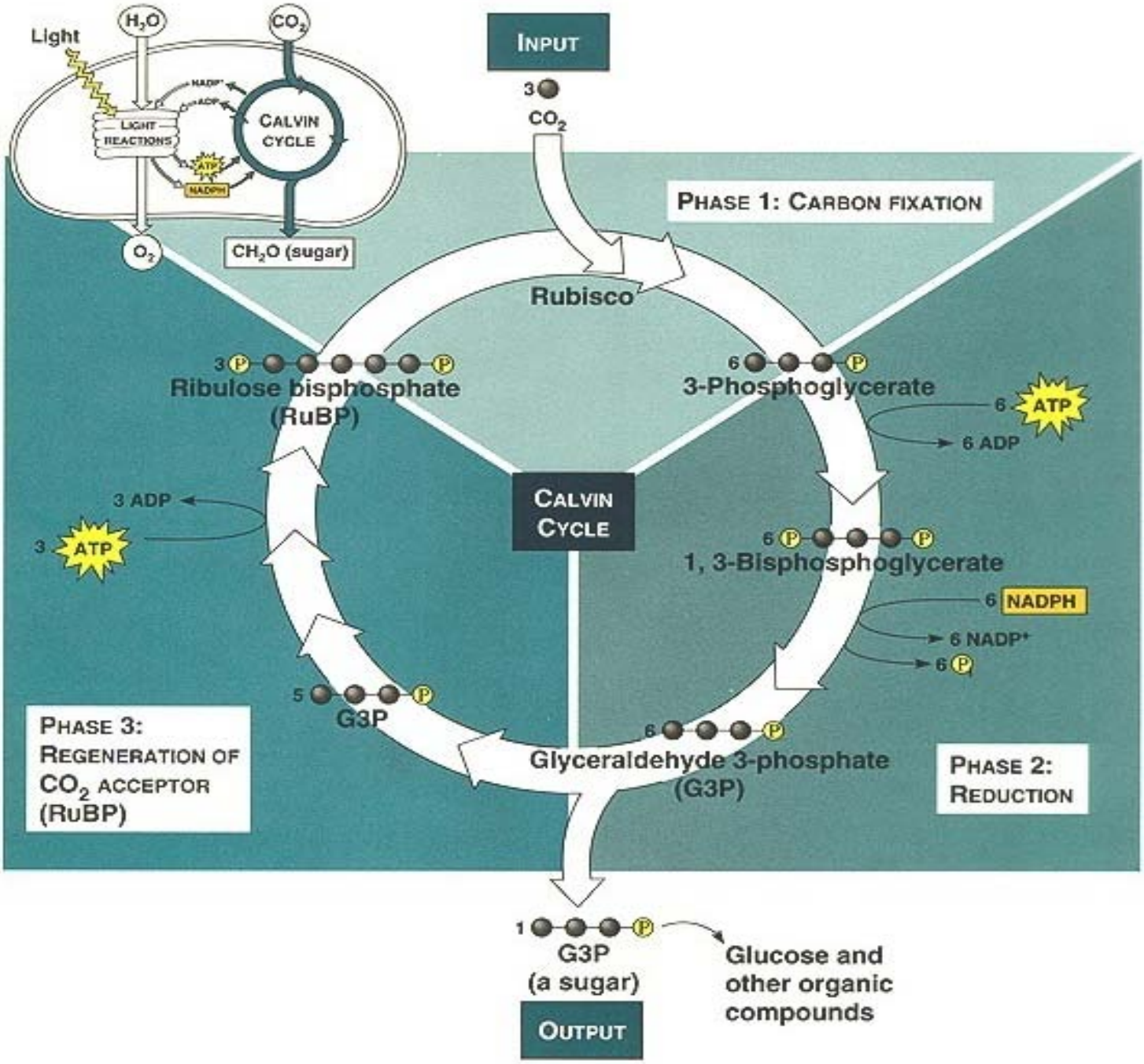
8. When carbon is “fixed”, the atoms from carbon dioxide gas become part of the RuBP molecule to form an unstable 6-carbon compound that quickly degenerates into two 3-PG molecules.

9. Formation of glucose is a complex process that requires many changes in carbon molecules. It would actually require showing many chemical reactions to demonstrate what happens.

Teacher Diagram of the Light Independent Reactions

Source: https://www.msu.edu/~smithe44/calvin_cycle_process.htm

(The website includes a complete explanation and pictures of molecules constructed with ball-stick model kits.)



NADPH Energy Check **Value = Lose 1 Phosphate** **NADPH is a used to remove a phosphate from a molecule**	**NADPH Energy Check** **Value = Lose 1 Phosphate** **NADPH is a used to remove a phosphate from a molecule**
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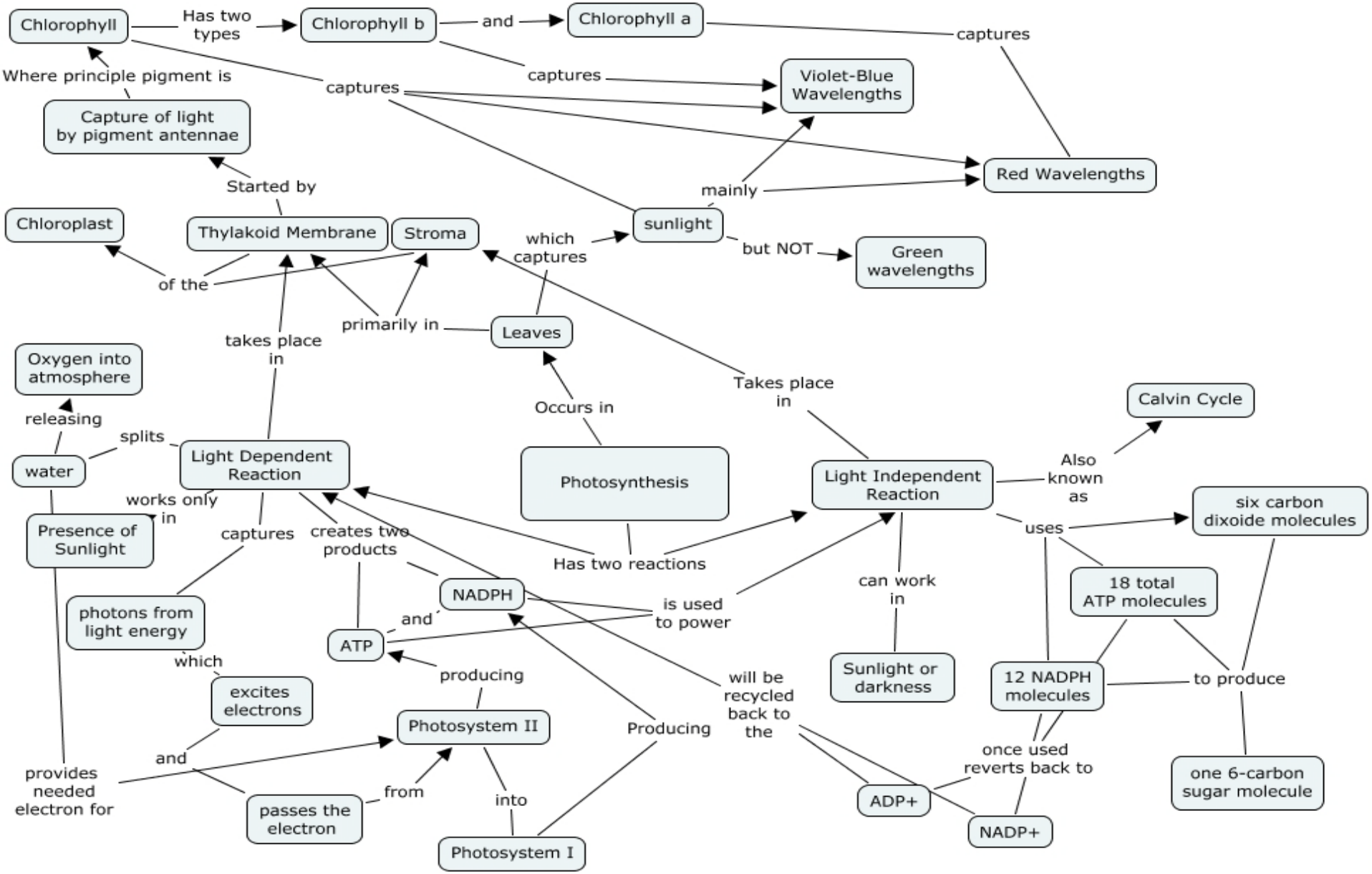

Chlorophyll
Has two types
Chlorophyll b
and
Chlorophyll a
captures
Where principle pigment is
captures
captures
Violet-Blue Wavelengths
Capture of light by pigment antennae
Red Wavelengths
Started by
mainly
Chloroplast
Thylakoid Membrane
Stroma
which captures
sunlight
but NOT
Green wavelengths
of the
primarily in
Leaves
takes place in
Oxygen into atmosphere
releasing
splits
water
Light Dependent Reaction
Occurs in
Takes place in
Calvin Cycle
Photosynthesis
Light Independent Reaction
Also known as
works only in
Presence of Sunlight
captures
creates two products
Has two reactions
uses
six carbon dixoide molecules
NADPH
can work in
18 total ATP molecules
photons from light energy
and
is used to power
ATP
which
producing
Sunlight or darkness
12 NADPH molecules
to produce
excites electrons
will be recycled back to the
Photosystem II
Producing
once used reverts back to
and
provides needed electron for
from
into
ADP+
one 6-carbon sugar molecule
passes the electron
NADP+
Photosystem I

Photosynthesis

Cross Curriculum Application

****Cross Curriculum**	Family Consumer Science	6.12.1-Demonstrate measuring techniques, measures dry and liquid supplies; 1.4.13-Describes/explains scientific principles related to reactions; 1.4.2-Analyze environmental issues;
	Agriculture	Aquaculture:2.6.1-Contrast circulatory/respiratory systems; 4.11.1-Use a dissolved oxygen meter to determine DO levels; 4.12.2-Determine DO levels in various temperatures; 1.4.23-Use equipment/techniques to measure dissolved oxygen; 5.4.1-Observe aquaculture facilities for signs of oxygen depletion; 5.4.2-Determine conditions that contribute to current oxygen levels in a sample; 5.5-List/explain causes of oxygen depletion; 5.12.1-Use a DO meter; Plants in Agriculture: 4.3-label parts of plant and discuss functions; Greenhouse Management: 5.2.1-Demonstrate through experimentation how light or dark affects seed germination; 8.3.1-Adjust lighting conditions to promote plant growth; Forestry: 2.2-Discuss the parts/functions of a tree; 2.4.1-Write the photosynthesis equation/formula; 2.5.1-Label the parts of a complete flower; 3.5-Label parts of a leaf; Biological Plant Sciences: 3.3.1-Conduct a simple experiment following approved methods; 11.4.1-Observe the effect of different herbicides on plants; Plant Science: 7.4-Distinguish between photosynthesis and respiration; 7.4.1-Explain the chemical processes that are involved in photosynthesis and how they sustain the plant; 7.4.2-Write the chemical equation for photosynthesis; 4.4.1-Prepare report on function of leaves; 4.7.1-Diagram chemical equation for photosynthesis.
	PE	HRF.2.PEL.1 and HRF.2.PEL.2 - Cardio respiratory fitness and production/processes/functions of oxygen in the body
	Media	Students can research real world water issues in newspapers and magazines. The Futures Channel - Water Supply video
	History	Arkansas History (7-8) G.1.AH.7-8.5 Examine the economic effect of Arkansas' natural resources (forestry products).
		Arkansas History (9-12) G.1.AH.9-12.5 Examine the effect of Arkansas' natural resources (forestry products).
		Contemporary U.S. History E.7.CH.1 Examine the influence of the following on the environmental movement: -The Novel *Silent Spring,* -Environmental Protection Agency, -Green Peace, and Earth Day; E.7.CH.2 Investigate the consequences of environmental disasters; E.7.CH.3 Discuss contemporary environmental issues.
		World Geography SG 1.WG.5 Evaluate reasons for choosing a specific technology to analyze geographic problems (deforestation); PS.3.WG.1 Features of the hydrosphere and biosphere.

Photosynthesis Formative Assessment

1. How are photosynthesis and cellular respiration similar?
    a. They occur in animal cells.
    b. They take place in the same organelle.
    c. They involve the conversion of energy.
    d. They produce the same complex carbohydrate.

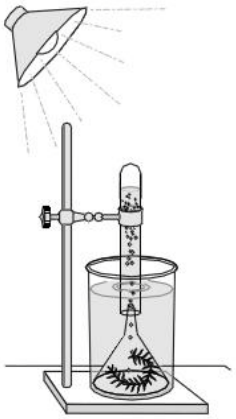
2. What is formed during photosynthesis and broken down during cellular respiration?
    a. Water
    b. Glucose
    c. Lactic acid
    d. Carbon dioxide

3. Which process occurs in the chloroplasts of plant cells?
    a. Reproduction
    b. Photosynthesis
    c. Protein synthesis
    d. Cellular respiration

4. Which of the following is needed to transfer and release energy?
    a. Nitrate
    b. Calcium
    c. Potassium
    d. Phosphate

5. In the basic process of photosynthesis, light energy is converted to
    a. Thermal energy
    b. Electrical energy
    c. Chemical energy
    d. Mechanical energy

6. Where does the light independent reaction occur?
    a. Stroma
    b. Granum
    c. Thylakoid membrane
    d. Chloroplast membrane



7. In the experiment above, which factor was most responsible for the production of oxygen by *Elodea*?
    a. Sugar was present in the liquid.
    b. The presence of light stimulated photosynthesis.
    c. The plant contained a large number of mitochondria.
    d. The liquid contained enough oxygen for the plant to absorb.

8. During photosynthesis, energy from the sun is trapped in –
    a. Enzymes
    b. Golgi bodies
    c. Chemical bonds
    d. The nuclei of atoms

9. The glucose produced during photosynthesis is an example of a –
    a. Lipid
    b. Protein
    c. Nucleic acid
    d. Carbohydrate

10. Which of the following is produced during the light dependent reaction?
    a. O_2
    b. ATP
    c. NADPH
    d. All of the above

Photo-Formative Assessment - Key

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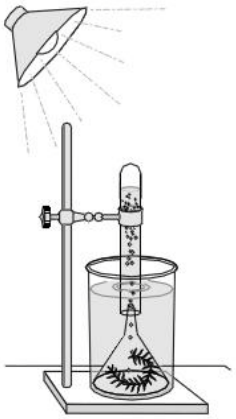

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Photosynthesis
Standards Based Formative Assessment

Implementation

Formative assessments are designed to provide information for both students and teachers in assessing what content areas are "proficient" and what areas are still "learning in progress". They can provide students descriptive feedback on specific student learning expectations (SLEs) and instruct teachers on content that might need to be readdressed. This formative assessment covers only the learning targets for photosynthesis and should be given after all sessions and activities are explored.

Learning Targets

SLEs- MC.3.B.4- Describe and Model the conversion of light energy to chemical energy in photosynthetic organisms:

- Light dependent reactions
- Light independent reactions

Item #	Learning Target Assessed	Pattern of Reasoning	Item Type
1	Light Dependent Reaction	Knowledge	MC
2	Light Independent Reaction	Knowledge	MC
3	Form and Function of Photo system parts	Comprehension	SA
4	Light Dependent/Independent Reaction	Analysis	ER
5	Photosynthesis general process	Comprehension	MC
6	Photosynthesis general process	Comprehension	MC
7	Light Dependent Reaction	Knowledge	MC
8	Light Independent Reaction	Knowledge	MC
9	Photosynthesis general process	Comprehension/Application	SA
10	Form and Function of Photo system parts	Knowledge	MC
11	Photosynthesis general process	Application/Analysis	SA

MC- Multiple Choice, ER- Extended Response, SA- Short Answer

Resources:

Miller, K. & Levine, J. (2006) *Prentice Hall Biology*. Upper Saddle River: Pearson Publication.

- Answers and select questions (page 217, questions 6, 10;) on assessment were provided by the book)

Format of Formative assessment was modified from example of Dr. Donna Snodgrass, Director of Classroom Assessment, Cleveland Municipal Schools found in *Leading Professional Development in Assessment for Learning* notebook facilitated by Jan Chappuis on February 25-26, 2009.

Format for Student Self-Assessment was taken from *Leading Professional Development in Assessment for Learning* notebook facilitated by Jan Chappuis on February 25-26, 2009.

Standards Based Formative Assessment
Photosynthesis

1. What two products are created by the light dependent reactions?
   a) Glucose and O_2
   b) RUBP and CO_2
   c) CO_2 and H_2O
   d) ATP and NADPH

2. The Calvin Cycle reactions of photosynthesis are also known as the
   a) ATP synthesis
   b) NADPH synthesis
   c) light-independent
   d) light-dependent

3. Briefly describe how a photosystem absorbs light.

4. Explain four differences between light dependent and light independent reactions.

5. Photosynthesis converts
   a) light energy to chemical energy.
   b) chemical energy to light energy.
   c) light energy to heat energy.
   d) chemical energy to mechanical energy.

6. The first process in the light-dependent reactions of photosynthesis is
   a) ATP production.
   b) electron transport.
   c) oxygen production.
   d) light absorption.

7. Which process is most directly driven by light energy?
    a) ATP synthesis
    b) Carbon fixation in the stroma
    c) Reduction of NADP+ molecules
    d) Removal of electrons from chlorophyll molecules

8. Which of the following occurs in the Calvin Cycle?
    a) Release of oxygen
    b) Creation of ATP
    c) Carbon fixation
    d) Splitting of water

9. Briefly explain how the events in the Calvin cycle depend on the light-dependent reactions.

10. Chloroplast is the part of the leaf that captures the sun's energy. What two chloroplast structures execute the entire process of photosynthesis?
    a) Rubisco and Stomata
    b) Thylakoid and Stroma
    c) Carotenoids and Stroma
    d) Thylakoid and Pigment molecules

11. What color of light is least effective in driving photosynthesis? Explain.

Standards Based Formative Assessment
Photosynthesis

Answer Key

1. D

2. C

3. **2 points**- Response includes sun's energy is absorbed in molecules called pigments. The primary pigment is called chlorophyll, with two main types: Chlorophyll a and Chlorophyll b.
   1 points- Response gives only a generalized statement that the leaf absorbs sunlight, but does not identify chlorophyll a, b or pigments.
   0 points- no response or incorrect response.

4. **4 points**-Answers could vary, but should identify to which reaction they are referring. For example- Light Dependent- a) occurs in thylakoid membrane, b) converts light into chemical energy by making NADPH and ATP. Light Independent- a) takes place in stroma, b) Uses ATP and NADPH to convert CO2 into sugar.
   3 points- Contains only three correct answers
   2 points- Contains only two correct answers
   1 point- Contains only one correct answer
   0 points- no response or incorrect response.

5. A

6. D

7. D

8. C

9. **2 points**- The response should include the production of ATP and NADPH as chemical energy resources for the Calvin Cycle.
   1 point- Only identifies one of the two molecules or only states the Calvin Cycle receives chemical energy from the light dependent reaction.
   0 points- no response or incorrect response.

10. B

11. **2 points**- Response identifies correctly the color that is least effective (Green and or wavelength ~550nm) and two reasons for the explanation. Chlorophyll a and b absorb violet- blue and red light waves primarily. The action spectrum illustrates light absorption versus wavelength and supports this finding. Carotenoids absorb shades of yellow and orange.
   1 point- Response contains correct color but only one correct reason.
   0 points- no response or incorrect response.

Student Self Assessment on Target Learning

Standards Based Formative Assessment
Photosynthesis

Formative Assessment Results					Student Understanding		
Problem #	**Learning Target**	**Right**	**Wrong**		**Knew the answer**	**Somewhat knew / Guessed**	**Did not know at all**
1	LD Reaction						
2	LI Reaction						
3	Form/Function						
4	LD/LI Reaction						
5	Photosynthesis						
6	Photosynthesis						
7	LD Reaction						
8	LI Reaction						
9	Photosynthesis						
10	Form/Function						
11	Photosynthesis						

What are my strengths?

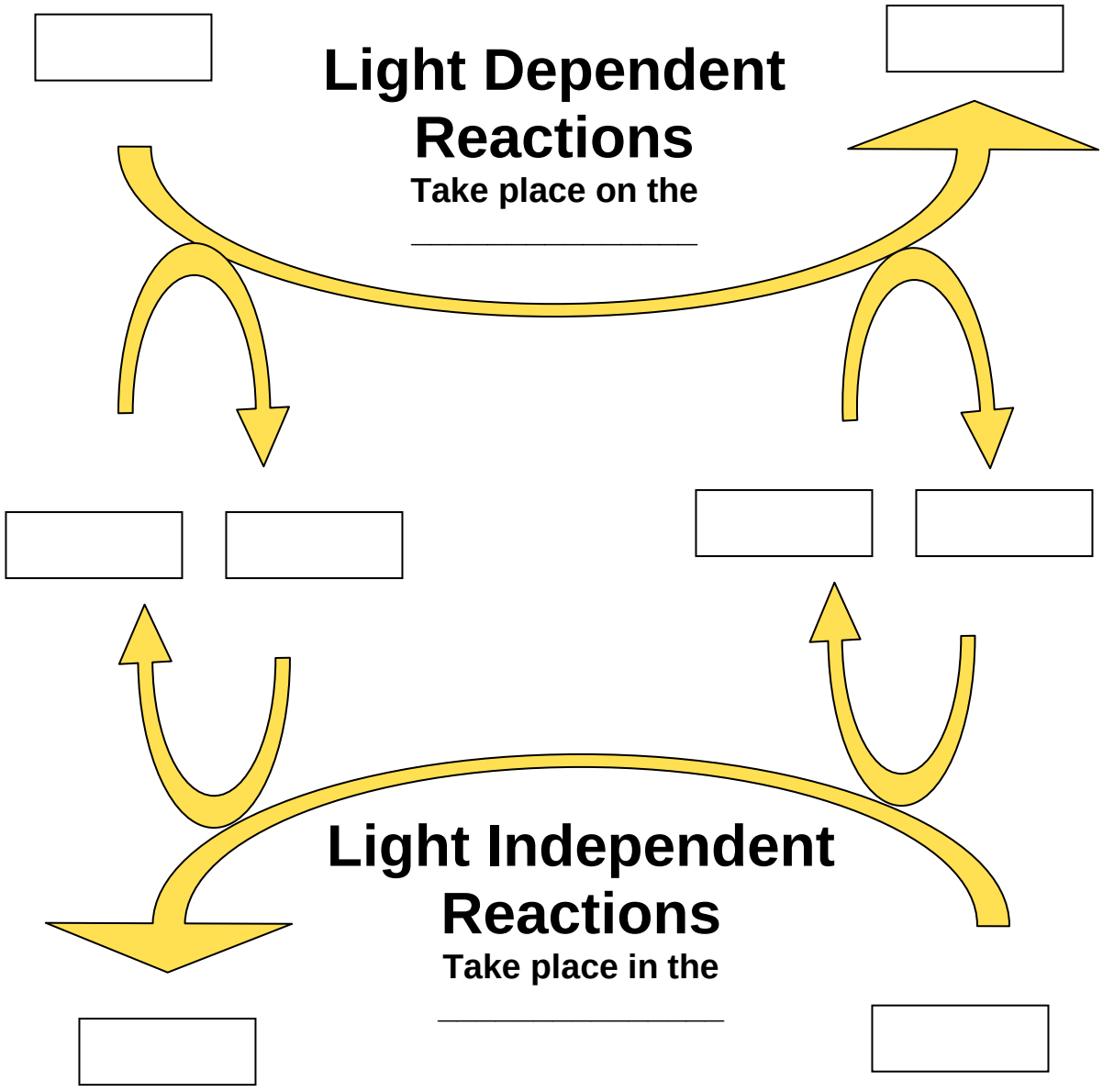
My highest priority for studying:

What I need to review:

Action Plan:

- **I'll start studying** _____
  - **DATE**
- **And work until**_____
  - **DATE**
- **And retest on**_____
  - **DATE**

Photosynthesis
An Overview of the Light Dependent and Light Independent Reactions



Place the following terms into the proper boxes to make the diagram accurate:

H_20 Carbohydrate O_2 $CO_2 + H_20$

ADP ATP $NADP^+$ NADPH

Place the following terms on the proper lines to make the diagram accurate:

Stroma Thylakoid membrane

Questions

1. When does the light dependent reaction occur?

2. When does the light independent reaction occur?

3. What are the resulting products of photosynthesis?

4. What are the reactants (substrates) required for photosynthesis?

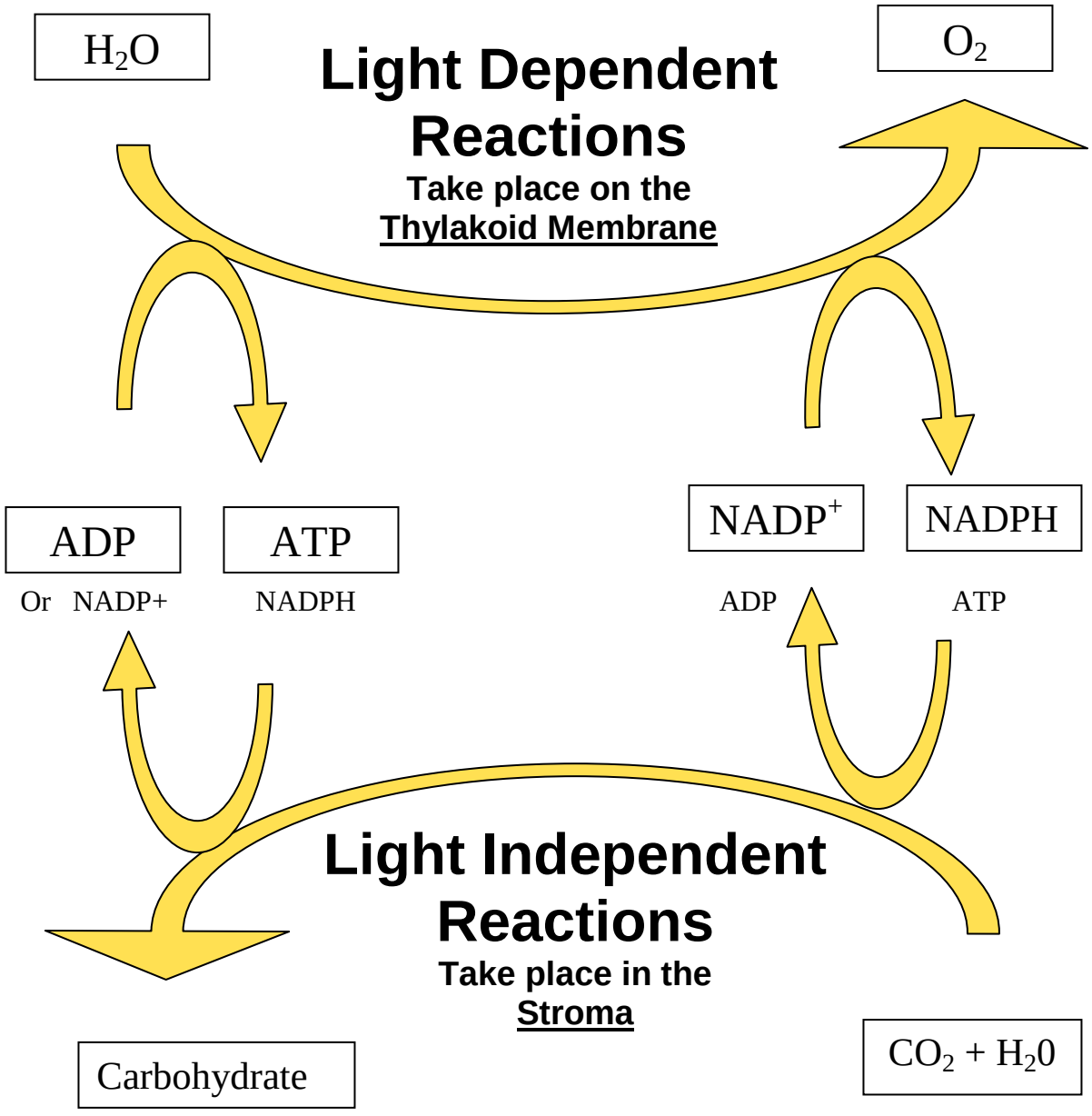
5. As long as photosynthesis is occurring, which compound(s) is/are cycled?

6. In your own words, explain the light dependent reaction.

7. In your own words, explain the light independent reaction.

8. Explain why the light dependent-light independent reactions are often called "coupled reactions"

KEY for Photosynthesis
An Overview of the Light Dependent and Light Independent Reactions



Place the following terms into the proper boxes to make the diagram accurate.

H_20 Carbohydrate O_2 $CO_2 + H_20$
ADP ATP $NADP^+$ NADPH

Place the following terms on the proper lines to make the diagram accurate.

Stroma Thylakoid membrane

KEY for Questions

1. When does the light dependent reaction occur?

Anytime the correct wavelengths of light are present for the particular autotroph (plant, algae).

2. When does the light independent reaction occur?

Anytime there is enough ATP, NADPH, CO_2 and H_2O present in the chloroplast.

3. What are the resulting products of photosynthesis? O_2 and carbohydrates
4. What the reactants (substrates) of photosynthesis? CO_2 and H_2O
5. As long as photosynthesis is occurring, which compound(s) is/are cycled?

ADP and ATP, $NADP^+$ and NADPH

6. In your own words, explain the light dependent reaction.

1. The light dependent reaction occurs in the presence of light and 2. The light energy breaks down H_2O. 3. The H reacts with NADP+ and makes NADPH; 4. The O_2 is not needed and is released. 5. The energy also creates ATP from ADP. 6. This reaction takes place on the Thylakoid membrane in the chloroplast. (Many other enzymes and chemicals are present on the membrane).

All 6 ideas must be present to get all 6 points, the wording will be different.

7. In your own words, explain the light independent reaction.

1. The light independent reaction can take place with or without light; all that must be present are ATP, NADPH, H_2O and CO_2 (and of course, many other enzymes and chemicals that are present in the stroma). 2. The ATP to provide energy and NADPH to provide more H's were made 3. During the light dependent reaction, 4. The H_2O and CO_2 are present in the chloroplast. 5. These reactions take place in the stroma of the chloroplast. 6. Carbohydrates are made that store some of the energy released from the ATP, so ADP is formed and so is $NADP^+$.

All 6 ideas must be present to get all 6 points, the wording will be different.

8. Explain why the light dependent-light independent reactions are often called "coupled reactions"

The energy that is stored in ATP in the light dependent reaction is used to operate the light independent reaction. One reaction provides the energy for the other reaction.

Compare Mitochondria and Chloroplast Structure and Function Using a T-Chart

Directions:

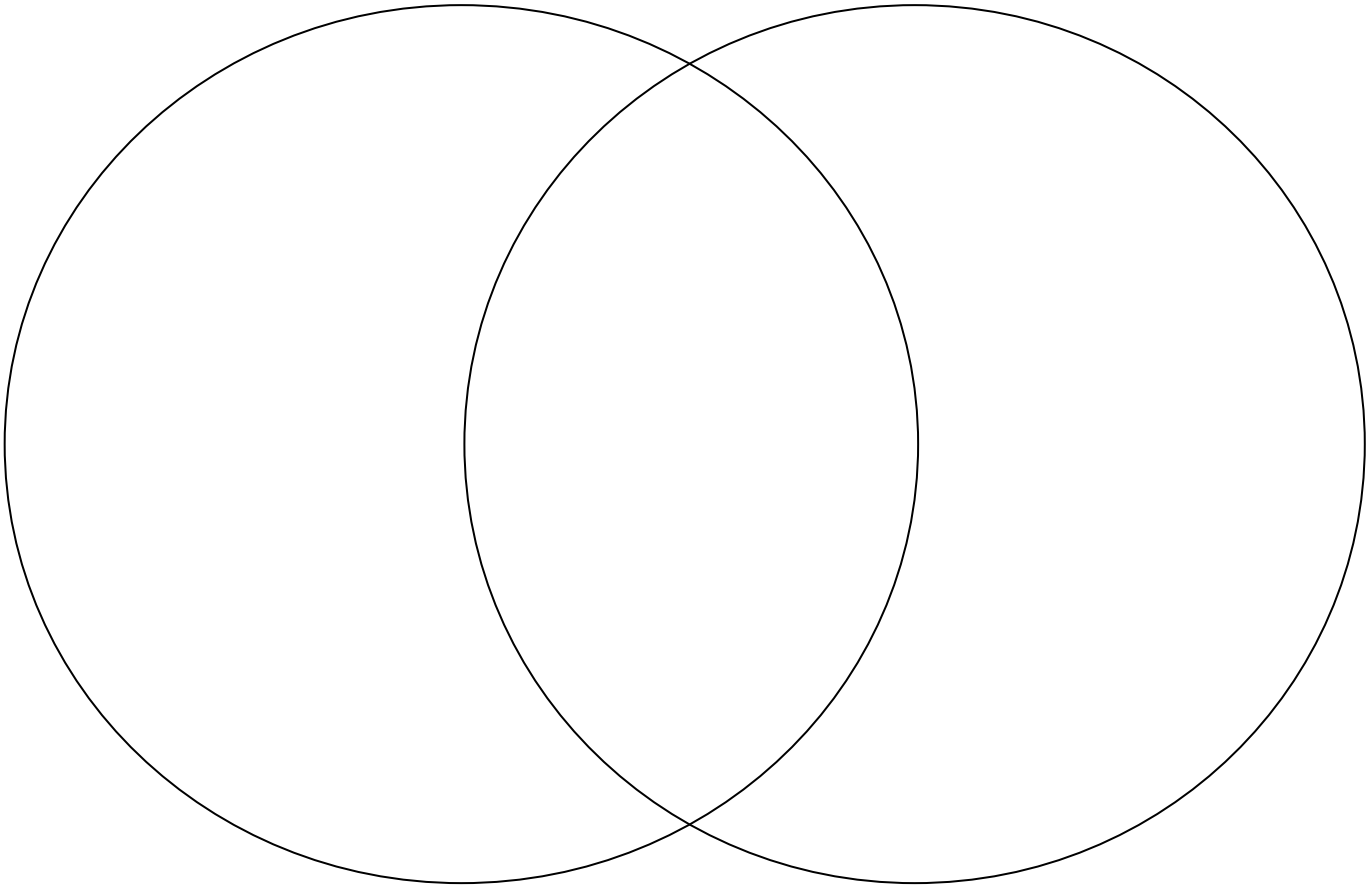
1. Describe the structure and function of each organelle in the chart below.
2. Compare your chart with your partners.
3. Add anything you did not already have listed.
4. Discuss contradictions between you and your partner and correct.

	Mitochondria	Chloroplast
Structure		
Function		

Comparing Cellular Respiration and Photosynthesis Using a Venn Diagram

Directions

1. Write the characteristics unique to Respiration in the circle on the left.
2. Write the characteristics unique to Photosynthesis in the circle on the right.
3. Write any characteristics of both where the circles overlap.



Cellular Respiration

Photosynthesis

The Photosynthesis Song

http://www.youtube.com/watch?v=_IV-E68rh18

I need a little light
So I can store energy
I need a little light
So I can make ATP
I need a little light
I'm gonna make some food
Its outta sight
And I need a little light

Been sittin here in this chloroplast, feeling green the whole day through
Yeah, I'm a little thylakoid, waitin for something to do
I'm gonna move some electrons through a chain
Thats gonna pump some hydrogen in
But its been dark all night and you can see the state I'm in

CHORUS

When the electrons leave the chain they're gonna join NADP (plus)
And that high concentration of hydrogens gonna want outside of me
Gonna go through a special protein thats gonna kick some ATP out
Thats what movin these electrons is really all about

CHORUS

The ATP and NADPH are gonna make a cycle go round
At the end of the Calvin cycle glucose can be found
You gotta put in 6 pieces of CO_2 to make that precious food
And use up the products of the thylakoid, darn this systems good

CHORUS

The chlorophyll that lost the electrons is gonna have to get some more
So an enzymes gonna break apart water (using 6 no less no more)
Its gonna produce 6 molecules of fresh O_2, though the plant just thinks its waste
Its amazing to think that this photosynthesis is happening all over the place