Photosynthesis:
Unit Plan

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Blacksburg High School
Mr. Wilkins’ Biology Courses
2006
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Summative Assessment - Quiz 34
Background and Needs Assessment:

Blacksburg High School is located in Blacksburg Virginia, home of the Virginia Tech Hokies. Because of this, a lot of the students are children of the faculty at the University. The students ethnic makeup is primarily Caucasian, however because of the University more ethnic groups are represented than other schools in Montgomery County. Judging from the surrounding area there is a mixture of social economic status.

This unit will be used to teach 3 sophomore level classes. These classes are at slightly different levels. Two of the classes are labeled as “College Prep” classes, and one is an "Honors" class. The term “College Prep” means that the students are on track to go to college but are not planning on majoring in the sciences. "Honors" is a distinction giving to the class containing students that are gifted in the sciences. Two of the classes have approximately 25 students each, and one has 11 students. The students in these classes are freshmen and sophomores.

There is a lot of diversity within my classroom. There are three visible ethnic groups represented including Caucasian, African American, and Asian students. There are a few students who noticeably come from low socio-economic areas. A few of my students have IEPs for learning disabilities. The accommodations mostly include providing information in a variety of ways, extra help on assignments, notes, reading exams to them and having extra time for exams. One student is legally deaf, and there is a sign interpreter in the classroom to aid in communication. In the same class there is a student with a speech impediment.

Another one of the students has multiple and severe disabilities. There is an aide with him at all times. Communication with him includes technology, sign language, and gestures. There are a few challenges that are associated with having this student in class. Two of the students miss approximately 10 minutes of class to bring him to class. The class is also very small, consisting of 11 students. This creates a very intimate environment where content is covered very quickly.

There are several classrooms in the science department, but they are not assigned to any one teacher. All of the teachers in the department share the classrooms. Because of this there is a lack of ownership in any of the classes. This creates several challenges when setting up labs because the set up must be moved from class to class. This can be alleviated slightly by setting lab materials on a cart.

Another challenge is that the school has limited access to computer technology. There is one computer in each classroom, however this is typically used for attendance and grades only. The computers are older and very slow. The only computers that the students have access to are in the library and the schedule quickly gets booked. There are projectors available to the teachers should they want to do a PowerPoint or show an animation on the computer. Each classroom is also equipped with a TV and VCR.
Objectives:
- Students will be able to describe the light and light independent (dark) reactions of Photosynthesis.
- Students will be able to relate physical plant characteristics (chloroplasts, pigments, stomata, etc) to their functions.
- Students will be able to distinguish between C3, C4, and CAM plants and relate their adaptations to their natural environment.
- Students will be able to explain the role of and conversion of energy in metabolic processes in plants.
- Students will use experimental data to make conclusions about the photosynthetic process.
- Students will be able to apply their knowledge to the social topics of deforestation and global warming.

Virginia Standards of Learning:
- BIO 1 – Student will plan and conduct investigations
  - (a) observations of living organisms are recorded in the lab
  - (b) hypotheses are formulated based on direct observations and information
  - (c) variables are defined and investigations are designed to test hypothesis
  - (e) conclusions are formed based on recorded data
  - (h) chemicals and equipment are used in a safe manner
  - (m) a scientific viewpoint is constructed and defended
- BIO.2 (e) the collaborative efforts of scientists, past and present.
- BIO 3 (d) – The capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration
- BIO 5 (b) – comparison of plant metabolic activities
  (Plants – C3, C4, CAM).

NSTA Content Standards:
- Content Standard A:  Science as Inquiry
  - Design and conduct scientific investigations.
  - Formulate and revise scientific explanations and models using logic and evidence
  - Recognize and analyze alternative explanations and models.
- Content Standard C:  Life Science
  - Matter, Energy, and Organization in Living Systems- The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form chemical bonds between the atoms of carbon-containing molecules. In addition, the energy stored in bonds between the atoms can be used as sources of energy for life processes.
- Content Standard F:  Science in Personal and Social Perspectives
  - Science and Technology in local, national, and global challenges – Humans have a major effect on other species
- Content Standard:  History and Nature of Science
  - Historical perspectives

Unifying Science Concepts:
- Evidence, Models, and Explanation
- Form and Function
Pedagogical Approach to Teaching and Learning:

In this unit I will be implementing the theoretical frameworks of Inquiry-based learning and Constructivism. It is important that students reflect upon what they know and then articulate their questions. By allowing the students to question and make connections with what they already know the material becomes less “challenging” and more relevant to their thinking.

It is important to determine the diversity within the classroom by assessing prior knowledge. No two students in any class have had exactly the same experiences or knowledge. By determining where the students are and what experiences the students have had, the teacher can tailor the unit to be relevant and engaging to the students. Students can learn a lot from each other and their experiences, and therefore it is very important that students participate in collaborative activities and have a forum in the classroom to share and explore the relevancy of their backgrounds.

I also believe that students require material, especially material as challenging as photosynthesis, to be presented in a multiple of mediums. This includes allowing students to design labs (within a set scope) to explore ways to expand their knowledge. By doing this, students take ownership of their learning and the teacher is no longer a total authority but a guide and facilitator. In addition to labs it is also important to provide visual diagrams, animations, and resources (including texts and materials). This is because students are diverse in the ways that they receive and understand information best. It is important to balance visual, audio and hands-on experiences in the classroom so that the students can enhance their ability to process information in a variety of mediums.

These philosophies are supported by the NSTA teaching standards. In particular the following standards:

- **Standard A - Inquiry-based science program**
  - Content adapted to relevant to the students interests, knowledge, understanding and abilities,
  - Teaching and assessment support the development of understanding.

- **Standard B - Teachers guide and facilitate learning**
  - Challenge students to accept and share responsibility for their own learning
  - Recognize and respond to students diversity
  - Encourage and model skills of inquiry

- **Standard E - Develop communities of science learners**
  - Display and demand respect for diverse ideas, skills, and experiences
  - Enable students to have a significant voice in decisions about the content and context of their work
  - Nurture collaboration
  - Structure and facilitate ongoing formal and informal discussion
Classroom Management Principles:

In this unit students will be involved in several collaborative learning exercises. This will require the teacher to design a classroom environment conducive to these activities. The major components that will need to be addressed are:

- Treating all members of the classroom with respect,
- Desks set up in a way that facilitates discussion and collaboration,
- Ensure that all students have access to the content being presented,
- Safe environment both physically and psychologically,
- Engagement of students with relevant material, and
- Organization of materials, directions (including time), information, and lessons.

Respect is a very important, if not most important, component of the classroom management. Students need to feel comfortable to express themselves in the classroom by sharing their knowledge and experiences as well as feeling secure enough to ask questions. In order to do this the teacher should define respect and consistently reinforce respectful and collaborative behaviors.

The placement of the desks in a classroom is important in defining how the students will interact. The desks are placed in a table format around the border of the room so that the students are able to participate in collaboration and lab exercises easily. This also means that some of the students' backs are turned to the front of the room. To overcome this the teacher should walk around the classroom when disseminating information to ensure that all students are engaged and receiving important information including safety and content. The teacher should also make sure that all students are able to see all visuals presented in class. By doing these things and providing relevant contexts for the content the students will remain engaged and behavioral problems will be reduced.

The desk placement is also key to safety. Planning should be done when conducting labs so that traffic jams do not occur in the classroom. Careful consideration should be made to ensure that safety concerns in labs, activities, and lectures are addressed.

These philosophies are supported by the NSTA teaching standards. In particular the following standards:

- **Standard D – Design and manage learning environments that provide students with time, space, and resources needed to learn science.**
  - Structure time for extended investigations
  - Ensure a safe working environment
- **Standard E – Develop communities of science learners**
  - Display and demand respect for diverse ideas, skills, and experiences
  - Enable students to have a significant voice in decisions about the content and context of their work
  - Nurture collaboration
  - Structure and facilitate ongoing formal and informal discussion
History of the development of Photosynthesis Knowledge:
A lesson on the historical figures and experiments that contributed to the body of knowledge scientists have on the processes of photosynthesis will be included in this unit. It is important that students are exposed to the culture and nature of science to understand how we know about these processes in addition to the “what” we know. This lesson will expand the students’ knowledge of different types of experiments that are used in the field of science.

Deforestation and Global Warming:
The topics of Deforestation and Global Warming will be discussed during this unit to provide a context for photosynthesis. It is important to address the question most students ask (“why do I need to know this?”) in a way that provides an application of photosynthesis that is relevant to their everyday lives. These topics were chosen because they relate very closely to photosynthesis and are social topics that are often discussed in the media. By exposing the students to the scientific background of these issues the students will gain a better understanding of the issues, therefore enabling them to give a rationale for their stance on these political issues. These skills prepare them to be thoughtful and critical members of society.

Index of Lessons:

Lesson 1 Introduction
Lesson 2 History of Photosynthesis
Lesson 3 Physiology of a Chloroplast
Lesson 4 Light Reactions – Capture of light (Pigments)
Lesson 5 Light Reactions – Molecular Pathway (Circus)
Lesson 6 Light Independent Reactions
Lesson 7 Comparison of C3,C4, CAM plants
Lesson 8 Jeopardy
**Calendar:**

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td><strong>Intro-</strong></td>
<td><strong>Lab -</strong></td>
<td><strong>Lecture-</strong></td>
<td><strong>Lecture-</strong></td>
<td><strong>Lab-</strong></td>
</tr>
<tr>
<td>• KWL</td>
<td>• Data collection</td>
<td>• History - Why do we care? Exit Slip</td>
<td>• Chloroplasts - form, function Exit slip</td>
<td>• Pigments/ Chromatography</td>
</tr>
<tr>
<td>• Design Inquiry lab and set up</td>
<td>• Complete lab</td>
<td></td>
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<td></td>
<td>• Lab write up (sheet)</td>
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<tr>
<td>Lab-</td>
<td>Lecture-</td>
<td>Lecture -</td>
<td>Lecture -</td>
<td>Light Reactions Review (Jeopardy)</td>
</tr>
<tr>
<td>• Pigments/ Chromatography</td>
<td>• Molecular Pathways</td>
<td>• Light Independent Reactions</td>
<td>• C3,C4,CAM</td>
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<tr>
<td>• Lab write up (sheet)</td>
<td>• Circus Exit Slip</td>
<td>• Models/Activity Sheet</td>
<td>Group Sheet</td>
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<tr>
<td>“L” of KWL Quiz</td>
<td>Lab write up</td>
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**Key:**

Assessments, Laboratory/Activity, Information/Lecture

**Assessment Plan:**

Students will be assessed in many different ways throughout the course of this unit as displayed in the above calendar. Types of assessments will include informal assessments including observation, participation, and exit slips; formal assessments such as pen and paper assessments (quizzes and tests (short-answer and multiple choice)) and projects.

In addition, student prior knowledge and perceptions of learning will also be assessed. This will be done using the KWL chart, where students will write down what they Know, what they Want to know, and finally what they Learned. This will be a valuable tool not only to assess if the unit objectives were met, but also on the unit as a whole.

This plan is supported by the NSTA teaching standards. In particular the following standards are addressed:

- **Teaching Standard C - Ongoing Assessment of teaching and student learning**
  - Use multiple methods and systematic data about student understanding and ability,
  - Use student data, teaching observations, and interactions with colleagues to reflect on and improve teaching practices.

- **Standard A - Inquiry-based science program**
  - Content adapted to relevant to the students’ interests, knowledge, understanding, and abilities,
  - Teaching and assessment support the development of understanding.
Lesson Plan 1

Title: Intro to Photosynthesis/ Does Photosynthesis Require Light?

Purpose:
The purpose of this lesson is to assess the knowledge that the students have about photosynthesis. This knowledge will then be used to develop an experiment to learn more about photosynthesis.

Objectives:
- Students will be able to design an experiment that will answer a question about photosynthesis.
- Students will be able to use data and observations to make a conclusion.
- Students will be able to hypothesize about the light reaction processes in photosynthesis.

SOLs:
- BIO 1 – Student will plan and conduct investigations
  - (a) observations of living organisms are recorded in the lab
  - (b) hypotheses are formulated based on direct observations and information
  - (c) variables are defined and investigations are designed to test hypothesis
  - (e) conclusions are formed based on recorded data
  - (h) chemicals and equipment are used in a safe manner
  - (m) a scientific viewpoint is constructed and defended
- BIO 3 (d) – The capture, storage, transformation and flow of energy through the processes of photosynthesis.

Materials:
- Elodea (Anacharis)
- Bromothymol Blue
- Goggles
- Test tubes
- Stoppers
- Carbonated water
- Beakers
- Test tube holders
- Foil

Classroom Management/ Safety:
- Students will be seated in groups so that they can collaborate and design easily
- The students will have to clear the desks when they begin to set up the experiment
- Lab materials will be set up on a cart for easy transport.
- Students will be moving around the room to gather materials. To limit traffic, one student from each lab group will be responsible for gathering materials.
- Glass test tubes and beakers will be used.
- Students will wear goggles
- Students will be reminded to not eat or drink any of the materials (for any amount of money)
Lesson Plan:

-Day 1-

Engage: (5min)
An audioclip with part of the song “The Rock and Roll of Photosynthesis” from: http://www.billybproductions.com/index.php?pageID=10&albumID=101&songID=21 will be played. An extra credit assignment for the students to create their own Photosynthesis song will be given. In order to get credit the students must perform the song to the class. The song must focus on Photosynthesis.

A short demo will be performed by the teacher showing what happens when one blows air into a solution of Bromothymol blue. A discussion will ensue to explain that the color change is an indication of CO\(_2\) being present in the solution.

Explore: (40 min)
Students will be given the materials and told to design an experiment to answer the question: Does Photosynthesis require light? After they are done planning their experiment the students will be required to set up their experiment and record their hypothesis and rationale of what will happen in each of their test tubes.

* During Engage and Explore students will be completing the K and W sections of the Activity sheet and turn them in on Day 1

-Day 2-

Explain: (25min)
Students will make observations and collect data from their experiment. They will record their results in a data table.

Elaborate: (20 min)
The students will form conclusions based on their data and explain any anomalies.

Evaluation: (25 min)
Students will complete the first two sections of the KWL chart on the activity sheet, Describing what they know about photosynthesis and questions that they want to know about photosynthesis. Participation of the students in the lab will be assessed informally on day one. After the lab is completed a short lab write up will be turned in to assess.

Reflection:
**PHOTOSYNTHESIS!!!!**

Instructions:

Fill in the following KWL chart. In the K box write down what you know about Photosynthesis. In the W box write down questions you have about Photosynthesis (what you would like to know). This chart will be returned to you at the end of the unit to complete the L box. In this box you will write what you have learned throughout the unit and see if your questions have been answered.

<table>
<thead>
<tr>
<th>K (What you know)</th>
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<th>W (What you want to know)</th>
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<table>
<thead>
<tr>
<th>L (What you learned)</th>
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</table>
Does Photosynthesis Require Light?

Instructions: Design an experiment using the materials on the cart to answer the question: Does Photosynthesis require light? This sheet will serve as your Lab write up. Be sure to complete the entire sheet.

Hypothesis: (What are your expected results?)

Rationale: (Why do you think that?)

Materials:

Variables:

Detailed Procedure: (Write a detailed account of how you will set up your experiment)

Notes: (Write down any events that occurred during the lab set up that may affect your results)
Data: (Construct a data chart that contains observations and results)

Compare your results to one other group’s results. Make sure that you understand their procedure.

Conclusion: (Write a conclusion that discusses what your results in your data chart mean. Be sure to address the question, does light require photosynthesis. Also analyze your hypothesis and discuss future experiments that may be done to get a further understanding of the question.)
Title: Outline of the processes of Photosynthesis with a Historical Perspective

Purpose: The purpose of this lesson is to provide an overview of the processes of Photosynthesis. This will be done in a historical context to expose the students to the nature of science.

Objectives:
- Students will be able to list the processes in photosynthesis
- Students will be able to identify past experiments informing scientists of photosynthetic processes.
- Students will be able to name a few of the scientists that contributed to the scientific body of knowledge of photosynthesis.
- Students will be able to create a chemical equation describing photosynthesis

SOLs:
- BIO.2 (e)the collaborative efforts of scientists, past and present.
- BIO 3 (d) – The capture, storage, transformation and flow of energy through the processes of photosynthesis.

Materials:
- Projector
- Laptop
- extension cord

Classroom Management/ Safety:
- Students are seated at group tables, therefore care should be taken to ensure that all students are able to see the visuals.
- Students are seated at group tables, therefore the teacher will move around the classroom to ensure that students are on task.
- Should a projector be available, special consideration will be taken to determine where the cords will be in the classroom. An extension cord may be needed.

Technology:
- Technology served as a valuable resource putting this lesson together. Pictures and information were gathered from several websites including:
  - Information from World of Biology (McGrath, 1999, p.600) http://www.geocities.com/barefeetchild/history.html?200611
  - Jeffery Kahn: Calvin Photosynthesis Group Subject of History Project http://www.lbl.gov/Science-Articles/Archive/Calvin-history-project.html
  - Discovery of Photosynthesis http://www.biocrawler.com/encyclopedia/Photosynthesis
- In addition valuable animations of the processes were found at the website: http://science.nhmccd.edu/biol/bio1int.htm#photo
- Technology in the classroom, when available, provides an ideal situation in which multiple representations of information can be disseminated to the students.
Lesson Plan:
Engage: (3 min)
Students will participate in a classroom discussion about the experiments that they completed the day before and analyze their results.

Explore: (5 min)
Students will be asked to hypothesize how scientists in the past learned about photosynthesis.

Explain: (30 min)
Several scientists and experiments will be discussed including:
- Joseph Priestly (minister) – Plants can “restore” air
- Jan Ingenhousz (court physician; 1778) – Reproduced Priestly’s experiment showing that light was a factor
- Jean Senebier (pastor; 1796) – Defined “injured” air as CO₂ and plants take it up.
- Julius von Sachs (Botanist; 1800s) – Starch is a product of carbon dioxide; chlorophyll is the catalyst
- Theodor Wilhelm Engelmann – Chloroplasts respond to red and blue hues of natural light
- Robin Hill (1937-39) – Identified chloroplasts ability to give off oxygen after exposure to light; developed the Hill reaction (2 H₂O + 2 A -> (light, chloroplasts) -> 2AH₂ + O₂ (A is electron acceptor)
- Samuel Ruben and Martin C(K)amen – Used radioactivity to determine that the oxygen came from water
- Melvin Calvin and Benson – Used radioactivity and paper chromatography to determine the pathway involved in the light independent reactions
- Rudolf Marcus (Nobel Prize) – Discover the significance of the electron transport chain.

Pictures, Animations, and Diagrams will be used either on an Overhead or using a laptop and projector.

Elaborate: (2 min)
Students will be given an assignment where they will research current research in deforestation and global warming and its relationship to photosynthesis. They will be required to work in a group of no less than 2 people, no more than 3.

Evaluation: (5 min)
Students will be informally assessed during lecture. They will also be asked to complete an exit slip answering the following questions:
- Which scientist did you find most interesting and why?
- What did you learn about the nature of science from the lecture today?

At the end of the unit students will be graded on the Elaborate portion of this lesson plan. This will be considered a test grade. The following elements must be present in their brochure:
- Attractiveness (Pictures, Neatness, etc)
- Complete introduction of the topic including definition
- Connection to photosynthesis/topic related to photosynthesis
- Description of how topic affects society
- Personal Recommendations of the students
- Inclusion of one scientist and a description of their contribution to the topic
- Citations

See Rubric on Handout

Reflection:
Task: Design a brochure about one of the two current “Hot Topics” related to photosynthesis, either Deforestation or Global Warming. This project will count as an exam grade.

Content: Be sure to include the following items in your brochure:
- Complete introduction of the topic including definition
- Connection to photosynthesis (how this topic is related to photosynthesis)
- Description of how topic affects society.
- Personal Recommendations of the students.
- Inclusion of one scientist and a description of their contribution to the topic.

Methods:
You are allowed to use the following resources:
- Scientific Journal Articles
- Newspaper Articles
- Books
- Internet
You must compare at least two points of view within your brochure. You also must include citations from at least one Newspaper Article and one Scientific Journal.

The final product should be constructed using Microsoft Word or Publisher. Contact the teacher should you want to include original artwork.

Make sure that all pictures obtained from the Internet are cited

Grading:
You will be graded using the following rubric:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Total Points</th>
<th>Points Earned</th>
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<tbody>
<tr>
<td>Complete introduction of the topic including definition</td>
<td>10</td>
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</tr>
<tr>
<td>Connection to photosynthesis (how this topic is related to photosynthesis)</td>
<td>25</td>
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</tr>
<tr>
<td>Description of how topic affects society.</td>
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<tr>
<td>2 view points presented</td>
<td>20</td>
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<td>Recommendations</td>
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<td>Thoughtful</td>
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<td>5</td>
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<td>Supported by Research</td>
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<td>Inclusion</td>
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<td>one scientist and a description</td>
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<tr>
<td>their contribution to the topic.</td>
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<tr>
<td>Attractiveness</td>
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<td>Neatness</td>
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<tr>
<td>Pictures</td>
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<tr>
<td>Citations</td>
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<td>Included references for pictures/information</td>
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<td>newspaper citation</td>
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<td>scientific journal citation</td>
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Comments: Final Grade:_________
Title: Chloroplast: Form and Function

Purpose:
The purpose of this lesson is to review the information that students have about chloroplasts and expand their knowledge of the organelle. This will include the introduction of the different structures within the chloroplasts and determine their function.

Objectives:
• Students will be able to label the different parts of a chloroplast
• Students will be able to describe the functions of the different components of the chloroplast

SOLs:
• BIO 3 (d) – The capture, storage, transformation and flow of energy through the processes of photosynthesis.

Materials:
Colored butcher paper

Classroom Management/ Safety:
• Students are seated at group tables; therefore care should be taken to ensure that all students are able to see the visuals.
• Students are seated at group tables, therefore the teacher will move around the classroom to ensure that students are on task.
Lesson Plan:

Engage: (5 min)
Questions will be posed to the students to assess their prior knowledge of chloroplasts. These questions will include:
- What do we know about chloroplasts?
- Why do we think that photosynthesis occurs in the chloroplasts?
These ideas will be recorded on the board or transparency.

Explore: (20 min)
The students will use these ideas to make a giant 3-D chloroplast. The students will present their chloroplasts to the class.

Explain: (10 min)
After the presentations the class will discuss which photosynthetic processes take place in each structure using their models as a guide.

Elaborate: (10 min)
Students will use their new knowledge to readdress the questions posed at the beginning of class. They will record these answers and turn them in as an exit slip.

Evaluation:
Students will be informally assessed on their participation in the 3-D model building. They will also turn in an exit slip.

Reflection:
Lesson Plan 4

Title: True Colors: Plant Pigments
(adopted from Miss Tiffany Bowers)

Purpose:
The purpose of this lesson is to have the students discover what pigments are in the different plant leaves and how they relate to photosynthesis.

Objectives:
• Students will be able to describe the roles of pigments in photosynthesis.
• Students will be able to list the types of pigments that are contained in leaves.

SOLs:
• BIO 1 – Student will plan and conduct investigations
  o (b) hypotheses are formulated based on direct observations and information
  o (c) variables are defined and investigations are designed to test hypothesis
  o (e) conclusions are formed based on recorded data
  o (h) chemicals and equipment are used in a safe manner
  o (m) a scientific viewpoint is constructed and defended
• BIO 3 (d) – The capture, storage, transformation, and flow of energy through the processes of photosynthesis.

Materials:
- Strips of filter paper
- Blender(s)
- 150-mL beaker
- Prisms
- Cover for the beaker
- Rubbing alcohol
- Capillary tubes
- Metric ruler
- Acetone
- Pencil/Colored Pencils
- Fresh spinach leaf or Coleus leaf (red leaf)
- Flashlight (?)

Classroom Management/ Safety:
• Students will be seated in groups so that they can collaborate and design easily
• The students will have to clear the desks when they begin to set up the experiment
• Lab materials will be set up on a cart for easy transport.
• Students will be moving around the room to gather materials. To limit traffic, one student from each lab group will be responsible for gathering materials.
• Glass test tubes and beakers will be used.
• Students will wear goggles
• Students will be reminded to not eat or drink any of the materials (for any amount of money)
• Acetone is flammable and an irritant. Clean up with water.
Lesson Plan:
-Day 1-

Engage: (15 min)
Students will be engaged in a discussion answering the following questions:
- Why are some plants green?
- What do you think white light is composed of?

Teacher will then distribute prisms (or demonstrate) for the students to see the spectrum of light. Students will be asked to draw what they see through the prisms.

Explore: (30 min)
Students will hypothesize what pigments they think will be in the leaves and conduct a chromatography lab activity on spinach and coleus or another red leaf. (Directions are on students’ activity sheet).

-Day 2-

Explain: (15min)
Students will record their data by using a chart and drawing as well as answer three questions that require them to draw conclusions based on their lab experience. There will be short class discussion of results and the implications of them.

Elaborate: (30 min)
Student will apply what they just learned to answer questions on the lab including one about pigments to the change of colors we are seeing in leaves in the Fall.

Evaluation:
Participation of the students in the lab will be assessed informally on day one. After the lab is completed a short lab write up will be turned in to assess.

Reflection:
**True Colors: Plant Pigments**

We can see the pigments that capture the light using a method called paper chromatography. In paper chromatography, the solvent (acetone) moves up the paper carrying with it the dissolved substances (plant pigments). The pigments are carried along at different rates because they are not equally soluble in the solvent and are attracted in different degrees to the paper.

**Materials** (per pair):
- Strips of filter paper
- Acetone
- 150-mL beaker
- Cover for the beaker
- Fresh spinach leaf
- Coleus leaf (or other red leaf)
- Coin
- Pencil
- Metric ruler

**Procedure:**
1. Using a pencil, draw a base line 1.5 cm from the bottom of the strip of paper.
2. Place the spinach leaf over the line and use the coin to rub the leaf onto the paper. (The teacher will demonstrate)
3. Repeat for the Coleus leaf
4. Add enough acetone to cover the bottom of the beaker (no more than 1cm).
5. Lower the filter paper into the beaker. Be careful to keep the paper in an upright position. Cover the beaker. Do not disturb the beaker for approximately 15 minutes or until the solvent is about 1 cm from the top of the strip of paper.
6. When the solvent is about 1 cm from the top of the paper, remove the paper and mark the farthest point of the solvent’s progress (front line) with your pencil before this line evaporates.

**Hypothesis and Rationale:** What do you think is going to happen and why?
Observations:
Use the space below to draw a sketch of your chromatogram. Use appropriate colors.

Possible colors: faint yellow-carotenes; yellow-xanthophyll; bright green-chlorophyll a; yellow-green-chlorophyll b; red-anthocyanin.

Using your data and the other partner group’s data to fill in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Line</th>
<th>Color Observed</th>
<th>Probable Pigment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPINACH</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
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<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COLEUS</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
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<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Photosynthesis begins with the absorption of light, specifically the **white light**. What is white light composed of? We can use a device called a **prism** to answer this question.

What colors did you observe through the prism? List all of them (there should be 7)

What pigments did you observe in the spinach leaf? The coleus leaf?

How are the two leaves different?

Which of these leaves can carry out photosynthesis? Please explain your answer.

When you look outside in the Fall you see many vibrant colors like red, yellow, orange, and yellow. Where do you think these colors were during the summer?

How can they suddenly appear in autumn?

Why are leaves green?
Title: Molecular Pathways: The Flying Photosynthetic Circus
(adapted activity from Mrs. Elizabeth Skarzinski from Loudoun Valley High School)

Purpose:
The purpose of this lesson is to investigate how the chloroplast converts energy from light into chemical energy (ATP). The focus of this lesson will be on the light reactions.

Objectives:
- Students will be able to identify the tylakoid membrane as the location of key proteins involved in the light reactions
- Students will be able to define electron transport chain.
- Students will be able to describe the light reactions in photosynthesis.
- Students will be able to describe how the concentration gradient of H\(^+\) role in the production of ATP.

SOLs:
- BIO 3 (d) – The capture, storage, transformation and flow of energy through the processes of photosynthesis.

Materials:
- Tennis can lids
- Cards that can be flipped ADP to ATP
- Three tennis balls
- Cards that can be flipped NADP\(^+\) to NADH
- One balloon
- Labeled cards for roles (electron carrier, sun, etc)

Classroom Management/ Safety:
- Students will do this activity outside or in a common area in the school large enough to handle the movement involved.
- Tennis balls can hurt. It will be emphasized that the students pass the tennis balls rather than throw them. Kooshballs may be substituted to limit bruises.
Lesson Plan:

Engage: (5 min)
Students will be told that they will be acting today. Roles will be assigned. These roles are:
- Sun
- P₆₈₀
- P₇₀₀
- Water molecules/Hydrogen
- Primary electron acceptor for photosystem I
- Primary electron acceptor for photosystem II
- Electron Carriers for Photosystem II

Explore: (5 min)
The class will find a place to spread out and act out the light reactions.

Explain: (20 min)
The students will act out the light reactions as the teacher reads the “story” on the activity sheet.

Elaborate: (15 min)
The class will return to the classroom. A short animation will be shown to illustrate what they just acted out. Special emphasis will be placed on what happens to the Hydrogen atoms and the products that are made from the light reactions.

Evaluation:
Students will turn in their Activity sheets in for a class participation grade. This will serve as an exit slip.

Reflection:
**The Flying Photosynthetic Circus**

**Story Line:**
The sun hits $P_{680}$ with 4 photons (tennis can lid). $P_{680}$ becomes excited and throws 4 electrons (tennis balls) to a higher energy level (up in the air). The electron acceptor II catches the electrons and begins to pass them down the chain to the other electron carriers. One ATP is produced. In the meantime, $P_{680}$ grabs four electrons from the two molecules of water to replace the ones lost. The oxygen (balloon) is released and 2 protons for each of the two molecules of water are freed to join NADP$^+$. At the same time the sun hits $P_{700}$ throws up 4 electrons just in time to grab the electrons that have been passed down the chain of electron carriers. The electrons from $P_{700}$ are caught by the primary electron acceptor in Photosystem I. These electrons are passed on to NADP$^+$ which along with the 4 protons from the water molecules become NADPH and enters the dark reaction.

Fill in the squares/rectangles with the names of the different molecules involved.

Answer the following questions on the back of this sheet:
- Where are these molecules located?
- What factor(s) would limit this process?
- Was this activity helpful in helping you understand the process? Why?
- Any suggestions on improving this lesson?
Title: Light Independent Rxns

Purpose:
The purpose of this lesson is to have the students discover how the carbon fixation cycle through building models of the process. Students will learn how glucose is actually produced in the plant.

Objectives:
• Students will be able to describe the processes of the light independent reactions.
• Students will be able to explain the experiment conducted to discover the cycle.

SOLs:
• BIO 1 – Student will plan and conduct investigations
  o (m) a scientific viewpoint is constructed and defended
• BIO 3 (d) – The capture, storage, transformation and flow of energy through the processes of photosynthesis.

Materials:
Round objects (beads, Styrofoam balls, etc)
Toothpicks
String

Classroom Management/ Safety:
• Students will be using many materials: beads, toothpicks, balls, etc. They will be reminded not to put anything in their mouths during lab. Also they will have to be cleaned up immediately should the materials fall on the floor. The teacher will also make sure that no student is poked with toothpicks.
• Students are seated at group tables, therefore care should be taken to ensure that all students are able to see the visuals.
• Students are seated at group tables, therefore the teacher will move around the classroom to ensure that students are on task.
Lesson Plan:

Engage: (5 min)
Students will review the products of the light reactions and will brainstorm answers to the question:
   • How does the plant make Glucose from these products?

Explore: (10 min)
A short lecture will be conducted by the teacher explaining the Calvin Cycle and defining a few key terms.

Explain: (25 min)
Students will be broken up into groups and will design a model to illustrate the steps of the Calvin cycle. They will be able to use their book and notes from lecture. As they participate in this activity they will complete an activity sheet.
(The directions to this activity were found on page 117 of the Teachers Edition: Modern Biology)

Elaborate: (5 min)
Students will be reminded of the experiments that were conducted by Calvin and Benson and discuss how the radioactive molecules were helpful in discovering the steps to the process. They will also answer the question:
   • Why is the Calvin cycle more efficient biochemical pathway for synthesizing new molecules than a noncyclical pathway would be? (Cyclical pathways always regenerate their own starting materials) (from pg 118 Teachers Edition: Modern Biology)

Evaluation:
Students will complete an Activity sheet that will serve as a class participation grade.

Reflection:
Light Independent Reactions of Photosynthesis

Define the following terms and describe their role in the Calvin cycle:

NADPH:

RuBP:

PGAL:

ATP:

Glucose:

Draw a picture of the model you created of the Calvin Cycle:

Why is the Calvin cycle more efficient biochemical pathway for synthesizing new molecules than a noncyclical pathway would be?
Title: C3/C4/CAM pathways

Purpose:
The purpose of this lesson is to inform students about the different adaptations of plants. These include differences in molecular pathways.

Objectives:
- Students will be able to describe the adaptations of plants from different environments.
- Students will be able to compare and contrast C3 and C4/CAM plants.

SOLs:
- BIO 5 (b) – comparison of plant metabolic activities (Plants – C3, C4, CAM).

Materials:
C3 plants (or pictures)
C4/CAM plants (or pictures)

Classroom Management/ Safety:
- Students will be seated in groups so that they can collaborate and design easily
- Students are seated at group tables, therefore the teacher will move around the classroom to ensure that students are on task.
- Students will be reminded not to eat any of the specimens (regardless of how much money is offered to them)
Lesson Plan:

Engage: (5 min)
Students will discuss in their groups the answer to the following question:
- What type of adaptations that animals have in desert environments.

Explore: (5 min)
Still in their groups students will be given these instructions:
- Using what you already know about photosynthesis and plant anatomy describe the adaptations that you think plants will have to survive in these conditions.

Explain: (20 min)
There will be a short lecture on C4 and CAM pathways that desert plants implement for survival in desert climates.

Elaborate: (15 min)
Students will observe different plants, and based on their experiences in class, decide if they are a C3 plant or a C4/CAM plant.

Evaluation:
Participation will be assessed informally. Students will be required to create a group paper outlining the answers to the questions asked in class and the plant classification activity. This will count as a class participation grade.

Reflection:
Title: Photosynthesis Jeopardy

Purpose:
The purpose of this activity will be to review and assess the information that we have covered including: History, Light Reactions, Pigments, Light Independent Reactions, C3/C4/CAM and Societal Issues. This will also prepare the students for the quiz that will be the next class day.

SOLs:
- BIO 3 (d) – The capture, storage, transformation and flow of energy through the processes of photosynthesis.

Materials:
- Chalkboard or Transparency
- Writing implement

Classroom Management/ Safety:
- Students will be split up into teams. Room must be made for the students to collaborate within the activity.

Lesson Plan:
The students will participate in a class game of Jeopardy. On the board there will be categories and levels. The categories will be History, Light Reactions, Pigments, Light Independent Reactions, C3/C4/CAM and Societal Issues. Five questions will be allotted to each category. Two rounds will be played and there will be a final jeopardy question.

The 5 Es: Engage, Explore, Explain, Elaborate, and Evaluate will be used intermittently through out the whole lesson because of the design of the activity. Students will be Engaged because they will be participating in a game. They will be Exploring by choosing topics and constructing questions. As each of the questions are presented, the Evaluation and Explanations will be made. Elaboration is covered by the Societal Issues category.

Reflection:
Photosynthesis Quiz

1. The Cavlin Cycle takes place in which of the following structures:
   a. Thylaokid membrane
   b. Thylakoid stroma
   c. Chloroplast membrane
   d. Chloroplast stroma

2. The electron transport chain is located in which of the following structures:
   a. Thylakoid membrane
   b. Thylakoid stroma
   c. Chloroplast membrane
   d. Chloroplast stroma

3. Accessory pigments:
   a. Add color to plantd but do not absorb light energy
   b. Absorb colors of light that chlorophyll a cannot absorb
   c. Receive electrons from the electron transport chain of photosystem I
   d. Are not involved in photosynthesis

4. C4 plants:
   a. Are usually found in cool, moist environments
   b. Loose more water than C3 plants during photosynthesis
   c. Have no stomata
   d. Fix CO₂ into four-carbon compounds

5. Write the chemical formula for Photosynthesis.

6. Why is it efficient to have a cyclical biochemical pathway?

7. Describe one of the experiments that contributed to our understanding of Photosynthesis.
8. Describe the role of water in the light reactions of photosynthesis.

9. How is ATP made during photosynthesis?

10. What is the difference between the roles of photosystems I and II in photosynthesis?

* Most questions obtained from Chapter 6 Review in Modern Biology (Holt, Rinehart and Winston)