LIGHT! CARBON! ACTION!: A PORTABLE SCIENCE SUITCASE ON PHOTOSYNTHESIS FOR HIGH SCHOOL BIOLOGY STUDENTS

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DEDICATION

I would like to thank all the members of my committee: Kim Hoggatt Krumwiede, Joel Goodman, and Kenneth Coulter for all your support and guidance. Thank you Lynn Tam, Kristie Conner, and Steve Hinkley for all your help and input. Thank you Jorge Escobar, Bill Smith, and Paul Vinson for helping with the board game. Thank you to the Howard Hughes Institute for providing the funding for this project. Thank you to my fiancée, Elisa Wong, for all of the help with editing and proof-reading all of the written materials. Thank you to my family and friends for your moral support and encouragement through this entire process. Finally, thank you to Lewis Calver and the faculty at the Biomedical Communications Graduate Studies Program at the University of Texas Southwestern Medical Center at Dallas for equipping me with the necessary tools to be successful in my future career as a medical illustrator.

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by

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THESIS

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LIGHT! CARBON! ACTION!: A PORTABLE SCIENCE SUITCASE ON PHOTOSYNTHESIS FOR HIGH SCHOOL BIOLOGY STUDENTS

DEREK THOMAS WU, M.A.

The University of Texas Southwestern Medical Center at Dallas, 2010

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The goal of this thesis was to create a traveling “science suitcase” teaching aid that could encourage the improvement of 9th and 10th grade students’ understanding of the complex physical, chemical, and biological processes involved in photosynthesis. The suitcase includes a narrated animation, an interactive board game, three laboratory experiments, and a hands-on cell model. The suitcase is a resource to enhance the teacher's curriculum on photosynthesis, possibly help students meet the state of Texas science education requirements, and stimulate student interest to take advances science classes such as Advanced Placement Biology.

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Adobe® After Effects – a digital motion graphics and compositing software published by Adobe® Systems. Its main purpose is for film and video post-production.

Adobe® Encore – a DVD authoring software tool produced by Adobe® Systems.

Adobe® Illustrator – a vector-based drawing program developed and marketed by Adobe® Systems.

Adobe® Photoshop – is a graphics editing program developed and published by Adobe® Systems.

Adobe® Premiere Pro® – a real-time, timeline based video editing software application published by Adobe® Systems.

Autodesk® Maya® 2009 – a modeling, animation and rendering package developed by Autodesk Media and Entertainment.

Microsoft® PowerPoint – a presentation program developed by Microsoft.

Portable Document Format (PDF) – a file format created by Adobe® Systems for document exchange.

QuickTime – a multimedia framework developed by Apple Inc. capable of handling various formats of digital video, media clips, sound, text, animation, music, and interactive panoramic images.

CHAPTER 1

Introduction

Photosynthesis plays an essential role for sustaining all life on this planet. At the high school level, photosynthesis is a difficult concept for students to grasp and challenging for teachers to explain. Based on teacher feedback and low test scores, students in the DISD struggled with this and other science topics.

This poor understanding of science subjects in the DISD has led to lower enrollment in Advanced Placement (AP) science classes in the 11th and 12th grades. Of those enrolled, less than thirty percent pass the AP exam (TAKS Scores 2008). Low academic interest and performance in science subjects may consequently lead to the unlikelihood of pursuing science majors at a higher academic learning institution, or being ill-equipped to handle higher level science concepts. This could ultimately mean fewer qualified scientists working in the United States and that could impact innovation and invention of new technologies.

Thesis Question

Can a portable science suitcase on photosynthesis be created as a teaching aid for high school biology teachers to help explain photosynthesis concepts to high school students and possibly stimulate interest in Advanced Placement science courses?

Goals and Objectives

The goal of this thesis was to produce, (i.e. a traveling science suitcase), for use by high school teachers in the Dallas Independent School District (DISD) to present the concept of photosynthesis to 9th and 10th grade students. This suitcase explained the concepts of light absorption, conversion of light energy, and storage of energy using a narrated, 2D animation. The suitcase also included interactive materials in the form of a physical cell model and a group board game to help the students review and reinforce key concepts in photosynthesis. Additionally, the suitcase included laboratory exercises. The material covered met standards required by the Texas Essential Knowledge & Skills (TEKS). The suitcase also presented advanced information to enable teachers to stimulate students to further their biological knowledge and enroll in classes like Advanced Placement Biology.

To achieve this goal, I had to meet the following objectives:

1. Conducted an initial survey of teachers and students to determine their current level of understanding and teaching methods regarding photosynthesis and the teachers' needs for increased effectiveness of teaching the concepts.

2. Researched materials concerning the current modalities of teaching K-12 students and the effectiveness of using visual aids as part of the teaching curriculum.
3. Formulated a plan that would address the overall concepts of photosynthesis and specific topics using the following mediums: 2D animation, an interactive group board game, laboratory exercises, physical plant cell model and pre- and post- tests.
4. Conducted a formative evaluation the science suitcase by surveying teachers. To conduct a formative evaluation by surveying students was not a viable option based on the timing of when teachers typically teach photosynthesis in the classroom and when the suitcase was fully functional.

Persons Involved with the Suitcase

During this thesis project, I worked with Dr. Joel Goodman, Jorge Escobar, Lynn Tam, and Steve Hinkley. Dr. Goodman is Director of the Science Teachers Access to Resources at Southwestern (STARS) program at the University of Texas Southwestern. He advised on the content and design of the science suitcase. Jorge Escobar is Senior Exhibits Designer at the Dallas Nature and Science Museum and guided me in creating any models or materials. Lynn Tam is Assistant Director for the STARS program and helped me to develop laboratory exercises and materials. Steve Hinkley, Director of Education at the Dallas Nature and Science Museum, provided insight and feedback on the animation script.

Of these above individuals, Kim Hoggatt Krumwiede, Joel Goodman, and Kenneth Coulter, served as my thesis committee and provided guidance and support. I met with the committee regularly to discuss my ideas and progress throughout the entire process of creating this photosynthesis suitcase.

Background Information

This traveling "science suitcase" I created was funded by the the Howard Hughes medical Institute's Pre-College Program, administered through the Science Teachers Access to Resources at Southwestern (STARS) Program at UT Southwestern. The STARS Program was developed in 1991 to improve the quality of science education in North Central Texas, specifically within the Dallas Independent School District (DISD). In 2007, the Howard Hughes Medical Institute awarded a grant to the STARS Program, which works in collaboration with Advanced Placement Strategies, Dallas' Museum of Nature and Science, and National Instruments. This grant funded the development of science suitcases – mobile demonstration modules of scientific principles, including the introduction to chemistry, biochemistry, enzymes, membranes, organelles, cell respiration, and photosynthesis.

These science suitcases are created by students in the Biomedical Communications Graduate Program at UT Southwestern Medical Center in collaboration with staff from the Museum of Nature and Science. The goal of these science suitcases are aligned with the goals of the STARS Program. The STARS program's goals are to: (1) increase science awareness, (2) stimulate an appreciation of health-related careers, (3) provide ongoing support for science teachers and students, (4) improve science education by broadening the knowledge base of teachers, and (5) assist science education by providing instructions aids. Teaching aids to supplement the current science textbooks are needed by teachers to help students understand essential science topics, including photosynthesis.

Significance

Each year, students take the Texas Assessment of Knowledge and Skills (TAKS) exams as an academic indicator of how schools, districts, and the state of Texas as a whole are doing. Based on the 2009 Texas Education Agency DISD Academic Excellence Indicator System report, the percentage of students meeting the TEKS (i.e. state standards) in the DISD is consistently lower than that of the state as a whole. For example, 10th and 11th graders in the DISD only met the science standards for 53% and 83% of students, respectively. These scores are below the state's score of 67% and 86% of 10th and 11th graders meeting the science standards, respectively. Furthermore, only 16% of all students in the DISD achieved commendable science scores, compared to 26% in the state of Texas. (TEA AEIS 2009)

This poor understanding of science subjects in the DISD has led to lower enrollment in Advanced Placement (AP) science classes in the 11th and 12th grades. Of those enrolled, less than thirty percent pass the AP exam (TAKS Scores 2008). Low academic interest and performance in science subjects may consequently lead to the unlikelihood of pursuing science majors at a higher academic learning institution, or being ill-equipped to handle higher level science concepts. This could ultimately mean fewer qualified scientists working in the United States and that could impact innovation and invention of new technologies.

A comprehensive teaching aid focused on high school level students would help teachers clearly explain photosynthesis, engage students visually, and stimulate further understanding to an advanced level.

Scope of the Project

The scope of this thesis project had a number of limitations. The audience was limited to high school students in the 9th and 10th grade biology classes in the Dallas Independent School District. The development of the science suitcase had to addressthe learning objectives of the Texas Essential Knowledge and Skills, relating to photosynthesis. The suitcase had to include material designed for easy incorporation into any science class in the DISD. The suitcase had to include all laboratory materials and supplies, DVDs of animations, a clear and concise teacher's manual, student handouts that couldbe easily reproduced, and any additional components, e.g. board games and models, deemed necessary to explain photosynthesis concepts. At least one component had to utilize the production services of the Dallas Nature and Science Museum. This suitcase also had to be stored in a durable and easily transportable case or container.

CHAPTER 2

Review of the Literature

Establishing a Knowledge Base of Photosynthesis

The purpose of the literature review is to determine the knowledge standards required by the Texas Essential Knowledge and Skills, explore the current teaching methods and available subject material, and examine effective learning styles to create a successful teaching module.

Texas Essential Knowledge and Skills (TEKS)

To begin, I researched the current educational standards set forth by the Texas State Board of Education regarding photosynthesis. This information could be found in the Texas Essential Knowledge and Skills (TEKS) curriculum. "The Texas Essential Knowledge and Skills identify what Texas students should know and be able to do at every grade and in every course in the required curriculum". To test the application of TEKS in the classroom, the Texas Educational Agency developed the Texas Assessment of Knowledge and Skills (TAKS).

The standards for TEKS can be found in Chapter 112 under Title 19, Part II of the Texas Administrative Code (TAC). The objectives for high school biology is found in

Subchapter under 112.43.Biology. The standards regarding photosynthesis reads as follows:

> “5) Science concepts. The student knows how an organism grows and how specialized cells, tissues, and organs develop. The student is expected to:
>
> > (A) compare cells from different parts of plants and animals including roots, stems, leaves, epithelia, muscles, and bones to show specialization of structure and function;
>
> (9) Science concepts. The student knows metabolic processes and energy transfers that occur in living organisms. The student is expected to:
>
> > (B) compare the energy flow in photosynthesis to the energy flow in cellular respiration”

Current Teaching Methods and Materials

These standards for photosynthesis defined by TEKS were very broad and left little guidance as I was forming a detailed plan for the suitcase. To supplement the TEKS objectives, I researched what current methods and material teachers were using in the classroom.

DISD Science Curriculum Planning Guide

I obtained the 2009 Science Curriculum Planning Guide for the DISD. Under the section “Instruction Considerations”:

- Identify the reactants and products of photosynthesis and cellular respiration as they relate to the carbon cycle.
- Summarized the major events of photosynthesis and identify where they occur.
- Photosynthesis is a metabolic foundation for the biosphere.
- Plants and other autotrophs are producers of the biosphere.

The curriculum also suggested to design a flowchart summarizing all the reactants and products at each step to give an overview of how the processes work. This was a very useful resource since the science suitcases were being produced specifically to be used in DISD schools.

Textbooks

The sponsored science textbook for the DISD is Biology by George B. Johnson and Peter H. Raven. The teacher's edition included suggestions for simple elodea plant lab activities and pointed out which chapters covered specific TEKS objectives. Most of the visual teaching aids in the book included color illustrations that described multiple stages of photosynthesis in a single image. Diagrams described the biochemical pathways written as chemical equations, but with limited description of what they meant or represented.

Teacher PowerPoint Presentations

I reviewed several PowerPoint presentations (Chatman 2008, Goodman 2007) on photosynthesis provided by Joyce Wang, a former DISD science teacher at L.G Pinkston High School. These presentations were useful because they were packed full of information that was spread over several slides. The teacher had control over the rate of information presented to students more than assigning students to read a paragraph of text from a book. Images were easily added to text descriptions in the presentations. However, the pictures were collected from the Internet or teachers' presentations, and there was no continuity to the images. There was no incorporation of animation to explain multiple stage processes, like the Calvin Cycle.

Preliminary Survey

From the preliminary survey distributed to approximately 50 teachers participating in STARS Triathlon workshops (See Appendix A), I assessed the methods teachers were using to teach photosynthesis. The group of participants included some teachers that taught in other school districts outside of the DISD, such as the Richardson Independent School District. A few were middle school teachers and one educator was from a local community college. Many teachers had used images, posters, and PowerPoint presentations. Several included 3-dimensional (3D) paper models of organelles and simple animations found on the Internet or in textbooks. One teacher had engaging methods of using interactive games and models to teach students. However, teachers in the DISD did not mention these resources. With the exception of one teacher who was not part of the DISD, all other teachers did not have available to them a comprehensive package that would present multiple concepts of photosynthesis using different types of media to engage students.

Learning Styles

After I determined that there were no other teaching aids on photosynthesis similar to the proposed suitcase, I researched learning styles to understand the best approaches to reach students. Students learn information in a variety of ways and it was important to include components in the suitcase that covered a wider range of learning styles to impact the most number of students. Repeating information in different ways is important to reinforce the key concepts. “Learners are better able to grasp new pieces of information and discern patterns when they are presented with “numerous, effective examples” (Using Multimedia Tools 2008).

There are three basic modalities of learning: visual learning, auditory learning, and tactile & kinesthetic learning (Learning Styles Explained 2009). Visual learners prefer visual displays diagrams, image, and videos and have a tendency to think in pictures. (Learning Styles Explained 2009) Auditory learners learn best through listening to lectures, discussions, and have greater understanding when reading things out loud. Tactile and kinesthetic learners do best with moving, doing, and touching, like role playing or interacting with a physical model (Learning Styles Explained 2009)). Students may have a dominant style of learning, but incorporating multiple styles together improve the potential to retain and understand information. “The more senses involved does not only mean more information, better perception, more efficient memorizing and deeper understanding, but ensure the same chance for students with different dominant senses” (Katai 2008).

I concluded that including a narrated animation in the suitcase would stimulate visual and auditory learners. Interactive games, labs activities, and a physical model would be included for tactile and kinesthetic learners. Once I decide on the components, I researched each component further to determine the most effective use for each type of media.

Animation

I decided that an animation was a good starting point to present the concepts of photosynthesis in media beyond words in a textbook. “A visual input such as an animation is a major factor in drawing attention to a topic, which in turn acts as a stimulus to transfer the content into working memory” (McClean 2003). Animations are also effective teaching tools even if students are not able to interact. “[Learners] can engage in active learning (such as the processes of selecting, organizing, and integrating) even when the presentation media do not allow hands-on activity (such as printed text and illustrations, or animation and narration)" (Mayer 2003). However, an animation alone was not sufficient to actively engage students. There needed to be an integration of auditory and textual information to maximize effectiveness of the animation as a teaching tool.

It is important to include narration with the animation. Described as a “multimedia effect”, students learn more deeply from a multimedia explanation presented in words and pictures than in words alone (Mayer 2003). The mental integration of auditory and visual information leads to greater understanding of the information. As such, I developed a narration script simultaneously with the animation.

Visual correspondence with text is an important “spatial contiguity effect”. T”Students learn more deeply when printed words are placed near rather than far from corresponding pictures” (Mayer 2003). Thus, the animation needed to include labels of important structures and concepts for emphasis. It is also vital to not overload the animation with too much or leave too little information. “The *coherence effect* refers to the finding that students learn more deeply from a multimedia explanation when extraneous material is excluded rather than included.” So review of the animation script by high school science teachers was necessary to verify the level of explanation of photosynthetic processes is appropriate for the high school audience. Thus, it was important that the animation and other elements visually link together. “Animations that are well paced, stage-appropriate, focused, and narrated verbally with complementary visual text as appropriate can help students learn dynamic processes” (O'day 2005).

Board Game

High school classrooms put a lot of emphasis on auditory and visual learning through lectures, textbook reading, and visual presentation. Using manipulatives and game activities increases interest and participation among students, especially among tactile and kinesthetic learners. “Games help students improve self-esteem, peer relationships, and learning" (Nemerow 1996). The board game brought this kinesthetic element by instructing players to physically move game pieces around the board, use various game cards to achieve an objective. "Even students who couldn't be motivated by anything else enjoyed being in the room and watching or participating in role-playing simulations and competitive games" (Nemerow 1996). The board game I designed included a basic competitive element to encourage participation.

Laboratory Experiments

Labs are a proven method to learning scientific concepts. "Students often develop scientific understandings as a result of their own observations and what they can see to be true" (Using Multimedia Tools 2008) Laboratory experiments are what real scientist perform to prove or disprove facts and theories. Placing student in the same environment will train them to think and observe scientifically. You think like a scientist when you work like a scienctist. When students are engaged in "actively constructing knowledge from a combination of experience, interpretation and structured interactions with peers and teachers, they are more likely to gain an expert understanding of science concepts" (Using Multimedia Tools 2008). Laboratory exercises also provide students with an opportunity to discuss and learn collectively with other students. In a process akin to peer review, students can present hypotheses and observations, engage in debate, and build upon each others' work and ideas (multimedia). Discussion and debate help students to think like scientist and make connections from basic ideas to advanced concepts.

Review of Available Resources

After I researched the learning styles and exploring the use of various media to accommodate each style, I evaluated the resources available to teachers in animation, games and laboratory experiments. I reviewed the activities provided in the Biology textbook, material provided by teachers, and resources on the Internet.

Animation

I reviewed online resources available on YouTube.com. There are a lot of animations on photosynthesis available. Many were home-made videos explaining photosynthesis, some of which provided a solid presentation of photosynthetic concepts. But, these video usually consisted of static images taken off the internet and then edited together. The images were drawn in various styles and skill levels, and gave a very visually disjointed presentation. The most complete animations that I saw were the Virtual Cell, a computer generated animation created by the University of North Dakota, and the photosynthesis series created by Dagger Biology.

The Virtual Cell video is visually interesting with a colorfully modeled electron transport chain in the thylakoid membrane and everything was rendered as a 3D animation. The narration was thorough in explaining the light dependent reactions. However, this animation covered material and concepts for an AP Biology or college level class. The numerous technical terms and complex molecular pathways would overwhelm a 9th or 10th grade student seeing this for the first time. Also, the Virtual Cell video only covered the light dependent reaction, and there was no video on the Calvin Cycle or even a video that presented broader concepts of the photosynthetic process such as the chemical equation. From a technical standpoint, the 3D renderings seemed to be created with a limited understanding of animating in a 3D program and use of graphic design. Most of the plant cell objects were shaded green so it was difficult to distinguish certain foreground elements from the background. There was no use of a 3-point lighting system so shadows on objects looked very dark on one side, and the dimensionality of the scene was reduced because there was a single light source casting the same level of light to the foreground and background. Also, there was no use of surface texturing, so all the objects had the same plain, matted color surface that gave no indication that the viewer was at the molecular level.

The Dagger Biology video was good because it used a simpler 2D animation style that was suitable for a regular high school biology class. The explanations were clear and the visual elements had been simplified so that the viewer could follow along very easily. However, this animation lacked visual creativeness and was slightly mundane. The level of animation skill was basic and there was little dynamic to the special effects. The visual elements were all so simple to the point that even the variety of color was limited to a lot of orange, light blue, and gray. The narration switched back and forth between a male voice and female voice, and the recording sounded like a low quality audio file.

Interactive Game

Currently there are virtually no board games that involve photosynthesis. Teachers have come up with their own activities and explain the electron transport chain by having students role-play different proteins in the chain. However, the calvin cycle is very rarely addressed because of its complexity. I found several interactive flash games online, but a majority of them were just quiz questions. The closest representation of a board game was a simple game i found online at that had players collect resources, represented as candy, and use them to complete the photosynthesis chemical equation. I also found a product, t-605 teaching photosynthesis, by national teaching aids that diagramed out the photosynthetic process with simple graphics, and included attachable word labels. However, the graphics were very basic, the diagram itself was visually confusing, and the presentation looked out-dated. The cost to purchase the rudimentary set of 4 presentation boards was extremely high ranging in the hundreds of dollars.

Laboratory Experiments

A large variety of laboratory activities were readily available to teachers. The Biology textbook described labs Tthere were many labs posted on science learning websites. I was also given multiple labs by former science teachers, Lynn Tam and Joyce Wang. The focus of the labs ranged from big picture concepts to specific steps in the photosynthetic process.

There were a couple of labs that were commonly used that I wanted to avoid including in the suitcase. The most common one was an Elodea Plant lab that involved counting the air bubbles produced by the plant when exposed to a light source. The second was a paper chromatography lab where the student would test for different types of chlorophyll pigments. The science suitcase needed to provide teachers with a variety of unique activities, and not present them with the same labs they were already using.

Plant cell models

I looked at a variety of products sold online through Amazon.com, scientific websites, and educator websites. There were many good examples of plant cells models that displayed the basic plant cell anatomy. The price of these manipulatives ranged from simplistic fifteen dollar models, to complex five hundred dollar models. Since there were already many examples of physical plant models available to teachers, it seemed redundant to try to develop one from scratch. I decided I would purchase

Conclusion

Based on my literature review, there was nothing available similar to the proposed science suitcase on photosynthesis. Although teachers have excellent PowerPoint presentations, they lack reasonable media that could supplement their lesson plan. Many of the videos on photosynthesis were no more than image slide shows, and a couple potential animations seemed to be lacking either visually, or in content. I needed to design an animation that would address these shortcomings. Also, there were no physical, interactive board games relating to photosynthesis that were available. I needed to create a board game that would review a major concept of photosynthesis and present in a fun and engaging way for students. It was important to provide teachers with a package that is capable of engaging multiple learning styles in the classroom.

CHAPTER 3

Methodology

Concept Development

The goal of this thesis was to produce a teaching aid, (i.e. a traveling science suitcase), for use by high school teachers in the DISD to present the concept of photosynthesis to 9th and 10th grade students. Using a narrated 2D animation and video, this suitcase needed to explain the concepts of light absorption, conversion of light energy, and storage of energy. Interactive materials in the form of a physical cell model and a group board game were included to help the students review and reinforce the information. The suitcase also includes laboratory exercises. The covered material was organized to meet standards required by the Texas Essential Knowledge & Skills (TEKS). The suitcase also needed to present advanced information that give teachers a tool to expose and stimulate students to further their biological knowledge and enroll in classes like Advanced Placement Biology.

To achieve this goal, I met the following objectives:

1. Conducted an initial survey of teachers and students to determine their current level of understanding and teaching methods regarding

photosynthesis and the teachers' needs for increased effectiveness of teaching the related concepts.

2. Researched materials concerning the current modalities of teaching K-12 students and the effectiveness of using visual aids as part of the teaching curriculum.
3. Formulated a plan that would address the overall concepts of photosynthesis and specific topics using the following mediums: 2D animation, an interactive group board game, laboratory exercises, physical plant cell model and pre- and post- tests.
4. Conducted a formative evaluation the science suitcase by surveying teachers. Conducting a formative evaluation by surveying students was not a viable option since the suitcase was not fully functional when teachers typically teach photosynthesis in the classroom.

Target Audience

The target audience for the science suitcase consisted of high school biology students in the 9th and 10th grade studying the topic of photosynthesis and their teachers in the Dallas ISD and surrounding districts.

The 2D animation, interaction group board game, laboratory exercises, physical plant cell model, and pre- and post tests were for the benefit of the students. These items would not be effective without providing their teachers the appropriate guidance. As such, I included a clear and comprehensive teacher's manual in the suitcase, which is full of teacher's notes to help connect the concepts with the other activities, suggested answers to the tests and lab exercises, and other helpful hints.

Pre-project Planning

Meetings

In the first meeting, I met with my thesis committee and Dr. Goodman explained the purpose the science suitcases and how it would fit into the STARS Triathlon. I was allowed to pick any topic relating to science, and as a suggestion, they provided a list of topics that was covered during the STARS workshop. I decided to choose from this list since I had little preference. Two of the topics, organelles and enzyme were already used to make suitcases. Of the remaining choices, I decided to choose Photosynthesis because it sounded the most interesting. The components could be anything except that they had to include lab materials and some type of manipulatables that would be built with the help of the Dallas Museum Nature and Science.

In the subsequent monthly meetings, I established a list of concepts that I considered the essentials of photosynthesis. With the help of my committee and preliminary surveys, we gradually determined the types of components that would go into the suitcase. I then started meeting with several people to begin development of the various components. I met with Steve Hinkley, the Director of Education at the Dallas Museum Nature and Science, to discuss details of the script. As a former high school teacher, he was able to provide useful explanations of difficult key concepts. I also met with Jorge Escobar at the museum and began planning the board game. My thesis committee and I would continue to meet to discuss storyboards and review my progress as I built the animation.

Preliminary Surveys

Distribution

I conducted an initial survey of teachers to determine their current teaching methods and needs for teaching photosynthesis. Surveys were given to 20 teachers at a science symposium held by the STARS program in February 2009. 14 completed surveys were returned. (See Appendix A)

I also surveyed, Joyce Wang in February, 2009. She was a science teacher at L.G Pinkston High School in Dallas. Joyce's interview was invaluable because she was a science teacher in the DISD system and had first-hand experience teaching photosynthesis and preparing 10th and 11th graders for the TAKS exams. Joyce was able to provide me with PowerPoint presentations she used for teaching the photosynthesis curriculum, along with the related labs and student worksheets. She was also able to give me input on what were the difficult topics of photosynthesis for students, as well as concepts that were difficult to teach.

Furthermore, I presented an initial survey to a handful of high school students to determine their current level of understanding of photosynthesis. These surveys were given to high school students that lived in the San Francisco Bay Area in California.

Although the demographics of these students differ in geographical location, school district, and resources, the students surveyed are of the same age group as my target audience and are also taught photosynthesis as part of their education. Surveying these students was helpful in providing insight into what they learned in classrooms about photosynthesis and what interests they had in different learning methods. Six completed preliminary surveys were returned. (See Appendix B)

Lastly, I conducted final preliminary survey in May 2009 with another 20 teachers that took part of a STARS workshop. I also held a question and answer forum in which we discussed what the essential concepts of photosynthesis were, how the topic is currently taught to students, and ideas they had regarding how they wish photosynthesis could be taught to students. (See Appendix A)

Survey Feedback

After gathering all the teacher surveys and interviews, the responses were consolidated into 4 issues: Available visuals, commonly used labs, difficult concepts, and desired components to enhance their curriculum.

The most common visuals available to teachers were images taken off the Internet, or provided from other teachers. Most teachers used a PowerPoint presentation and had foldable paper models. A few teachers had animations provided from textbooks CDs or from the Internet. A select few had games, manipulative models, or large visual posters. This lack of visuals beyond images and PowerPoint presentations influenced my decision to included elements such as the animation, board game and plant cell model into the suitcase.

Based on the surveys, there were several commonly used laboratory exercises. The most common one was an Elodea Plant lab that involved counting the air bubbles produced by the plant when exposed to a light source. The second was a paper chromatography lab where students tested for different types of chlorophyll pigments. Several teachers also had some sort of leaf anatomy lab. I wanted to make sure that the lab exercises I chose to include in the science suitcase were not commonly used by teachers.

Most teachers had difficulty teaching the two reactions cycles, especially the Calvin Cycle. There were other troubling topics, according to teachers, such ashow oxygen was produced, the chemical equation, the photosystems, and basic chemistry. All of these topics could be introduced and addressed in the animation. Almost all of the teachers wanted more models, games, and outdoor activities. Several teachers expressed the necessity to have activities that would engage the student into learning.

From the student surveys, most of the students were aware of chemical equations and electron charges, but did not know about oxidation and reduction or hydrogen protons. Everyone was receptive to a board game and had played games similar to The Game of Life© by Milton Bradley™.

Choosing Components to Include in the Science Suitcase

After reviewing the teacher survey results and feedback, I detailed a list of main concepts that teachers had trouble with. Using my research on current methods of teaching, I decided what kind of components would help to enhance the teacher's current curriculum and materials. I decided an animation explaining the overall concept of photosynthesis would be very beneficial. To stimulate student engagement, a board game, laboratory exercises, and a hands-on model were included as well.

Animation

Art style

I chose to create animation art that was a 2D cartoon because it allows me to control the level of visual information for the viewer. I believed detailed life-like illustrations of plant cellular anatomy and molecular structures would have overwhelmed the viewer with extra information unnecessary for a high school audience. Looking at examples of diagrams teachers were using in their 9th teaching curriculum, they included almost nothing more than the title of the two reactions and a few names such as NADPH and ATP. I kept concepts relating to chemistry were kept to a bare minimum. In designing the content for the animation, I made sure to meet the minimum information requirements, and then took it one step further by introducing molecular concepts.

Initially, I had the idea that I could create an animation in which the viewer would feel like they in a different world – as if they were immersed in the cell. I made some concept drawings that had a soft loose feel and an overall green color palate (**Figure 3-1**). That transitioned into a cleaner style with thick borders around the shapes and bright colors. I used blocked shading to give the images depth instead of soft, blended gradients. This style was similar to cartoons such as Fairy Odd Parents, Avatar: The Last Air Bender, and Chowder.

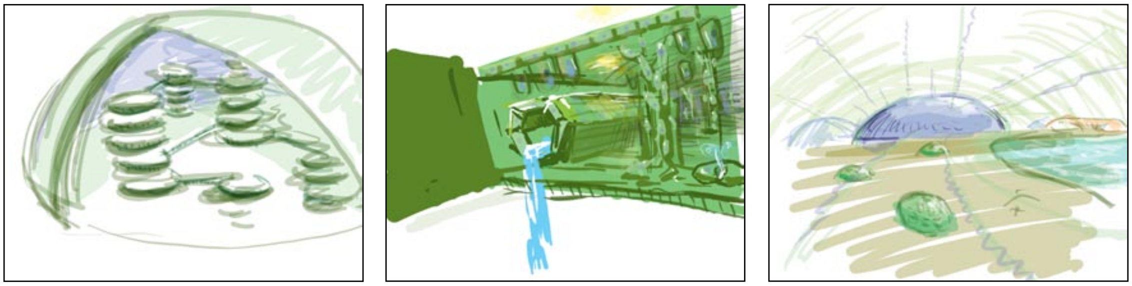


FIGURE 3-1. ORIGINAL CONCEPT DRAWINGS IN ADOBE® PHOTOSHOP

I also used the same artistic style was in the board game and labs to give all the elements of the suitcase the feeling of consistency. This was intended to help make connections for the viewer that the concepts presented in the animation was also applicable to the objectives of the board game and labs.

Script

The script for the animation was built upon my research on photosynthesis. (See Appendix C) I gathered all the information from reading online sources (Orrl 2007), textbooks, and from discussions with Steve Hinkley and Dr. Ayre. The concepts naturally consolidated into 3 main topics: basic function of photosynthesis, light dependent reactions, and light independent reactions.

I gathered all of the research information into one document, then organized the information into what I believed was the most logical order. I then reworded the concepts as a narrative to be read during the animation sequences. This became the first draft of the script.

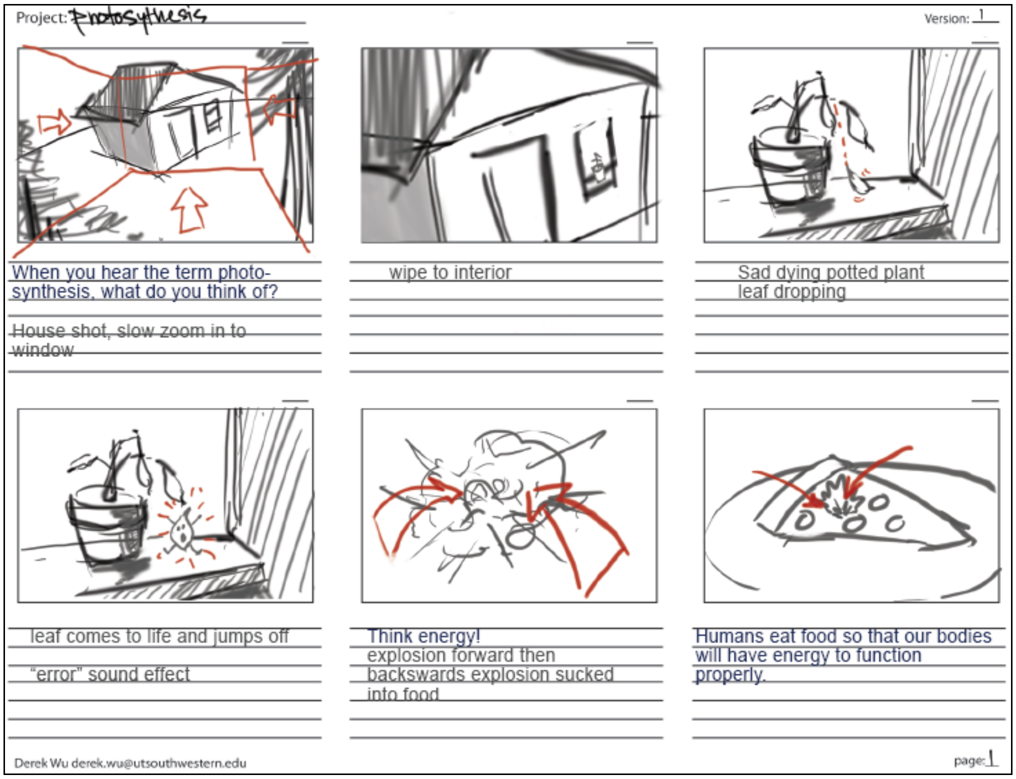
The script was then sent to Dr. Joel Goodman, Steve Hinkley, Kim Krumwiede, and Lynn Tam (i.e. members of my suitcase committee) for review. Through the review process, the concepts were cleaned up and tightly defined. Under the three main topics, sub-concepts were defined in the following order:

- Basics of photosynthesis
    - What photosynthesis is at the basic level
    - The photosynthetic chemical equation
    - Oxidation and reduction
    - Introduction of the two reaction cycles that take place in photosynthesis
- The light dependent reactions
    - Capturing light for use as energy
    - The electron transport chain
    - The use of NADPH as an energy carrier to the cight independent reactions

  - The creation of ATP
  - The production of oxygen as a byproduct of splitting water
- The light independent reactions
  - The use of ATP and NADPH from the light dependent reactions
  - The use of CO_2
  - The reorganization of carbons during the Calvin cycle
  - The creation of sugar

Storyboard

I used to the script to create a storyboard for the animation (**Figure 3-2**). (See Appendix D) A storyboard was a simple way to explain how each paragraph of the script might be depicted visually and show what animation or effects might be involved in each scene.



When you hear the term photo-synthesis, what do you think of?

House shot, slow zoom in to window

wipe to interior

Sad dying potted plant leaf dropping

leaf comes to life and jumps off

"error" sound effect

Think energy!

explosion forward then backwards explosion sucked into food

Humans eat food so that our bodies will have energy to function properly.

FIGURE 3-2. FIRST PAGE OF STORYBOARD.

I review the storyboard with my committee several times and made minor changes to wording of the script and some scenes were changed, or simplified.

Animatic

Once the committee reviewed and approved the storyboard, I created a short rough animation of the first 90 seconds of storyboard. The still images in the storyboard were cut up then quickly animated in Adobe® AfterEffects. For this first rough cut, I recorded the script with my own voice. These two elements were composited together using Adobe® Premiere Pro®. This animatic was created so my committee members could have a better idea for the vision and pacing I had envisioned for the actual animation. Creating this short rough animation helped to save time because I didn’t have to spend a lot of time and effort to create finalized stills and animate them just to show the committee how I envisioned the animation. This short rough animation served its purpose well and I was able to communicate my vision for the committee.

Recording the Script

A professional voice talent, Brina Palencia, was hired through the Mary Collins Agency in Dallas, Texas. A clear narration of the script was necessary to engage the audience and explain what the viewer was seeing visually. I chose Mrs. Palencia because she had a bright, young voice that could still speak with authority. I wanted to avoid narrators with an older sounding voice that might cause students to associate the animation with dry, old science documentaries. The raw audio footage was edited and consolidated into a clean track using Adobe® Premiere Pro®. This final audio track was rendered and then added to a separate Adobe® Premiere Pro® file created for editing the final animation.

Leaf Character

I incorporated a leaf character to the animation to provide intermittent comic relief as the viewer learns the concepts. Originally, this character was going to be rendered as a computer generated 3D model. I created an initial working model using Autodesk® Maya® 2009 (**Figure 3-3**). However, after further discussion, it did not make sense to incorporate a single 3D element when the rest of the animation was in 2D. Also the additional time to build and animate the character in a 3D program, then render and composite the footage in a 2D animation and then re-render all the elements a final time would have been more time consuming. As such, it was determined that a 2D leaf character would provide more consistency throughout the animation and also help same time.

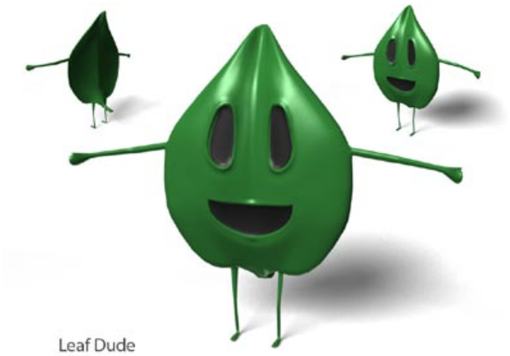


FIGURE 3-3. ORIGINAL 3D LEAF CHARACTER IN AUTODESK® MAYA® 2009.

In the end, the final 2D leaf character was created in Adobe® Illustrator as two files. The first file contained all of the leaf body and limbs separated into views of the leaf from every angle (**Figure 3-4**). The second file was created with all the facial expressions (**Figure 3-5**). This way, I could animate the body in multiple scenes as I needed, then add the specific expressions at a later time.

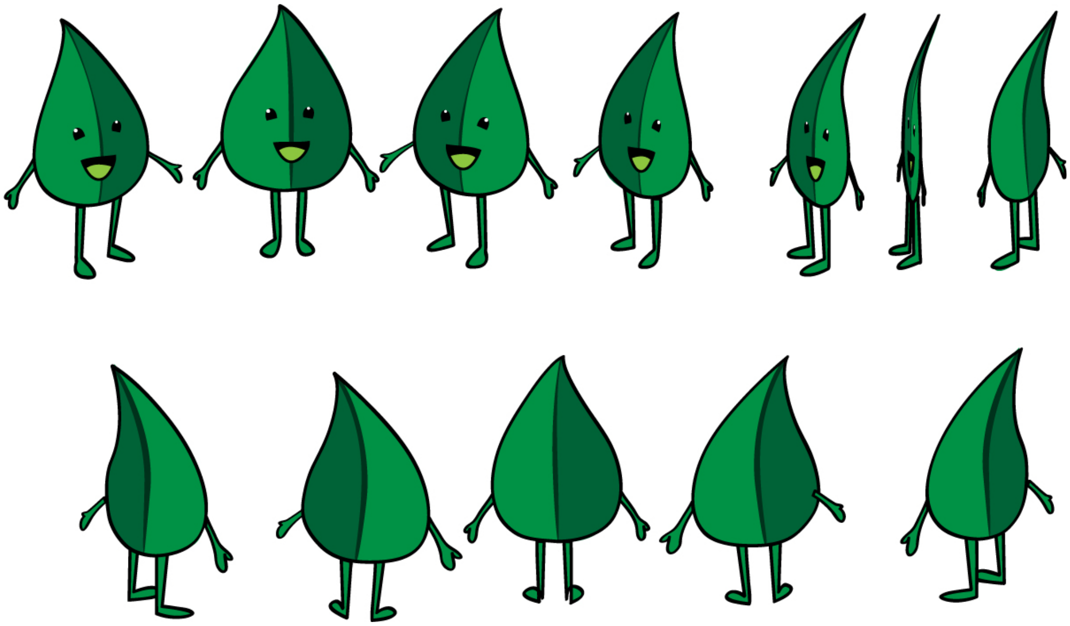


FIGURE 3-4. LEAF CHARACTER BODY AND LIMBS IN ADOBE® ILLUSTRATOR

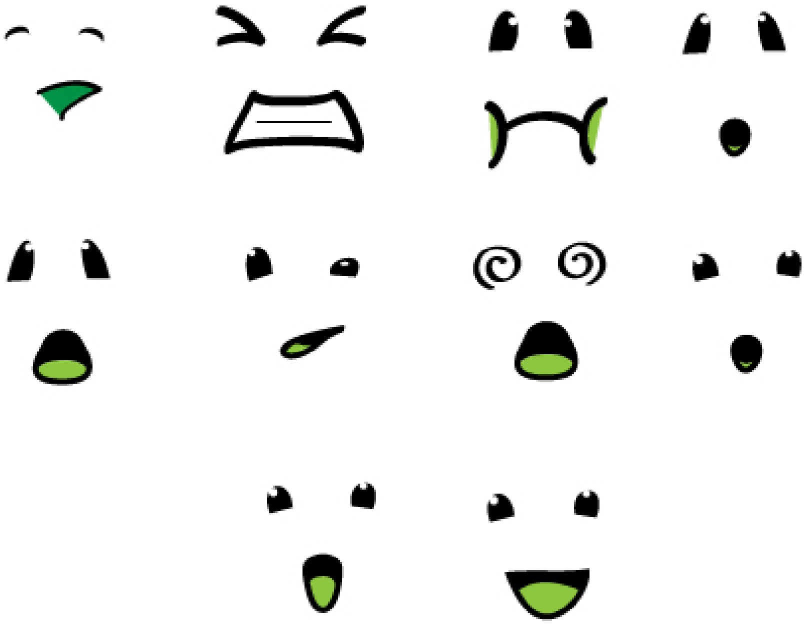


FIGURE 3-5. LEAF CHARACTER FACIAL EXPRESSIONS IN ADOBE® ILLUSTRATOR

Building the Visual Elements

After my storyboard was completed and approved by my committee, I reviewed each scene and made a list of all the unique visual elements in the storyboard. From this list I could keep track of elements that were made and what still needed to be made.

I created some of the introduction shots in Adobe® Photoshop because it was easier to control background gradients. However, it soon became apparent that working in Adobe® Photoshop was inefficient because the art style consisted mainly of hard edged, solid colored images with little use of gradients or soft edges. It was harder to make minor edits to elements in Adobe® Photoshop after they had been created. Adobe® Illustrator was more suitable for creating and editing hard edged images because it is based on vectors rather than rasters images in Adobe® Photoshop. Subsequent movie elements were created in Adobe® Illustrator.

Adobe® Photoshop method

In order to create images in Adobe® Photoshop, I first started with the outline of the image. I would use the pen tool, which is a vector-based tool to create a path. Then I would stroke the path to a determined thickness (**Figure 3-6**). If I wanted to control the thickness of the path, like the shadow at the bottom of the windowsill in Figure 3-6, I had to create two separate paths and stroke them individually. Then I would have to clean up the pixels using the eraser tool or brush tool.

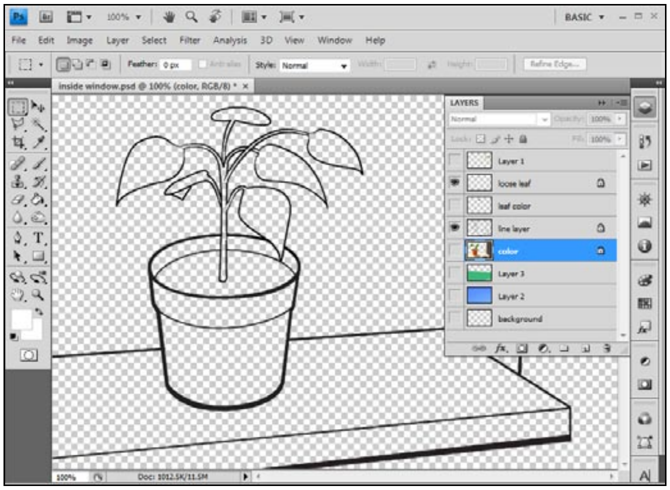


FIGURE 3-6. INTRODUCTION SHOT IN ADOBE® PHOTOSHOP

On a separate layer, I created the blurred background gradient (**Figure 3-7**). Then on another layer, I created a mask inside the image outline to prevent color bleeding as I added color.

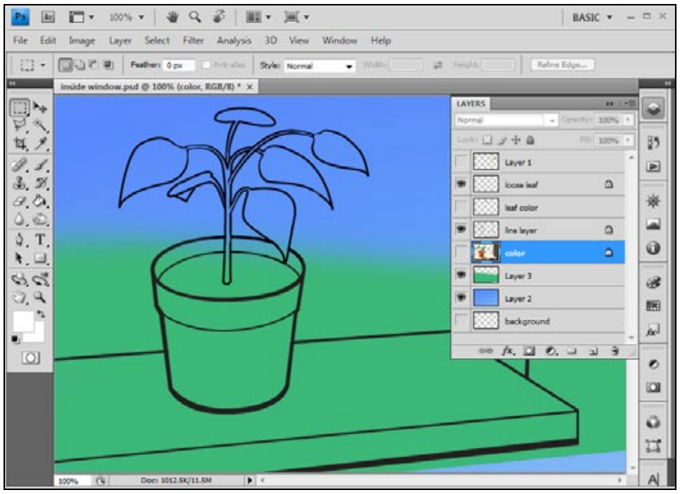
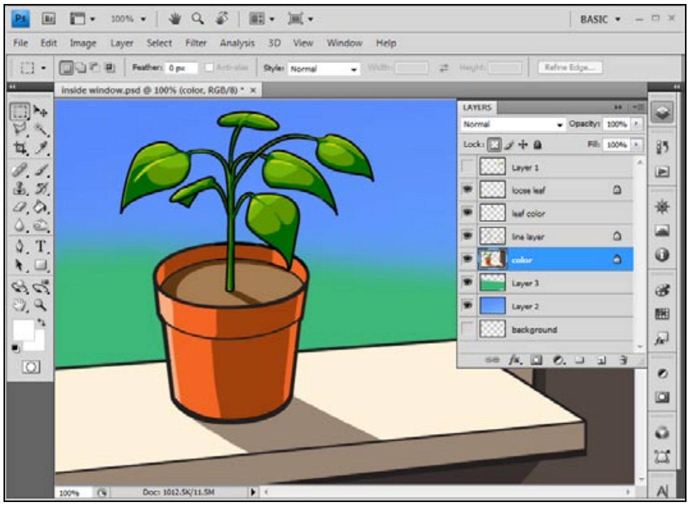


FIGURE 3-7. INTRODUCTION SHOT WITH BACKGROUND COLORS ADDED IN ADOBE® PHOTOSHOP.

I then saved a mask selection of individual elements and filled the elements with the desired colors. The problem I encountered was that if I wanted to adjust a shape slightly, all the layers need to be changed, and I had to adjust any mask I created. It was all very inefficient working in the raster format of Photoshop. (**Figure 3-8**).



Feather: 0 px

Style: Normal

Normal

Opacity: 100%

Fill: 100%

FIGURE 3-8. FINAL INTRODUCTION SHOT IN ADOBE® PHOTOSHOP.

Adobe® Illustrator Method

Essentially, the cartoon effect I was trying to achieve in Adobe® Photoshop was the specialty of Adobe® Illustrator. The following is the method I employed to create elements in Adobe® Illustrator. First, I created an image outline by creating a path to add a stroke (**Figure 3-9**). Then I would covert the stroked path to a filled object using the outline path tool. This allowed me to manipulate the thickness of the stroke in specific areas. In figure 3-9, the method was used to add shadow weight to the bottom ATP synthesizer enzyme.

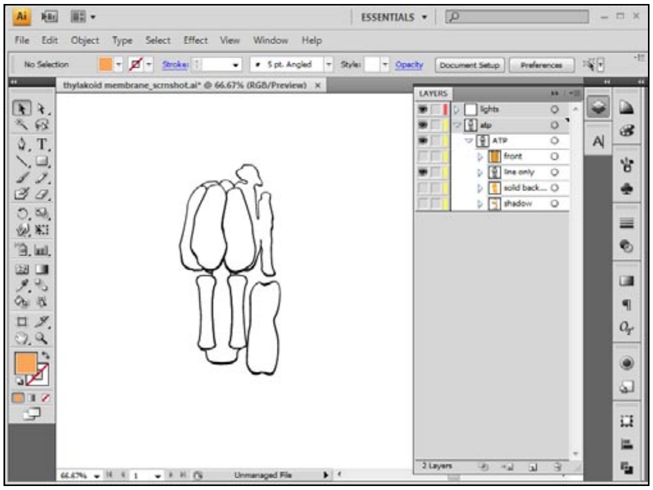


FIGURE 3-9. ATP PROTEIN SYNTHESIZER LINE DRAWING IN ADOBE® ILLUSTRATOR .

To color the element, I simply copied the path prior to converting it to a filled outline. I flipped the stroke path to a fill and designate the desired color (**Figure 3-10**). This colored path would then be placed underneath the image outline in the layers outline.

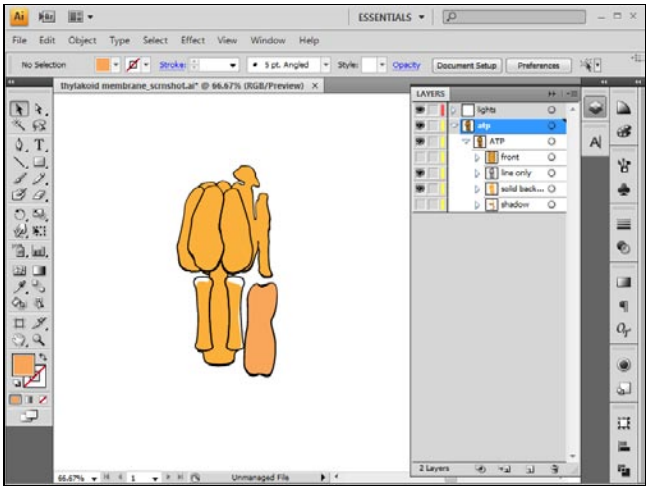


FIGURE 3-10. ATP PROTEIN SYNTHESIZER WITH COLOR ADDED IN ADOBE® ILLUSTRATOR.

To give the image visual depth, I used the pen tool to create a filled path depicting a shadowed area, and then create a filled path depicting a light area (**Figure 3-11**). Adjustments in Adobe® Illustrator were much easier to manipulate the points since everything was a vector versus raster format, and thus there was no loss of pixel detail.

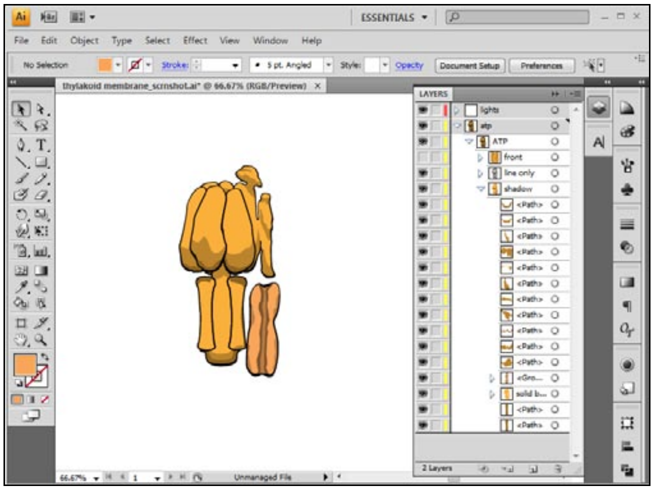


FIGURE 3-11. ATP PROTEIN SYNTHESIZER WITH SHADOWS ADDED IN ADOBE® ILLUSTRATOR.

Most objects were colored with a 3 color tone lighting system. I started with a base color and used that as the mid value range, then using the palate in Adobe® Illustrator to select a value that was one shade darker to be the shadow. For the highlight, I selected a value that was one level lighter from the middle color value (**Figure 3-12**).

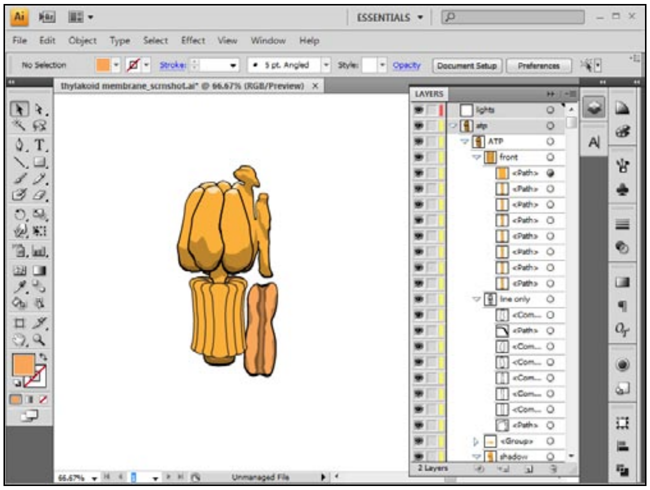


FIGURE 3-12. ATP PROTEIN SYNTHESIZER WITH HIGHLIGHTS ADDED IN ADOBE® ILLUSTRATOR.

Animating and Compositing

When starting to animate and composite, I first created an Adobe® Premiere Pro® project that would become the final animation (**Figure 3-13**). This included the narrated audio track and a movie track that was "dynamically" linked to an Adobe® AfterEffects file. I set it up this way so that I could create animated sequences and make edits using the Adobe® AfterEffects file and the dynamic link would automatically update the movie track in Adobe® Premiere Pro®. I could then conveniently synchronize the audio track with the movie timing. This method was chosen versus using only Adobe® AfterEffects because with Adobe® AfterEffects, you could not actively listen to the audio track while working on the animation.

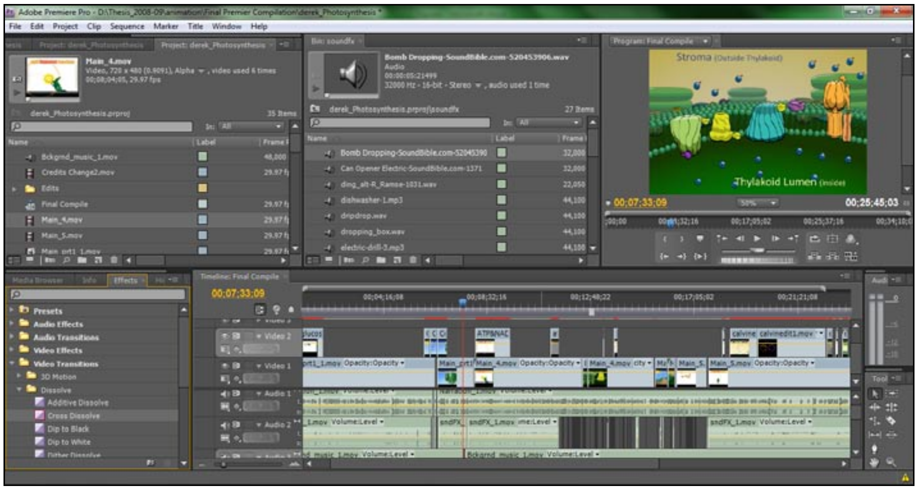


FIGURE 3-13. FINAL ANIMATION FILE IN ADOBE® PREMIERE PRO®.

Animation Work Flow:

- Import movie elements created in Adobe® Illustrator to the Adobe® AfterEffects library.
- Create a main composition that would serve as the collection point for all the individually animated scenes. (**Figure 3-14**)
- Create a scene composition. This would correspond with a scene defined by the storyboard and script. This could contain imported image elements or nests sub-compositions. (**Figure 3-15**)
- Import the elements pertaining to the scene and key the motions. For animated sequences that might repeat, it's necessary to create a sub-composition that could be nested into the scene composition.
- Employ the use of parenting objects to a hidden or "null" object help increase the intricacy of certain sequences.

One example is the leaf character walking. All the limbs were animated in one sequence, and then were parented to the main leaf body which was key to move in space. This gave the illusion that the limbs were walking and the leaf character was moving in space and walking forward. This character could then be placed in the scene and interact with other elements in the scene. After all of the animated sequences were created, I utilized the Adobe® Premiere Pro® program, and through the dynamic link the movie track was automatically updated with any changes made in Adobe® AfterEffects.

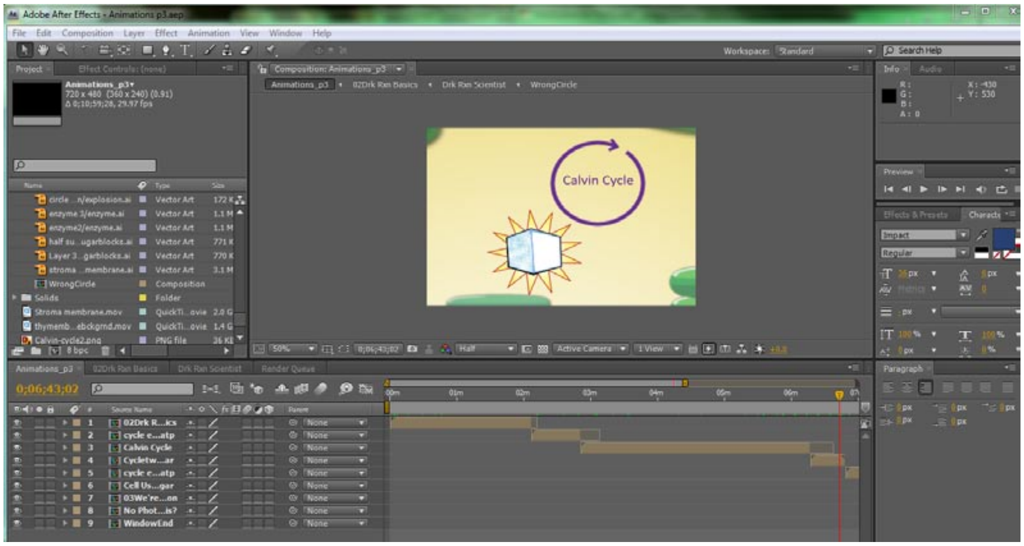


FIGURE 3-14. MAIN MOVIE COMPOSITION IN ADOBE® AFTEREFFECTS.

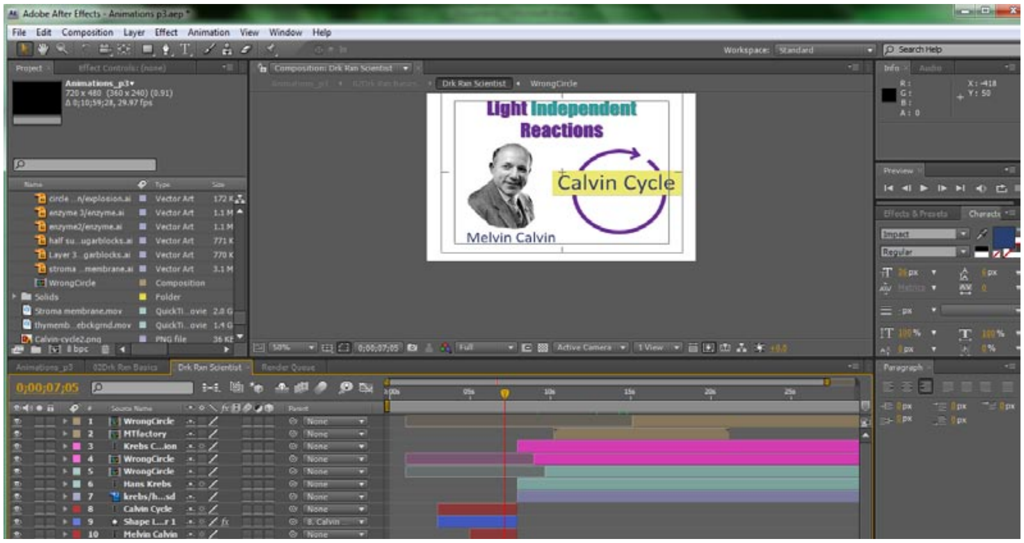


FIGURE 3-15. SCENE COMPOSITION IN ADOBE® AFTEREFFECTS.

Complications During Production

The initial Adobe® AfterEffects file became too robust and I had to start a new Adobe® AfterEffects file for another section of the animation. Eventually, the animation was separated into three files, which corresponded to the 3 parts of the script: 1. basics of photosynthesis, 2. the light dependent reactions, and 3. the light independent reactions. This meant more dynamically linked file had to be added to the Adobe® Premiere Pro® program. The Adobe® Premiere Pro® file soon also became too large. When I first tried to render the original Adobe® Premiere Pro® file which included all the Adobe® AfterEffects files, the estimated rendering time was 27-31 hours. To remedy this, I rendered the sections of Adobe® AfterEffects files into QuickTime movie files. These rendered files were then imported into a new Adobe® Premiere Pro® file. The newly rendered movie files decreased the size and therefore allowed the computer to process less information and work more efficiently. After I had rendered the Adobe® AfterEffects files and used a second Adobe® Premiere Pro® file, the estimated rendering time was only 2.5 hours.

Compiling the Final Video

I Layer the sound effects, background music, and narration onto the new Adobe® Premiere Pro® file (**Figure 3-16**). I then set the volume levels so that the narration was the loudest to ensure all the content could be heard; sound effects were set at a slightly lower level and background music was set at the lowest level as to not overtake the narration and sound effects.

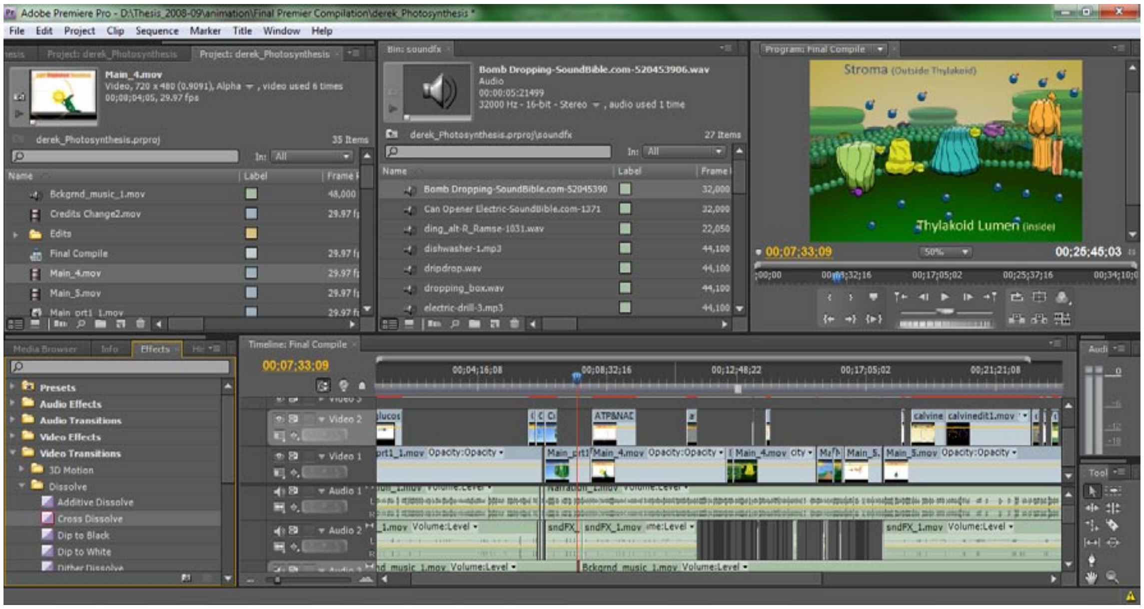


FIGURE 3-16. COMPILING VIDEO FILE IN ADOBE® PREMIERE PRO®.

To produce the final output, I rendered the movie in QuickTime format using the following specifications: 720 x 480 pixels at a 0.9 pixel ratio using H.264 compression. (**Figure 3-18 to 3-20**).

DVD Creation

The final video footage was imported into Adobe® Encore to be encoded onto a DVD. I created a main menu and chapter menus using Adobe® Photoshop and imported them into Adobe® Encore (**Figure 3-17**). Once all the files were combined, quiz questions were integrated into the animation DVD.

Name	End Action
Chapter1	Stop
Chapter2	Stop
Chapter3	Stop
Chapter4	Stop
Chapter5	title:Default
noquizchapselection	Stop
noquizchapselection2	Stop
Question01	Questio...str:Default
Question01 1Wrong	Stop
Question01 2Correct	Stop
Question01 3Wrong	Stop
Question01instr	Stop
Question02	Stop
Question02 1Wrong	Stop
Question02 2Wrong	Stop
Question02 3Correct	Stop
Question03	Stop
Question03 1Correct	Stop
Question03 2Wrong	Stop

Name: title
Description:
End Action: Stop
Override: Not Set
Default Button: 1
Offset: 0
Color Set: Automatic
☑ Automatically Route Buttons
Operations: All Permitted
Aspect Ratio: ● 4:3 ○ 16:9

title
(+#) Button Play All
(+#) Button Chapter Selection
(+#) Button Play no questions
(+#) Button No quiz chap
bckground

FIGURE 3-17. MAIN MENU AND CHAPTER MENUS IN ADOBE® ENCORE.

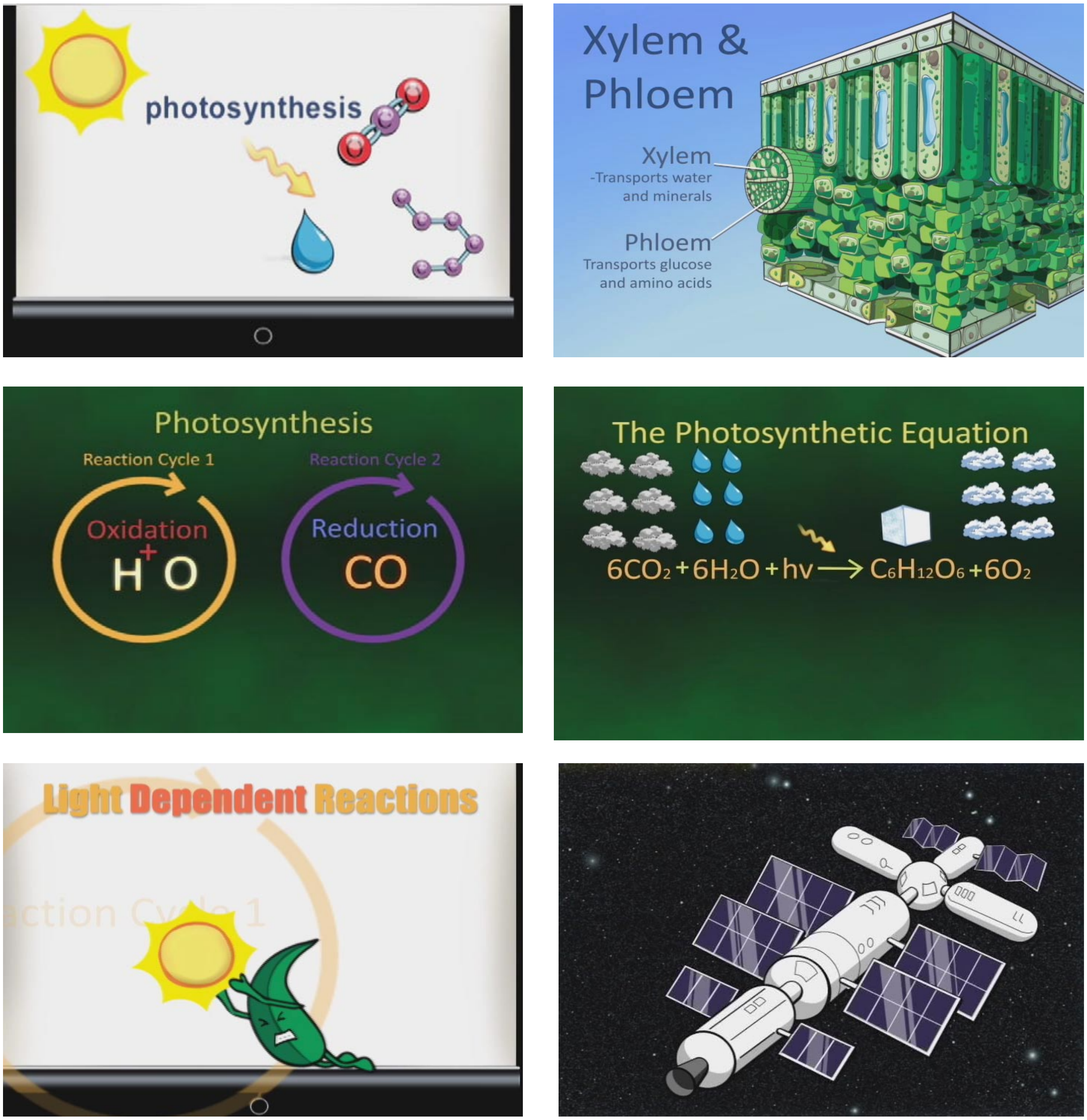


FIGURE 3-18. STILLS FROM FINAL ANIMATION DVD.

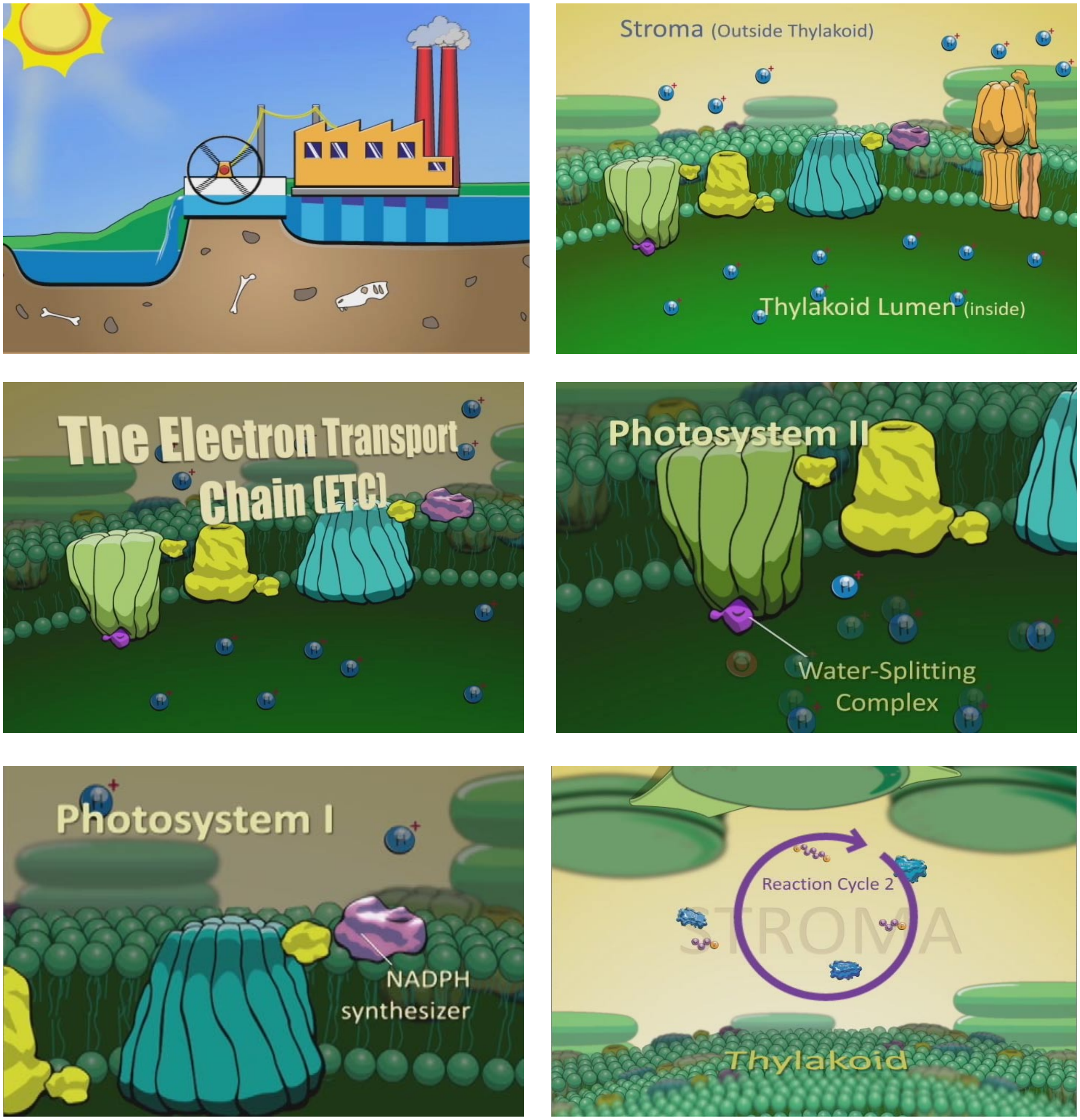


FIGURE 3-19. STILLS FROM FINAL ANIMATION DVD.

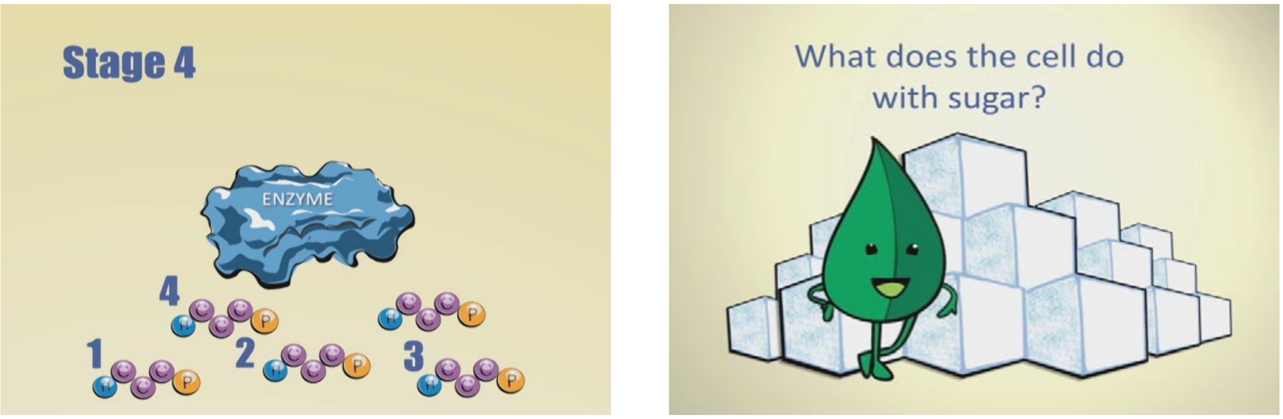
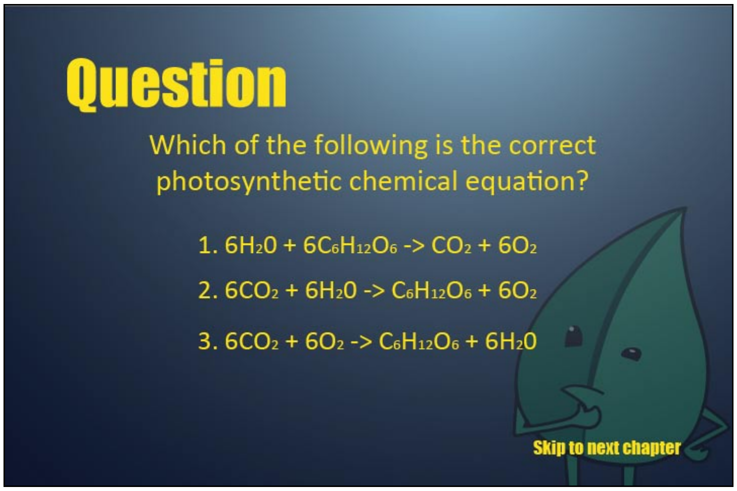


FIGURE 3-20. STILLS FROM FINAL ANIMATION DVD.

Video Quiz Questions

To review the concepts presented in the animation, I added seven quiz questions after certain animation movie chapters. The movie would stop and a sub-menu containing a question and several possible answers would appear (**Figure 3-21**). The viewer would then use the DVD remote control to interact with the submenu. If the wrong answer is selected, a screen with explanations of why the answer was incorrect would appear (**Figure 3-22**). After that screen is reviewed, the user must attempt to answer the question again. The movie will continue once the viewer selected the right answer (**Figure 3-23**) or if the viewer decided to skip the quiz question.



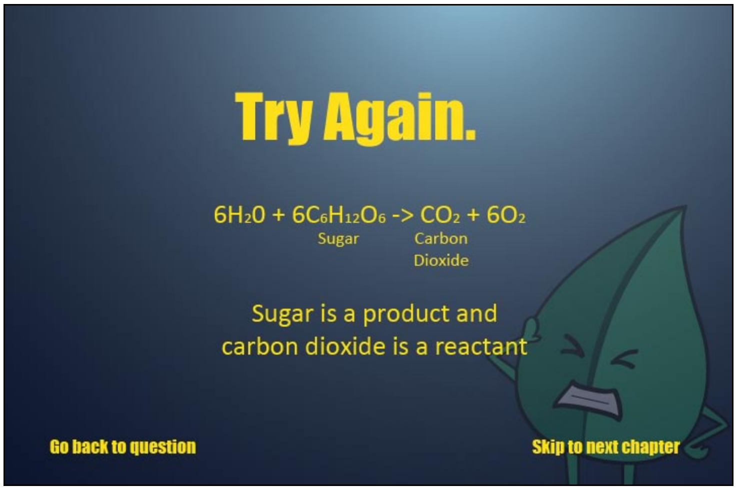
Question

Which of the following is the correct photosynthetic chemical equation?

1. $6H_20 + 6C_6H_{12}O_6 \rightarrow CO_2 + 6O_2$
2. $6CO_2 + 6H_20 \rightarrow C_6H_{12}O_6 + 6O_2$
3. $6CO_2 + 6O_2 \rightarrow C_6H_{12}O_6 + 6H_20$

Skip to next chapter

FIGURE 3-21. EXAMPLE QUIZ QUESTION IN ANIMATION DVD.



Try Again.

$6H_20 + 6C_6H_{12}O_6 \rightarrow CO_2 + 6O_2$

Sugar

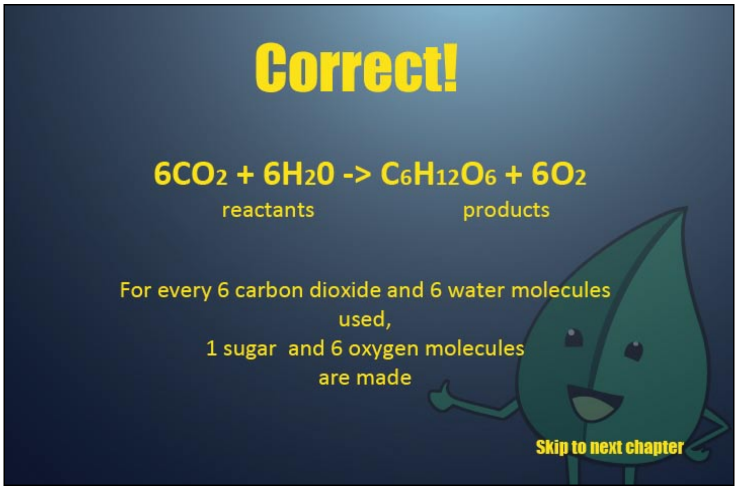
Carbon Dioxide

Sugar is a product and carbon dioxide is a reactant

Go back to question

Skip to next chapter

FIGURE 3-22. EXAMPLE INCORRECT ANSWER TO QUIZ QUESTION IN ANIMATION DVD.



Correct!

$6CO_2 + 6H_20 \rightarrow C_6H_{12}O_6 + 6O_2$

reactants products

For every 6 carbon dioxide and 6 water molecules used,
1 sugar and 6 oxygen molecules are made

FIGURE 3-23. EXAMPLE CORRECT ANSWER TO QUIZ QUESTION IN ANIMATION DVD.

Quiz Question Construction

Typically, an entire movie was placed into a single Adobe® Encore timeline, and so that when it finishes playing the default command was to go back to the Start Menu. To create these quiz breaks, the movie had to be separated into multiple timelines. Each sub-timeline corresponded to a pre-designated length of movie time between each question (**Figure 3-24**). By organizing movie this way, it allowed me to program the DVD player, to jump to a specific quiz sub-menu once it reached the end of a sub-timeline. If the entire movie was within the same timeline, you could define multiple chapter breaks, but you would be limited to defining only one destination once the end of the timeline was reached. You could not command the player to jump to a submenu after playing a chapter break.

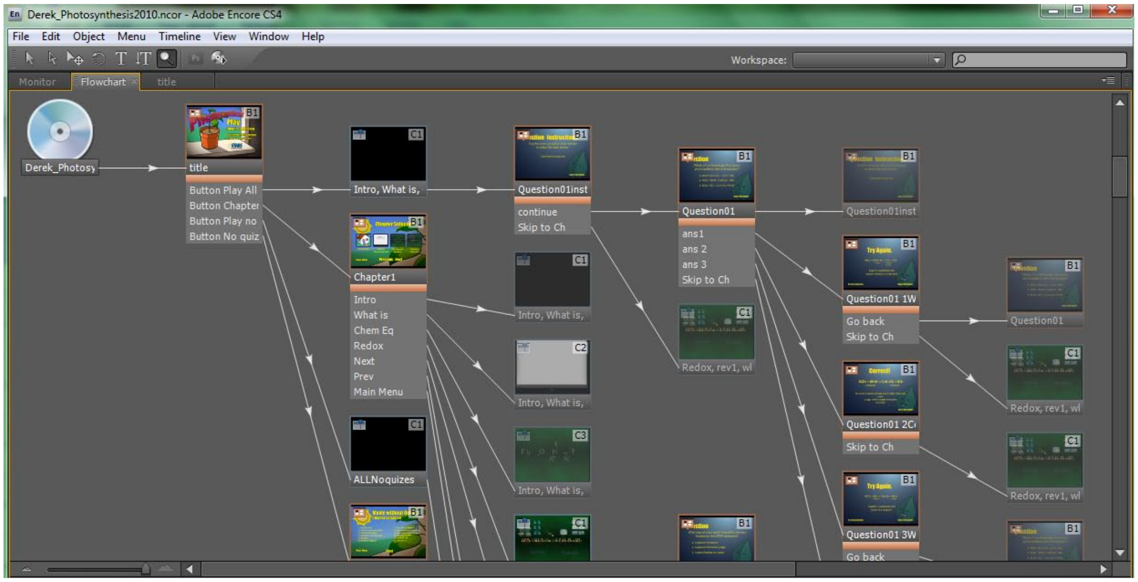


FIGURE 3-24. SUB-TIMELINE MENUS IN ADOBE® ENCORE.

Sugar Rush Board Game

One of the interactive components of the suitcase is the "Sugar Rush!" board game. The original concept of this game draws from my experience playing other board games. I had exposure playing strategy games such as Monopoly™, Stone Age™, Settlers™, and the Game of Life™. All of these games incorporate players taking turns to gather resources and spending them to perform a specific action or to gain an asset.

I took these game concepts and applied them to the light-independent reactions (Calvin Cycle) of photosynthesis. One aspect of the board game follows the real-life situation where a cell collects energy, such as ATP and NADPH, from the light-dependent cycle and uses enzymes to activate the reactions in the Calvin cycle. The reactions modify designated molecules in stages until the final product is produced. (**Figures 3-25 – 26**)

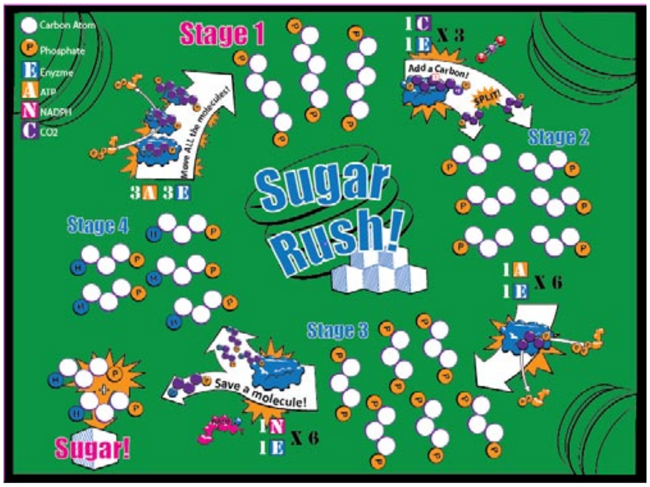


FIGURE 3-25. SUGAR RUSH! GAME BOARD.

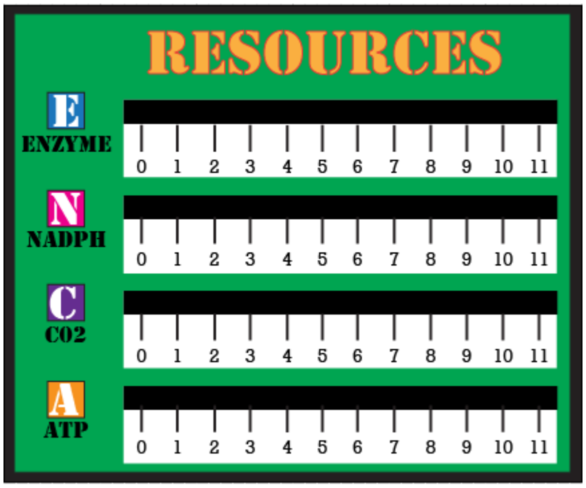
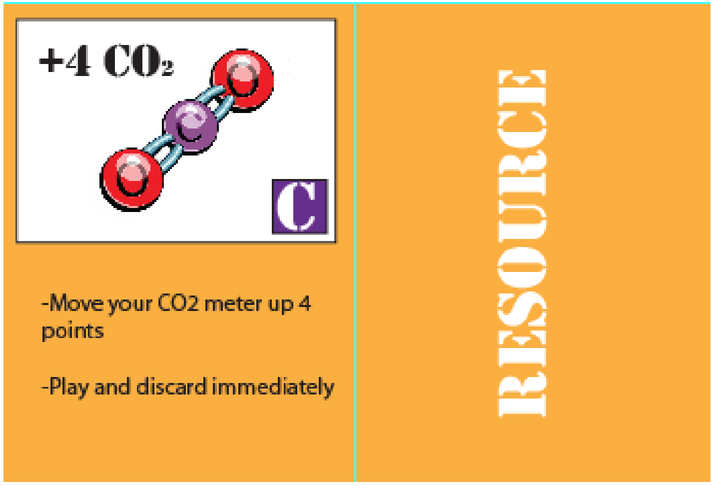


FIGURE 3-26. RESOURCES METER.

I chose to focus on the carbon atom chains contained within the molecules being modified in the Calvin Cycle and have the players observe how the carbon configurations change at each stage of the reaction cycle (**Figure 3-27**). Each player is responsible for their own Calvin Cycle and must be the first one to create a sugar molecule. The players must gather specific resources (**Figure 3-28**) and spend them to move their carbon chains game pieces to the next reaction stage. To add strategy and variability to game play, action cards (**Figure 3-29**) are introduced where players can steal resources from each other or garner extra turns in order to gain a competitive edge.

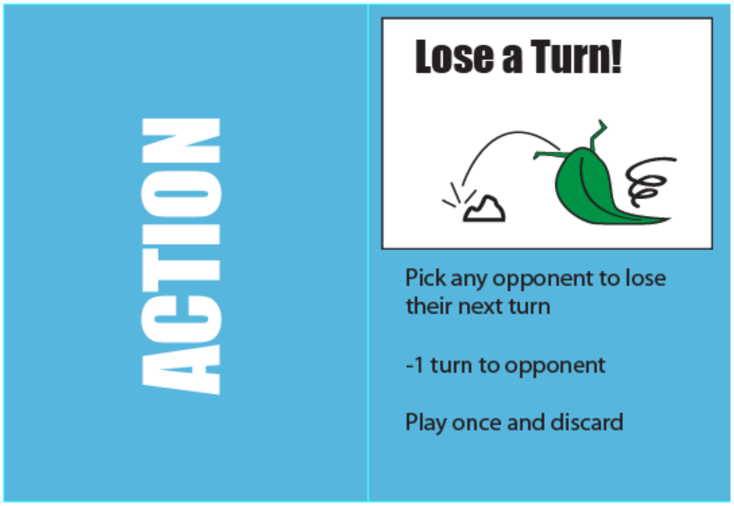
FIGURE 3-27. CARBON CHAINS.



-Move your CO2 meter up 4 points

-Play and discard immediately

FIGURE 3-28. EXAMPLE RESOURCE CARD.



ACTION

Lose a Turn!

Pick any opponent to lose their next turn

-1 turn to opponent

Play once and discard

FIGURE 3-29. EXAMPLE ACTION CARD.

Game Materials

Each game package contained a game instructions (See Appendix E), a card holding center (**Figure 3-30**), a box for game pieces (**Figure 3-31**), four sets of game boards and four sets of resource meters (**Figure 3-32**). All packages were numbered, but the sets were otherwise identical.

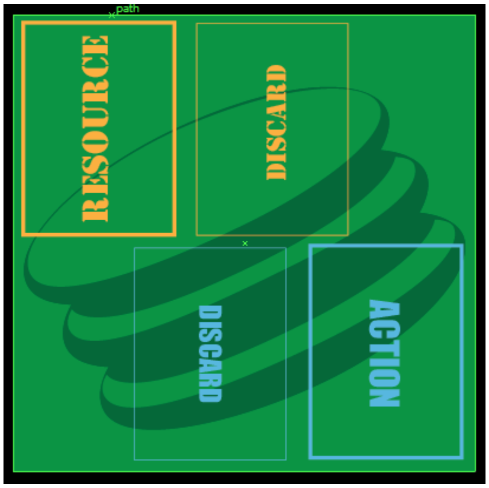


FIGURE 3-30. CARDHOLDING CENTER.

FIGURE 3-31. BOX FOR GAME PIECES

FIGURE 3-32. RESOURCES METER WITH SLIDERS.

Testing the Game

The first version of the game was tested on four 2nd year biomedical communication students. In the game, each player takes a turn to draw one resource card and one action card. During a player's turn, that person can choose to play an action card and, if they had the right specific resources, spend their gathered resources to move carbon-chain game pieces to the next stage. Gathered resources are recorded on a meter that corresponds with each type of resource. The game keeps going until a player is the first to cycle around the game board twice to create a sugar and return their game pieces back to the start. The students were able to finish the version 1 board game in about an hour. After playing the game they gave me feedback and suggestions on how to improve the game. The changes made to the game are described in detail below.

A second version of the board game was tested in a classroom of twenty teachers at a STARS Science Triathlon workshop. I gave some initial instruction and then allowed the teachers to read the rules and play the game on their own. The teachers were given thirty minutes to play the game and most teachers finished a third of the game.

Version two of the game was tested a third time at the Adamson High School, in Dallas Texas. High school science teacher, Bibianna Mendez, generously opened her classroom and allowed the game to be tested by a group of 15 AP Biology students (**Figure 3-33**). The students were given forty minutes and most finished two-thirds of the game.

FIGURE 3-33. ADAMSON HIGH SCHOOL STUDENTS PLAYING BOARD GAME

Feedback and Changes Made to the Game

During these 3 test runs of the game, there were 3 recurring themes: confusion over the basic game rules, pace of the game, and how to choose who which player goes first. After receiving feedback, I made changes to fix issues that were identified with the game play.

Although the premise of the game was simple: gather resources, play action cards, and spend resources to move game pieces, there was an initial learning curve to understanding the rules of the game and what a player can do during their turn. This confusion of the game rules would slow the pace of the game down. Often, some people would not completely read the instructions before starting their turn and this would later lead to confusion during game play. Therefore, the instructions needed to be rewritten in a clearer manner and include bold fonts for important steps and rules.

Also, the pace of the game lagged because of low value resource cards and repeated gathering of the same resources by the same player. Initially, a resource card may have read “+2 ATP”, meaning the card was worth 2 resource points of ATP. These were changed to read “+5 ATP” so that player would have better chance of advancing quickly through the game. Many of the “steal a resource” action cards were too specific to one resource type and thus useless to a player that already had an abundance of that particular resource. These problems were fixed by increasing the value of each resource card and by allowing players to draw two resource cards during their turn. Furthermore, the steal resource cards were generalized to allow a player to steal any type of resource and a greater variety of action cards were incorporated to increase game play strategy.

To start the game, the players originally took turns drawing a card from the resource stack. The first player to draw a CO_2 resource card would take the first turn, and the person to their left would go second. This method was too confusing and it was replaced with letting the players decide who went first.

I received multiple feedbacks from teachers and some students that the game instructions were not clear. I decided to redo the instruction sheet to be visually clear and less crowded. (See Appendix E)

Laboratory Experiments

I met with Lynn Tam who provided me with many labs relating to photosynthesis. I chose three labs that reviewed leaf stomata anatomy, the production of sugar through the Calvin cycle, and the release of oxygen gas as a byproduct of the photosynthetic process. All of these topics were addressed in the animation, but some, like the leaf stomata anatomy, were only mentioned briefly. The Calvin cycle and the creation of oxygen were difficult concepts to explain, and so lab activities would help to review and apply these topics for students. Lynn had used these labs previously during her teaching career, and they were already proven to work. These labs were selected because of the concepts they reinforced and because they were unique and not commonly used. Using Adobe®

Illustrator and Photoshop, I created unique images for the labs that were visually similar to the animation. All the labs lesson plans from Mrs. Tam were reworded and arranged to have the same formatted layout.

Ordering Supplies

It was important to provide as much equipment within the suitcase as possible because the materials available to teachers and students in one high school may not be available to teachers and students at a different school. Common scientific equipment such as beakers, Petri dishes, and syringes were obtained from the STARS program. Kristie Conner ordered special items like hot plates, stopwatches, and iodine droppers through Fisher Scientific and Ward's Science. I personally purchased common household items from various hardware stores and supermarkets. Several of these items, such as the hotplates and lamps, were too bulky to fit in the main suitcase. As an alternative, teachers could check out specific equipment that was placed in a smaller auxiliary suitcase. All equipment would be available to teachers upon request free of cost.

Testing the Laboratory Experiments

I tested each lab prior to being added to the suitcase so that I would know first-hand the outcome of the exercises and that they would perform as intended. I tested only the procedural sections of the lab, and did not review the questions or record data for analysis. (See Appendix F)

Lab 1: Stomata, Stomata!

The lab instructions required that the students use use nail polish on the underside of a leaf to create an impression of the leaf stomata. I used a fast drying nail polish that was effective in applying to leaf and removal using a clear tape. The Inch plant leaf did not require any nail polish preparation and its stomata anatomy was clearly visible under the microscope. I found the lab results to be straight-forward and the lab was completed successfully.

Lab 2: Reactions in the Dark!

I purchased a plant from a local hardware store and placed it in my apartment closet away from sunlight for 48 hours. I then took the plant out of the dark closet, prepared a leaf as instructed in the lab, and then placed the plant under continuous light for 24 hours. After 24 hours of light exposure, the leaf was plucked, boiled, and treated in iodine to test the production of glucose. The results were successful with the unexposed areas of the leaf staining dark brown and the cover area staining a light yellow. The use of an opaque material like aluminum foil proved to be effective in attaining maximum results.

I also had the opportunity to observe Bibianna Mendez's AP Biology class at Adamson High School in Dallas, Texas perform this lab. They had used small semi-opaque, circular stickers instead of aluminum foil. However, the results after the iodine test were not consistent throughout the class. Also, plants with abundant white streaks on their leaves did not yield consistent results. As such, I added helpful hints in the teacher’s manual that if aluminum foil is not used, an alternative could be fully opaque stickers, and that plants with lots of white streaks should not be used in the lab for the best results.

Lab 3: Floating Leaf Disks

For this lab, I used a plant that had broad, thin and dense,leaves. Also, it took several attempts to make sure the disks were sufficiently filled with fluid so that they would sink in the initial setup. This step in the procedures section of the lab worksheet was emphasized with diagrams. In my results, only half the leaf disks floated to the surface within the 15 minute timetable. A less dense leaf, such as from a spinach plant, could provide better results. Unfortunately, due to time constraints I was not able to test the experiment using the alternative spinach plant.

Teacher's Instructional Manual

I compiled instructions for all aspects of the science suitcase into a single manual for the teachers to use. The manual contained all the answers to the laboratory exercises and tests, and also included student versions of the material for photocopying in the appendix. I designed the manual to be straight forward and with little visual frills so that teachers could read what they needed to know and move on.

Instead of using photos to accompany the laboratory instructions, I created diagrammatic images using Adobe® Illustrator. These graphics were placed at important steps of the laboratory instructions. This method ensured the image quality would not be lost when photocopied and the length of the instructions was reasonable. The manual also included the full narration script of the animation for the teacher's reference.

Included in the photosynthesis animation DVD case for the teacher's convenience is a digital copy of the manual, labs, and quizzes added to a CD. A QuickTime video explaining the board game was also included in the CD.

Pre-test and post-test

To help teachers gauge the students' learning of the photosynthetic concepts, I created a pre-test to be given at the beginning of the instruction period, and a post-test that was to be administer after the lesson plan was completed. Lynn Tam provided questions and materials.

The Suitcases and Containers

Choosing the Suitcase

After I purchased all the lab materials and completed the board game, a physical container was needed to transport everything together. Initially, the Dallas Museum of Nature and Science purchased a Pelican™ Case 27.70" x 20.98" x 15.50". Although these cases are well-built and sturdy, they are heavy and bulky. The case and foam weighed 36 pounds; added with an additional 30 pounds of equipment and the whole case would weigh almost 70 pounds. The case was very difficult to load into a car and would barely fit through a passenger side door.

As such, I opted to purchase a Versailles hard-case travel suitcase made by Travel Concepts with the dimensions of 21.5” x 14.5” x 30.0” and weighing 13.2 pounds. This suitcase is lighter and is less cumbersome, while still providing the durability and sturdiness. For extra insulation, I used foam from the Pelican suitcase and lined the interior of the Versailles suitcase. Although the Versailles case may not survive extreme weather conditions, it is sufficient to provide protection from everyday transporting from the car to the classroom. A second, smaller suitcase with the dimensions of 25.0” x 17.5” x 11.5” was also purchased as the auxiliary suitcase for optional laboratory equipment.

Choosing the Containers

The containers holding the lab supplies were purchased from the Container Store. I brought an example of each piece of lab equipment to the store, and I went through each store aisle testing the sizes of various containers until I found ones that fit best.

Fitting the Containers inside the Suitcases

I used Pick ‘N’ Pluck™ foam that was from the Pelican suitcase to line the inside of the suitcase. This foam was perforated into ½ inch squares for easy removal and was customizable to fit any item. I then added the containers in various configurations until I found an acceptable fit for all the components. Some containers fit better than others, so I had to make a couple trips to the Container store until I found the exact containers that fit my needs.

Labeling the Containers

Labels for the containers were printed from the computer on to Avery® Permanent I.D. Labels. Each container was labeled with the item name and the lab number that they were used for. I then sealed the each label with clear packing tape to protect from water damage.

Photographing the Containers and Suitcases

The containers and suitcases were all photographed to be included in the teacher's instructional manual. These images would accompany instructions detailing how to remove and replace materials used in the suitcases.

Suitcase Labels

I created labels for the suitcases in Adobe® Illustrator and adhered them to the front side of each suitcase. The labels identified that the suitcase contained the Light! Carbon! Action! Photosynthesis components and also indicated whether it was the main suitcase or auxiliary suitcase.

Conclusion

In order to create an effective portable Science Suitcase on photosynthesis designed to supplement the current high school biology curriculum in the Dallas Independent School District, several objective were met. I designed a 2D animation, an interactive board game, three laboratory experiments, a teacher's instructional manual, and included a physical plant cell model. These components were all incorporated into a main Travel Concepts™ suitcase and a smaller auxiliary suitcase. The Science Suitcase was then presented to a group of teachers for evaluation.

CHAPTER 4
Results

Presentation and Testing

I presented the science suitcase in front of 20 teachers at a STARS Symposium held on December 5, 2009. Approximately 1 hour and 15 minutes was allotted for the presentation. I gave the teachers a handout of all the components that were in the science suitcase and discussed each section. I presented the animation, although, it was not fully completed yet. The teachers watched the first 5 minutes of completed animation and a rough cut of the storyboard art for the remaining 20 minutes. I then demonstrated the board game and had the teachers break up into group the play for approximately 30 minutes. Finally, I gave a demonstration of two the labs, and had the teachers run through a third lab.

On December 9, 2009 one of the biology teachers from the STARS Symposium invited me to Adamson High School in Dallas, Texas to test the board game, Sugar Rush!, in an AP Biology classroom. I demonstrated the rules and then, the class of 20 students was given 40 minutes to play the game.

At the end of each presentation, a survey was handed out the participants to fill out. The teachers completed a survey that asked their opinion on the contents of the science suitcase. The students responded to a survey that asked only about the board game.

Survey Development

I created a survey to record their responses in order to test if the teachers found the materials in the science suitcase to be effective as a learning tool.. The teacher survey started with 4 questions that determined the demographic of respondents and the resources available to them at their schools. These questions were followed by 16 statements that asked about the contents of the science suitcase. These statements were based on a 5- point Likert Scale that ranged from strongly agree to strongly disagree. The teachers would circle the sentiment that most closely responded to their attitude toward the statement. Space for additional comments was also provided below each statement. At the end of the survey, I asked the teachers to choose which components of the science suitcase they would use in their classroom, which component they felt was most effective, and which component they felt was least effective.

Although the objective of this thesis was to test the response of teachers to the materials in the science suitcase, I was given an opportunity to survey student responses' to the board game. Teachers are the end users of the science suitcases, but students are the final recipients of the material. The student survey was similar to the teacher survey, but only asked questions about the board game. It also contained 7 statements that were based on the 5-point Likert Scale.

Survey Distribution

The teacher survey was given to 20 teachers at the STARS symposium. They were asked to view the presentation, fill out the survey, and return it to me. Fourteen of the teachers filled out the survey. The student survey was given to 20 students at the Adamson High School. They were asked to play the board game, fill out the survey, and return it to me. Fifteen surveys were given out and returned.

Survey Question Results

The questions are in bold, the response is in italics, followed by an evaluation of the responses. The following is the teacher survey administered December 5, 2009 at the STARS symposium.

Teacher Survey

1. **Are you a: Teacher Administrator**

   Other:_____________

   14 responded as teachers.

   This question was to see which respondents were, in fact, teachers.

2. **Do you currently teach Biology? Yes No**

   a. **If yes, what grades? ____________**

   9 responded as currently teaching biology.

   6 taught only 9th Grade

   2 taught 9th and 10th Grade

   1 taught 9th and 11th grade

   1 taught 9th and 12th grade

1 taught 7th grade

4 did not respond.

This question was to define which respondents were teaching biology, and therefore, would most likely be using the science suitcase. The second part of the question was to identify who would be teaching the material's target audience, which is 9th and 10th graders.

3. **Do you have access to a DVD player or a project to play a DVD in your classroom? Yes No**

   All responded with yes.

   Since the photosynthesis animation would be playing from a DVD, it was important to see if the majority of teachers had DVD players in their classrooms.

4. **Do you have access to light microscopes for student use? Yes No**

   All responded with yes.

   One of the labs required microscopes to perform the experiment, and it was important to see if microscopes were readily available to students in the classroom.

List of Statements:

1. **The graphics for the animation and board game are appropriate for the high school audience.**

   9 responded with 5, Strongly Agree

   4 responded with 4, Agree

   1 responded with 3, Neutral

The overall positive response confirms that teachers would believe that their students would respond well to the graphical style used in the board game and animation.

Comments:

Very nice showing the example of oxidation/reduction

[The game] seemed somewhat confusing at first.

Very good for honors biology

The game instructions was revised to be clearer and an instructional video was included to add extra clarification. Some of the concepts in the latter half of the animation were more in depth. To give flexibility to teachers who may instruct a regular biology class, chapter markers were placed at each subject on the DVD. This way the teacher could choose to skip a certain advance concept or replay basic concepts.

2. **The animation clearly explains the basic concepts of photosynthesis.**

   8 responded with 5, Strongly Agree

   5 responded with 4, Agree

   1 responded with 3, Neutral

   Most responded positively, indicating that they identify and follow important concepts presented in the animation. The positive response may have been stronger if they had the opportunity to view the completed version of the animation. Although one person responded as neutral, this person later selected the animation as the most likely component to use in the classroom, and as the most effect component of the suitcase.

Comments:

Great animations- lots of fun ones for the students to watch

Students can easily understand; a little fast; can you put a slide for chapters?

To address the second comment, the pace of the animation was slowed down and chapter markers were included in the DVD.

3. **The Electron Transport Chain is effectively introduced in the animation.**

5 responded with 5, Strongly Agree

6 responded with 4, Agree

2 responded with 3, Neutral

1 did not respond

Most teachers agreed that this was an important concept and it was presented well in the animation.

Comments:

Too much jump from structure of chloroplast to ETC

Too much molecular detail in ETC for freshman level

good job ☺

Very difficult for 9th grade - explained well

Transitions from the out cellular layer, to the cell, and finally to the molecular layer was fully developed in the final animation. Teachers were given the option to skip this part of the animation in the DVD if they believed the level of detail was too great for their students.

4. **The basic concept of the Calvin Cycle is understood in the animation.**

3 responded with 5, Strongly Agree

8 responded with 4, Agree

2 responded with 3, Neutral

1 did not respond

The general positive response to this statement indicates that most teachers agree that this was a proper introduction of the Calvin Cycle.

Comments:

Depends on the animation - looks like it will.

Again, too much detail for freshmen level, but great for Honors or AP level

Review component was nice, but need review quizzes.

The viewers were only able to view the storyboard stills for this section. The response may have changed if they had seen the final version. Quizzes are also available in the final animation. The teacher is also given the opportunity to skip this section if the information is too advanced.

5. **The graphical symbols are beneficial for remembering the Photosynthetic Equation.**

7 responded with 5, Strongly Agree

6 responded with 4, Agree

1 responded with 3, Neutral

A overall positive response implies that the use of graphic symbols to represent each element in the photosynthetic was effective.

Comments:

Help[ful to] visualize the process - like the "happy molecules"

CO_2 *and* O_2 *graphics too similar- both are clouds?*

For that graphics representing CO_2 and O_2, I changed the CO_2 cloud to have a dashed outline and a gray color, while the O_2 cloud maintained a solid outline and white color.

6. **The board game instructions are clear and easy to follow.**

   1 responded with 5, Strongly Agree

   8 responded with 4, Agree

   3 responded with 3, Neutral

   1 responded with 2, Disagree

   Most respondents agreed to the clarity of the game instructions. But from my personal observation watching the teachers play, some people became confused when they did not read the instructions closely. Revisions to the instructions were made. (See Appendix E)

   Comments:

   Once we played the game, it was easy to follow - it does need to be demonstrated.

   Need to explain that you draw both cards each turn.

   To add clarity, an instructional video explaining the rules and game play is included in the DVD package.

7. **The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.**

   4 responded with 5, Strongly Agree

   8 responded with 4, Agree

   2 responded with 3, Neutral

The overall response to the board game was positive. Most teachers understood that the carbons would return to the beginning, allowing the cycle to be repeated.

Comments:

Again the actual details are too much for a freshmen level.

This comment is helpful to show that at even the most basic level, the application of chemistry to biology may be too much to introduce at a freshmen level.

8. **The use of competition will keep students involved and interested in the game.**

8 responded with 5, Strongly Agree

6 responded with 4, Agree

There is a strong positive response validating the style of game play and the use of competition may be effective.

Comments:

Just a lot of fun in general even without learning about [the] Calvin Cycle.

My honors kids would love to play if we have time.

9. **The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.**

8 responded with 5, Strongly Agree

6 responded with 4, Agree

The positive response confirmed that using a similar graphic style would increase possibility that students would learning the basic concept of the Calvin cycle.

Comments:

Not too strong or weak of a connection.

This comment may be due to fact that all the animation graphics were still in storyboard sketch form at the time of viewing.

10. **The lab instructions are clear and easy to follow.**

    3 responded with 5, Strongly Agree

    10 responded with 4, Agree

    1 did not respond

    The overall positive response shows that, although the layout design was compact, teachers were able to follow along with the instructions.

    Not sure about floating leaf disks lab. Students would get frustrated with vacuum part.

    In response to this tricky step in the Floating Leaf Disk Lab, extra emphasis was placed on the need to hold the vacuum in the syringe for at least ten seconds. (See Appendix F)

11. **The diagram illustrations are beneficial to the lab instructions.**

    5 responded with 5, Strongly Agree

    6 responded with 4, Agree

    1 responded with 3, Neutral

    2 did not respond

    Based on the positive responses, the diagrams were effective in clarifying lab instructions.

    Comments:

    Would like student answer sheet in Microsoft Word.

    A electronic copy of the labs is be included in the Instructional CD.

12. **The lab experiments are beneficial in teaching students about photosynthesis.**

    8 responded with 5, Strongly Agree

    6 responded with 4, Agree

    The stronger positive response indicates that the teachers agree with the selection of labs included in this science suitcase

13. **The components of the suitcase are appropriate for the high school audience.**

    7 responded with 5, Strongly Agree

    7 responded with 4, Agree

    An overall positive responds confirms that the materials in the suitcase are applicable to high school level, although the comments show that more advanced biology classes may benefit more than the standard or remedial classes.

    Comments:

    Watch levels of instruction - freshmen regulars are much different than AP seniors!

    Appropriate if on different levels- regular/honors

    These comments show that the information level of the suitcase materials may be a little above the 9th grade target audience. This emphasizes the need for versatility of the suitcase materials so that it can fit into any level teaching curriculum.

14. **The components of the suitcase will enhance my current curriculum for teaching photosynthesis.**

    8 responded with 5, Strongly Agree

5 responded with 4, Agree

1 responded with 3, Neutral

The strong positive response confirms that there is material in the suitcase that is applicable to the teacher's own curriculum. This statement was helpful to determine the actual utility of the suitcase components to a classroom.

Comments:

Really neat to see something new in this area.

15. **The components of the suitcase will help students with the TEKS and TAKS.**

    6 responded with 5, Strongly Agree

    4 responded with 4, Agree

    4 did not respond

    The overall positive response to this statement suggests that the material will help students meet the TEKS requirements of photosynthesis. So, the students may be successful on the TAKS answering questions concerning photosynthesis. It is unclear why some teachers did not respond to this question, even though they were 9th grade biology teachers.

16. **I would recommend this Science Suitcase to other teachers.**

    6 responded with 5, Strongly Agree

    4 responded with 4, Agree

    4 did not respond

    The strong positive response indicated to me that this suitcase was successful enough to be used the future, and teachers see it as a use resource to recommend to others.

Additional Questions

1. **Which component(s) would you most likely use in your classroom?**

   13 Responded Animation

   6 Responded Board Game

   11 Responded Leaf Stomata Lab

   9 Responded Floating Leaf Disk Lab

   8 Responded Dark Reactions Lab

   This was to also test the actual utility of the suitcase materials to a high school classroom. The was a general positive response to all components except for the board game. This may be because it is initially difficult to understand how to play the game, and class time is too limited to play the game entirely.

2. **Which component(s) is most effective?**

   7 Responded Animation

   5 Responded Board Game

   5 Responded Leaf Stomata Lab

   5 Responded Floating Leaf Disk Lab

   5 Responded Dark Reactions Lab

   The animation received the highest marks, helping to validate its effectiveness as a teaching tool for teachers.

   Comments:

   Effective with honors (class), if time to complete game.

   I will use this for exit level TAKS review with my 11th and 12th graders.

3. Which component(s) is least effective?

1 Responded Animation

5 Responded Board Game

0 Responded Leaf Stomata Lab

1 Responded Floating Leaf Disk Lab

1 Responded Dark Reactions Lab

The board game received the most negative response from this statement. This is most likely due to teachers not understanding the rules and game play, and that the addressing a topic that was beyond the scope of a 9th academic level.

Comments:

Time is a factor [to play the game].

Charts of Survey Results

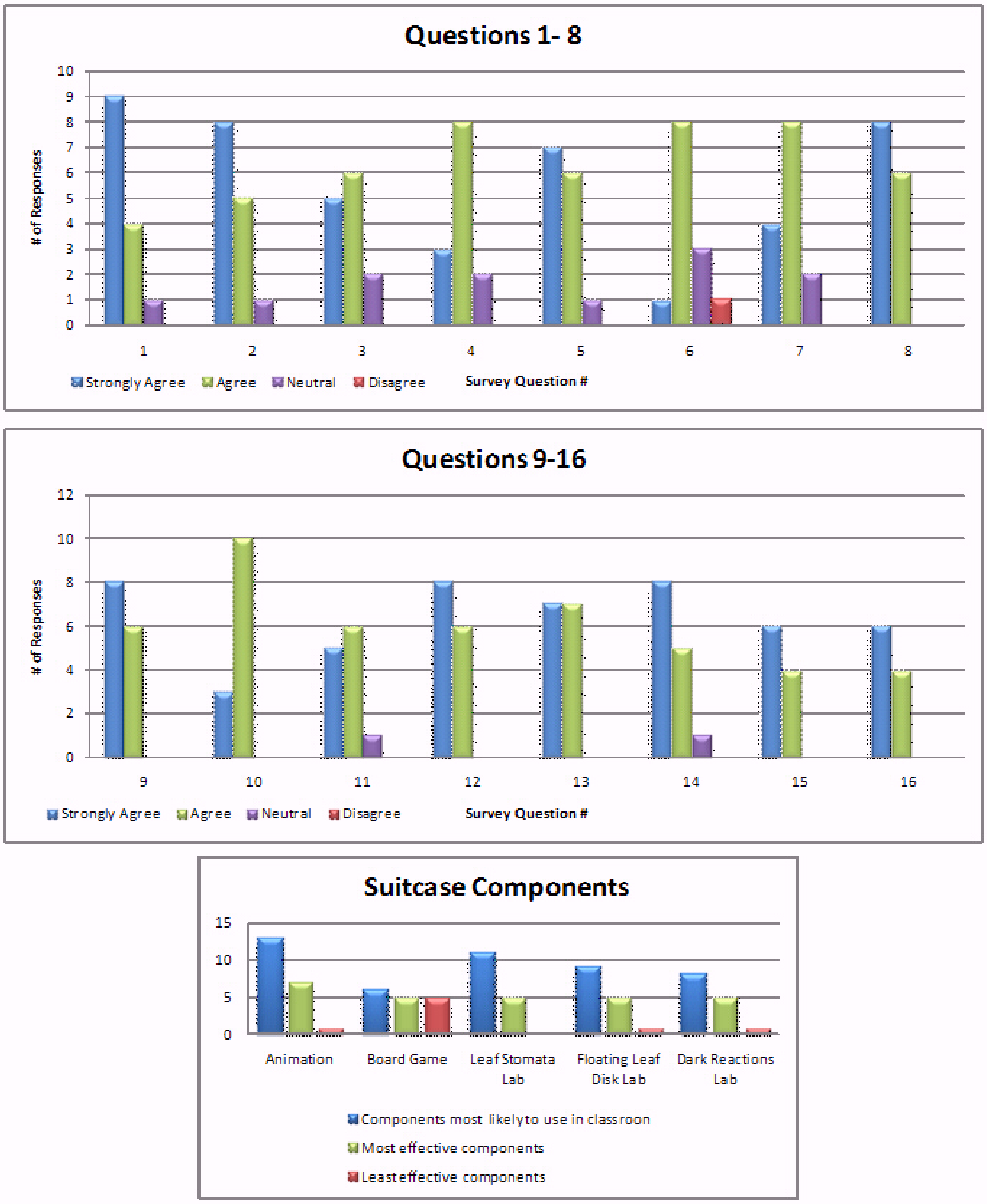


FIGURE 4-1. SUMMARY OF SURVEY RESULTS - TEACHERS

The following is the student survey administered December 9, 2009 to the AP Biology class at Adamson High School.

Student Survey

1. What is your grade level?

   3 Responded 10th Grade

   12 Responded 12th Grade

   This was to determine who respondents were. It was interesting to see there were three students who were in the 10th grade, but none from the 11th grade.

2. Media your teacher has used to teach photosynthesis:

   7 Responded Video

   10 Responded Textbook text/images

   1 Responded Poster Diagram

   9 Responded Activity

   7 Responded Labs

   This question was to explore what types of teaching media were being used in the classroom, and if a board game activity would be utilized.

List of Statements:

1. The graphics on the board game are appropriate for a high school audience.

   13 responded with 5, Strongly Agree

   2 responded with 4, Agree

   The strong positive response confirms that the graphics are interesting and acceptable to high school students.

2. The board game instructions are clear and easy to follow.

   10 responded with 5, Strongly Agree

   3 responded with 4, Agree

   2 responded with 3, Neutral

   Though the responses show that the game instructions were easy to follow, based on my observations of the students, I noticed that it still took some time for the students to understand how to play the game. Only after the instructions were clarified and the students started to play the game, did the students really grasp the game instructions. This reaffirms the necessity to make the board game instructions even clearer. Furthermore, an instructional CD was added to help add more clarity to the game play.

3. The instructions on the game cards are clear and easy to follow.

   13 responded with 5, Strongly Agree

   2 responded with 4, Agree

   Although the overall game instructions required revision, this positive response indicated that the action and resource cards were proficiently labeled.

4. I have a basic understanding of the Calvin Cycle.

   12 responded with 5, Strongly Agree

   3 responded with 4, Agree

   This was to determine whether they would be able understand the underlying premise of the board game.

5. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

   12 responded with 5, Strongly Agree

   3 responded with 4, Agree

   The positive response to this question confirms that the students are able to make the connection to concepts they learned in class with the game.

6. The board game is successful in showing that the Calvin Cycle requires resources to function.

   13 responded with 5, Strongly Agree

   2 responded with 4, Agree

The overall response was positive that the game emphasized the necessity of resources to drive the Calvin Cycle reaction.

7. The use of actions cards enhanced the game play.

   11 responded with 5, Strongly Agree

   4 responded with 4, Agree

   The positive response to this question confirms that the use of action cards added variety to game play.

8. The pace of the game was:

   15 Responded with a "good pace"

   The statement was confirmed with complete agreement. However, the students did not finish the game within the allotted class time and so the pacing of the game is still questionable. As such, if teachers feel the classroom time is insufficient to complete two rounds of the game (i.e. make one sugar), then it's recommended in the teacher's instructional manual to have students complete just one round (i.e. make half a sugar). Repetition of the round would further the students understanding of the Carbon Cycle; however, one round should be sufficient to get the point across, if time is a factor.

Charts of Survey Results

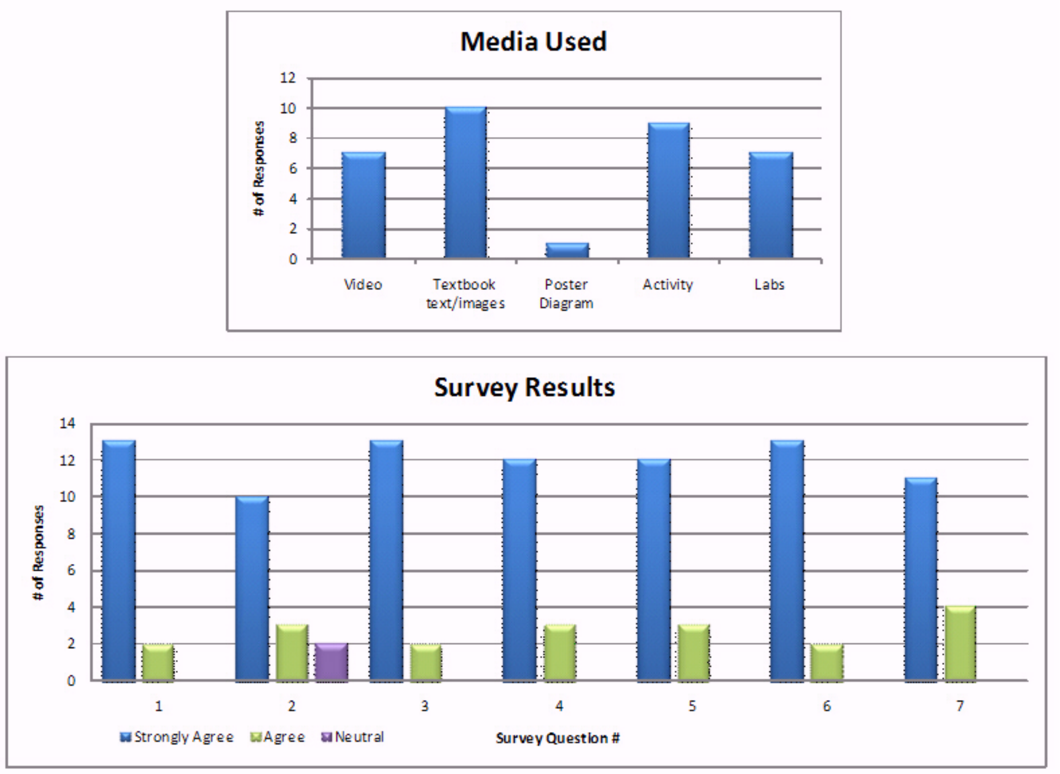


FIGURE 4-2. SUMMARY OF SURVEY RESULTS - STUDENTS

Conclusion

Drawing from the responses of the teacher surveys and the student surveys, the overall reception to the materials in the suitcase is positive. The animation is shown to be the strongest component, resulting in the highest likely component that a teacher would use in their curriculum. Some components like the board game received mixed responses and that reflected in a lower likelihood that teachers would be utilized it in the classroom. However, given the appropriate audience and clear instructions, the board game has great potential for as an effective teaching tool. This could be concluded from the overwhelming positive response of the AP Biology student surveys. To test the true effectiveness of the suitcase, a pre-test and post-test needs to be administered over the course of a few years. Currently the number of feedback surveys is statistically insignificant. More students need to be tested to be able to definitely conclude of the success of the suitcase.

CHAPTER 5
Conclusions and Recommendations

Project Summary

I designed and produced a teaching aid, (i.e. a traveling science suitcase), for use by high school teachers in the DISD to present the concept of photosynthesis to 9th and 10th grade students. Using a narrated 2D animation and video, this suitcase explains the concepts of light absorption, conversion of light energy, and storage of energy. Interactive materials in the form of a physical cell model and a group board game are included to help the students review and reinforce the information. The suitcase also includes laboratory exercises.

To achieve this goal, I met several objectives. I conducted an initial survey of teachers and students to determine their current level of understanding and teaching methods regarding photosynthesis and the teachers' needs for increased effectiveness of teaching the concepts. I investigated materials concerning the current modalities of teaching K-12 students and the effectiveness of using visual aids as part of the teaching curriculum. I researched the standards required by the TEKS.

I then formulated a plan that would address the overall concepts of photosynthesis and specific topics using the following media: a narrated 2D animation, an interactive board game, laboratory exercises, physical plant cell model and pre- and post- tests. Finally, I combined all the elements into a traveling Science Suitcase that was presented to a workshop for teachers. A formative evaluation of the science suitcase was conducted using a survey. The results of the survey would determine whether the final product met the goals and objectives planned for this project.

Discussion

The overall response to the Science Suitcase and to its utility as a teaching aid was positive. Most of the respondents either agreed or strongly agreed to almost all of the statements. All the teachers indicated that they would use at least one component of the suitcase in the classroom. The animation was shown to be the strongest component, resulting in the highest likely component that a teacher would use in their curriculum. Some components like the board game received mixed responses and is probably reflected in a lower likelihood that teachers would utilize it in the classroom. However, with the right audience and clear instructions, the board game has great potential as an effective teaching tool. This could be concluded from the overwhelming positive response of the AP Biology student surveys.

This suitcase was less clear in addressing the common concern from the teachers that the level of information was too high for the 9th grade level. Most 9th graders have little prior knowledge of chemistry and basic principles of molecular biology, and so portions of the animation and the board game may have been too much information. However, in my opinion, even if the 9th graders do not need to know all the concepts presented in this suitcase, they are at least being exposed to untold intricacies of life that surrounds them. This new found awareness could lead to the ultimate goal of stimulating some students to pursue science at a higher level.

The majority of teachers agreed that the material would enhance their teaching curriculum and help students with the TEKS and TAKS. Based on the positive results of the surveys, the goal and objectives to create a useful science suitcase for teachers was essentially completed.

Suggestions for Further Research

To test the true effectiveness of the suitcase, a pre-test and post-test needs to be administered to students over the course of a few years of use. Currently the number of feedback surveys is statistically insignificant. Surveying more teachers and students would definitively validate the utility of this science suitcase. It would be usefully the track the results from the TAKS and to see if there is an improvement in AP science class enrollment. There also needs to be an investigation on the impact of incorporating interactive flash games, or computer games as a teaching medium of photosynthesis.

BIBLIOGRAPHY

"Chapter 112. Texas Essential Knowledge and Skills for Science Subchapter C. High School." Texas Education Agency. 4 Sept. 2008. 25 Sept. 2008 <http://www.tea.state.tx.us/rules/tac/chapter112/ch112c.html#112.43>.

Chatman, Leon. “Photosynthesis” PowerPoint Presentation. 2008

Dallas Independent School District. Projected Enrollment 2008-09 School Year. Raw data. 2008.

Gesn, Randy, Shawn Thomas, and Rachel Au. Advanced Placement and International Baccalaureate Examination Results in Texas 2006-07. Department of Assessment, Accountability, and Data Quality, Texas Education Agency. Austin, TX: Texas Education Agency, 2008. 95-96.

Goodman, Robert, and Marsha Goodman. “Photosynthesis” PowerPoint Presentation. 2007

Graham, Parry. "Improving Teacher Effectiveness through Structured Collaboration: A Case Study of a Professional Learning Community." Research in Middle Level Education Online 31 (2007): 1-17.

Groleau, Rick. "Illuminating Photosynthesis." Nova Online. Nov. 2001. 02 Nov. 2008 <http://www.pbs.org/wgbh/nova/methuselah/photosynthesis.html>.

Harrison McArthur, Brenda L. "Enzyme Instigator: A Portable Suitcase Exhibit for Ninth Grade Biology." Thesis. Dallas, Texas: The University of Texas Southwestern Medical Center at Dallas, 2008. 9-11.

Hulsey, Jennifer. “Organelle Extravaganza: A Portable Suitcase Exhibit for High School Biology Students.” Thesis. Dallas, Texas: The University of Texas Southwestern Medical Center at Dallas, 2008. 9-11.

Hopkins, Gary. "Photosynthesis: Don't "Leaf" Out Fall's Most Valuable Lesson." Education World. 22 Aug. 2008. 02 Nov. 2008 <education world>.

Johnson, George B., and Peter H. Raven. Biology: Teacher Edition. Austin, Texas: Holt, Rinehart and Winston, 2004. 94-103

Kátai, Zoltán, Katalin Juhász, and Alpár K. Adorjáni. "On the role of senses in education." Computers & Education 51 (2008): 1707-717.

Kyrk, John. "Photosynthesis." Cell Biology Animation. 16 Nov. 2007. 3 Nov. 2008 <http://www.johnkyrk.com/photosynthesis.html>.

“Learning Styles Explained” LdPride. March 23, 2009 <http://www.ldpride.net/learningstyles.MI.htm>

Mayer, Richard E. "The Promise of Multimedia Learning: Using the Same Instructional Design Methods Across Different Media." Learning and Instruction 13 (2003): 125-39.

McClean, Phil, Alan White, Brian Slator, Roxannae Roger, and Christina Johnson. "Photosynthesis." Virtual Cell Animation Collection. 2007. Molecular and Cellular Biology Learning Center. 02 Nov. 2008 <http://vcell.ndsu.nodak.edu/animations/photosynthesis/movie.htm>.

Miller, David. Methods and Materials for Teaching Biological Sciences. New York and London, NY: McGraw-Hill Book Company, Inc., 1938. 4-19.

"National Teaching Aids: Photosynthesis Made Easy." Science Kit Elementary. 2005. 31 Oct. 2008 <http://skelementary.com/national-teaching-aids%3a-photosynthesis-made-easy/p/ig0020780/>.

Nemerow, Laurence G. "Do classroom games Improve Motivation and Learning?" Teaching and Change 3 (1996): 356-66.

O'Day, Danton H. "Animated Cell Biology: A Quick and Easy Method for Making Effective, High-Quality Teaching Animations." CBE- Life Sciences Education 5 (2006): 255-63.

O'Day, Danton H. "The Value of Animations in Biology Teaching: A Study of Long-Term Memory Retention." Life Science Education 6 (2007): 217-23. CBE. 4 Oct. 2007.

Orrl, Larry, and Govindjee. "Photosynthesis and the Web: 2008." Photosynthesis Research 91 (2007): 107-31.

McHenry, Ellen. “Photosynthesis Formula Game” Ellen McHenry’s Basement Workshop (2007) March 24, 2010 <http://www.ellenjmchenry.com/sitebuildercontent/sitebuilderfiles/photosynthesisformulagame.pdf>

Sener, Melih, John Olsen, and Klaus Schulten. "Atomic-level Structural and Functional Model of a Bacterial Photosynthetic Membrane Vesicle." Proceedings of the National Academy of Sciences 104 (2007): 15723-5728.

APPENDIX A:
Preliminary Surveys

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 8th Grad Science

Do you teach within the DISD? [✓ Yes] No

Do your students have access to computers in class? [✓ Yes] No if I schedule them

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? [✓ Yes] No

If yes, how often do you use the Smart Board as an interactive tool? It just got installed but I have not used it

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No But I would LOVE more

Please list:

Games - flipping coins, using beans to allele frequency changes

Are they effective? usually, somewhat

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

The whole we did not come from monkeys thing

Students (and most non science people in general) fail to understand that evolution happens at the species level, not the individual level

Many inner city Kids have what I almost Medieval types of beliefs about science

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : just posters

Are they effective? Could use something more

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

the cycles (esp back 'n' forth with respiration

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Mostly just allele frequency

What kind of labs do you conduct to teach about Photosynthesis?

Please list: elodea in a flask with H_2O + Baking Soda - to see bubbles of O_2 given off

Have you ever used an interactive educational flash game in your class? [✓ Yes] No

Was it effective (or relevant)? Yes - a game called I have, who has -

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

all the above - anything is better than paper + text book!

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach?

Do you teach within the DISD? [✓ Yes] No

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

natural selection

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list :

visual aids for chlorophyll & eletron transport chain

Are they effective?

for some students

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

oxygen production (drives me crazy that so many fail to understand this)

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: none

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Oxygen production by elodea

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes No depends on the year

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)? models & games

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Kathy Bodner
972-931-2187
experience wit
games & manip
ula

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 9th - Pre-AP Biology

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

work
469-593-5012

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? [✓ Yes] No

If yes, how often do you use the Smart Board as an interactive tool? once a month

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: video, (alleles) games
manipulatives, games, animations
(genetic drift)

Are they effective?

yes!

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

natural seletion
theories

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : manipulatives
models

Are they effective?

yes!

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Calvin cycle! Photosystem II &
chemistry part I

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: — Archeopteryx Lab (Fossil)

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Effects of Photosynthesis

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? Yes [✓ No]

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes [✓ No] We are busy teaching the TAKS test

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

anything but what we
are doing

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

yes! Hand-on, labs,
fun activites
make it real for
them.

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 9th - Biology

Do you teach within the DISD? [✓ Yes] No

Do your students have access to computers in class? Yes [✓ No]

Do they have access to internet in class? Yes [✓ No]

Does your class have a Smart Board? [✓ Yes] No

If yes, how often do you use the Smart Board as an interactive tool? every day

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

everything - we don't have enough time to teach evolution; just introduce the concept and some terminology

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : animations from one of the biology websites; games - Jeopardy game

Are they effective? Yes

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Calvin Cycle

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: None

What kind of labs do you conduct to teach about Photosynthesis?

Please list: None

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)? teaching outdoors field trips using models games and anything that will help students understand the concepts

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

more hands-on activities

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach?

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No] I'm on list to get one!

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: Visual for peppered moth
model-lab for natural selection - related to
sickle cell anemia

Are they effective? yes, however, see misconception below -

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Geological time - how long Earth has been here; variations exist - misconception that organisms change to environment.

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Huge model (paper) of Chloroplast
Visuals - PP on light reactions

Are they effective? Yes

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Calvin Cycle - often reduced so much that understanding is not very indepth.

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Lab: Natural Selection - backgrounds change how impact survival of species

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Leaf lab - crossection
Stomata Lab -
Chromatography - pigment analysis

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

I would do any of the above.

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

You may contact me at 214-334-4664 I teach PreAP Bio
HPHS
Highland Park High School

filled out one 2 months ago

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? soph. college microbiology + anatomy + physiology

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? Yes [✓ No]

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

don't really teach evolution

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

NA

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

NA

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes No NA

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 9th/10th BIOLOGY + HONORS BIOLOGY

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool? NA

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: musical chairs

Are they effective? Easy kind of - but weak...

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

vocabulary... Homologous, vestigial

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

all of it – the equation (they don't make the connection between the words + the formulas...)

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

YES! The more connections they can make + the more engaged they are, the better.

What kind of labs do you conduct to teach about Evolution?

Please list: Antibiotic Resistance LAB

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No + we try, but there is never enough times + some students are lost

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

all of the above sound great → key is getting them engaged.

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 7th grade - Life Science 8th grade Earth

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? Yes [✓ No]

Do they have access to internet in class? Yes [✓ No]

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: Natural Selection game
virtual labs

Are they effective? yes

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Evolution or Creationism

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Overheads
Virtual labs

Are they effective? Somewhat

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

They often think Carbon dioxide turns into Oxygen

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Elodea + light and dark

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 9th & 12th

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? Yes [✓ No] only 1 in room

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool? —

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: diagrams of evidence — fossils, embryos, homologus structure

Are they effective?

Sometimes

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

that it is a very small scale & slow process (doesn't happen in one generation)

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list : —

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

the idea that plants can actually make their own food from just H_2O, CO_2 & sun (they don't get chemistry yet)

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: camoflaged animals survive & reproduce (using goldfish crackers,

What kind of labs do you conduct to teach about Photosynthesis?

Please list: mini labs with one reactant missing each time (sun-no sun, vaseline on leaf so no CO_2, etc.)

look at stomata on microscope

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes [✓ No]

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)? go outdoors, use models & games

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 9-12

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: POWER POINT

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : POWER POINT

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes [✓ No]

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Field Trip

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? Biology

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

They do not want to think we came from apes

Some only want to go with creationism so they turn off the entire thing sometimes

Hard concepts: analogous, homologous because it requires effort to learn.

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : united streaming videos

cartoon cut out paper Lab

Are they effective?

More than lecture

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

The equation.

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

paper Lab analogous & homologous

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Colored light lab is awesome

Have you ever used an interactive educational flash game in your class? Yes No

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes [✓ No]

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

all of the above

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Less TAKS - more time for Labs

hands on models help

Games help

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 9th PreAP Biology

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No] (2 at the campus, though)

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: 3x3 square to match terms w/ definitions, videos, genetic drift game

Are they effective? for PAP, yes & sometimes with regular

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Natural Selection & some of the theories

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list: formula cut apart that they put together, thylakoid membrane on the floor that they walk the e^- through, animations

Are they effective?

yes

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Steps in order, photosystem II + I

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Fossil lab, camauflage/Natura Selection Lab, Peppered Moth Simulation on Computer

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Dark Reactions, Effects of Photosynthesis, Chromatography

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes [✓ No] Too busy teaching TAKS

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)? games, models, field trips with PAP <u>only</u> (not regular)

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

★ Games are the most important for at risk students

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? SCIENCE, EIGHTH GRADE

Do you teach within the DISD? Yes [✓ No] RICHARDSON I S D

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list:

BRIEF VIDEOS
PHOTOS FROM VARIOUS SOURCES

Are they effective?

REASONABLY SO. I'M ALWAYS LOOKING FOR MORE/BETTER RESOURCES.

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

NATURAL SELECTION

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes No

Please list :

BRIEF VIDEOS
POWERPOINT PRESENTATIONS
STUDENT-GENERATED ILLUSTRATIONS
DIAGRAMS
LABS for STUDENTS TO LOOK
STRUCTURES INVOLVED IN
PHOTOSYNTHESIS
3-D FOLDABLES

Are they effective?

REASONABLY SO

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

· IDENTIFICATION of CHLOROPLASTS
· THAT NOT ALL PIGMENTS ARE GREEN

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

ACTIVITIES MORE THAN LABS. I'D LOVE TO KNOW OF AN EASILY ACCESSIBLE LAB ABOUT THIS TOPIC THAT I CAN DO WITH EIGHTH GRADERS

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

SEE FRONT OF THIS PAGE.

Have you ever used an interactive educational flash game in your class? [✓ Yes] No

Was it effective (or relevant)?

REASONABLY SO

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

ALL OF THE EXAMPLES LISTED ABOVE + SOME FORM OF STUDENT-GENERATED PRESENTATION (i.e. ILLUSTRATIONS, FOLDABLES, ORAL PRESENTATION, RESEARCH PAPERS)

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach?

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list:

Dataprojector
Powerpoints

Are they effective?

yes

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Genetic understanding and how it leads to adaptations.

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list :

Power point
Virtual Lab / [illegible] Glencoe

Are they effective?

yes
Need Better.

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

PS I / PS II

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Paper Chromotagraphy of pigment
Pigments LAB
Phototrophic / Taxis
Rate of photosynthesis Lab.

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Teaching outdoors

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach?

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? [✓ Yes] No

If yes, how often do you use the Smart Board as an interactive tool?

My district is still installing the Board.

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

I teach in the health Science Technology Ed program so I do not have much of a chance to teach Evolution + photosynthesis in my Pathophysiology Anatomy + physiology or Medical microbiology classes

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

outdoor teaching, field trips, model, games
Virtual Lab and model would all be excellent
tools to use in teaching

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? 6th grade Science (7-8 Previous 3 years)

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? [✓ Yes] No

Do they have access to internet in class? [✓ Yes] No

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No] Evolution not in curriculum standards for 6th grade

Please list:

8th grade- used Socratic seminar

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

student are more familiar with the creatintism ideas/ theories because of religous home life structure,

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list :

Power Point

Cells alive website has photosynthesis link

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

younger students - chemistry - equation

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: None at present

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Use microscopes to view Elodea Plant/Leaf
View cytoplasmic streaming - green organelles

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)? ↳ ?

use e-instruction

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Yes!

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

(NEW SCIENCE)

- Texas textbooks are on hold waiting for the board to decide on the Evolution!

- Regardless of curriculum, teaching Evolution

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach? College - Inquiry Science

Do you teach within the DISD? Yes [✓ No]

Do your students have access to computers in class? Yes [✓ No]

Do they have access to internet in class? Yes [✓ No]

Does your class have a Smart Board? Yes [✓ No]

If yes, how often do you use the Smart Board as an interactive tool?

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: EVOLUTION video Series (PBS)
Activities on EVOLUTION website

Are they effective?

Yes.

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

That the process is fact, not theory.
Molecular basis of evolution.

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Foamy models of chloroplast with assorted foamy pieces to represent parts + moleculs in Light Reactions. Patterned after an illustration in Campbell's BIOLOGY text.

Are they effective?

Yes.

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Role of various molecules in Light Reactions + Calvin Cycle - seems to be too abstract.

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Variation within a species
Competition within species (Natural Selection)
Overpopulation (with cherry tomatoes)

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Fast Plant Lab
Chromatography

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? [✓ Yes] No

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? [✓ Yes] No

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Field work and investigations
More involved labs on the molecular level

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: WHITE BOARDS & MARKERS

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : FLASH CARDS w/ STRUC. & FUNC.

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: BEAN SELECTION (NAT. SEL. DUE TO COLOR)

What kind of labs do you conduct to teach about Photosynthesis?

Please list: MICROVIEWER (e-MICRO) & PROD. OF O_2 BY ELODEA

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

MODELS OF ORGANELLES SOME SORT OF FLOW CHART. POSSIBLE SHOW "CHANGES IN FOSSIL REMAIN OVER TIME

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes No [✓ sometimes] – if we use comp. lab or get out laptops (but laptops would be for groups)

Do they have access to computers and the internet outside of class? Yes No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Bird Beak lab w/ toothpicks

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes [✓ No]

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : BrainPop, Purple Cow

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

Not sure about these, they do photosynthesis in 7th grade, I teach 8th

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

The students love labs & hands on activities. Anything that they wouldn't normally come into contact with is always exiting.

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Fossil exploration – hands on work with classifying fossils from around DFW

What kind of labs do you conduct to teach about Photosynthesis?

Please list: None

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Evo → time scale simulations

Photo → solar energy demonstration

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes [✓ No]

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: don't teach any - I teach Nutrition & Anat. & Physiol at a Community College

What kind of labs do you conduct to teach about Photosynthesis?

Please list: I'm not sure what our botany teacher uses, but she would love anything new.

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes [✓ No]

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

What kind of labs do you conduct to teach about Photosynthesis?

Please list: "How color of light affects photosynthesis?"

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Animated CD?

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes [✓ No]

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Visual aids
+ films

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: No labs but for films.

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Pigment Lab
etc

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Haven't taught Biology class for 4 years now.
so I'm a little rusty

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes [✓ No]

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list:
Video segment from PBS "Evolution" mini-series
Portraits of Darwin + Mendel

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list :
Models of plant cell and X-sec. of chloroplast

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:
Variation within a species
Overpopulation
Competition among species

What kind of labs do you conduct to teach about Photosynthesis?

Please list:
Wet mount slides of Elodea leaves (chloroplasts)
X-section of leaf slide
Rate of photosynthesis with leaf discs + water/$NaHCO_3$ or clubsoda

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: powerpoints/video clips
moth/bird simulation - Industrial Melanism

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes No

Please list : Powerpoints / WS. - count carbons

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: bird beak adaptations - seeds

What kind of labs do you conduct to teach about Photosynthesis?

Please list: none this year

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Really looking for more student hands-on activities

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list: will be teaching it the first time this year in Freshman Bio

Don't use much except animations for AP Bio

Do you currently use any kind of visual aids, models, [✓ animations] or games to teach about Photosynthesis? Yes No

Please list : textbook CD has animations; also find from internet

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Fresh Bio → peppered moth activity no real lab | For AP Bio, Lab 8 on Hardy Weinberg

What kind of labs do you conduct to teach about Photosynthesis? For AP Bio, lab 4 on photosynthesis

Please list: Freshman Biology → BTB in flask, breathing or Elodea in flask with BTB

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Needs to be EASY PREP and Clean up

Done within a 45 minute period

Good pre- and post assessments

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? [✓ Yes] No

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Photosynthesis web. sites don't remember the name or address. I have it in my [illegible]

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: - Flying birds (Changing the wings)

-

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Elodea lab. (production of oxygen in Elodea)
picking out the pigments (Isolating and comparing plant pigments)

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] Most, not all No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list: posters

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : books, posters, models. (labs - look at real plants then talk about photosyn

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Take a look at evolution through diff areas = medicine
- animals (dogs/cats)
- microbes
- etc.

Teacher Survey for Science Suitcases

Do your students have access to computers in class? Yes [✓ No]

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? [✓ Yes] No

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list :

Jeopardy
Models

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: none

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

none

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Give us more hands-on activities
& different strategies to teach
evolution –

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? [✓ Yes] No

Do your students have interactive SchoolPads? [✓ Yes] No

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Overlays, videos, DVD's

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Transformation of E. Coli.
AP Biology Lab Kit

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Photosynthesis & Plant Pigments
AP Biology Lab Kit

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No 2 only

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? Yes [✓ No]

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? [✓ Yes] No

Please list: HAMI video

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? [✓ Yes] No

Please list : Prentice Hall animations w/ Bio Book

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: ~~Gene Flap~~ Have put together – multi discipline packet

Could Needs improvement – would share

What kind of labs do you conduct to teach about Photosynthesis?

Please list: Photo Cut Out cartoon version

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective: model of ETC

Briejeu
Central Jr High
11EPISD

Teacher Survey for Science Suitcases

Do your students have access to computers in class? [✓ Yes] No

Do they have access to computers and the internet outside of class? [✓ Yes] No Don't know

Does your class have a Smart Board? [✓ Yes] No

Do your students have interactive SchoolPads? Yes [✓ No]

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list:

I am Organic/Analytical Chemist. I enjoy working with students doing Sc. Fair/projects. Westinghouse...

What kind of labs do you conduct to teach about Photosynthesis?

Please list:

I am teaching Honors and AP/PreAP Chemistry

I use during Intel Sc. Fair / Talent Search Projects.

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

- DISD?

- Highschool Teacher?

- Have you used a interactive flash game.?
  - Stand alone
  - integrated. in conjunction

- integrated game / model /

- smart

- 3D Models
  - like / no like

- visual continuity.

what grade

- When do you have chemistry.

email.

- Joel

- about Teachers

sucess of suitcases?

- smart boards

- Chance to talk to students

- Green energy?

- what concept is difficulty to teach.

If you could have anything to teach what would it be?

- putting stuff together?

UTD Educ Gaming

If not related to TAKS would you teach

Survey for Science Suitcases

Are you a teacher? [✓ Yes] No

If yes, what grade and subject do you teach?

Do you teach within the DISD? [✓ Yes] No

Do your students have access to computers in class? Yes [✓ No]

Do they have access to internet in class? Yes [✓ No]

Does your class have a Smart Board? [✓ Yes] No

If yes, how often do you use the Smart Board as an interactive tool? none

Do you currently use any kind of visual aids, models, animations or games to teach about Evolution? Yes [✓ No]

Please list:

Are they effective?

What concepts about Evolution are difficult for your students to grasp (or difficult to teach)?

Homologous structures – They don't understand the evolutionary relationship between two organisms who have similar shapes but different structures.

Do you currently use any kind of visual aids, models, animations or games to teach about Photosynthesis? Yes [✓ No]

Please list :

Are they effective?

What concepts about Photosynthesis are difficult for your students to grasp (or difficult to teach)?

Kreb's cycle, Calvin Cycle, splitting of water molecules.

Do you think visual aids, models, animations and games are an effective way to help teach the subjects of Evolution and Photosynthesis? [✓ Yes] No

What kind of labs do you conduct to teach about Evolution?

Please list: Comparing amino acids of different organisms, Interpreting fossil footprints, natural selection simulations.

What kind of labs do you conduct to teach about Photosynthesis?

Please list: using Bromothymol Blue and Elodea to observe the effects of Photosynthesis

Have you ever used an interactive educational flash game in your class? Yes [✓ No]

Was it effective (or relevant)?

Are you willing to use an interactive educational game as part of your curriculum? Yes No [✓ Maybe]

Do you have time in your class to teach material about Evolution and Photosynthesis that goes beyond the TEKS requirements? Yes [✓ No]

If you could do anything to teach a subject in a class, what would you do (i.e. teaching outdoors, field trips, using models , games, etc.)?

Models and games

Please feel free to express your ideas about how we can make teaching the subjects of Evolution and Photosynthesis more fun, interactive and effective:

APPENDIX B:
Student Surveys

Photosynthesis Student Survey

1. What grade are you in? _going into 10_
2. Have you been taught photosynthesis in your classroom? Y / [✓ N]

If yes, in what grade and class? _9__/ ___Biology____

3. Did you have any understanding of chemistry **before** learning photosynthesis? Such as:

Chemical equations (ie. $2H_2 + 0_2$ -> $2H_20$) :[✓ Y] / N

Oxidation/ reduction: Y / [✓ N]

Hydrogen protons: [✓ Y] / N

Electron charges: [✓ Y] / N

4. Did you learn the Electron Transport Chain?[✓ Y] / N

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

[✓ ATP NAPDH]   Hydrogen Protons   [✓ Electron charge]

Proton Concentration Gradient   [✓ Light Reaction Center]

5. Did you learn the Calvin Cycle? [✓ Y] / N

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

Rubisco[✓ 36 ATP moleculesCO_2]   3 (5-carbon chains)

6. Have you played any of the following boardgames? (circle any you've played)
[✓ LifeSettlers of Catan]   Stone Age   Munchkin

7. Do you like board games? [✓ Y] / N

8. Has your teacher ever used the **computer lab** to teach a subject not relating to computers (like biology, math, history), andhave you used an interactive program?[✓ Y] / N

Thank you for participating!!!!

Photosynthesis Student Survey

1. What grade are you in? going to 11 in the fall
2. Have you been taught photosynthesis in your classroom? Yes

If yes, in what grade and class? biology 9th grade

3. Did you have any understanding of chemistry **before** learning photosynthesis? yes Such as:

Chemical equations (ie. $2H_2 + 0_2 \rightarrow 2H_20$) : Y

Oxidation/ reduction: N
Hydrogen protons: N
Electron charges: Y

4. Did you learn the Electron Transport Chain? Y

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

ATP NAPDH Hydrogen Protons Electron charge
Proton Concentration Gradient Light Reaction Center

>>all except proton concentration gradient

5. Did you learn the Calvin Cycle? Y

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

Rubisco 36 ATP molecules CO_2 3 (5-carbon chains)
>>all except rubisco

6. Have you played any of the following board games? (circle any you've played)

Life Settlers of Catan Stone Age Munchkin
>>life

7. Do you like board games? Y

8. Has your teacher ever used the **computer lab** to teach a subject not relating to computers (like biology, math, history), and have you used an interactive program? Y

Thank you for participating!!!!

Photosynthesis Student Survey

1. What grade are you in? 11
2. Have you been taught photosynthesis in your classroom? Y

   If yes, in what grade and class? 7th Grade/ Science

3. Did you have any understanding of chemistry **before** learning photosynthesis? Such as:

   Chemical equations (ie. $2H_2 + 0_2 \rightarrow 2H_20$) : Y

   Oxidation/ reduction: N

   Hydrogen protons: N

   Electron charges: Y

4. Did you learn the Electron Transport Chain? N (at least not in 7th grade)

   Circle **any** of the following phrases if your teacher mentioned them in the lesson:

   ATP NAPDH Hydrogen Protons Electron charge

   Proton Concentration Gradient Light Reaction Center

5. Did you learn the Calvin Cycle? N

   Circle **any** of the following phrases if your teacher mentioned them in the lesson:

   Rubisco 36 ATP molecules CO_2 3 (5-carbon chains)

6. Have you played any of the following board games? (circle any you've played) (i put a *)

   *Life Settlers of Catan Stone Age Munchkin

7. Do you like board games? Y
8. Has your teacher ever used the **computer lab** to teach a subject not relating to computers (like biology, math, history), and have you used an interactive program? Y, Y

Thank you for participating!!!!

Photosynthesis Student Survey

1. What grade are you in? Rising senior
2. Have you been taught photosynthesis in your classroom? Yes

If yes, in what grade and class? 9 and 10 / Biology and AP Biology

3. Did you have any understanding of chemistry **before** learning photosynthesis? Such as:

Chemical equations (ie. $2H_2 + 0_2 \text{ -> } 2H_20$) : Yes

Oxidation/ reduction: No

Hydrogen protons: No

Electron charges: No

4. Did you learn the Electron Transport Chain? Yes

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

ATP NAPDH Hydrogen Protons Electron charge

Proton Concentration Gradient Light Reaction Center

All of the above

5. Did you learn the Calvin Cycle? Yes

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

Rubisco 36 ATP molecules CO_2 3 (5-carbon chains)

All of the above

6. Have you played any of the following board games? (circle any you've played)

7. Do you like board games? Yes
8. Has your teacher ever used the **computer lab** to teach a subject not relating to computers (like biology, math, history), and have you used an interactive program? Yes

Thank you for participating!!!!

Photosynthesis Student Survey

1. What grade are you in? just graduated 12
2. Have you been taught photosynthesis in your classroom? Y
   If yes, in what grade and class? on a molecular level, 10th grade biology

3. Did you have any understanding of chemistry before learning photosynthesis? Such as:
   Chemical equations (ie. $2H_2 + 0_2 \rightarrow 2H_20$) : Y

   Oxidation/ reduction: N

   Hydrogen protons: N

   Electron charges: Y

4. Did you learn the Electron Transport Chain? Y
   Circle **any** of the following phrases if your teacher mentioned them in the lesson:

   learned all below

   ATP NAPDH Hydrogen Protons Electron charge

   Proton Concentration Gradient Light Reaction Center

5. Did you learn the Calvin Cycle? Y
   Circle **any** of the following phrases if your teacher mentioned them in the lesson:

   all the following: 36 ATP molecules CO_2 3 (5-carbon chains)

6. Have you played any of the following board games? (circle any you've played) played the following:
   Life

7. Do you like board games? Y
8. Has your teacher ever used the computer lab to teach a subject not relating to computers (like biology, math, history), and have you used an interactive program? Y

Thank you for participating!!!!

Photosynthesis Student Survey

1. What grade are you in? 10th
2. Have you been taught photosynthesis in your classroom? Yes

If yes, in what grade and class? 7th / General Science

3. Did you have any understanding of chemistry **before** learning photosynthesis? Such as:

Chemical equations (ie. $2H_2 + 0_2$ -> $2H_20$) : Yes

Oxidation/ reduction: No

Hydrogen protons: No

Electron charges: No

4. Did you learn the Electron Transport Chain? No

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

[✓ ATP] NAPDH Hydrogen Protons Electron charge

Proton Concentration Gradient Light Reaction Center

5. Did you learn the Calvin Cycle? No

Circle **any** of the following phrases if your teacher mentioned them in the lesson:

Rubisco 36 ATP molecules [✓ CO_2] [✓ 3 (5-carbon chains)]

6. Have you played any of the following board games? (circle any you've played)

Life Settlers of Catan Stone Age Munchkin

7. Do you like board games? Yes

8. Has your teacher ever used the **computer lab** to teach a subject not relating to computers (like biology, math, history), and have you used an interactive program? Yes; Yes

Thank you for participating!!!!

APPENDIX C:
Animation Script

Photosynthesis Animation DVD: Animation Script

The following is the full script of the animation for your reference. Answers and explanations to all quiz questions are in bold.

Chapter 1 Introduction

When you hear the term photosynthesis, what do you think of? Think energy!

Humans eat food so that our bodies will have energy to function properly. Like humans, plants need energy to live and grow too. But instead of stopping by your local fast food joint to grab a sandwich, plants make their own food and oxygen too. How? Through photosynthesis!

Chapter 2 What is Photosynthesis?

What is photosynthesis? Well, if we look at the word “photo-synthesis”, we see that it’s made up of two parts. “Photo” which means light, like a photon energy and “synthesis” which means combining simple things to create something complex. So if you put the two words together, We’re using “light” to combine simple things to create something complex, like sugar!

So basically, photosynthesis is the process during which certain organisms capture light energy and convert it into chemical energy and store the chemical energy as sugar.

Chapter 3 The Photosynthetic Chemical Equation

In science, often you see the reactants and products of photosynthesis described by the chemical equation:

$$6C0_2 + 6H_20 + hv \rightarrow C_6H_{12}0_6 + 6O_2$$

Although this chemical equation doesn’t actually describe the process of photosynthesis, it is helpful to see what reactants you start with and what products you will end up with. As you can see the process requires basic elements (or reactants) to occur like carbon dioxide and water and light energy. Then through the process of photosynthesis, the products sugar and oxygen are made.

So as a balance equation**,** for every 6 carbon dioxide molecule and 6 water molecule that is converted through photosynthesis, 1 sugar molecule and 6 oxygen molecule are made.

Question 1:

Which of the following is the correct photosynthetic chemical equation?

1. $6H_2O + 6C_6H_{12}O_6 \text{ -> } CO_2 + 6O_2$

   Oxygen is a product and water is a reactant

2. **$6CO_2 + 6H_2O \text{ -> } C_6H_{12}O_6 + 6O_2$**

   For every 6 carbon dioxide and 6 water molecules used,1 sugar and 6 oxygen molecules are made

3. $6CO_2 + 6O_2\text{-> } C_6H_{12}O_6 + 6\ H_2O$

   Sugar is a product and carbon dioxide is a reactant

Chapter 4 Oxidation and Reduction

Now looking at this equation, it might seem like a jumble of numbers and letters. How is carbon dioxide and water turning into sugar and oxygen? Let’s take away the numbers for now and look at just the elements.

$$CO + HO \rightarrow CHO + O$$

Reactants Products

In this simplified version of the reaction, we see 2 events occurring: water is stripped of its hydrogen and the hydrogen is attached to carbon dioxide. These two events are examples of oxidation and reduction.

Oxidation is the loss of an electron. Often when you break the bond between two elements like hydrogen and oxygen, energy in the form of an electron is released. And the molecules lose that electron.

Reduction is the opposite. Reduction is the gain of an electron. To form a bond between elements, energy is required. So the molecules gain an electron in order to bind with hydrogen.

Why is hydrogen the one moving from one molecule to the other?

Hydrogen is composed of a single electron and proton. It has a tendency to give up its electron easily. So often after breaking a bond containing hydrogen, the electron is lost and the proton is left behind. That's why when you see the symbol H+, they're called protons because the hydrogen has lost its only electron. You'll hear more protons later on.

Now in the process of photosynthesis, oxidation and reduction occurs in two reaction cycles. These reactions are cycles because the process can repeated as long as there are available resources (like carbon dioxide and water).

Chapter 5: Review 1

Whew! Let's review. The chemical equation of photosynthesis is:

For every 6 carbon dioxide molecule and 6 water molecule that is converted through photosynthesis, 1 sugar molecule and 6 oxygen molecule are made.

Oxidation is the loss of an electron. Reduction is the gain of an electron.

In photosynthesis, these two events occur in two separate reaction cycles. Now that we've seen the big picture, let's see where photosynthesis takes place!

Chapter 6: Where does it happen?

Where does it happen? For most plants, the prime location for photosynthesis to take place is within the leaf of the plant, where a broad surface area maximizes exposure to sunlight. At first glance, a plant leaf looks like mish-mash of random cells and is just green, lots of green. But if you take a closer look, the leaf is more similar to a self contained environment like a space station.

The structure is made up of individual cells with specialized tasks like piping that moves water and nutrients through the leaf, or preventing the loss of water, or monitoring the exchange of gases like CO_2 and O_2, or creating food for the plant.

In the leaf, the biggest cell layer is called the mesophyll, which is split into the palisade mesophyll and spongy mesophyll. Most cells specializing in photosynthesis are located in the palisade mesophyll. These cells have a higher number of chloroplasts and are oriented to have greater exposure to sunlight.

The chloroplast organelles contain special structures called thylakoids. These thylakoids arrange themselves in stacks. The substance surrounding the thylakoids with the chloroplasts is called the stroma. If you haven't noticed, we've zoomed past the structural and cellular level to the molecular level. Remember that photosynthesis is a molecular process.

Question 2:

What type of plant would have all its stomata located on the upper epidermis?

1. A plant in the desert
   If the stomata were on the topside of a desert plant, the intense exposure to sunlight would cause water vapors to evaporate quickly and the plant would die.
2. A plant in the humid jungle
   The humid jungle environment means there is water moisture everywhere. So the plant would have lots of stomata in the upper and lower epidermis.
3. **A plant floating on a pond**
   The underside of the plant would be submerged in water. So CO_2 and O_2 gas exchange must occur on the topside. Therefore the stomata would be located in the upper epidermis of the leaf.

Chapter 7: How does photosynthesis work?

Like we said before, the process of photosynthesis takes place in two MAIN Reactions Cycles, each composed of several individual reactions that are repeatable.

The Light dependent reactions comprise the first cycle, or Cycle One. This is the "photo" part of photosynthesis. Without the sun these reactions won't go.

The main job of cycle one is to:

1. Capture light energy
2. Store that energy by creating small amounts of ATP, Adenosine Tri-Phosphate, and binding free hydrogen protons to NADP, a "carrier molecule", that will transport the stored energy to Reaction Cycle 2
3. Create more free hydrogen protons and restore energy lost by splitting water and form oxygen as a byproduct.

The second cycle, Cycle Two, contains the Light-independent reactions. Like the name implies, this set of reactions doesn't need the sun to do its job, so cycle 2 can be working day or night. This is the "synthesis" part of photosynthesis.

The main job of cycle two is to:

1. Use the ATP and NADPH created from Cycle 1 to power the synthesis process.
2. Use the carbon in CO_2 to build the sugar.

Even though cycle 2 doesn't need sunlight to function, it is still dependent on the products created in cycle 1 to drive its own reaction. So if cycle 1 stops working, eventually cycle 2 will grind to a halt.

Now that you understand the basics of the two main cycles, we're going to dive deeper and learn how each cycle does its' job.

Chapter 8: Light-Dependent Reactions

Cycle 1: Light-Dependent Reactions. Cells contain many chloroplasts. Within a chloroplast are many stacks of thylakoids and the thylakoids float in the stroma.

The first cycle takes place within the membrane of the thylakoid and functions through a variety of specialized protein structures that dot the surface.

One of these specialized protein structures, called a photosystem, is in charge of capturing the sunlight energy. Photosystems are like solar panels on a space station that capture the sunlight for powering equipment and maintaining station functions. The solar panels are made of special materials to absorb the sunlight. In photosystems, there are material pigments called chlorophyll that absorb the sunlight. Electrons in the chlorophyll pigments become energetic as the light energy is absorbed.

Question: Why do you think plants are green? If you said because of the chlorophyll, your right! But why is chlorophyll green?

White light is made up of a spectrum of colors, and chlorophyll is capable of absorbing most colors *except* for green colored light. We see green light that is reflected off the object. Think about that when you look any colored surface. You're actually looking at the color that wasn't absorbed by the material and is being reflected back to you.

Now that you know how sunlight is captured, let see how the light energy is converted and stored as chemical energy for later use in Cycle 2. There are three main steps: the electron transport chain, the production of ATP (chemical energy), and the production of NAPDH, a carrier molecule.

Question 3:

What are the three main jobs of the Light Dependent Reactions?

1. **Make NADPH, Make ATP, Split H_2O**
   NADPH and ATP are made to carry energy to the Light Independent Reactions. Splitting water helps the Light Dependent Reactions to restore energy spent to make NADPH and ATP.
2. Make ATP, Use CO_2, Split water
   Using carbon dioxide is a job of the Light INDEPENDENT Reactions.
3. Make NADPH, Make Sugar Use CO_2
   Making sugar and using carbon dioxide are jobs of the Light INDEPENDENT Reactions.

Chapter 9: Electron Transport Chain

Remember we're still in within the membrane of the thylakoid. As you can see, there are multiple photosystems that capture the light energy and they are part of a larger string of proteins called: The Electron Transport Chain or ETC for short!

The Electron Transport Chain moves electrons, which have been excited by the photosystems, down a string of proteins. The energy absorbed by the chlorophyll pigments causes an electron to become "excited" to a higher energy level and is ejected from the chlorophyll molecule. This excited electron and the energy it contains is "lost" by the photosystem and the electron jumps out into the intermediate protein. These proteins continue to pass on an excited electron down the chain of proteins like a hot potato. And just like a hot potato that loses heat as it cools, each excited electron that is passed on loses energy. The energy required to move to the next protein is less than the previous so electron keeps moving down the chain.

Each ETC contains two photosystems. So you can see that this excitation of an electron and transporting it down a chain of proteins happens twice.

In photosystem I, the electron is passed down the chain to eventually power a NADPH synthesizer. This protein structure combines NADP with hydrogen proton, H+.

Question 4:

When light is received by the Electron Transport Chain, which photosystem activates first?

1. Photosystem I

   Making sugar and using carbon dioxide are jobs of the Light INDEPENDENT Reactions
2. Photosystem II

   Light Photons would arrive at the ETC at the same time.
3. **They activate at the same time**

   Light Photons would arrive at the ETC at the same time, therefore both photosystems would receive light simultaneously and activate at the same time.

Chapter 10: Making NADPH

Why is this NADPH important? Energy is released when bonds between molecules are broken. And vice versa, energy is required to bind molecules back together. Cycle 1 has no way of giving energy to Cycle 2 to use to make sugar. So that's where a molecule like NADPH can act as a carrier between the two reaction cycles! Binding NADP with Hydrogen uses the energetic electron released from the photosystem I. The resulting NADPH can be broken later in Cycle 2, releasing the energy to finish making sugar.

Photosystem II
The photosystem II also ejects an excited electron that passes down intermediate proteins, which activate to pull hydrogen protons into the thylakoid. The electron eventually restores the electron lost from photosystem I.

Now Photosystem II needs to replenish its own lost electron. So attached to PSII is special water splitting protein that breaks up H_20 and takes the electron for PSII. Hydrogen protons (H+) and oxygen byproducts are released.

This is an important point: Oxygen is produced when water is split in the light dependent reactions, cycle 1. NOT from CO_2 in the light-independent reactions, cycle 2. If we look back to the photosynthetic chemical equation, we can see that oxygen, one of the products, is created here in the electron transport chain of cycle 1.

Chapter 11: Making ATP

Adenosine Tri-phosphate. Now the whole time that Cycle 1 has been active, hydrogen protons pumped into the thylakoid from the ETC and created from splitting water has caused a concentration imbalance. There are too many protons inside the thylakoid.

Imagine a dam that has too much water on one side. To balance the water levels, a channel is put in place. But this flow of water can also do work by placing a water wheel. The energy produce can be used to power a factory.

The cell does the same thing to balance out the hydrogen proton concentrations inside the thylakoid and outside in the stroma. A special protein channel passively lets out the excess H+. This channel is put to work too and attached is an ATP synthesizer which drives the formation of ATP from ADP and phosphate. Remember, energy is stored in the molecular bonds. So when phosphate binds to ADP, Adenosine Di-Phosphate, energy stored in the bond making ATP. This energy stored in ATP can be used then to power cycle 2 or other areas of the cell.

Chapter 12: Review 2

Let's Review. Each ETC contains two photosystems. Photosystem I loses an electron to make NADPH. Photosystem II loses an electron to give to photosystem I. Photosystem II needs to replenish its own lost electron. So attached to PSII is special water splitting protein that breaks up H20 and takes the electron for PSII. Hydrogen protons (H+) and oxygen byproducts are released. Oxygen is produced when water is split in the light dependent reactions, cycle 1. NOT from CO_2 in the light-independent reactions, cycle 2.

Alright! We've made ATP and NADPH. The energy carried within each molecule can now be used by the cell for important functions. But what if we want to store that energy for a cloudy day? Then we make sugar!

Chapter 13: Light Independent Reactions

Cycle 2: Light independent reactions. Cycle 2 actively takes place in the stroma, the spaces between the thylakoid stacks. These reactions can work day or night.

REMEMBER: This is also called the Calvin cycle because it was worked out by Melvin Calvin many years ago. It should not to be confused with the Krebs Cycle, which is involved in the breaking down of sugar through cellular respiration.

Remember that two things are happening in the Cycle 2: It uses CO2 as material for synthesizing sugars, and it powers the cycle of reactions using ATP and NADPH made from Cycle 1 (the light dependent reactions).

Technically, the Calvin cycle itself doesn't actually make the 6-carbon sugar that you seen in the chemical equation. It makes a 3-carbon pre-sugar compound that can be joined later to make the 6-carbon sugar.

Essentially the Calvin cycle is a series of reactions that takes a base organic molecule and reshapes and modifies it until a pre-sugar compound is formed. Each step in the modification requires a specialized enzyme and energy to keep it going. This is a cycle because it is not only able to create a pre-sugar compound but also restore its original base molecule to repeat the process over again. Any spent ATP and NADPH, now ADP and NADP, is recycled back to be used by cycle 1.

Question 5:

What are the two main jobs of the Light Independent Reactions?

1. Use CO_2, Make NAPDH
   Making NAPDH is a job of the Light DEPENDENT Reactions
2. **Use CO_2, Use NADPH & ATP to make sugar**
   The carbon atom in carbon dioxide is used to make the 6-carbon sugar. NADPH and ATP provide the energy to drive the reactions.
3. Make ATP, Use NADPH & ATP to make sugar
   Making ATP is a job of the Light DEPENDENT Reactions

Chapter 14: Carbons of the Calvin Cycle

At this point, it's not so important that you know the details of the Calvin cycle. But to illustrate how this cycle is able to sustain itself so efficiently we'll focus on carbons that make up the base organic molecule. All enzymes have been generalized for simplicity. Let's follow the carbons!!

1. First we start with three carbon molecules made of five carbon atoms. A specialized enzyme activates to bind each 5-carbon compound with one CO2 molecule. This reaction initially results 6-carbon compounds that so unstable, it immediately splits into smaller 3-carbon compounds.
2. Six ATP and enzymes are used to stabilize the 3-carbon compounds
3. Six NADPH and enzymes are used to modify the 3-carbon compound into the pre-sugar compound.
4. One 3-carbon pre-sugar compound exits the cycle.
5. Finally through multiple reactions, 3 ATP and enzymes rearrange the remaining compounds back into the 3 (5-carbon compounds).

The cycle continues to repeat and every two 3-carbon pre-sugar compound is combined to make the full 6-carbon sugar. Remember, spent ADP and NADP are feed back into the light reactions to be reused.

Question 6:

If the leaf receives more light, the rate of photosynthesis will:

1. Stay the same

   The rate will stay the same IF there are no photosystems available to absorb light, or no enzymes to use the energy, or not enough reactants.
2. **Increase**

   More light means more photosystems in the ETC activate to absorb energy. More ATP and NADPH are created and more enzymes activate to create sugar.

   This will keep increasing until there no more photosystems available to absorb energy, or no more enzymes to create sugar, or no more CO_2 to provide carbon.
3. Decrease

   The rate will decrease IF the plant has already run out of reactants like CO_2 and H_2O and there is too much O_2 product built up in the system

Chapter 15: Sugar Application

Now that we made sugar, what does the cell do with it?

Store it! The plant makes cellulose in cell walls or turns sugar into starch like potatoes. Use it! Through cellular respiration that takes place in the mitochondria of the cell, the sugar can be broken down to bind a great number of ADP and P to make ATP for cellular function.

Chapter 16: Review 3

Let's Review. Light independent reactions actively take place in the stroma, the spaces between the thylakoid stacks. Essentially the Calvin cycle is a series of reactions that takes a base organic molecule and reshapes and modifies it until a pre-sugar compound is formed. The cycle continues to repeat and every two 3-carbon pre-sugar compound is combined to make the full 6- carbon sugar Any spent ATP and NADPH, now ADP and NADP, is recycled back to be used by cycle 1.

Question 7:

The Light Independent Reactions are called a cycle because:

1. **The reactions are repeatable**

    The base organic molecules used to make sugar are restored after each series of reactions. Allowing the cell to continuously make sugar.

2. The molecules move around in a circle

    While the molecules do move around in the stroma, the reactions do no move in a circle.

3. Hydrogen moves through the thylakoid membrane

    This does not influence the cyclical nature of the Light Independent Reactions

Chapter 17: What if there was no photosynthesis?

We play a part in photosynthesis too! Let's look at the photosynthetic equation again. The food we eat comes from sugars stored in plants and through cellular respiration, our bodies' covert the sugars into energy. We breath in oxygen given off by plants to survive and the CO_2 that we breathe out is used by plants is used to make more sugar. And we breathe in the O_2 byproduct from plants to live. We are part of a greater cycle that is dependent on each other.

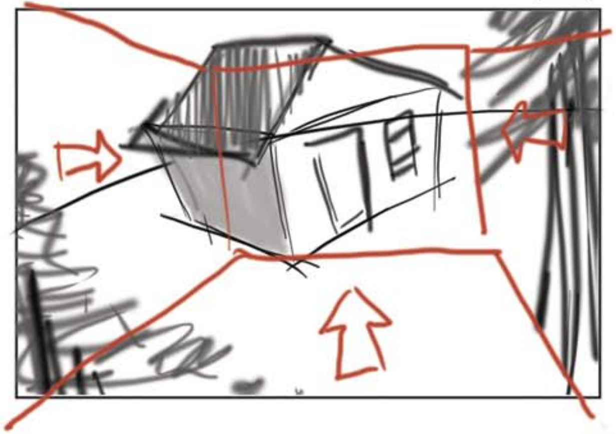
So if you were to imagine a world without photosynthesis: No plants, no animals, no food for us!. No oxygen being released, so no breathable air! None of the CO_2 are breaking down. So the planet would turn into an oven as the gases would trap all the heat from the sun. More global warming!

So the next time you look at the leaves on a plant, remember photosynthesis! Think energy!

APPENDIX D:
Animation Storyboard

Project: Photosynthesis

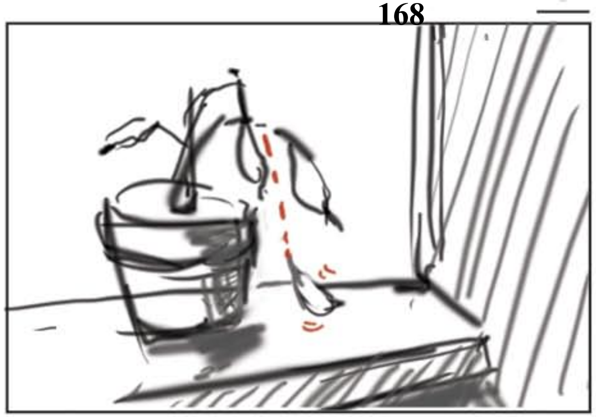
Version: 1



When you hear the term photosynthesis, what do you think of?

House shot, slow zoom in to window

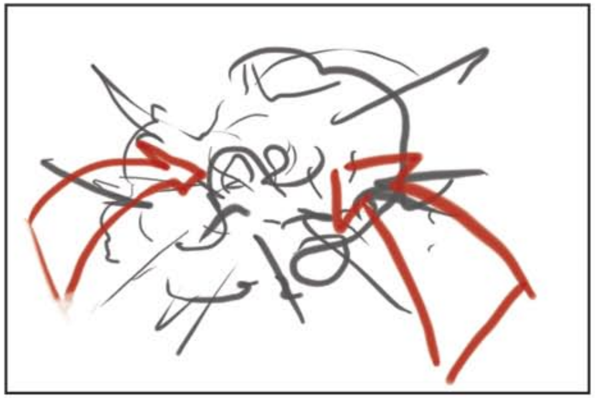
wipe to interior



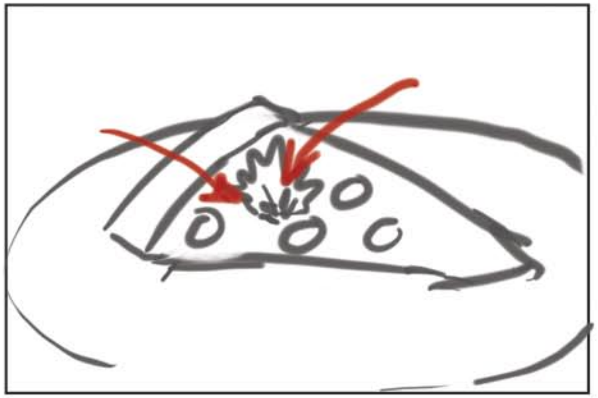
Sad dying potted plant
leaf dropping

leaf comes to life and jumps off

“error” sound effect

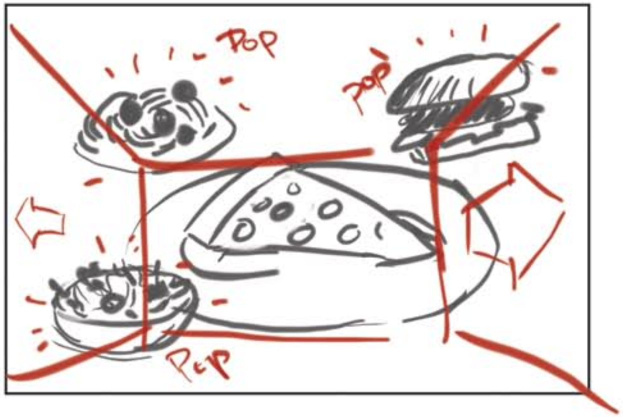


Think energy!
explosion forward then backswards explosion sucked into food



Humans eat food so that our bodies will have energy to function properly.

Derek Wu derek.wu@utsouthwestern.edu

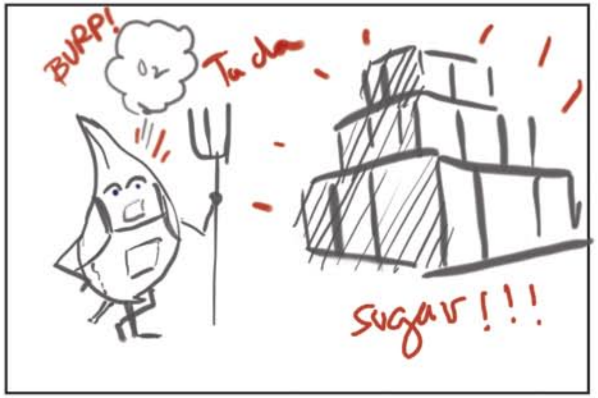


Like humans, plants need energy to live and grow too.

zoom out, multiple food items pop up

But instead of stopping by your local fast food joint to grab a sandwich,

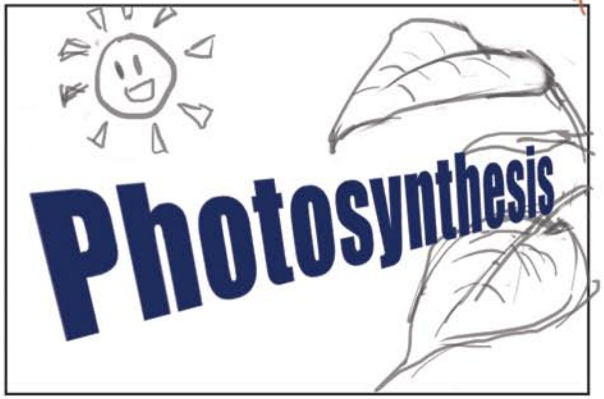
group of cut out ppl rush store



plants make their own food and oxygen too. How?

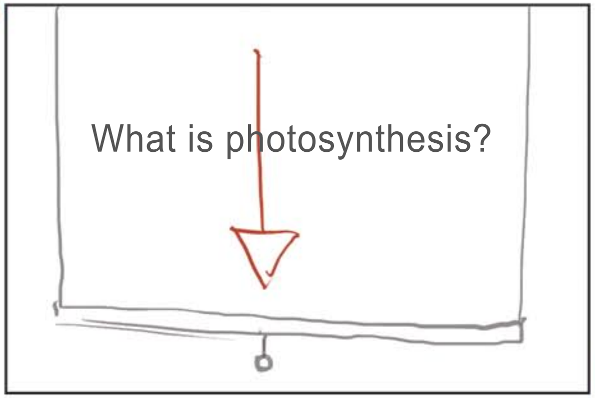
Sugar cubes pop.. Leaf belches out oxygen cloud

*Chapter Brk



Through photosynthesis!

Fade white in, text unveils left to right

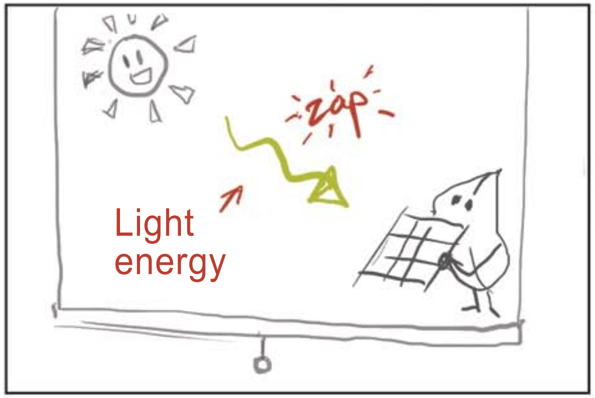


What is photosynthesis?

ADDITION: IN StryBrd 02B

Projector screen pulls down

2B



So basically, photosynthesis is the process during which certain organisms capture light energy

light energy "zap" sound affect
Pause to label as light energy

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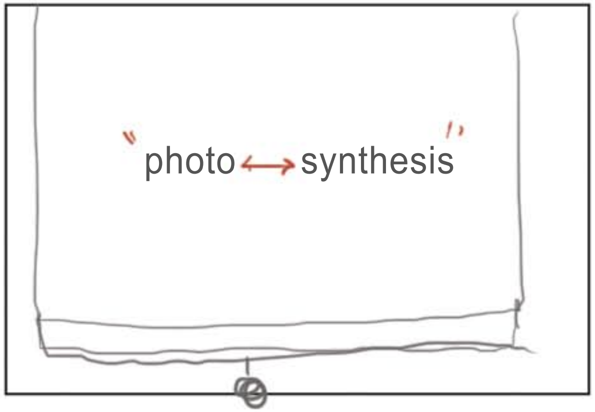
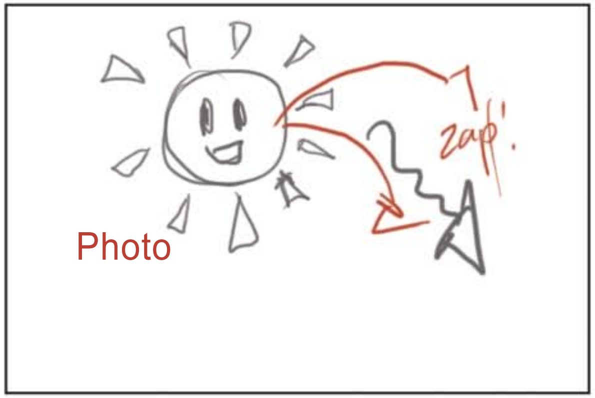


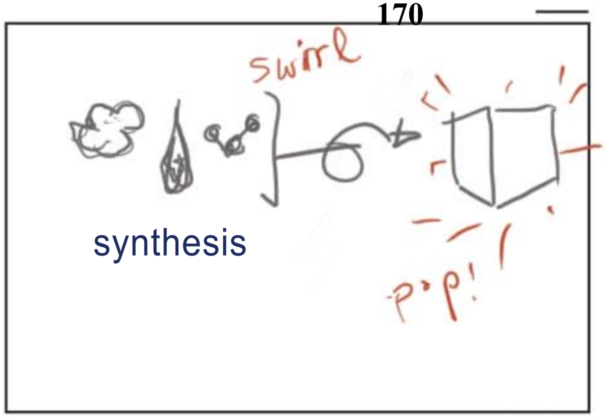
Well, if we look at the word "photo-synthesis", we see that it's made up of two parts.

the word split in two



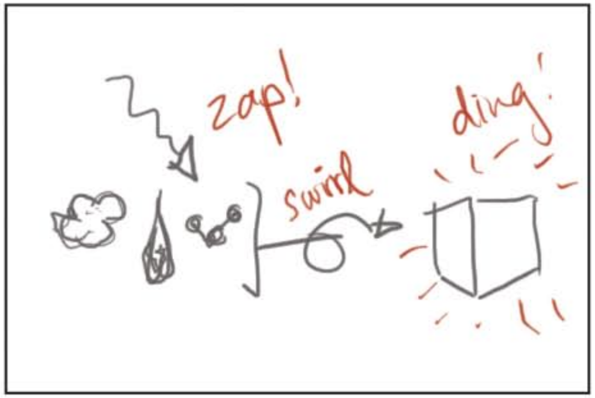
Photo" which means light, like a photon energy

Sun appears, and photon pops out



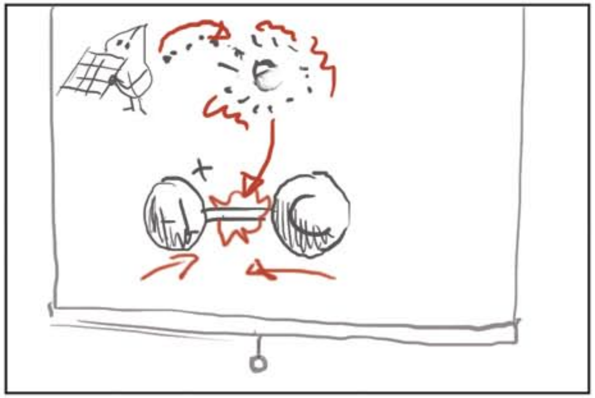
synthesis" which means combining simple things to create something complext

small elements combine into sugar

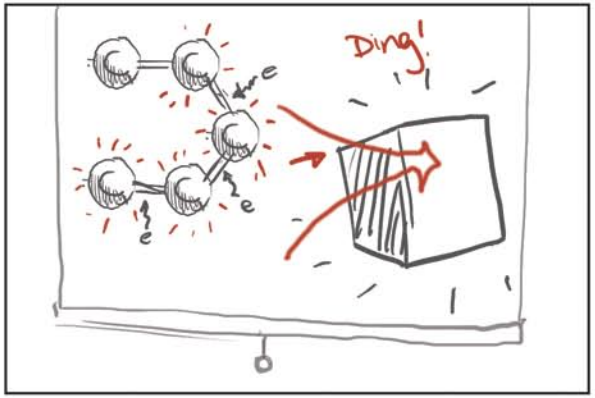


So if you put the two words together, we're using "light" to combine simple things to create something complex, like sugar!

Fade white in, text unveils left to right *ch Brk

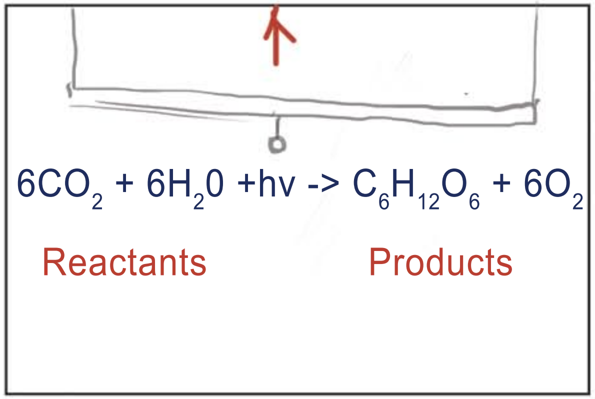


and convert it into chemical energy
electron “electricity” sound
electron jumps from leaf
and stores in molecular bond



and store the chemical energy as sugar.

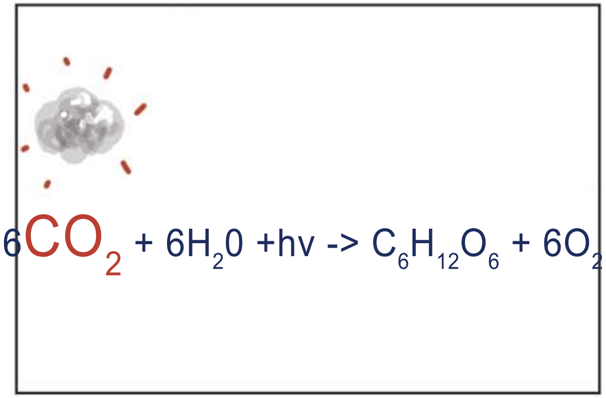
carbons pop into place faster and faster then morphs to sugar cube



$6CO_2 + 6H_20 +hv \rightarrow C_6H_{12}O_6 + 6O_2$

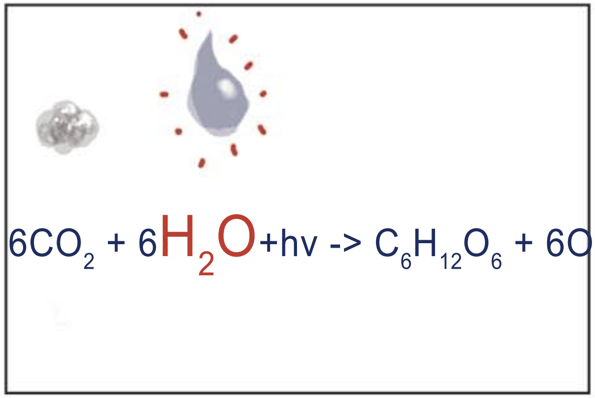
Reactants Products

Often you see the reactants and products of photosynthesis described by the chemical equation: “Although this chemical...
fade in products, then reactants



$6CO_2 + 6H_20 +hv \rightarrow C_6H_{12}O_6 + 6O_2$

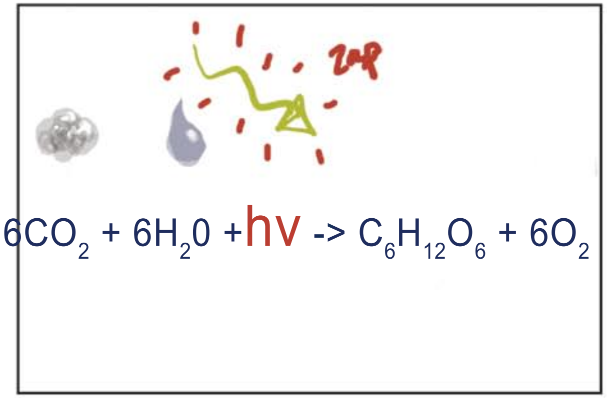
As you can see, the process requires several basic elements:
Carbon Dioxide
gray cloud appears



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

water

water droplet symbol appears



$6CO_2 + 6H_20 +hv \rightarrow C_6H_{12}O_6 + 6O_2$

and light energy

light wave appears

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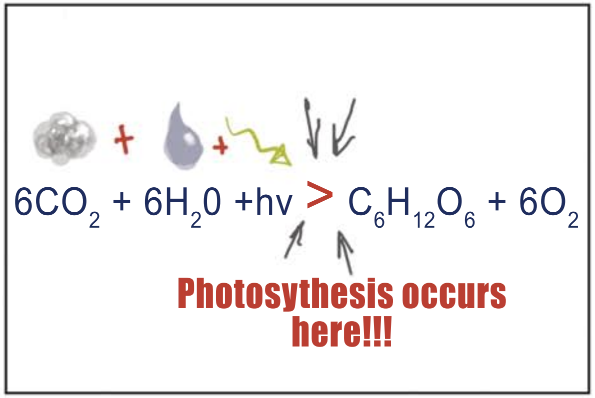
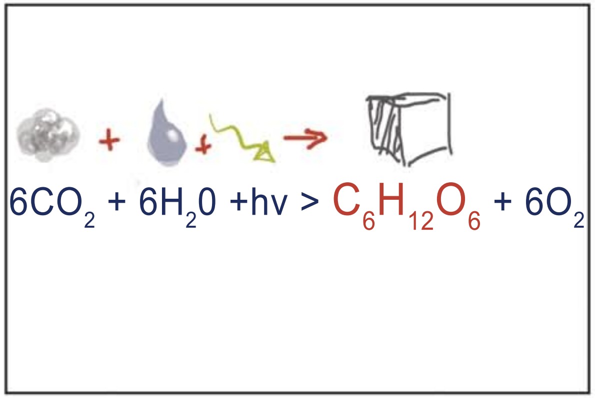
Project: Photosynthesis

Version: 1



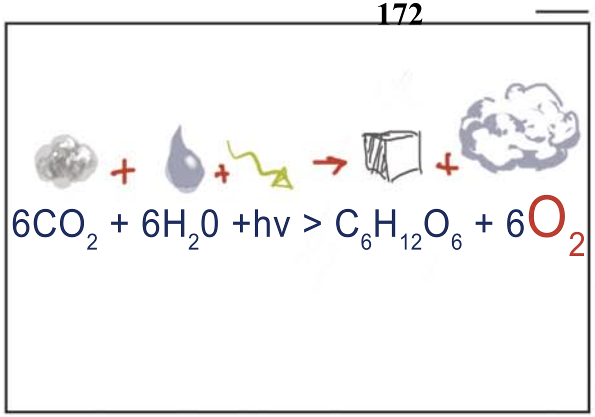
through process of photosynthesis

Big arrows point to the reaction arrow



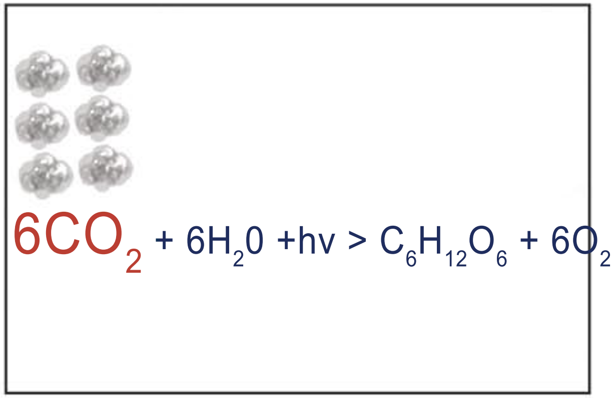
the products sugar

sugar cube appears



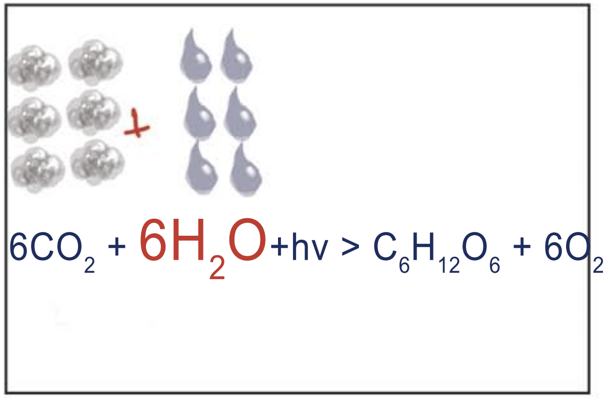
and oxygen are created.

white cloud of oxygen



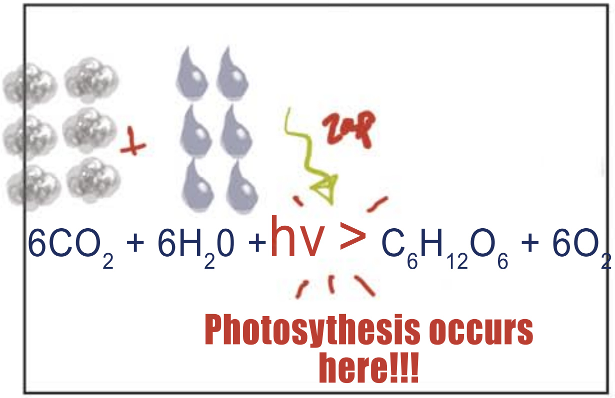
So as a balance equation, for every 6 carbon dioxide molecule

gray cloud splits to six



and 6 water molecule

water droplet splits to six

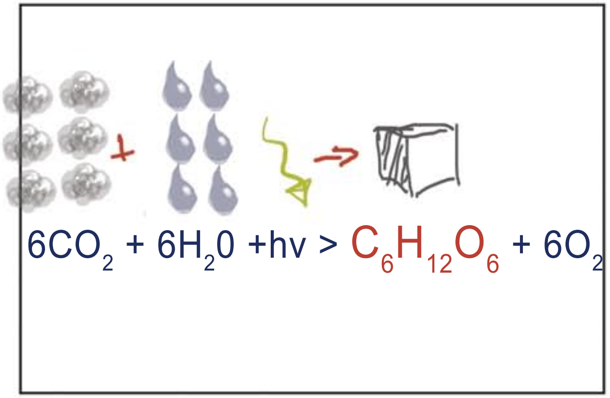


that is converted through photosynthesis

light wave zaps arrow, arrow lights up

Project: Photosynthesis

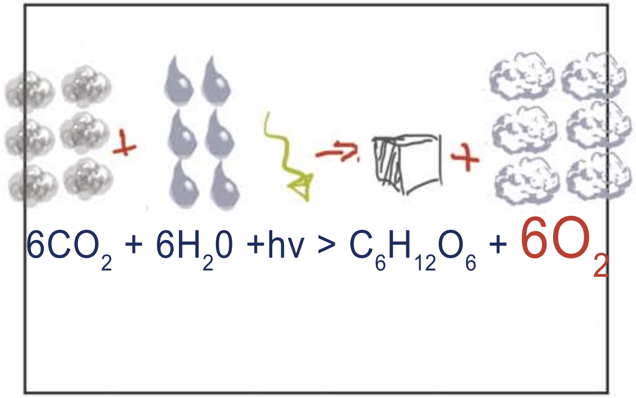
Version: 1



$6CO_2 + 6H_20 + hv > C_6H_{12}O_6 + 6O_2$

1 sugar molecule

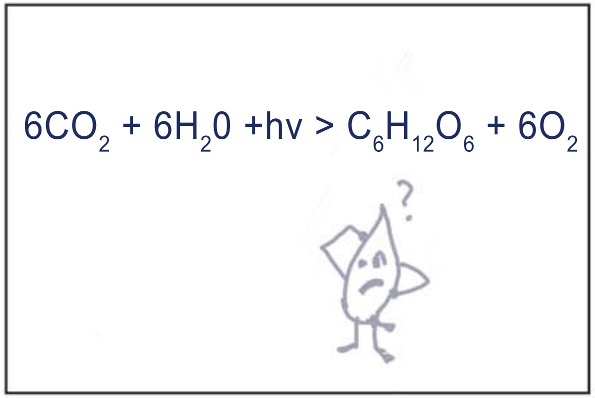
pop in sugar



$6CO_2 + 6H_20 + hv > C_6H_{12}O_6 + 6O_2$

6 oxygen molecules are made.

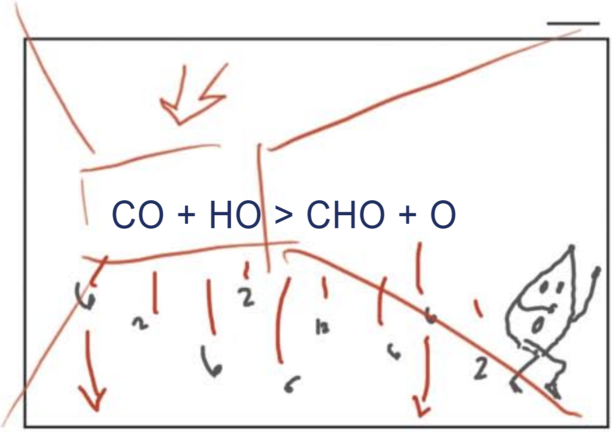
oxygen split to 6



$6CO_2 + 6H_20 + hv > C_6H_{12}O_6 + 6O_2$

Now looking at this equation, it might seem like a jumble of numbers and letters. How is carbon dioxide and water turning into sugar and oxygen?

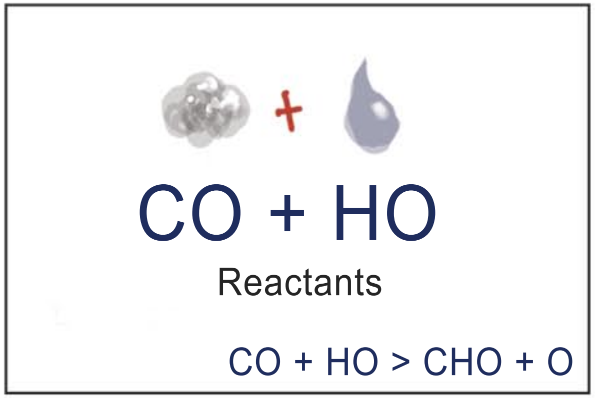
leaf enters scratches head at equation



CO + HO > CHO + O

Let's take away the numbers for now and look at just the elements.

Numbers all fall away leaf runs away



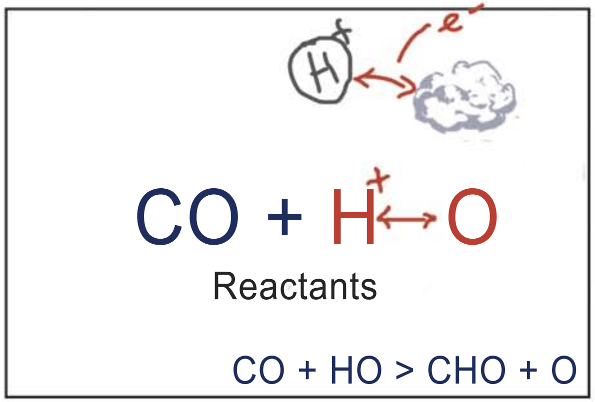
CO + HO

Reactants

CO + HO > CHO + O

In this simplified version of the reaction, we see 2 events occurring:

equation moves to corner, reactants pull up



$CO + H^{+} \leftrightarrow O$

Reactants

CO + HO > CHO + O

water is stripped of its hydrogen

water drop tears apart and forms cloud and proton

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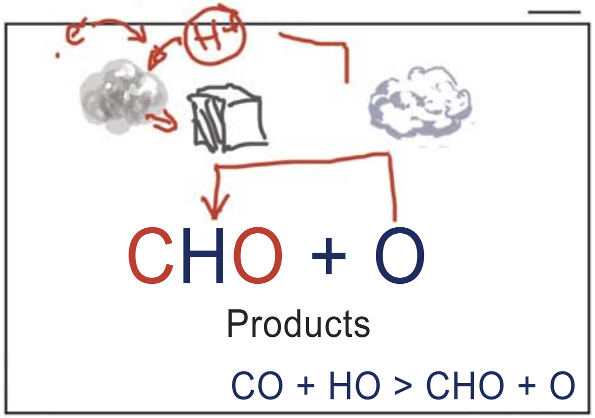
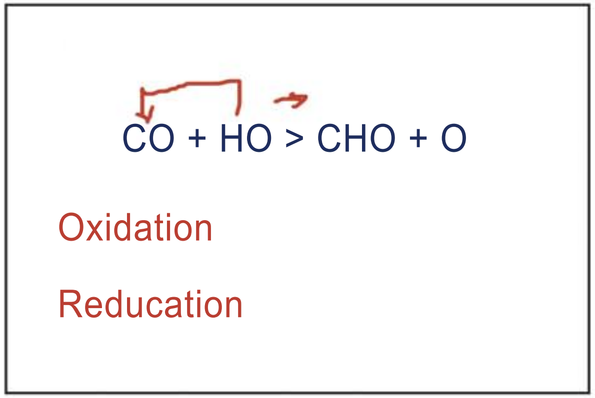
page: 5



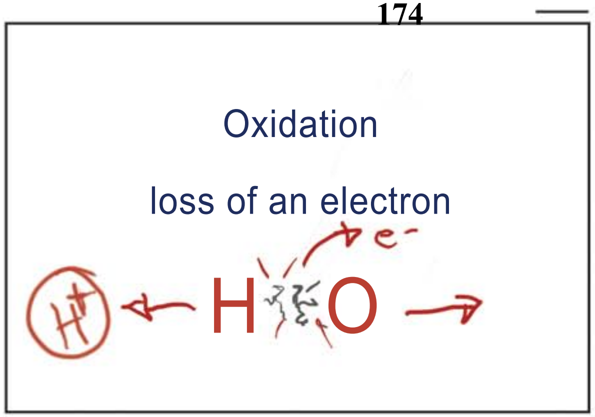
and the hydrogen is attached to carbon dioxide.

proton combines with CO2 and morphs into sugar

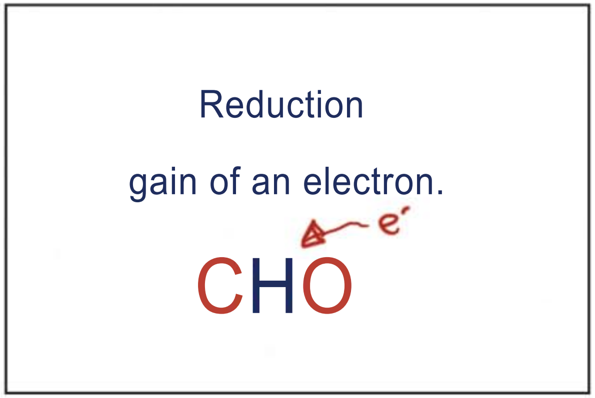


These two events are examples of oxidation and reduction.

equation play out
oxidation and reduction appear

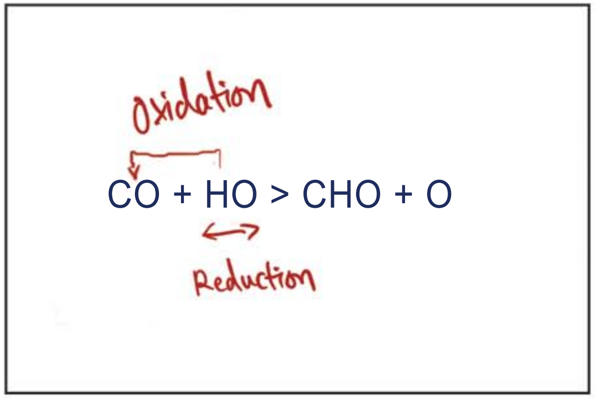


Oxidation is the loss of an electron Often when you break the bond between two elements like hydrogen and oxygen, energy in the form of an electron is released. And the molecules lose that electron.



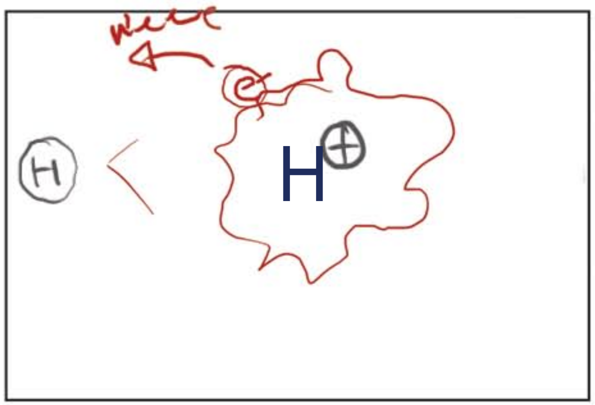
Reduction is the opposite.
Reduction is the gain of an electron

To form a bond between elements, energy is required. So the molecules gains an electron in order to bind with hydrogen



Why is hydrogen the one moving from one molecule to the other?

Redox still going
Zoom in on hydrogen



Hydrogen is composed of a single electron and proton. It has a tendency to give up its electron easily.

Hydrogen ball turns into letter
electron flys off on last sentence

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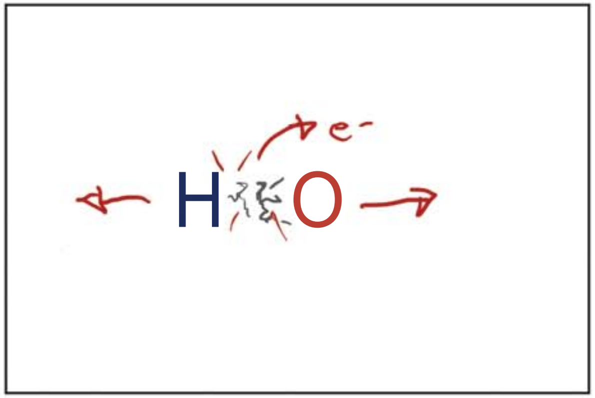
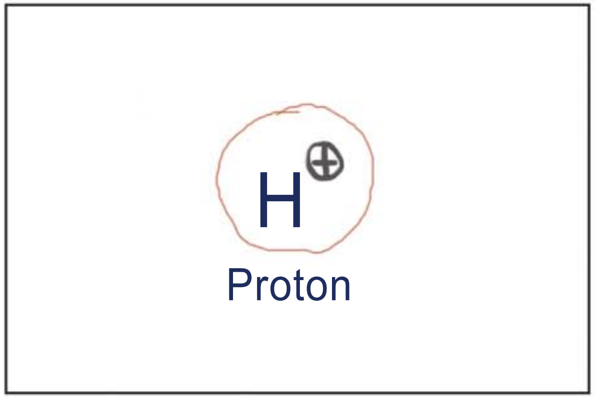
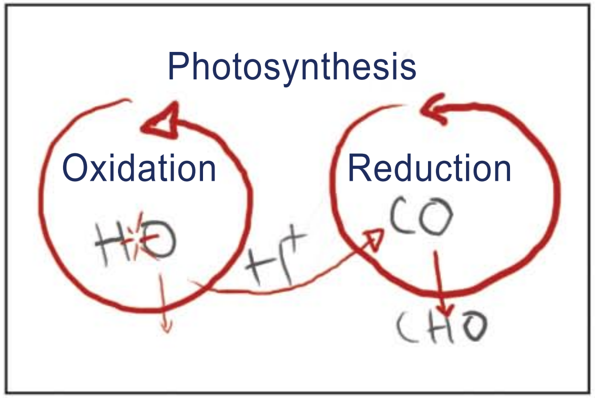


So often after breaking a bond containing hydrogen, the electron is lost

electron flys away, oxygen disappears



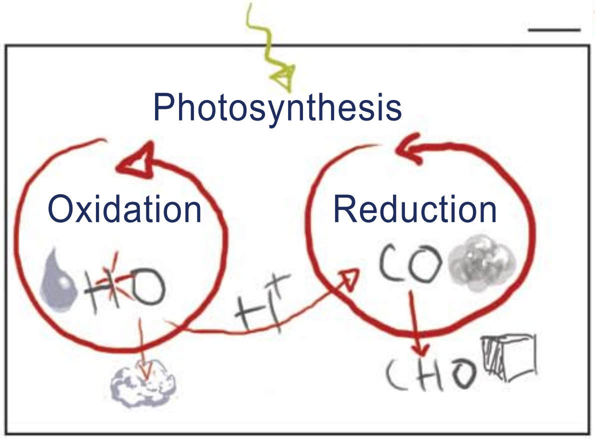
and the proton is left behind.That's why when you see the symbol H+, they're called protons because the hydrogen has lost its only electron You'll hear more protons later on..



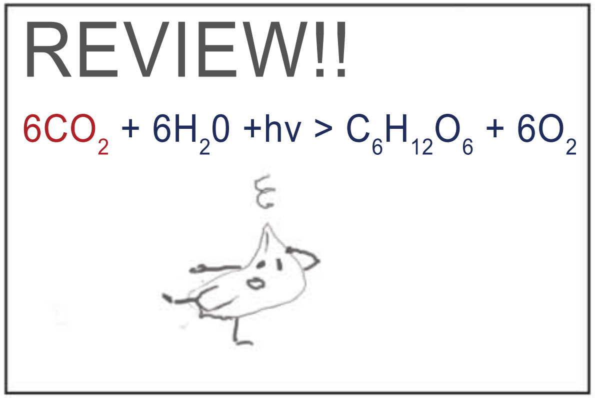
Now in the process of photosynthesis, oxidation and reduction occurs in two reaction cycles.

HO splits, H+ moves to the other cycle, CHO forms and falls away, new CO fades in

*CNBK

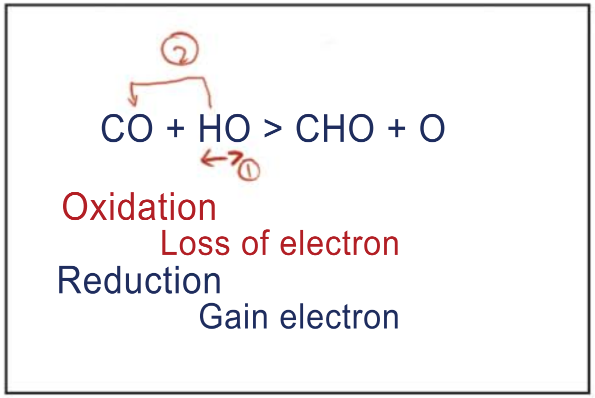


These reactions are cycles because the process can repeated as long as there are available resources like carbon dioxide and water and energy like sunlight.



Whew! Let's review. So the chemical equation of photosynthesis is: for every 6 carbon dioxide ... 6 oxygen molecule are made.

Corresponding molecule light up



Oxidation is the loss of an electron. Reduction is the gain of an electron.

Numbers fall away again

Oxidation occurs first, then reduction

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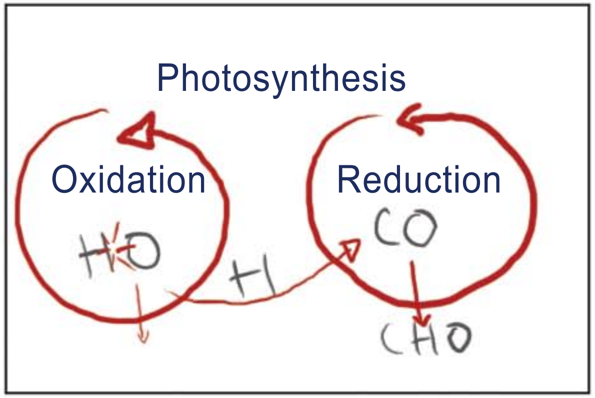
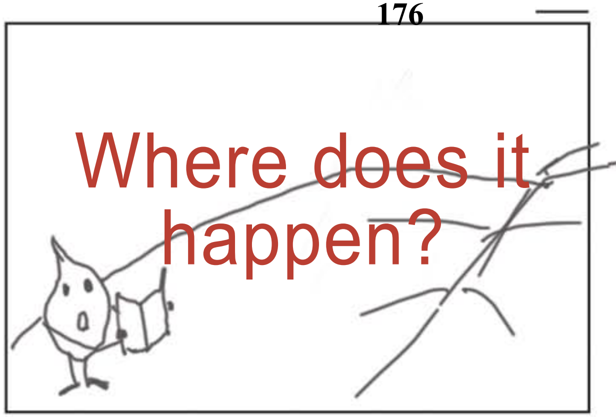
*Ch Brk

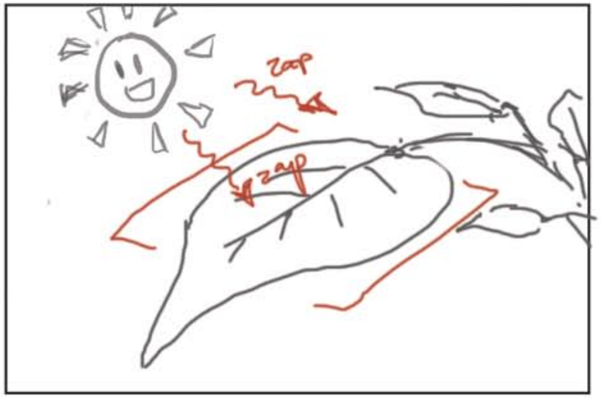


these two events occur in two separate reaction cycles.

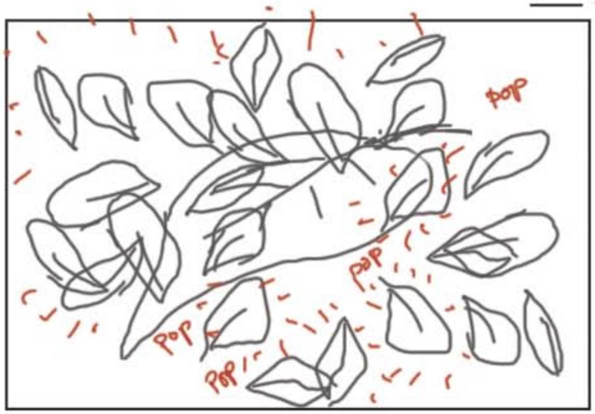
change into cycle

Now that we've seen the big picture, let's see where photosynthesis takes place!





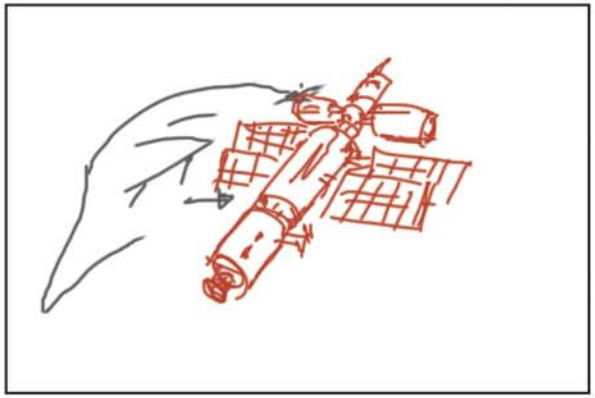
For most plants, the prime location for photosynthesis to take place is within the leaf of the plant, where a broad surface area maximizes exposure to sunlight.



At first glance, a plant leaf looks like mish-mash of random cells and is just green, lots of green.

big leaf is isolated

small leaves start popping up everywhere

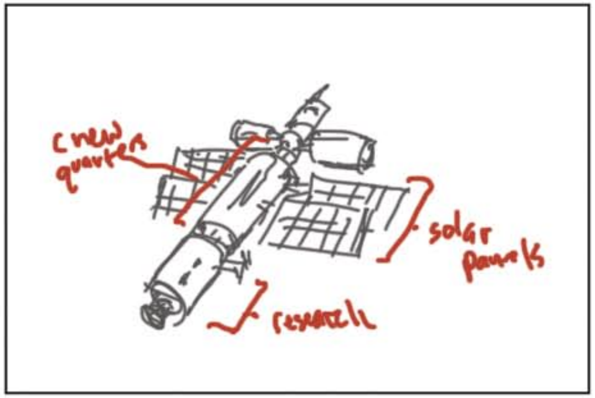


But if you take a closer look, the leaf is more similar to a self contained environment like a space station.

leaf morphs into space station

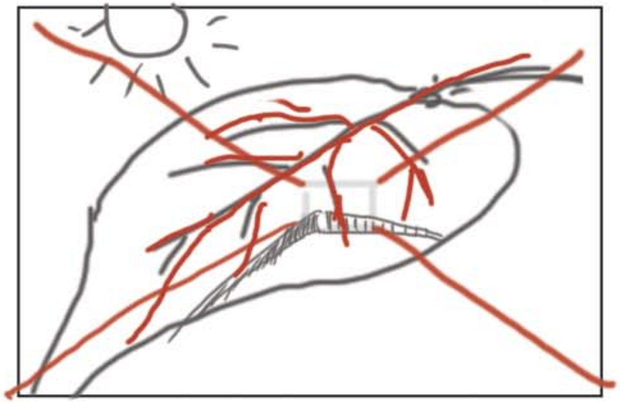
Project: Photosythesis

Version: 1



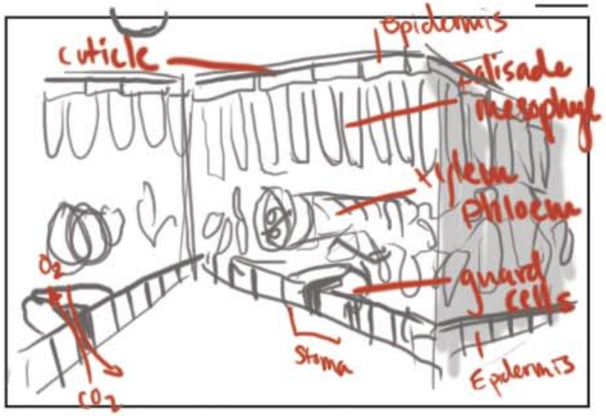
Just like a space station has solar panels to collect energy, living quarters for crew, and special sections for research,

highlight random sections



The structure is made up of individual cells with specialized tasks like piping that moves water and nutrients through the leaf,

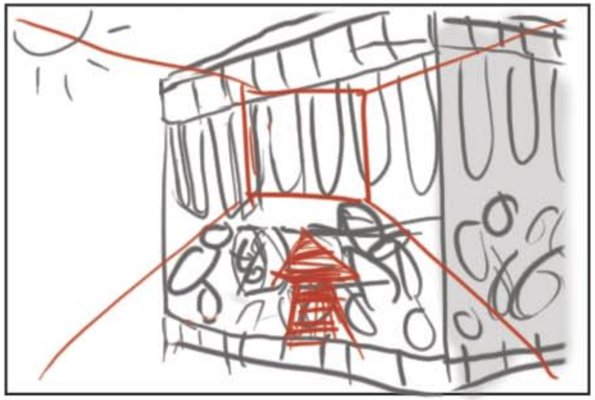
fade to leaf, zoom highlight sections



or preventing the loss of water, or monitoring the exchange of gases like CO2 and O2, or creating food for the plant.

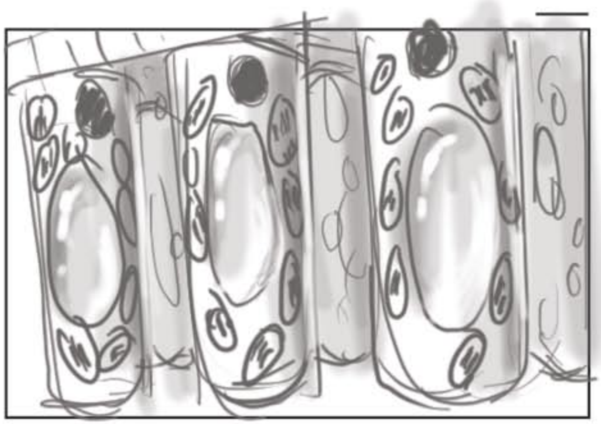
points to different cell layers

In the leaf, the biggest cell layer is called the mesophyll, which is split into the palisade mesophyll and spongy mesophyll.



Most cells specializing in photosynthesis are located in the palisade mesophyll.

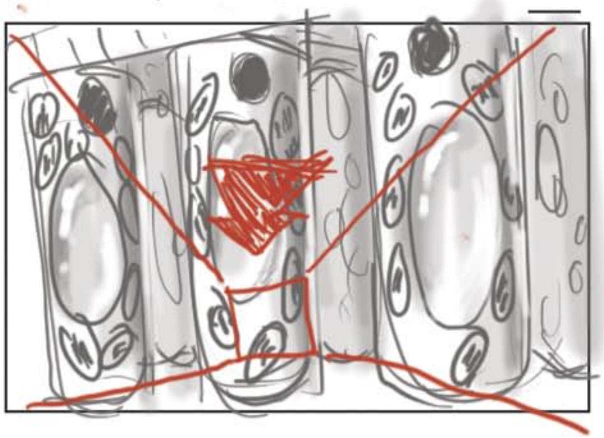
zoom in on palisade cells.



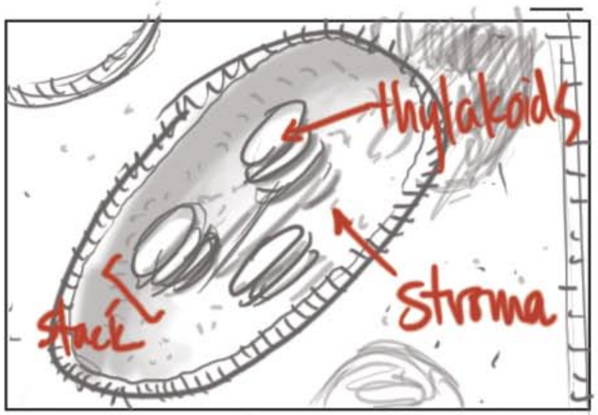
These cells have a higher number of chloroplasts and are oriented to have greater exposure to sunlight

Project: Photosynthesis

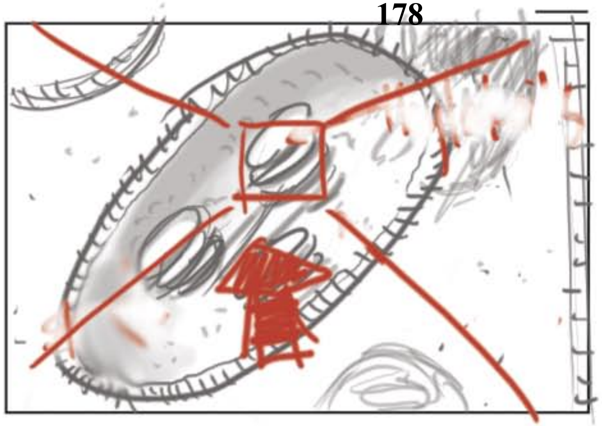
Version: 1



Zoom in on choloroplast



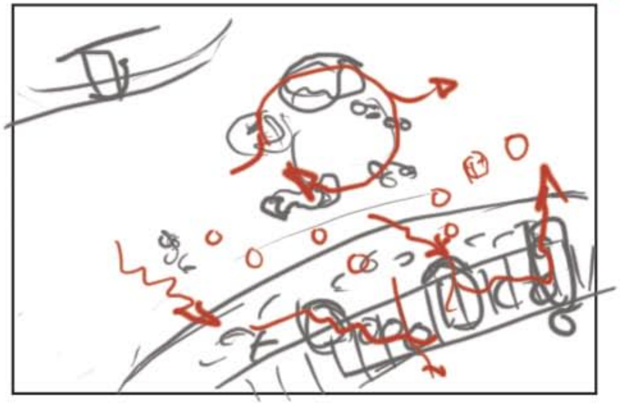
The chloroplast organelles contain special structures called thylakoids. These thylakoids arrange themselves in stacks. The substance surrounding the thylakoids with the chloroplasts is called the stroma.



If you haven’t noticed, we’ve zoomed past the structural and cellular level to the molecular level.

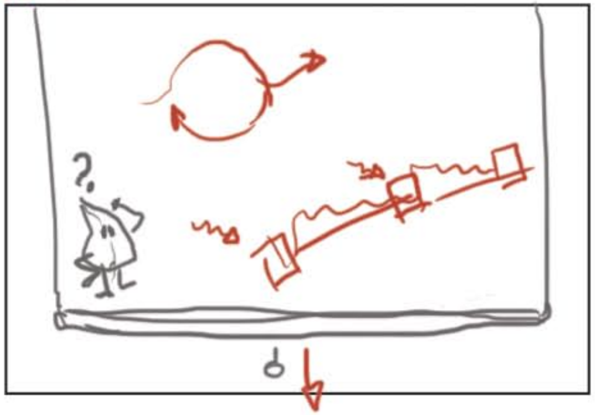
zoom in on cholorplast

*ChBrk



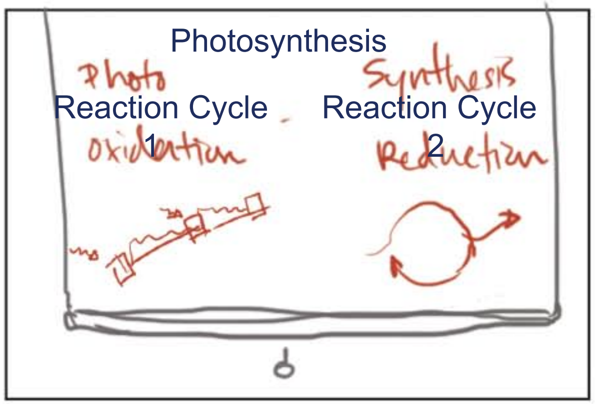
Remember that photosynthesis is a molecular process.

molecular activity taking place



HOW does photosynthesis work?

screen comes down, reactions simplified



Like we said before, the process of photosynthesis takes place in two MAIN Reactions Cycles, each composed of several individual reactions that are repeatable.

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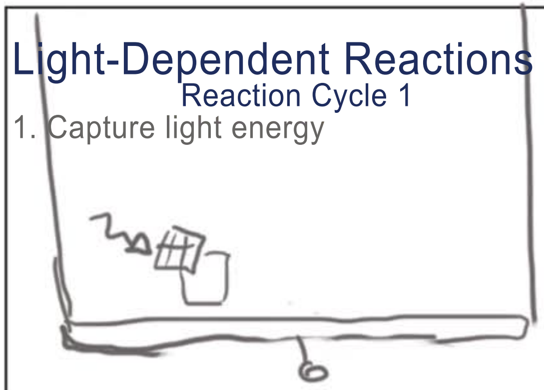
Light-Dependent Reactions
Reaction Cycle 1

The Light dependent reactions comprise the first cycle, or Cycle One.This is the “photo” part of photo-synthesis. Without the sun these reactions won’t go.

Light-Dependent Reactions
Reaction Cycle 1

1. Capture light energy



The main job of cycle one is to:
1. Capture light energy

Light-Dependent Reactions
Reaction Cycle 1

1. Capture light energy
2. Store energy by creating ATP and binding hydrogens to NADP, a “carrier molecule”

2. 2. Store that energy by creating small amounts of ATP and binding free hydrogen protons to NADP, a “carrier molecule” that will transport the stored energy to Reaction Cycle 2

Light-Dependent Reactions
Reaction Cycle 1

1. Capture light energy
2. Create ATP and store the free hydrogen as NADPH, a “carrier molecule
3. 3. Create more free hydrogen protons and form oxygen byproduct.

3. Create more free hydrogen protons and restore energy lost by splitting water and form oxygen as a byproduct.

Light-Independent Reactions
Reaction Cycle 2

The second cycle, Cycle Two, contains the Light-independent reactions. Like the name implies, this set of reactions doesn’t need the sun to do its job, so cycle 2 can be working day or night. This is the “syn-thesis” part.t

Light-Independent Reactions
Reaction Cycle 2

1. Use the ATP and NADPH created from Cycle 1 to make sugar.

The main job of cycle two is to:
1. Use the ATP and NADPH created from Cycle 1 to power the synthesis process.

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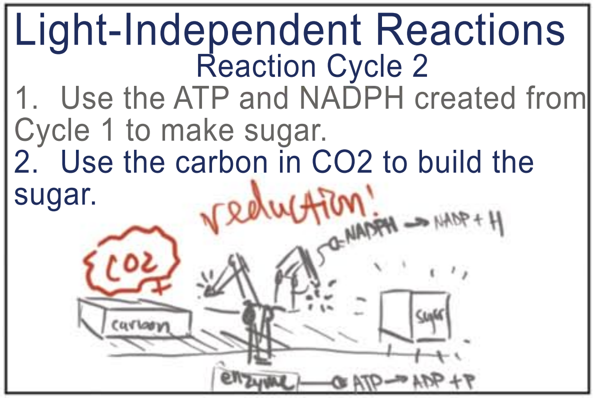
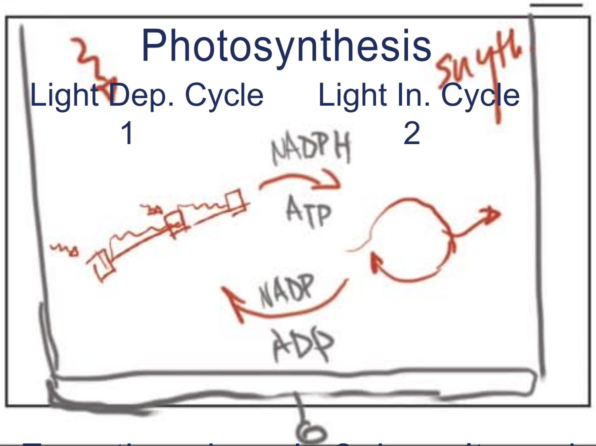


Light-Independent Reactions

Reaction Cycle 2

1. Use the ATP and NADPH created from Cycle 1 to make sugar.
2. Use the carbon in CO2 to build the sugar.

2. Use the carbon in CO2 to build the sugar.

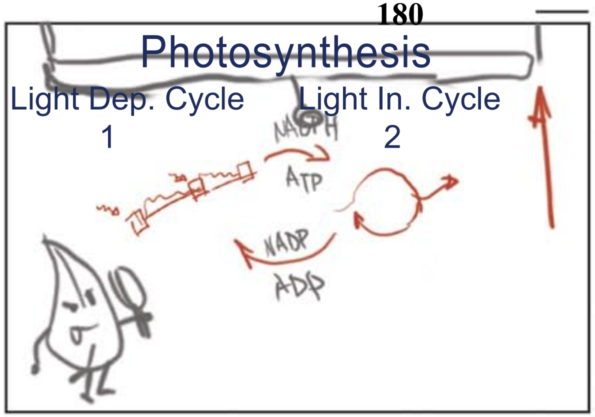


Photosynthesis

Light Dep. Cycle 1

Light In. Cycle 2

Even though cycle 2 doesn't need sunlight to function, it is still dependent on the products created in cycle 1 to drive its own reaction. So if cycle 1 stops working, eventually cycle 2 will grind to a halt



Photosynthesis

Light Dep. Cycle 1

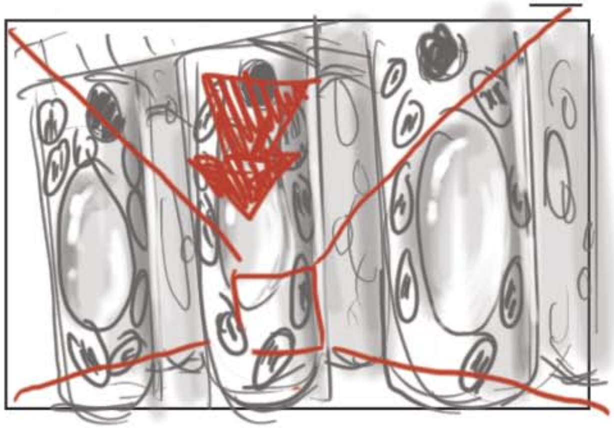
Light In. Cycle 2

Now that you understand the basics of the two main cycles, we're going to dive deeper and learn HOW each cycle does its' job.

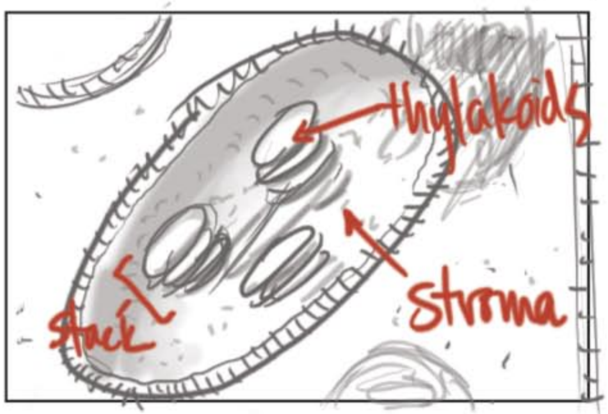
Cycle 1: Light-Dependent Reactions

REVIEW!

Let's review anatomy:



Cells contain many chloroplasts.



Within a chloroplast are many stacks of thylakoids and the thylakoids float in the stroma.

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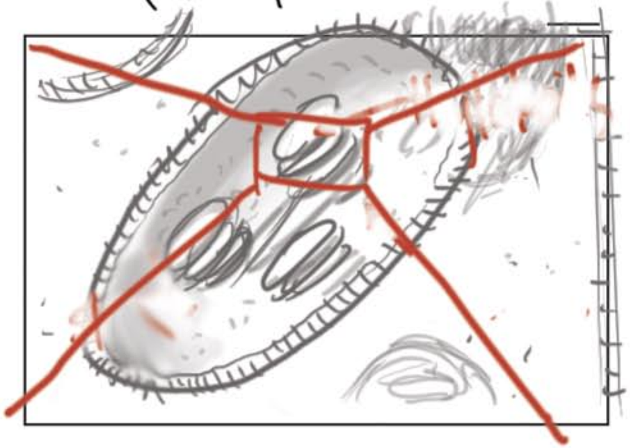
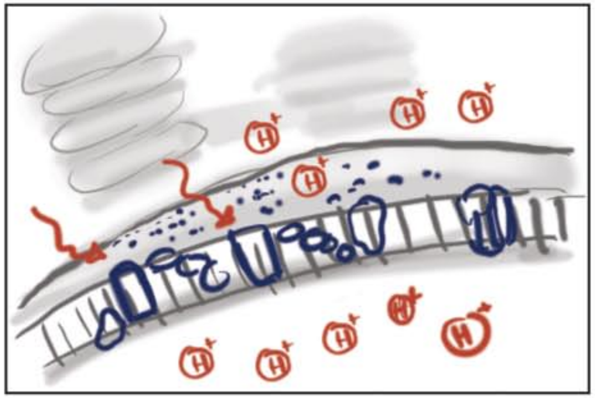
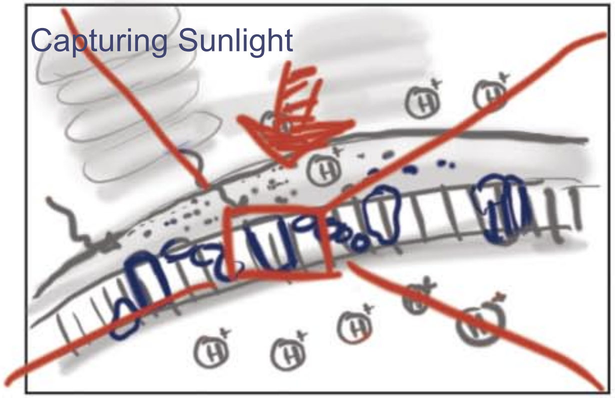


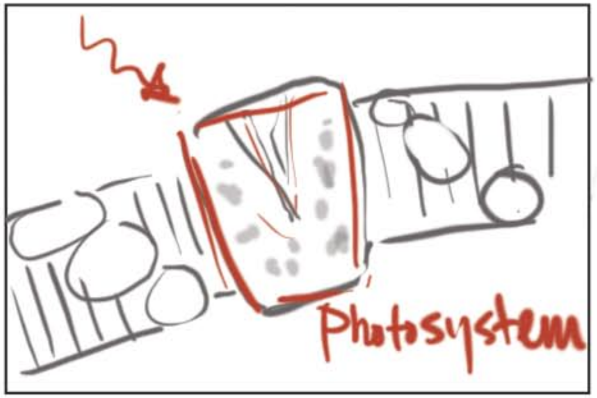
zoom in on stack



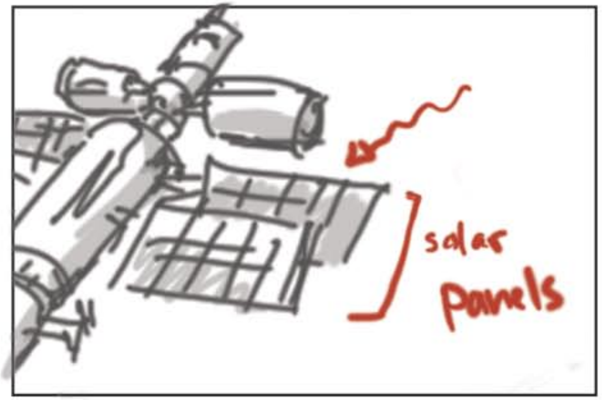
The first cycle takes place within the membrane of the thylakoid and functions through a variety of specialized protein structures that dot the surface.



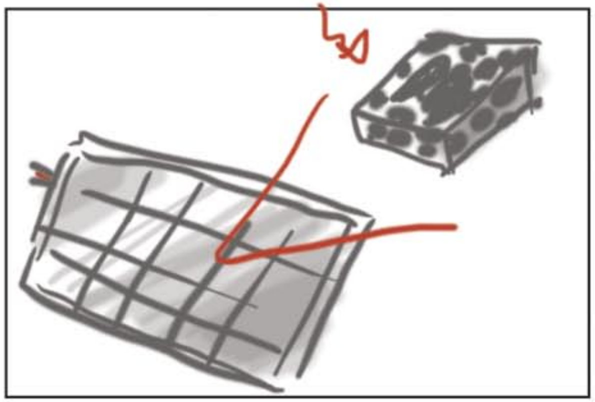
One of these specialized protein structures,



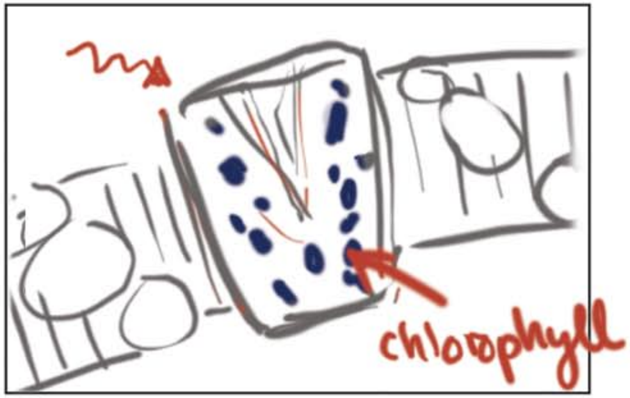
called a photosystem, is in charge of capturesthe sunlight energy.



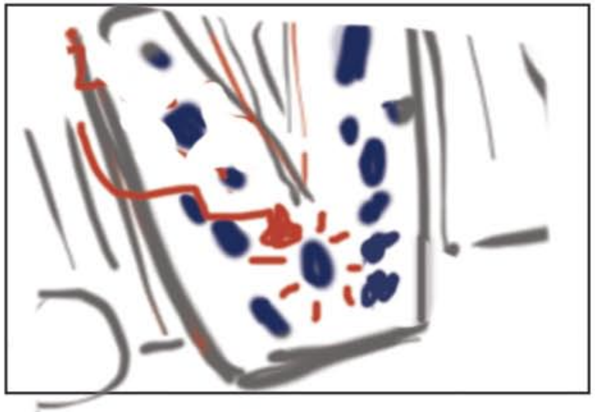
Photosystems are likesolar panels on a space station that capture the sunlight for powering equipment and maintaining station functions.



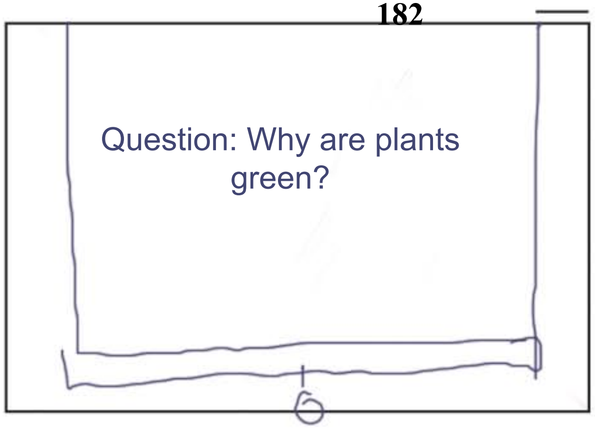
The solar panels are made of special materials to absorb the sunlight.



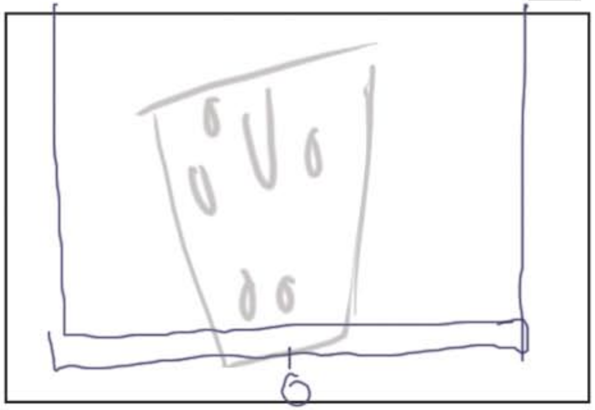
In photosystems, there are material pigments called chlorophyll absorb the sunlight.



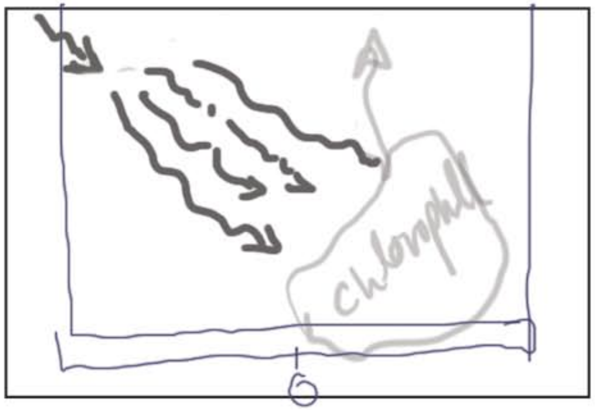
Electrons in the chlorophyll pigments become energetic as the light energy is absorbed.



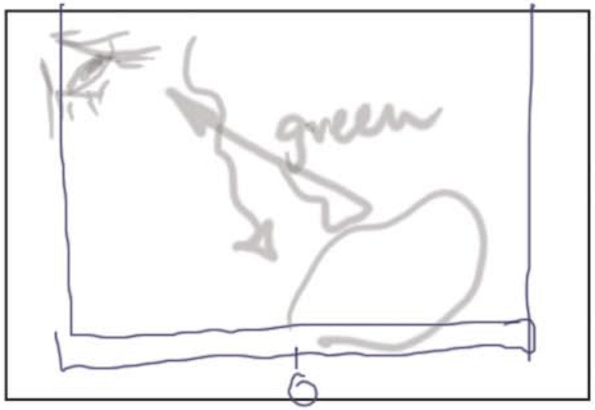
Question: Why are plants green?



If you said because of the cholorphyll, you're right! But why is chlorophyll green?



White light is made up of a spectrum of colors, and chlorophyll is capable of absorbing most colors except for green colored light.



We see green light that is reflected off the object. Think about that when you look any colored surface. You're actually looking at the color that wasn't absorbed by the material and is being reflected back to you.

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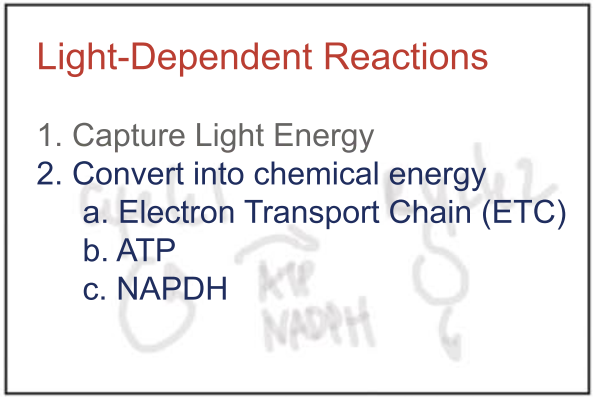
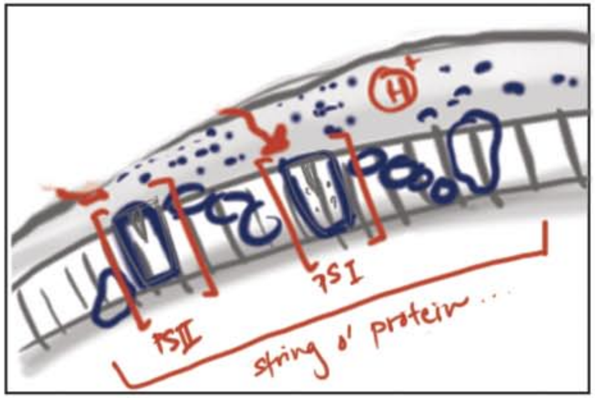


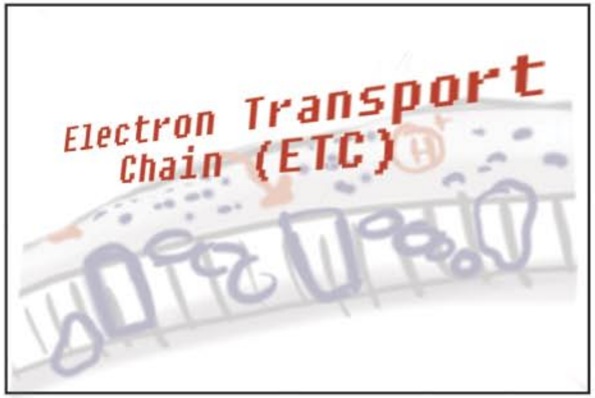
Light-Dependent Reactions

1. Capture Light Energy
2. Convert into chemical energy
    a. Electron Transport Chain (ETC)
    b. ATP
    c. NAPDH

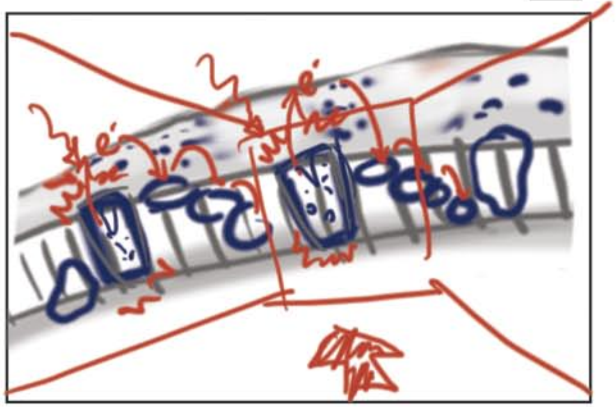
Now that you know how sunlight is captured, let see how the light energy is converted and stored as chemical energy for later use in Cycle 2. There are three main steps: the electron transport chain, the production of ATP (chemical energy), and the production of NAPDH, a carrier molecule.



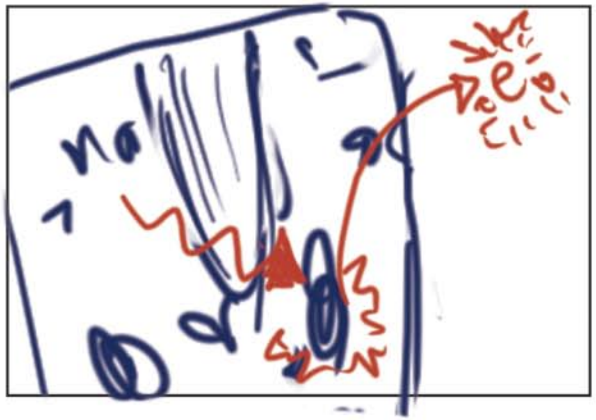
Remember we're still in within the membrane of the thylakoid. As you can see, there are multiple photosystems that capture the light energy and they are part of a larger string of proteins called:



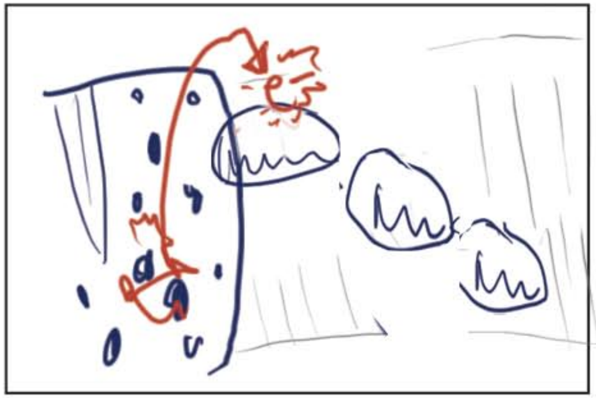
the Electron Transport Chain or ETC for short!



The Electron Transport Chain moves electrons, which have been excited by the photosystems, down a string of proteins.



The energy absorbed by the chlorophyll pigments causes an electron to become "excited" to a higher energy level and is ejected from the chlorophyll molecule.



This excited electron and the energy it contains is "lost" by the photosystem and it jumps out into intermediat protein.

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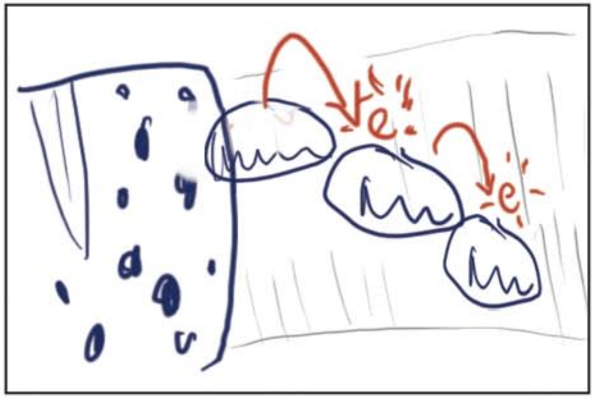
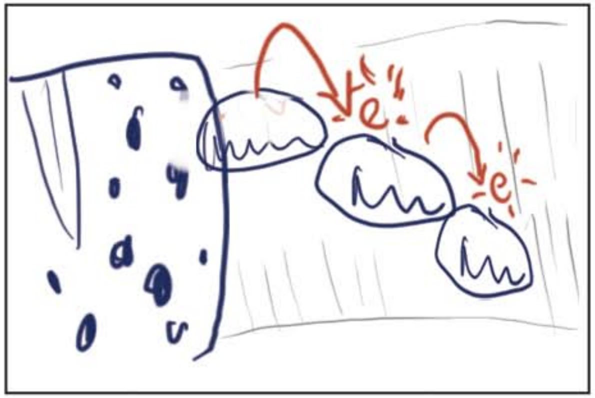
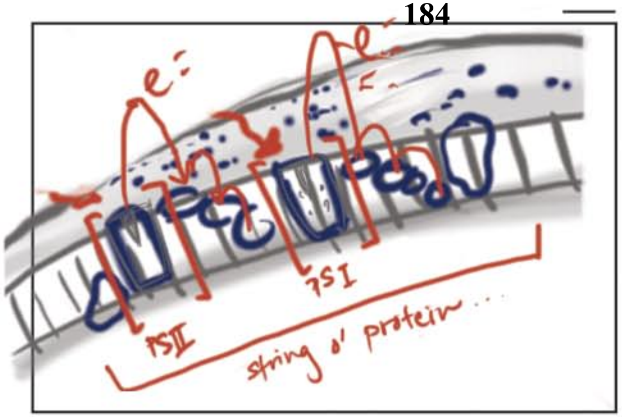


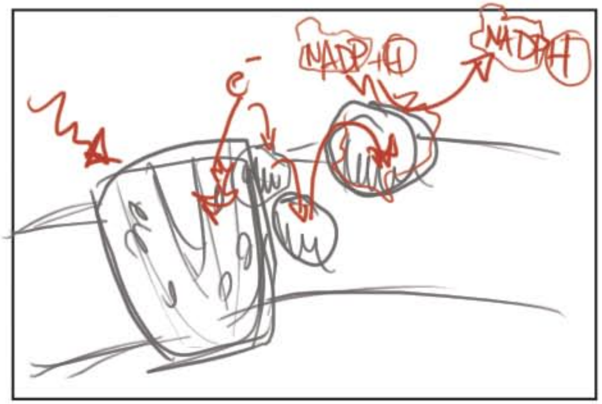
These proteins continue to pass on an excited electron down the chain of proteins like a hot potato.



And just like a hot potato that loses heat as it cools, each excited electron that is passed on loses energy. The energy required to move to the next protein is less than the previous so electron keeps moving.

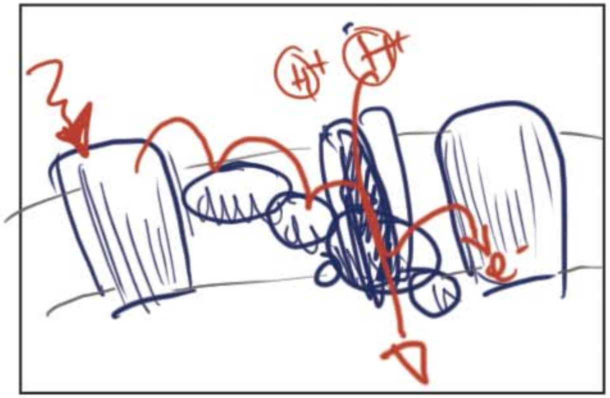


Each ETC contains two photosystems. So you can see that this excitation of an electron and transporting it down a chain of proteins happens twice.

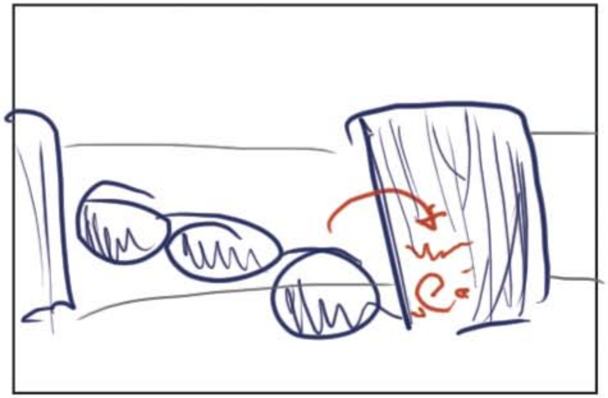


In Photosystem I, the electron is excited and passed through intermediate proteins to eventually power a NADPH synthesizer.. This protein structure combines NADP with hydrogen proton (H+) to make NADPH.

show acivity and camera pand right

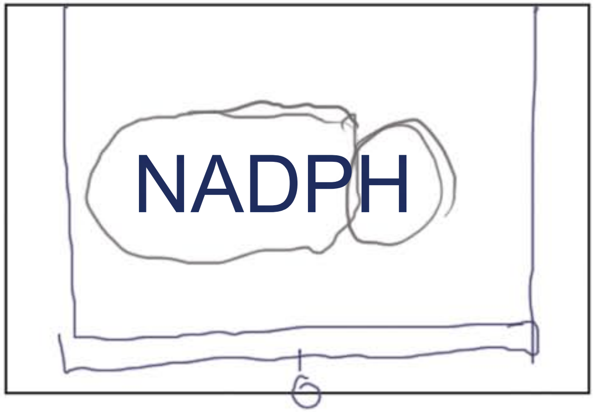


The Photosystem II also ejects an excited electron that is passed down intermediate proteins, which activate to pull H+ into the thylakoid

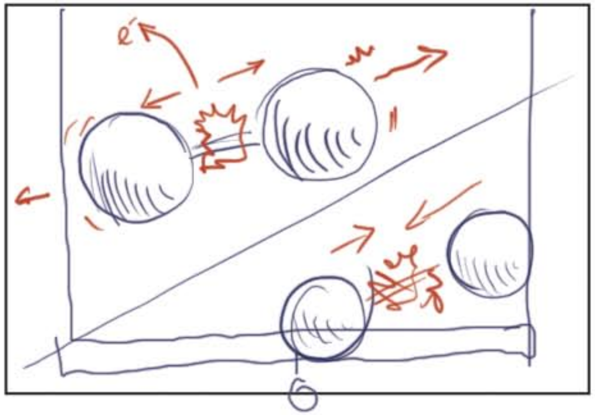


This electron eventually restores the electron lost from photosystem I.

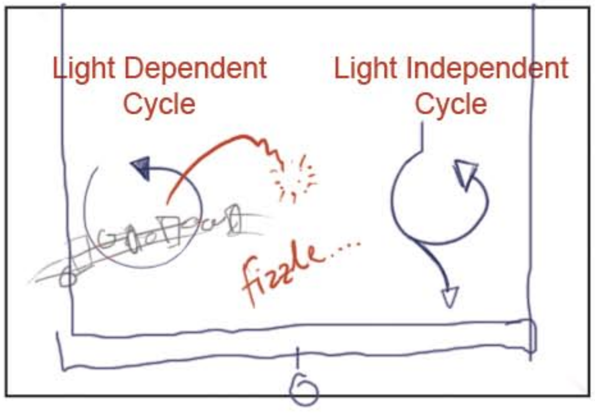
electron fades to nothing



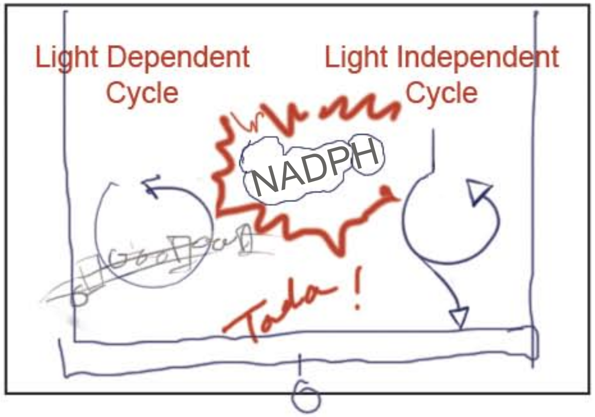
Why is this NADPH important?



Energy is released when bonds between molecules are broken. And vice versa, energy is required to bind molecules back together.

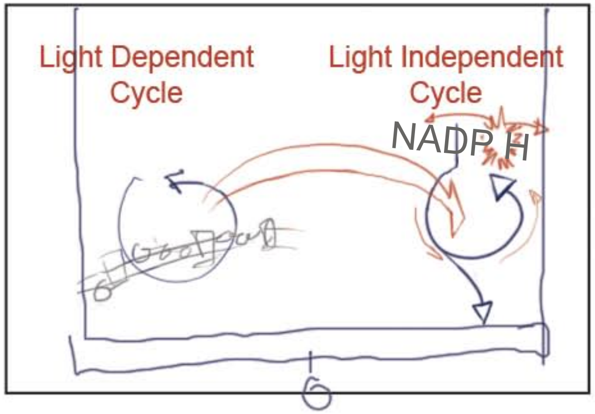


Cycle 1 has no way of giving energy to Cycle 2 to use to make sugar.



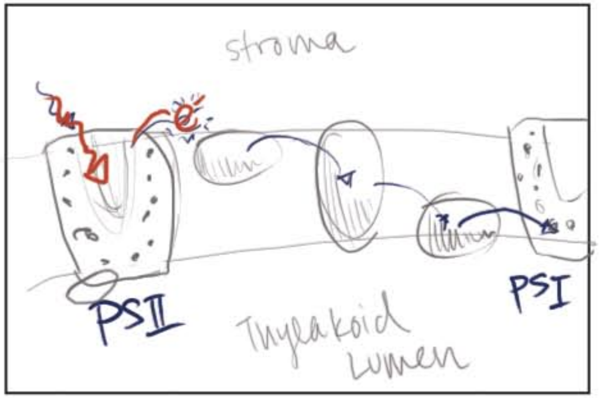
So that's where a molecule like NADPH can act as a carrier between the two reaction cycles!

By binding NADP with Hydrogen, the cell is able to use the energetic electron released from the photosystems and passed through the ETC.

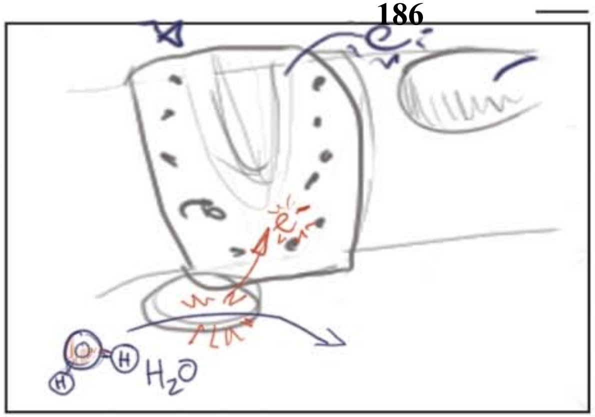


The resulting NADPH can be broken later in Cycle 2, releasing the energy to finish making sugar.

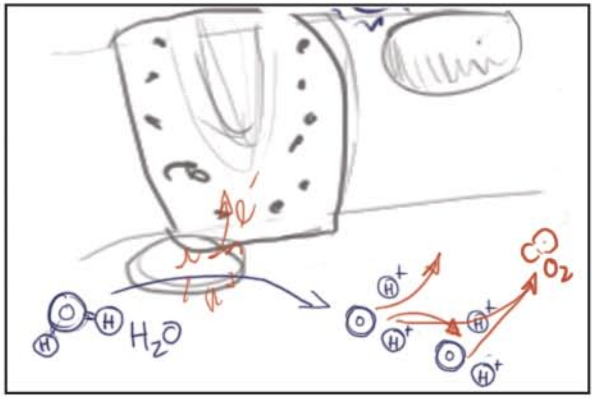
Photosystem I loses an electron to make NADPH.



Photosystem II loses an electron to give to Photosystem I. Now Photosystem II needs to replenish its own lost electron. That's where splitting water is needed!

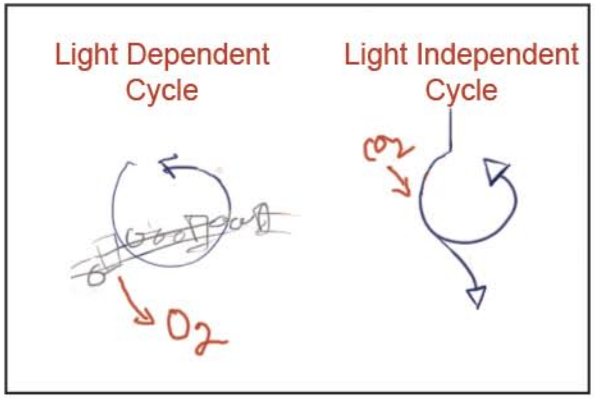


So attached to PSII is special water splitting protein that breaks up H20 and takes the electron for PSII.



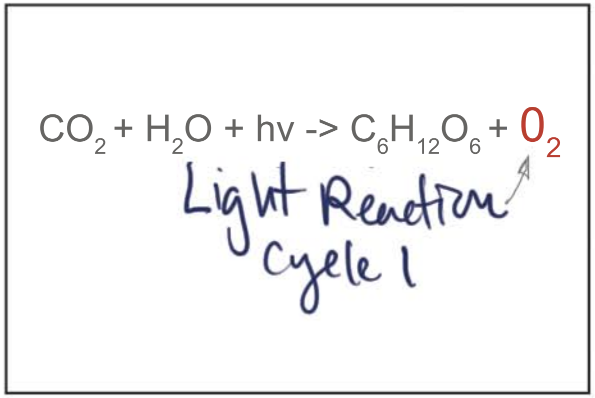
Hydrogen protons(H+) and oxygen byproducts are released.

Have the splitting H20 occure twice

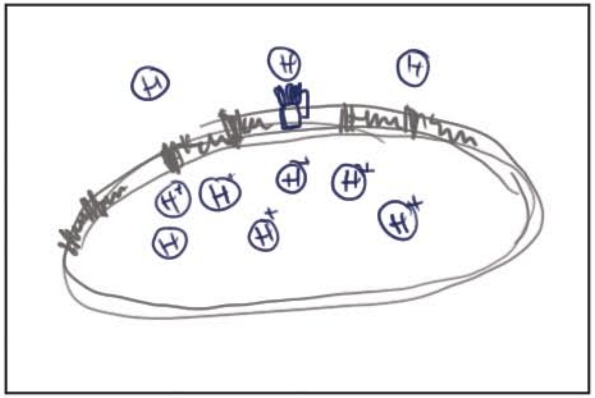


This is an important point: Oxygen is produced when water is split in the light dependent reactions, NOT from CO2 in the light-independent reactions

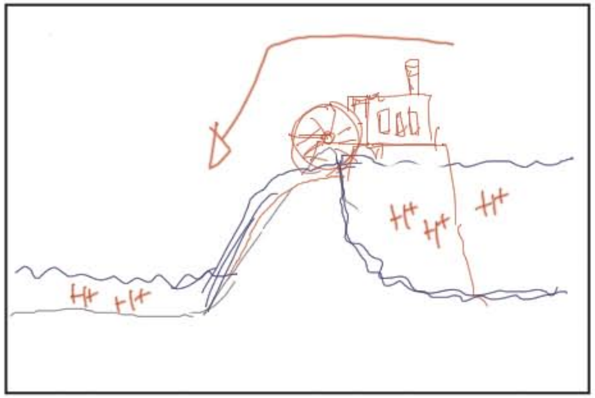
the cycles fade aways except O2.



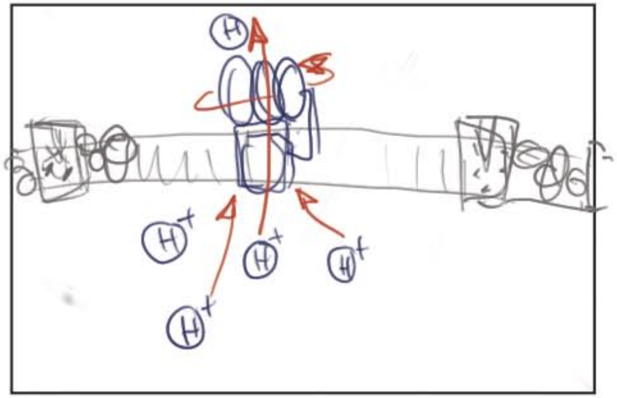
If we look back to the photosynthetic chemical equation, we can see that oxygen, one of the products, is created here in the electron transport chain of cycle 1.



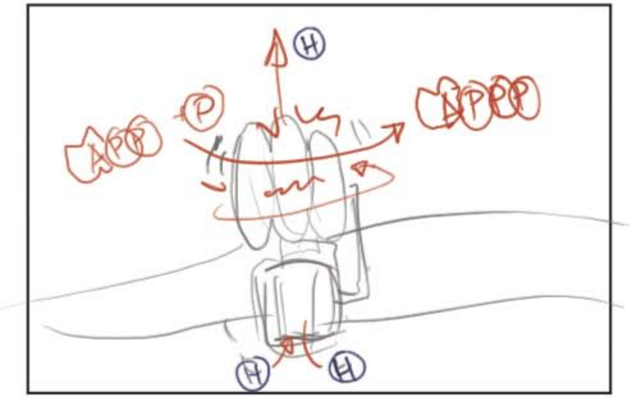
Now the whole time that Cycle 1 has been active, hydrogen protons pumped into the thylakoid from the ETC and created from splitting water has caused a concentration imbalance. There are too many protons inside the thylakoid.



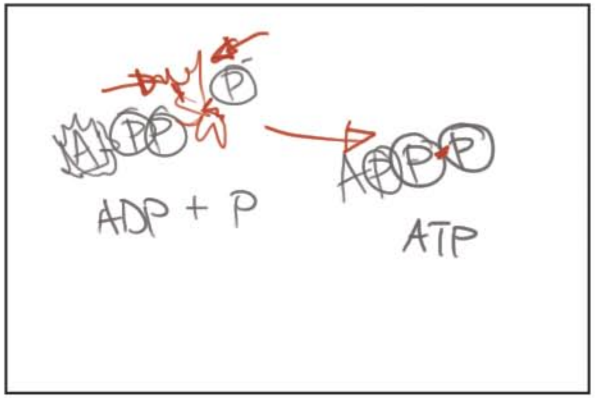
Imagine a dam that has too much water on one side. To balance the water levels, a channel is put in place. But this flow of water can also do work by placing a water wheel.The energy produce can be used to power a factory.



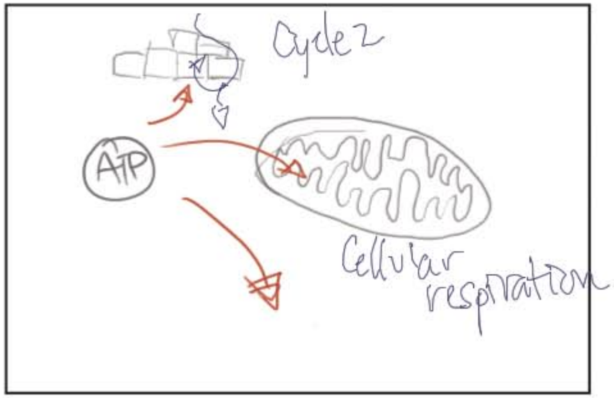
The cell does the same thing to balance out the hydrogen proton concentrations inside the thylakoid and outside in the stroma. A special protein channel passively lets out the excess H+.



This channel is put to work too and attached is an ATP synthesizer which drives the formation of ATP from ADP and P.



Remember, energy is stored in in molecular bonds. So when phosphorus binds to ADP, energy is stored in the bond.



This energy stored in ATP can be used in Cycle 2 or in other areas of the cell

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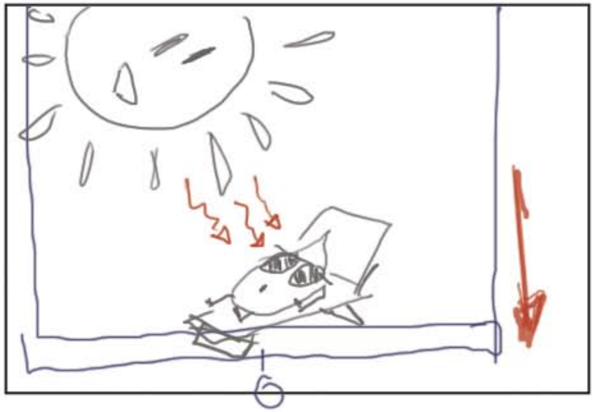
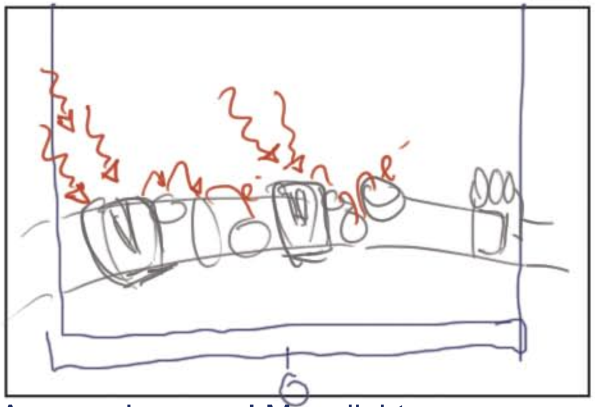
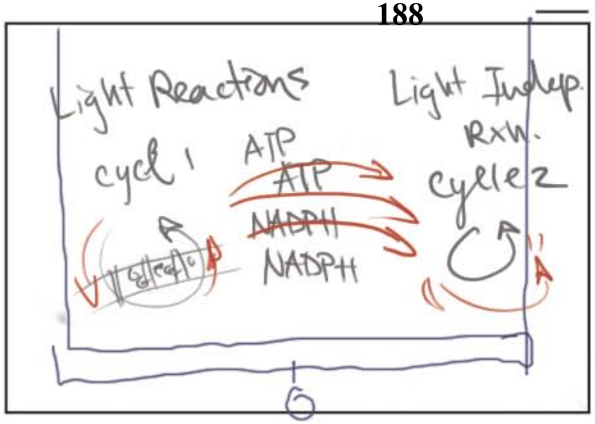


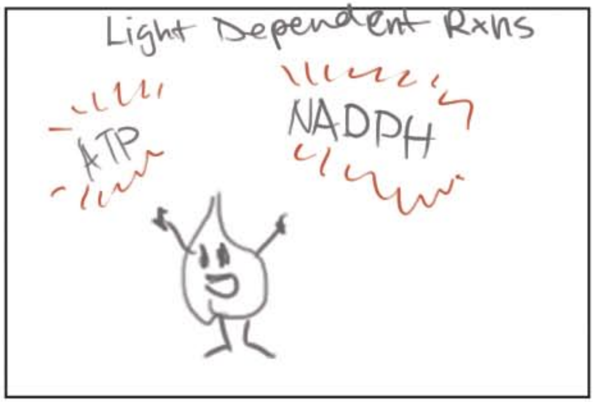
Based on what we learned, If a plant receives more light will the rate of photosynthesis increase or stay the same?



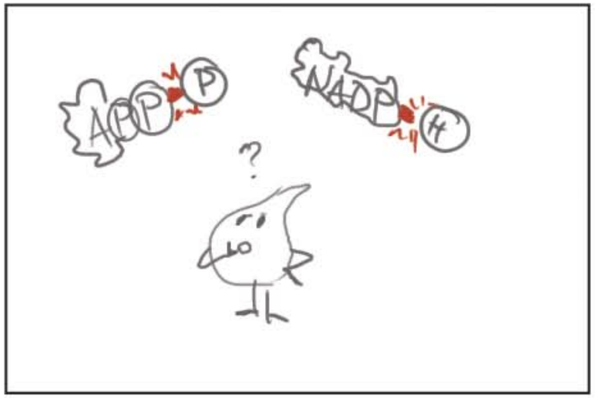
Answer: Increase! More light means more photosystems activated to absorb the energy. More ATP and NADPH is created through the ETC. This will keep increasing until the cell runs out of Electron Tranport Chains to capture and process the light energy.



More ATP and NADPH available will increase the production of sugar.

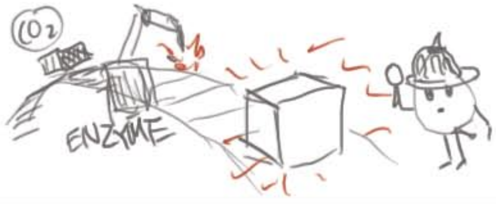


Yay! We've made ATP and NADPH. The energy carried within each molecule can now be used by the cell for important functions.

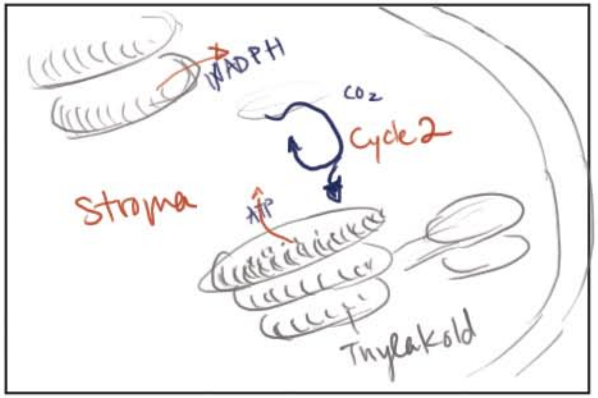


But what if we want to store that energy for a cloudy day? Then we make sugar!

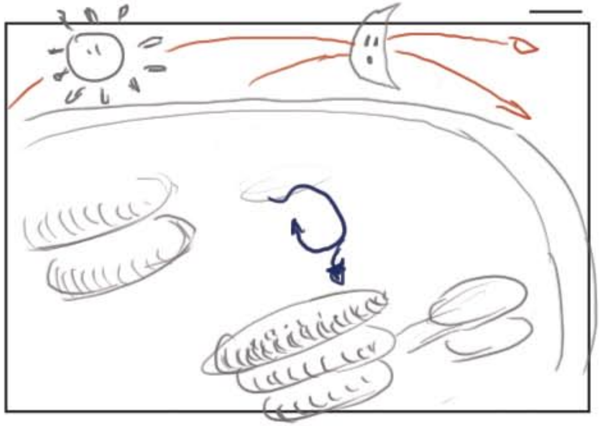
Cycle 2: Light Independent Reactions



Cycle 2: Light independent reactions

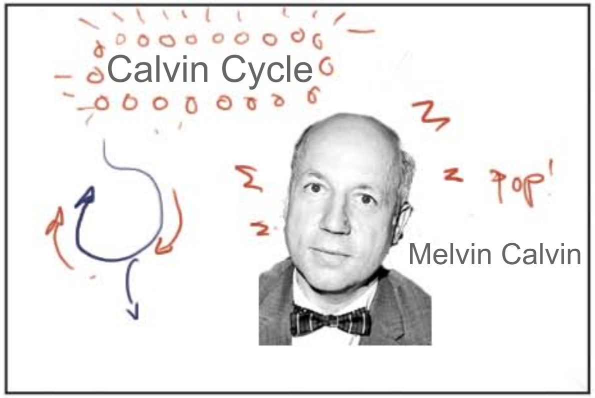


Cycle 2 actively takes place in the stroma, the spaces between the thylakoid stacks.

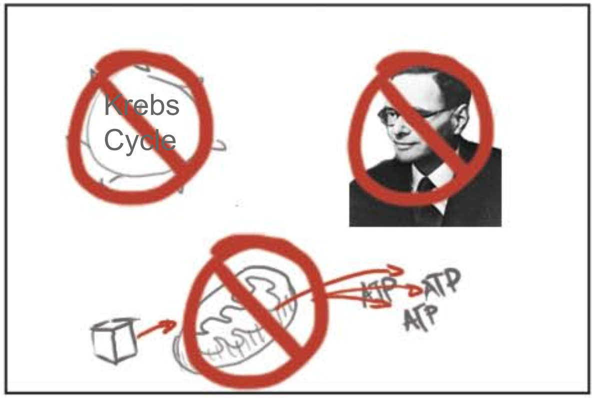


These reactions can work day or night

Sun comes up and sets
moon comes up and sets



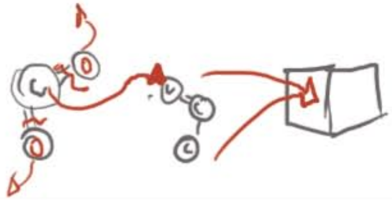
REMEMBER: Cyle 2 is also called the Calvin cycle because it was worked out by Melvin Calvin many years ago.



It should NOT to be confused with the Krebs Cycle, which happens in the mitochondria and is involved in breaking down sugar through cellular respiration.

Light Independent Reactions

-Use CO_2 to build sugar



Two things are happening in the Cycle 2: It uses CO2 as material for synthesizing sugars,

Light Independent Reactions

-Use CO_2 to build sugar
-Power the reaction with ATP and NADPH from Cycle 1

and it powers the cycle of reactions using ATP and NADPH made from Cycle 1 (the Light Dependent Reactions.)

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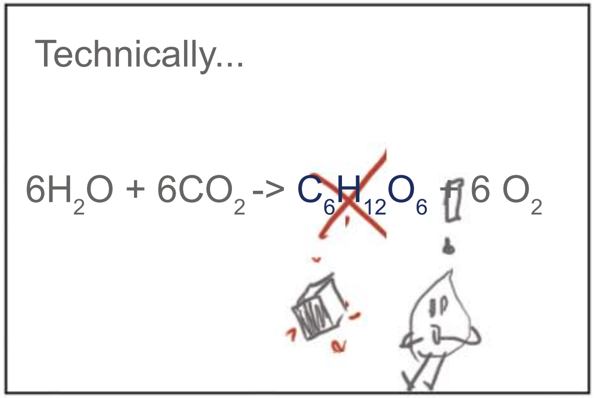
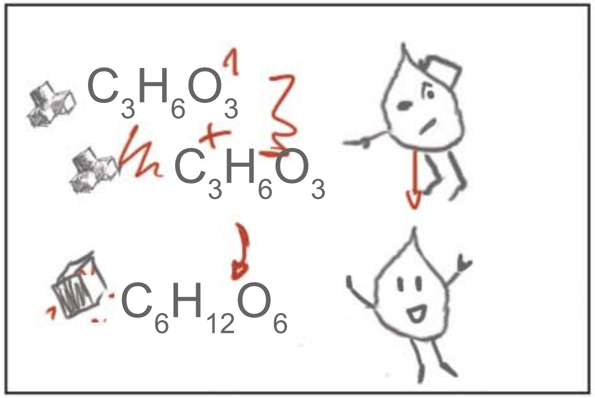
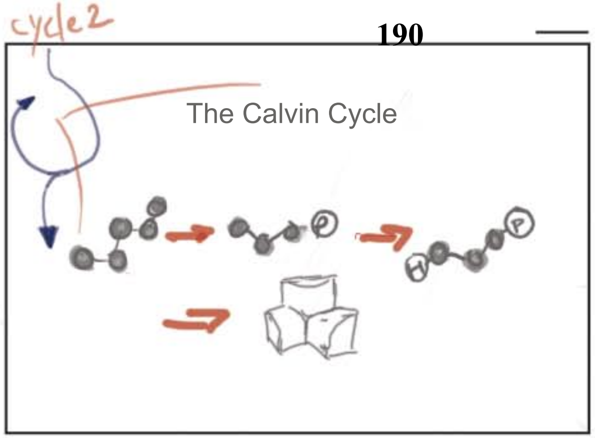


The Calvin Cycle itself doesn't make the final 6-carbon sugar that you see in the chemical equation.

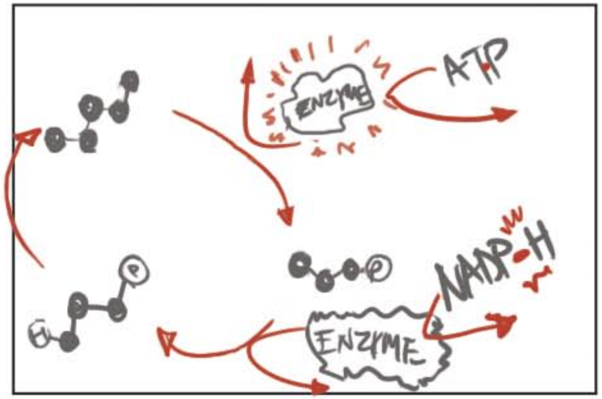


It makes a 3-carbon pre-sugar compound that can be joined later to make the 6-carbon sugar.

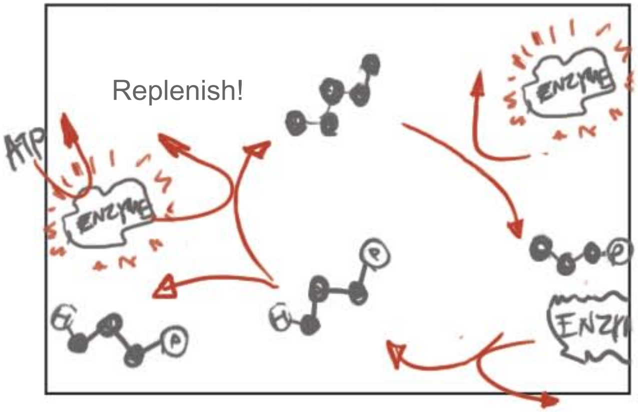


Essentially the Calvin Cycle is a series of reactions that takes a base organic molecule and reshapes and modifies it until a pre-sugar compound is formed.

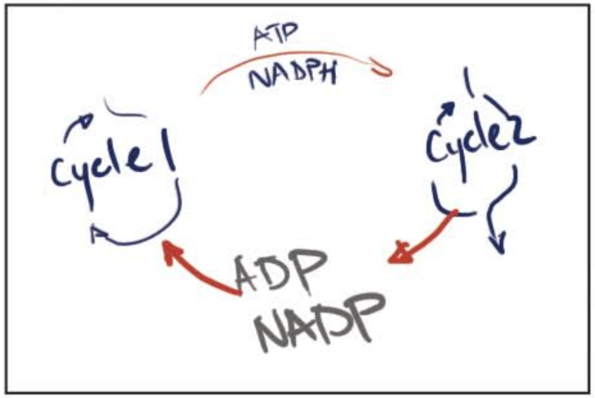
show cycles and expand into carbon molecules



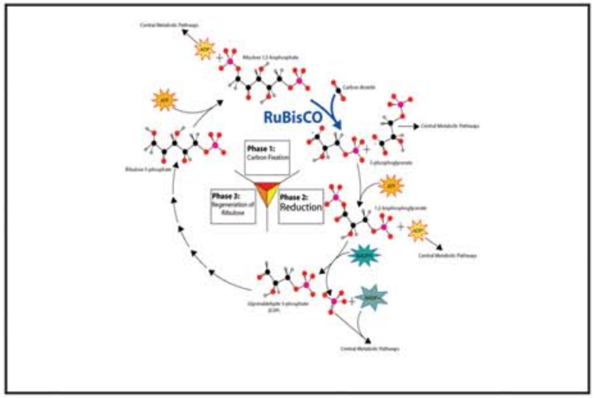
Each step in the modification requires a specialized enzyme and energy to keep it going.



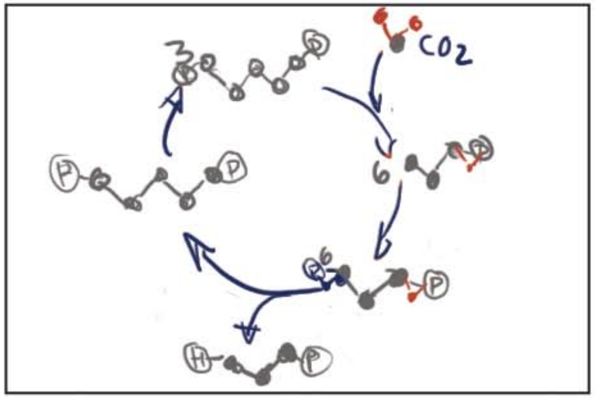
This is a cycle because it is not only able to create a pre-sugar compound but also restore its original base molecule to repeat the process over again



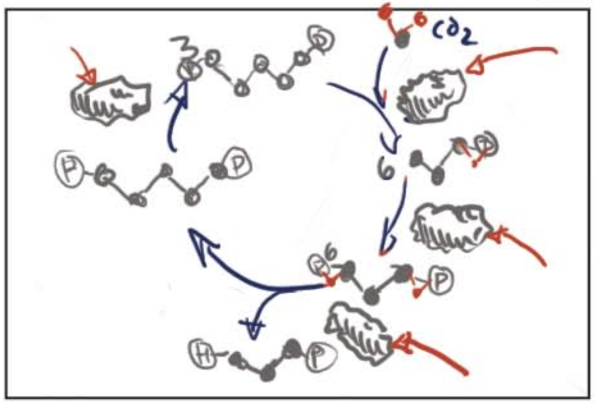
Any spent ATP and NADPH, now ADP and NADP, is recycled back by used by cycle 1.



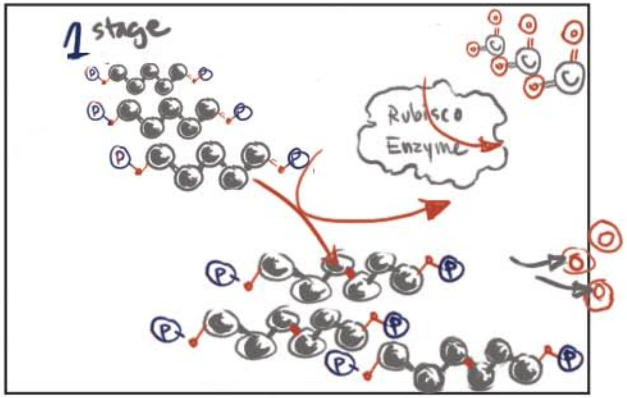
At this point, it’s not so important that you know the details of the Calvin cycle. But to illustrate how this cycle is able to sustain itself so efficiently we’ll focus on carbons that make up the base organic molecule.



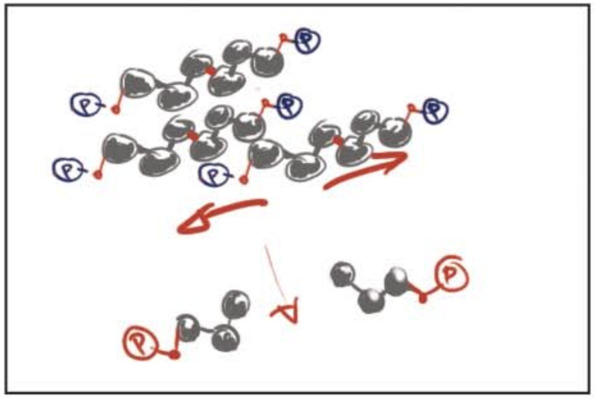
All enzymes have been generalized for simplicity.



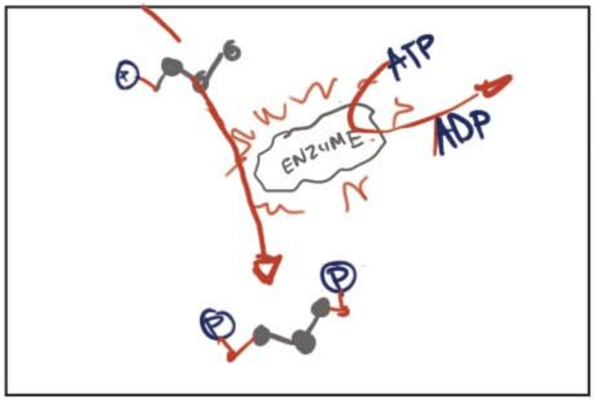
Let’s follow the Carbons!!



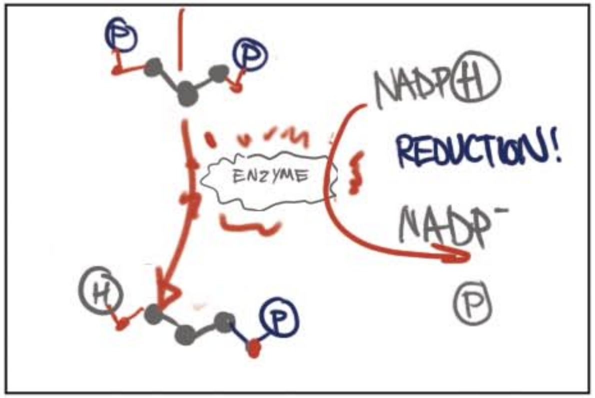
1. 3(5-carbon compounds) binds with 3CO2 molecules using a specialized enzyme



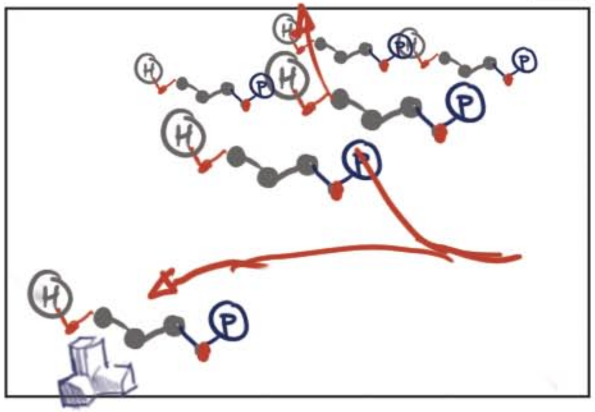
This reaction initially results in unstable 6-carbon compounds, which immediately split into 6 3-carbon compounds.



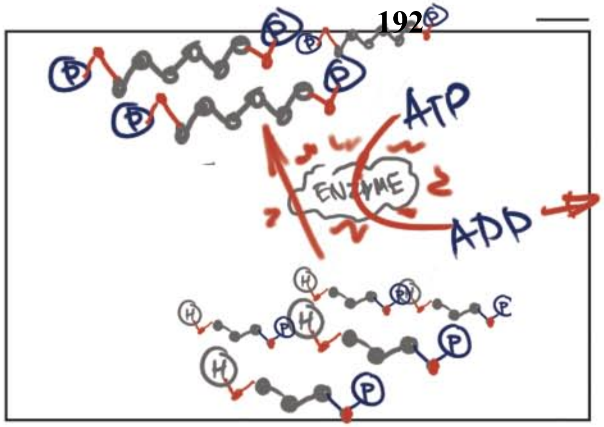
2. 6 ATP and enzymes are used to stabilize the 3-carbon compounds



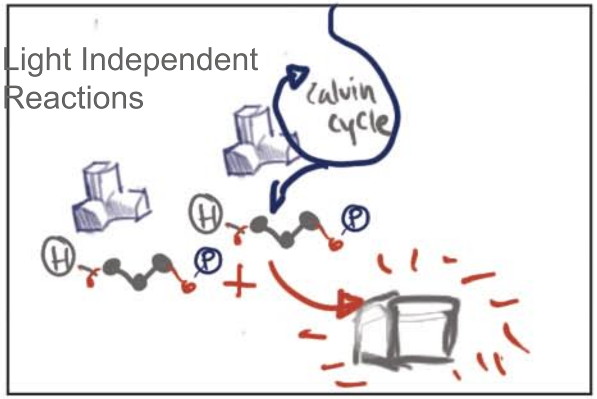
3. 6 NADPH and enzymes are used to modify the 3-carbon compound into the pre-sugar compound.



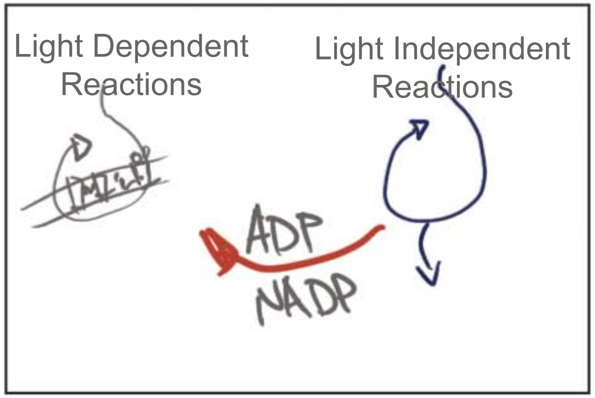
4. 1 (3 carbon pre-sugar compound) exits the cycle



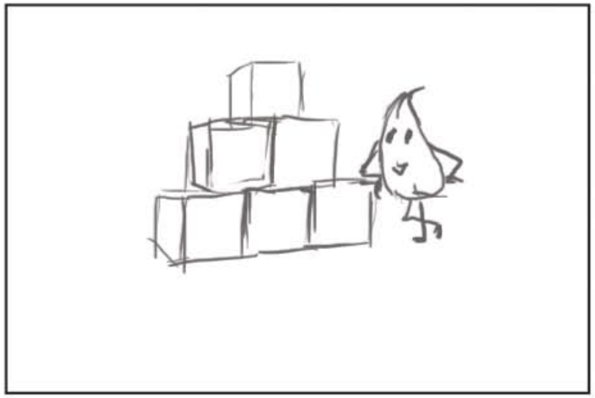
5. 3 ATP and enzymes rearrange the remaining compounds back into the 3(5-carbon compounds)



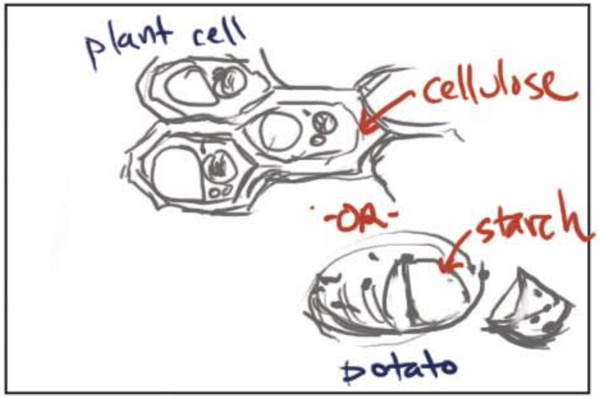
The cycle continues to repeat and every two 3-carbon pre-sugar compound is combined to make the full 6- carbon sugar.



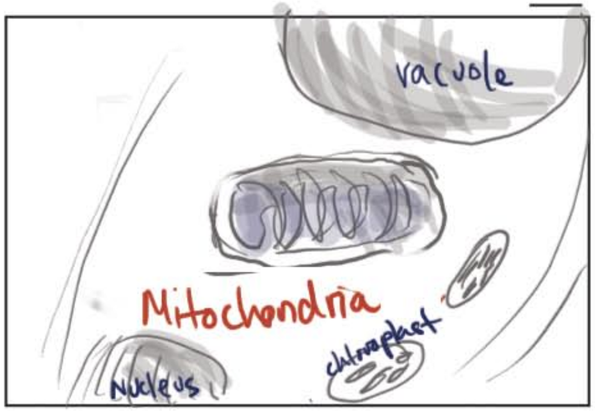
Remember: Spent ADP and NADP are fed back into the light reactions to be reused.



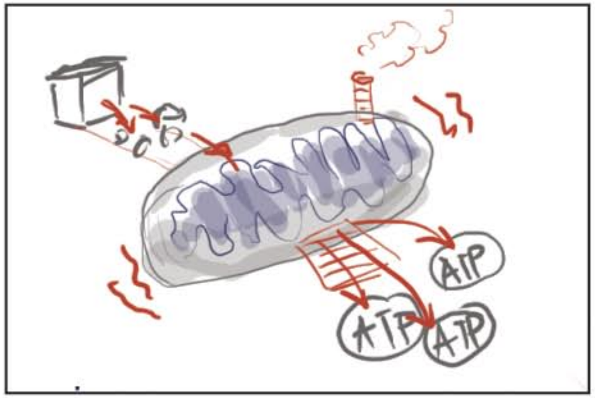
Now that we made sugar, what does the cell do with it?



Store it! The plant makes cellulose in cell walls or turns surgar into starch like potatoes.



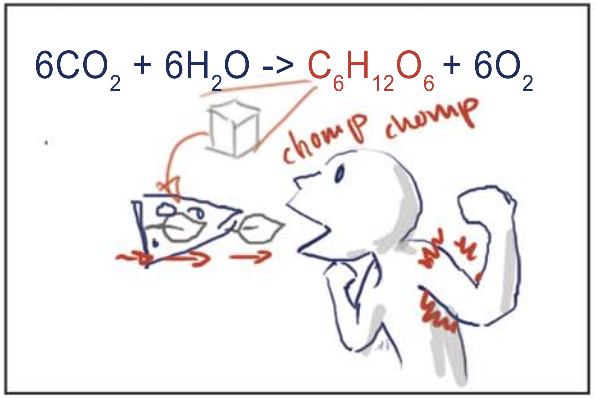
Use it! Through cellular respiration that takes place in the mitochondria of the cell



the sugar can be broken down to bind a great number of ADP and P to make ATP for cellular function.

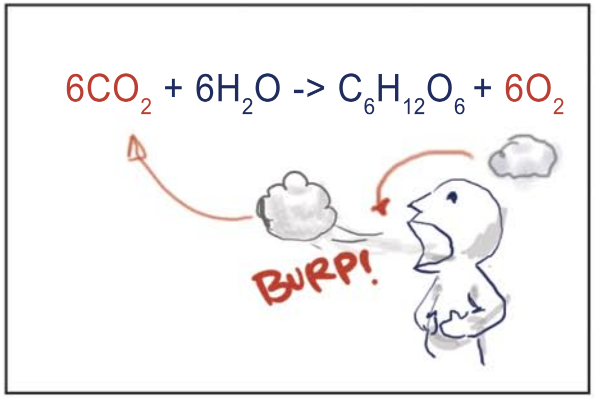
$$6CO_2 + 6H_2O \text{ -> } C_6H_{12}O_6 + 6O_2$$

We play a part in photosynthesis too! Let’s look at the photosynthetic equation again.



$$6CO_2 + 6H_2O \text{ -> } C_6H_{12}O_6 + 6O_2$$

The food we eat comes from sugars stored in plants and through cellular respiration, our bodies’ covert the sugars into energy



$$6CO_2 + 6H_2O \text{ -> } C_6H_{12}O_6 + 6O_2$$

We breath in oxygen given off by plants to survive and the CO2 that we breathe out is used by plants is used to make more sugar.

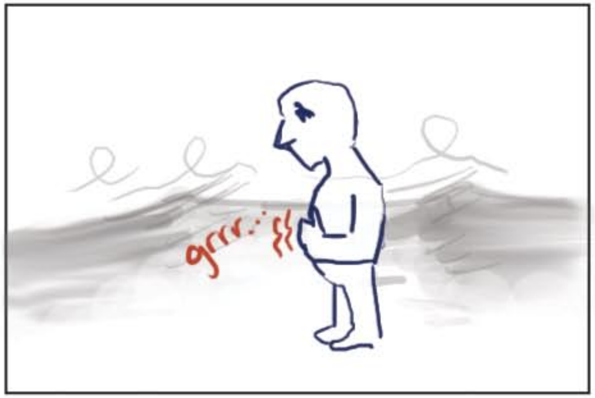
Derek Wu derek.wu@utsouthwestern.edu

Project: Photosythesis

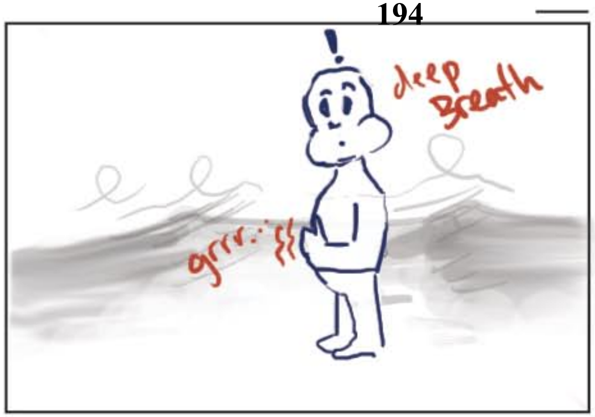
Version: 1

So if you were to imagine a world without photosynthesis:

The text melts away

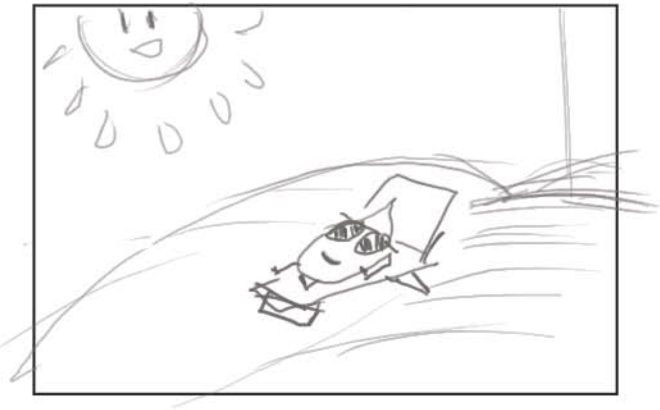


No plants, no animals (No food for us!).

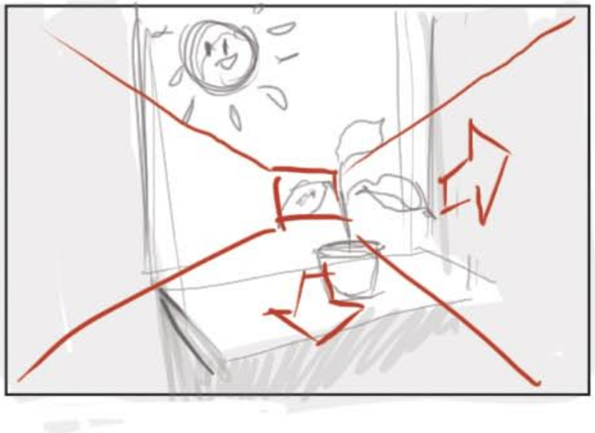


No Oxygen being released, no breathable air!

No breaking down of CO2 gases. The planet would turn into an oven as the gases would trap all the heat from the sun. Global Warming!



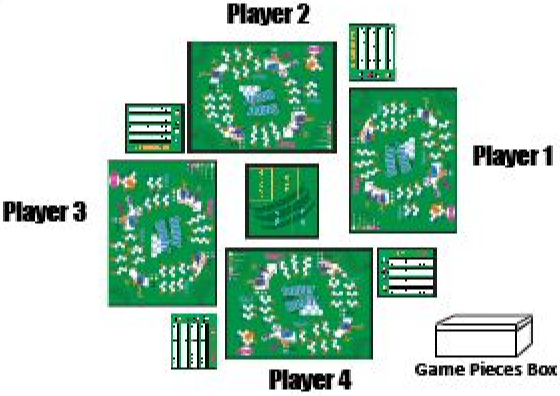
So the next time you look at the leaves on a plant- remember photosynthesis! Think sugar and energy for you and me!



Derek Wu derek.wu@utsouthwestern.edu

APPENDIX E:
Sugar Rush! Board Game Instructions

Setup



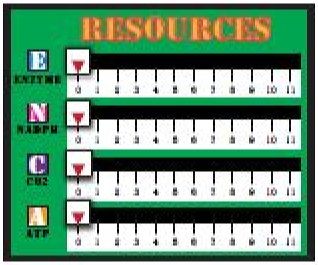
1. Setup the game boards so that each player faces the center.

2. Each player should have one game board and one resource meter

3. Everyone shares a card center and game piece box.

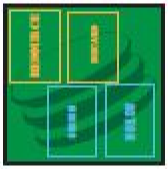
---

1. Each player has a resource counter. Place an arrow slider ▼ at zero on each resource meter for ATP, NADPH, CO2, and Enzymes.



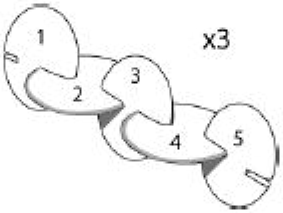
Resource Meter

2. Shuffle the RESOURCE and ACTION cards, and place them the Card Center labeled RESOURCE and ACTION.



Card Center

3. For each player: At Stage 1, connect 5 carbon pieces together to make a molecule and place it in the circular areas. Make three sets.



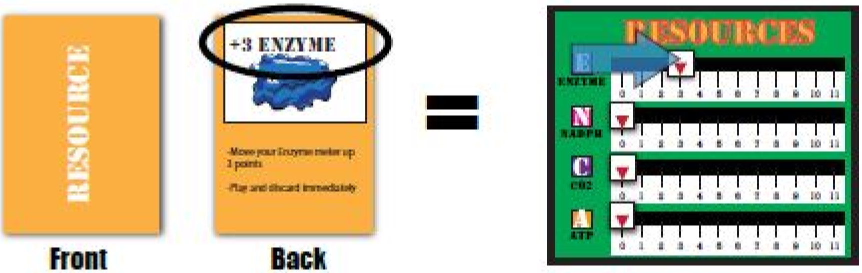
Stage 1 on Game Board

5. Each player: draw one ACTION card and SAVE IT in your hand.

Save it in your hand for now!

6. Each player: draw one RESOURCE card and USE IMMEDIATELY. Move your respective resource meter up accordingly and place the card back into the pile.

Use ALL RESOURCE cards IMMEDIATELY!



Front **Back**

Objective

Each player is in charge of their own Calvin Cycle and must be first to successfully modify their carbon molecules (purple game pieces) to create a sugar (glucose).

Collect resources to activate reactions that will allow you to modify and move your carbon molecules to each stage of the Calvin Cycle.

Set aside a pre-sugar molecule (3-purple pieces) at **Stage 3** and return your other molecules back to stage on.

Complete the cycle twice to make the winning sugar.

How to Play

Choose one person to go first. Each player takes a turn. **Each turn has 3 STEPS**

STEP 1 : Draw Cards

1. Draw one ACTION card and two RESOURCE cards.

2. Play the RESOURCE cards by moving your resource meter up accordingly and discard the cards immediately.

Save it for now!

Use and Discard immediately!

STEP 2 : Play Action Card

1. At the beginning you will have 2 ACTION cards in your hand.

2. Play an ACTION card or save it in your hand for the next turn.

3. Read the instructions on the card and discard after use.

4. Only one ACTION card may be played per turn. You may **save up to five action cards** in your hand, and the rest must be discarded.

Lose a Turn!

Pick any opponent to lose their next turn

-1 turn to opponent

-Play once and discard

Read the instructions carefully!

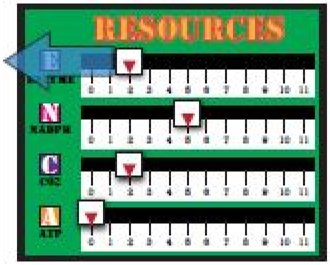
STEP 3 : Spend Resources

1. On the game board, each stage have specific resource requirements to cause a reaction.

2. If you meet the resource requirements to activate, move your resource meter down accordingly, and shift a string of carbon molecules to the next stage. (READ **STAGE RULES**!!!)

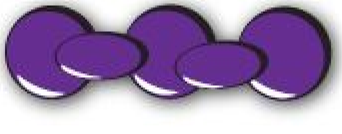
3. All carbon molecule chains must be within one stage of each other. (i.e. you cannot have part of your game pieces at stage 1 and stage 3 at the same time)

1 C
1 E



For Example:

1 C
1 E
=



Resources required

To move ONE chain to the next stage*

X 3 =

1 C 1 C 1 C
1 E 1 E 1 E

*exception from Stage 4 to Stage 1
Read STAGE RULES for details

Each Stage has specific rules and requirements.

Read the STAGE RULES carefully!

APPENDIX F:
Teacher's Manual

Photosynthesis Teacher's Manual

UT SOUTHWESTERN MEDICAL CENTER

STARS

Biomedical Communications
Graduate Studies Program

HHMI
HOWARD HUGHES MEDICAL INSTITUTE

Teacher’s Manual

Light! Carbon! Action!
Photosynthesis Science Suitcase

Contents

Purpose of the Science Suitcase

This science teaching aid is intended to supplement your current teaching curriculum for the subject of photosynthesis and plant anatomy. The materials provided are sufficient for 5 days of instruction and are organized so that you may choose to either use all the material or individual sections.

This science suitcase includes 5 sections:

1. Photosynthesis DVD:
   An animation presenting the basics of photosynthesis and introduction to the Light Dependent Reactions and the Light Independent Reactions (Calvin Cycle)

2. Sugar Rush! Board Game:
   Further exploration of the Calvin Cycle and indirect teaching of the cyclical nature of the Light Independent Reactions

3. Laboratory Exercises:
   The dry lab emphasizes various types of plants stomata, and wet labs investigate the production of sugar, and the creation of oxygen as a byproduct of the photosynthetic process.

4. Leaf Cell Model:
   Hands-on 3D model to review plant cellular anatomy

5. Instructional CD:
   The instructional CD includes digital copies of the labs, the teacher's manual, pre & post-test, and the board game instructions.

Further description of each section is provided below.

Suitcase Contents

Main Suitcase

This suitcase includes the animation DVD, teacher's manual, Sugar Rush! board game, and materials for the laboratory exercises.

Auxiliary Suitcase

This suitcase is customizable to include hotplates, lamps, or extra lab supplies (aluminum foil, dishwasher detergent, and aluminum pans) not included in the main suitcase.

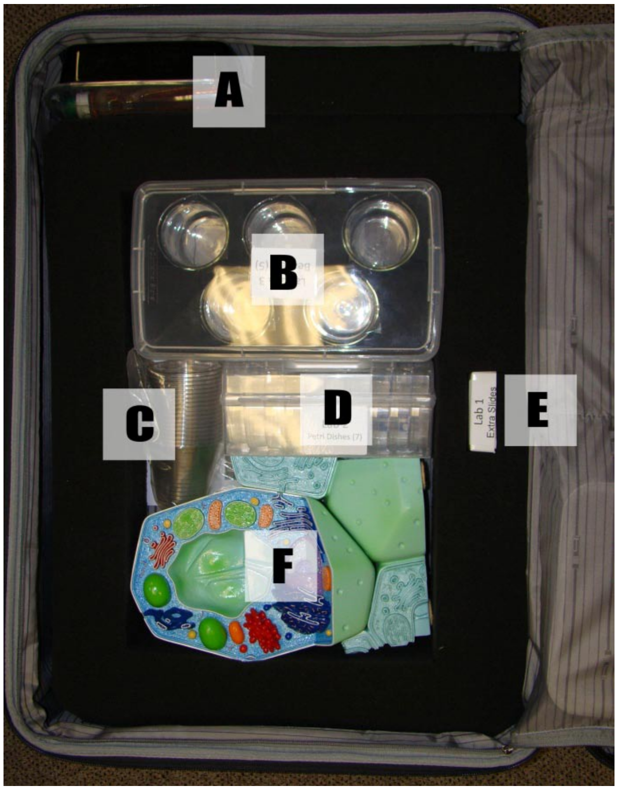
Please contact the STARS Program to request specific items at 1-800-81-STARS.

Main Suitcase:

This suitcase includes the animation DVD, teacher's manual, Sugar Rush! board game, and materials for the laboratory exercises.

There are three sections:

Section 1:



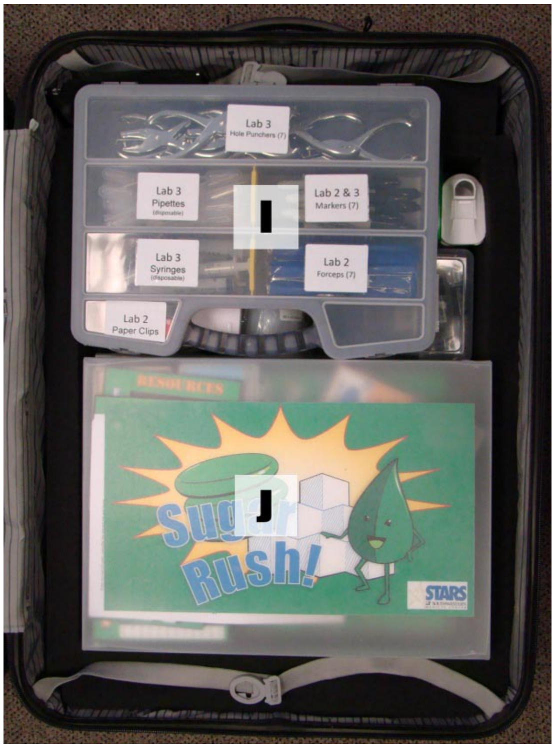
A. Detergent Box
B. Beakers (5)
C. Plastic Cups (disposal)
D. Petri Dishes (10)
E. Extra Slide Box
F. Plant Cell Model

Section 2:

G. Photosynthesis Animation DVD and Teacher's Instructional Manual

H. Aluminum Pans

Section 3: TOP



I. Multiple Lab Tool Box

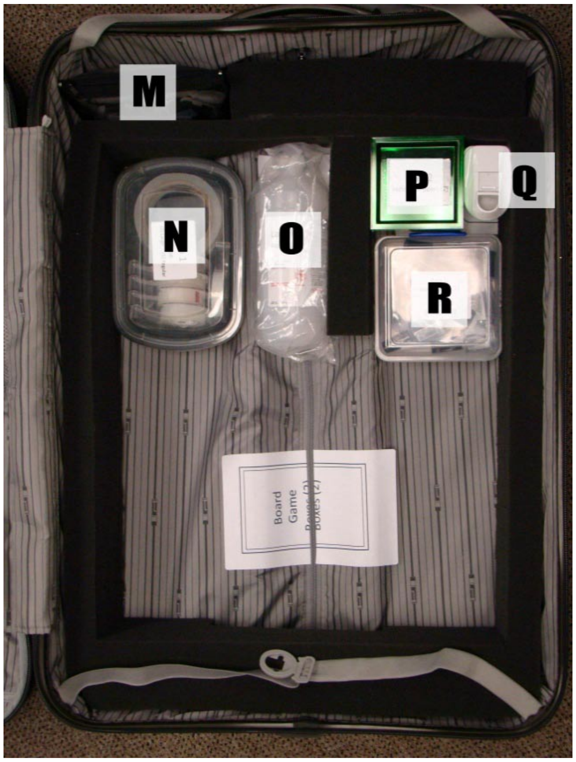
J. Sugar Rush! Board Game (Box 1)

Section 3: MIDDLE

K. Glass Slide Box

L. Sugar Rush! Board Game
(Box 2)

Section 3: BOTTOM



M. Stopwatches (7)

N. Tape (7)

O. Alcohol

P. Iodine Droppers

Q. Baking Soda

R. Nail Polish (7) and Scissors (7)

Auxiliary Case

This suitcase is customizable to include hotplates, lamps, and aluminum foil.

Please contact the STARS Program to request specific items at 1-800-81-STARS.

Suitcase Re-Assembly:

Section 1:

- Refer to the image on page 5 and replace items in the same order.

Section 2:

- Refer to the image on page 6 and replace the items in the same order

Section 3:

- Start with the BOTTOM (page 7 lower image) and replace items
- Replace items in the MIDDLE (page 7 upper image)
- Replace items in the TOP (page 6 lower image)

Suitcase Inventory List

Refer to the Suitcase Contents images for location (page 5-8)

A. Detergent Box (1)
B. Beakers (5)
C. Plastic Cups (disposal)
D. Petri Dishes (10)
E. Extra Slide Box (1)
F. Plant Cell Model
G. Photosynthesis Animation DVD (1)
G. Teacher's Instructional Manual (1)
H. Aluminum Pans (5)
I. Multiple Lab Tool Box
    a. Hole Punchers (7)
    b. Pipettes (disposable)
    c. Markers (7)
    d. Syringes (7)
    e. Forceps (7)

J. Sugar Rush! Board Game (Box 1)
K. Glass Slide Box (1)
L. Sugar Rush! Board Game (Box 2)
M. Stopwatches (7)
N. Tape (7)
O. Alcohol (10)
P. Iodine Droppers (6)
Q. Baking Soda (1)
R. Nail Polish (7) and
R. Scissors (7)

Suggested Curriculum

Day 1

Give students the pre-test to test their knowledge of photosynthesis before using the suitcase.

Introduce photosynthesis and the Light Dependent Reactions through a lecture or PowerPoint™ presentation. This is not included in the suitcase.

Use the leaf cell model as part of lecture.

Have students read about photosynthesis in their textbooks for homework.

Day 2

Watch the first 18 minutes of the Photosynthesis Animation. Stop the animation after *Review 2 (Chapter 12)*, before the Light Independent Reactions Chapter.

Review the concepts of the Light Independent Reactions with the class.

Run Lab 1: Stomata Stomata! Discuss how this leaf cell structure plays a part in photosynthesis. You will need leaves from three different plants. The lab should take 25 minutes.

Day 3

Continue lecture by introducing the Light Independent Reactions and the applications of photosynthesis.

Watch the remaining 7 minutes of the Photosynthesis Animation beginning at the *Light Independent Reactions (Chapter 13)*.

Prepare Lab 2: Reactions in the Dark. You need live potted plants to perform this exercise. The students must prepare their plants and allow for 24 hours of exposure to their leaf. The prep should take 15 minutes.

Day 4

Complete Lab 2: Reactions in the Dark! The remainder of the lab should take 20 minutes.

Run Lab 3: Floating Leaf Disks. Connect how the production of oxygen that causes floating leaf disks is a byproduct of photosynthesis. The lab should take 30 minutes.

Day 5

Play the Sugar Rush! board game. It may be helpful to replay the *Carbons of the Calvin Cycle (Chapter 14)* in the Photosynthesis Animation. The images used in the animation are similar to the images used in the board game.

It is very important to demonstrate the game play and rules of the board game to reduce confusion. Allow for 15 minutes of game instruction & setup, and 30 minutes to play the game.

Give students the post-test to test their knowledge of photosynthesis after using the suitcase.

Pre-Test & Post Test

The pre-test would be helpful to gauge the student's initial understanding of photosynthesis and the post-test would be useful to assess their knowledge after having used the materials in the science suitcase.

The following test pages are for the teacher, as they include the answers highlighted in **BLUE**. Blank test forms for students are found in the appendix of the teacher's manual.

Would you like to see more Science Suitcases created?

Submit your Pre-Test and Post-Test results to the STARS Program!

The STARS Program receives funding to produce the Science Suitcases from the Howard Hughes Medical Institute. By submitting your results, you will help STARS gather data on the effectiveness of these teaching aides. Your data may help the STARS Program win future grants that will fund the creation of additional Science Suitcases.

For more information, please contact the STARS Program at 1-800-81-STARS.

Photosynthesis: Teacher's Manual

Magic Squares!

Photosynthesis Pre Quiz

Question

A. The organelle in which photosynthesis occurs
B. Where is energy stored in ATP
C. Organism that makes its own food
D. Photosynthesis occurs in what organisms
E. Cells' usable source of energy
F. Reactants of photosynthesis
G. Organism that cannot make its own food
H. Structural formula for ATP
I. The organelle where aerobic respiration takes place
J. Process by which energy of glucose is released in the cell
K. Photosynthesis is separated into __(#) reaction cycles
L. Three elements needed for photosynthesis to occur
M. Tiny packet of light energy
N. Function of NADPH
O. Stored in plant cell walls and as starch
P. Products of photosynthesis
Q. The reactions where oxygen product is created
R. Photons are absorbed by this material
S. Where the light reactions take place
T. The reactions where carbon dioxide is split
U. Plant structure that allows the exchange of gases
V. The main cell layer where most photosynthesis occurs
W. What a stack of thylakoids is called
X. Protein structure that contains the chlorophyll pigments
Y. Number carbon dioxide molecules needed to make one glucose

Answer Choices

1. 2
2. In bonds between phosphate groups
3. Chlorophyll pigments
4. Mitochondria
5. 2 molecules
6. ATP
7. $C_6H_{12}O_6 + O_2$
8. Heterotroph
9. Granum
10. Energy carrier
11. Thylakoid membrane
12. Cellular respiration
13. Stomata
14. Water, carbon dioxide, and sunlight
15. Autotroph
16. A - P ~ P ~ P
17. Reaction Center
18. Glucose
19. Chloroplast
20. Light Dependent Reactions
21. Mesophyll
22. Photon
23. Plants and few microorganisms
24. Light Independent Reactions
25. $6CO_2 + 6H_2O$ + light

A 19	B 2	C 15	D 23	E 6	= 65
F 25	G 8	H 16	I 4	J 12	= 65
K 1	L 14	M 22	N 10	O 18	= 65
P 7	Q 20	R 3	S 11	T 24	= 65
U 13	V 21	W 9	X 17	Y 5	= 65

Photosynthesis Post-Quiz

1. What are the products of photosynthesis?
   a. Sugar and carbon dioxide
   b. Water and sugar
   c. Glucose and oxygen
   d. Water and carbon dioxide

2. There are ____ materials needed for photosynthesis to occur: ____________________
   a. 2, water and oxygen
   b. 3, light, carbon dioxide, and water
   c. 2, sugar and water
   d. 3, sugar water and oxygen

3. Photons are tiny packets of _____.
   a. Electrons
   b. Pigments
   c. ATP
   d. Light energy

4. Light reactions occur in the _____.
   a. Stroma
   b. Chloroplast
   c. Thylakoid membrane
   d. Starch grains

5. Dark reactions occur in the _____.
   a. Stroma
   b. Starch grains
   c. Thylakoid disk
   d. Starch grain

6. There are ___stages(s) in photosynthesis.
   a. 1
   b. 3
   c. 2
   d. 4

7. Light is captured from _____.
   a. Sunlight
   b. Pigments
   c. Photons
   d. Electrons

8. The source of oxygen (waste) comes from _____.
   a. Water
   b. Sugar
   c. Carbon dioxide
   d. oxygen

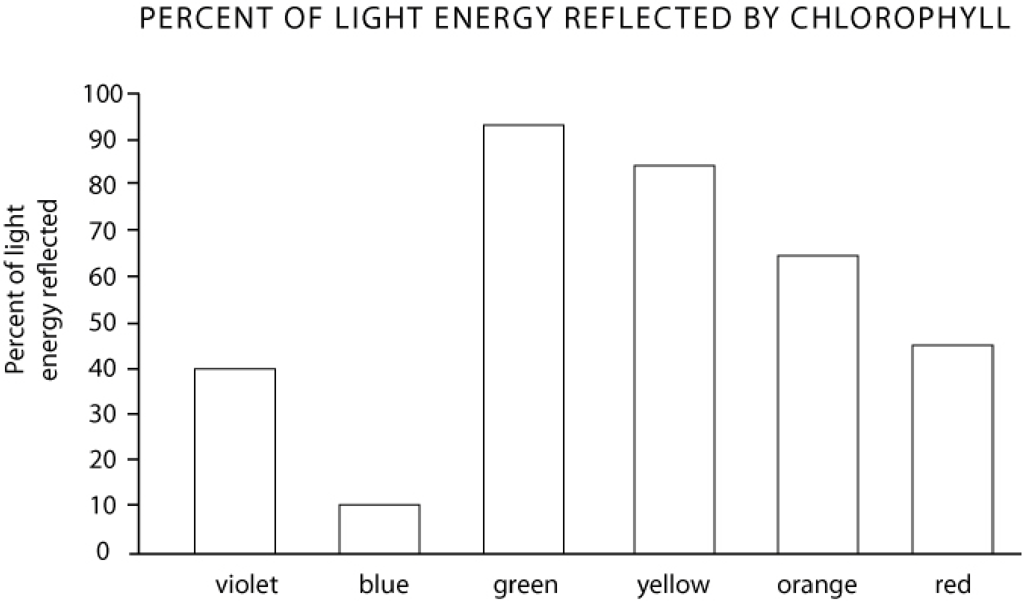
9. NADPH gets release into the _____, so that sugar can be made.
   a. Granum
   b. Stroma
   c. Thylakoid

10. Carbon Dioxide is split in the _____.
    a. Calvin cycle
    b. Photosystems
    c. Light Reaction

Photosynthesis: Teacher's Manual

11. Photosynthesis takes place in the _____ organelle

a. Thylakoid	c. Chlorophyll
b. Chloroplast	



Use the bar graph above, which shows the percentage of light energy reflected by chlorophyll, to answer the following questions. The graph was derived from the chlorophyll absorption spectrum.

12. Which color in this spectrum is most visible?
    Green color
13. What is the approximate percentage of light energy reflected for this color (answer to 12 above)?
    90 Percent
14. What is the approximate percentage of light energy absorbed for this color (answer to 12 above)?
    10 Percent
15. If everything above 50 percent of light energy reflected is visible to the human eye, is the red light part of the mixture of colors seen in light reflected by chlorophyll?
    No, below 50 percent
16. ATP stands for

a. Adenosine Diphosphate	**c. Adenosine Triphosphate**
b. Alpha T-phosphorus	

17. The electron Transport Chain is used in _____.

a. Calvin cycle, Photosystem II	**c. Photosystem II, photosystem I**
b. Photosystem I, Calvin cycle	

18. NADPH is made in Photosystem ___ and used in the _____.

a. I, Photosystem II	**c. I, Calvin cycle**
b. II, Calvin cycle	

Photosynthesis Animation DVD

Duration: 25 minutes

This animation is ideal for introducing or reviewing photosynthesis concepts. The photosynthesis animation topics are broken up into individual chapters. You may choose to start at any chapter using the chapter selection menu on the DVD. Please view the video yourself so that you may decide which chapters are appropriate for your curriculum and class level.

Chapters:

1. Introduction
2. What is photosynthesis?
3. Photosynthetic Chemical Equation
4. Oxidation and Reduction
5. Review 1
6. Where does it happen?
7. How does it work?
8. Introduction to the Light Dependent Reactions
9. Electron Transport Chain
10. NAPDH
11. Making ATP
12. Review 2
13. Introduction to the Light Independent Reactions
14. Carbons of the Calvin Cycle
15. Sugar application
16. Review 3
17. What if there was no photosynthesis?

The content is quite dense and it is recommended that you break up the animation viewing into two days or allow the class an intermission halfway. An appropriate place to pause the video is after the *Review 2 (Chapter 12)*. This way you can allow the students to absorb what they have seen, and you may have an opportunity to review the concepts.

The animation includes three review sections that will repeat the major concepts, and are placed after the following chapters: *Oxidation and Reduction (Chapter 4), Making ATP (Chapter 11),* and *Sugar application (Chapter 15).*

There are also seven multiple choice questions that will test memory and application of concepts. Use the arrow pad on your DVD controller to navigate the questions. You may also choose to skip these sections by selecting the “skip to next chapter” option in the bottom right corner of each question page.

There is also an option to play the animation without the questions. You may access the uninterrupted animation at the main menu.

Photosynthesis Animation DVD: Animation Script

The following is the full script of the animation for your reference. Answers and explanations to all quiz questions are in bold.

Chapter 1 Introduction

When you hear the term photosynthesis, what do you think of? Think energy!

Humans eat food so that our bodies will have energy to function properly. Like humans, plants need energy to live and grow too. But instead of stopping by your local fast food joint to grab a sandwich, plants make their own food and oxygen too. How? Through photosynthesis!

Chapter 2 What is Photosynthesis?

What is photosynthesis? Well, if we look at the word “photo-synthesis”, we see that it’s made up of two parts. “Photo” which means light, like a photon energy and “synthesis” which means combining simple things to create something complex. So if you put the two words together, We’re using “light” to combine simple things to create something complex, like sugar!

So basically, photosynthesis is the process during which certain organisms capture light energy and convert it into chemical energy and store the chemical energy as sugar.

Chapter 3 The Photosynthetic Chemical Equation

In science, often you see the reactants and products of photosynthesis described by the chemical equation:

$$6C0_2 + 6H_20 + hv \rightarrow C_6H_{12}0_6 + 6O_2$$

Although this chemical equation doesn’t actually describe the process of photosynthesis, it is helpful to see what reactants you start with and what products you will end up with. As you can see the process requires basic elements (or reactants) to occur like carbon dioxide and water and light energy. Then through the process of photosynthesis, the products sugar and oxygen are made.

So as a balance equation**,** for every 6 carbon dioxide molecule and 6 water molecule that is converted through photosynthesis, 1 sugar molecule and 6 oxygen molecule are made.

Question 1:

Which of the following is the correct photosynthetic chemical equation?

1. $6H_2O + 6C_6H_{12}O_6 \text{ -> } CO_2 + 6O_2$
   Oxygen is a product and water is a reactant
2. **$6CO_2 + 6H_2O \text{ -> } C_6H_{12}O_6 + 6O_2$**
   For every 6 carbon dioxide and 6 water molecules used,1 sugar and 6 oxygen molecules are made
3. $6CO_2 + 6O_2 \text{-> } C_6H_{12}O_6 + 6\ H_2O$
   Sugar is a product and carbon dioxide is a reactant

Chapter 4 Oxidation and Reduction

Now looking at this equation, it might seem like a jumble of numbers and letters. How is carbon dioxide and water turning into sugar and oxygen? Let's take away the numbers for now and look at just the elements.

$$\text{CO} + \text{HO} \rightarrow \text{CHO} + \text{O}$$

Reactants Products

In this simplified version of the reaction, we see 2 events occurring: water is stripped of its hydrogen and the hydrogen is attached to carbon dioxide. These two events are examples of oxidation and reduction.

Oxidation is the loss of an electron. Often when you break the bond between two elements like hydrogen and oxygen, energy in the form of an electron is released. And the molecules lose that electron.

Reduction is the opposite. Reduction is the gain of an electron. To form a bond between elements, energy is required. So the molecules gain an electron in order to bind with hydrogen.

Why is hydrogen the one moving from one molecule to the other?

Hydrogen is composed of a single electron and proton. It has a tendency to give up its electron easily. So often after breaking a bond containing hydrogen, the electron is lost and the proton is left behind. That’s why when you see the symbol H+, they’re called protons because the hydrogen has lost its only electron. You’ll hear more protons later on.

Now in the process of photosynthesis, oxidation and reduction occurs in two reaction cycles. These reactions are cycles because the process can repeated as long as there are available resources (like carbon dioxide and water).

Chapter 5: Review 1

Whew! Let’s review. The chemical equation of photosynthesis is:

For every 6 carbon dioxide molecule and 6 water molecule that is converted through photosynthesis, 1 sugar molecule and 6 oxygen molecule are made.

Oxidation is the loss of an electron. Reduction is the gain of an electron.

In photosynthesis, these two events occur in two separate reaction cycles. Now that we’ve seen the big picture, let’s see where photosynthesis takes place!

Chapter 6: Where does it happen?

Where does it happen? For most plants, the prime location for photosynthesis to take place is within the leaf of the plant, where a broad surface area maximizes exposure to sunlight. At first glance, a plant leaf looks like mish-mash of random cells and is just green, lots of green. But if you take a closer look, the leaf is more similar to a self contained environment like a space station.

The structure is made up of individual cells with specialized tasks like piping that moves water and nutrients through the leaf, or preventing the loss of water, or monitoring the exchange of gases like CO_2 and O_2, or creating food for the plant.

In the leaf, the biggest cell layer is called the mesophyll, which is split into the palisade mesophyll and spongy mesophyll. Most cells specializing in photosynthesis are located in the palisade mesophyll. These cells have a higher number of chloroplasts and are oriented to have greater exposure to sunlight.

The chloroplast organelles contain special structures called thylakoids. These thylakoids arrange themselves in stacks. The substance surrounding the thylakoids with the chloroplasts is called the stroma. If you haven't noticed, we've zoomed past the structural and cellular level to the molecular level. Remember that photosynthesis is a molecular process.

Question 2:

What type of plant would have all its stomata located on the upper epidermis?

1. A plant in the desert

   If the stomata were on the topside of a desert plant, the intense exposure to sunlight would cause water vapors to evaporate quickly and the plant would die.
2. A plant in the humid jungle

   The humid jungle environment means there is water moisture everywhere. So the plant would have lots of stomata in the upper and lower epidermis.
3. **A plant floating on a pond**

   The underside of the plant would be submerged in water. So CO_2 and O_2 gas exchange must occur on the topside. Therefore the stomata would be located in the upper epidermis of the leaf.

Chapter 7: How does photosynthesis work?

Like we said before, the process of photosynthesis takes place in two MAIN Reactions Cycles, each composed of several individual reactions that are repeatable.

The Light dependent reactions comprise the first cycle, or Cycle One. This is the "photo" part of photosynthesis. Without the sun these reactions won't go.

The main job of cycle one is to:

2. Capture light energy
3. Store that energy by creating small amounts of ATP, Adenosine Tri-Phosphate, and binding free hydrogen protons to NADP, a “carrier molecule”, that will transport the stored energy to Reaction Cycle 2
4. Create more free hydrogen protons and restore energy lost by splitting water and form oxygen as a byproduct.

The second cycle, Cycle Two, contains the Light-independent reactions. Like the name implies, this set of reactions doesn’t need the sun to do its job, so cycle 2 can be working day or night. This is the “synthesis” part of photosynthesis.

The main job of cycle two is to:

1. Use the ATP and NADPH created from Cycle 1 to power the synthesis process.
2. Use the carbon in CO_2 to build the sugar.

Even though cycle 2 doesn’t need sunlight to function, it is still dependent on the products created in cycle 1 to drive its own reaction. So if cycle 1 stops working, eventually cycle 2 will grind to a halt.

Now that you understand the basics of the two main cycles, we’re going to dive deeper and learn how each cycle does its’ job.

Chapter 8: Light-Dependent Reactions

Cycle 1: Light-Dependent Reactions. Cells contain many chloroplasts. Within a chloroplast are many stacks of thylakoids and the thylakoids float in the stroma.

The first cycle takes place within the membrane of the thylakoid and functions through a variety of specialized protein structures that dot the surface.

One of these specialized protein structures, called a photosystem, is in charge of capturing the sunlight energy. Photosystems are like solar panels on a space station that capture the sunlight for powering equipment and maintaining station functions. The solar panels are made of special materials to absorb the sunlight. In photosystems, there are material pigments called chlorophyll that absorb the sunlight. Electrons in the chlorophyll pigments become energetic as the light energy is absorbed.

Question: Why do you think plants are green? If you said because of the chlorophyll, your right! But why is chlorophyll green?

White light is made up of a spectrum of colors, and chlorophyll is capable of absorbing most colors *except* for green colored light. We see green light that is reflected off the object. Think about that when you look any colored surface. You're actually looking at the color that wasn't absorbed by the material and is being reflected back to you.

Now that you know how sunlight is captured, let see how the light energy is converted and stored as chemical energy for later use in Cycle 2. There are three main steps: the electron transport chain, the production of ATP (chemical energy), and the production of NAPDH, a carrier molecule.

Question 3:

What are the three main jobs of the Light Dependent Reactions?

1. **Make NADPH, Make ATP, Split H_2O**
   NADPH and ATP are made to carry energy to the Light Independent Reactions. Splitting water helps the Light Dependent Reactions to restore energy spent to make NADPH and ATP.
2. Make ATP, Use CO_2, Split water
   Using carbon dioxide is a job of the Light INDEPENDENT Reactions.
3. Make NADPH, Make Sugar Use CO_2
   Making sugar and using carbon dioxide are jobs of the Light INDEPENDENT Reactions.

Chapter 9: Electron Transport Chain

Remember we're still in within the membrane of the thylakoid. As you can see, there are multiple photosystems that capture the light energy and they are part of a larger string of proteins called: The Electron Transport Chain or ETC for short!

The Electron Transport Chain moves electrons, which have been excited by the photosystems, down a string of proteins. The energy absorbed by the chlorophyll pigments causes an electron to become “excited” to a higher energy level and is ejected from the chlorophyll molecule. This excited electron and the energy it contains is “lost” by the photosystem and the electron jumps out into the intermediate protein. These proteins continue to pass on an excited electron down the chain of proteins like a hot potato. And just like a hot potato that loses heat as it cools, each excited electron that is passed on loses energy. The energy required to move to the next protein is less than the previous so electron keeps moving down the chain.

Each ETC contains two photosystems. So you can see that this excitation of an electron and transporting it down a chain of proteins happens twice.

In photosystem I, the electron is passed down the chain to eventually power a NADPH synthesizer. This protein structure combines NADP with hydrogen proton, H+.

Question 4:

When light is received by the Electron Transport Chain, which photosystem activates first?

1. Photosystem I
   Making sugar and using carbon dioxide are jobs of the Light INDEPENDENT Reactions
2. Photosystem II
   Light Photons would arrive at the ETC at the same time.
3. **They activate at the same time**
   Light Photons would arrive at the ETC at the same time, therefore both photosystems would receive light simultaneously and activate at the same time.

Chapter 10: Making NADPH

Why is this NADPH important? Energy is released when bonds between molecules are broken. And vice versa, energy is required to bind molecules back together. Cycle 1 has no way of giving energy to Cycle 2 to use to make sugar. So that’s where a molecule like NADPH can act as a carrier between the two reaction cycles! Binding NADP with Hydrogen uses the energetic electron released from the photosystem I. The resulting NADPH can be broken later in Cycle 2, releasing the energy to finish making sugar.

Photosystem II
The photosystem II also ejects an excited electron that passes down intermediate proteins, which activate to pull hydrogen protons into the thylakoid. The electron eventually restores the electron lost from photosystem I.

Now Photosystem II needs to replenish its own lost electron. So attached to PSII is special water splitting protein that breaks up H_20 and takes the electron for PSII. Hydrogen protons (H+) and oxygen byproducts are released.

This is an important point: Oxygen is produced when water is split in the light dependent reactions, cycle 1. NOT from CO_2 in the light-independent reactions, cycle 2. If we look back to the photosynthetic chemical equation, we can see that oxygen, one of the products, is created here in the electron transport chain of cycle 1.

Chapter 11: Making ATP

Adenosine Tri-phosphate. Now the whole time that Cycle 1 has been active, hydrogen protons pumped into the thylakoid from the ETC and created from splitting water has caused a concentration imbalance. There are too many protons inside the thylakoid.

Imagine a dam that has too much water on one side. To balance the water levels, a channel is put in place. But this flow of water can also do work by placing a water wheel. The energy produce can be used to power a factory.

The cell does the same thing to balance out the hydrogen proton concentrations inside the thylakoid and outside in the stroma. A special protein channel passively lets out the excess H+. This channel is put to work too and attached is an ATP synthesizer which drives the formation of ATP from ADP and phosphate. Remember, energy is stored in the molecular bonds. So when phosphate binds to ADP, Adenosine Di-Phosphate, energy stored in the bond making ATP. This energy stored in ATP can be used then to power cycle 2 or other areas of the cell.

Chapter 12: Review 2

Let's Review. Each ETC contains two photosystems. Photosystem I loses an electron to make NADPH. Photosystem II loses an electron to give to photosystem I. Photosystem II needs to replenish its own lost electron. So attached to PSII is special water splitting protein that breaks up H20 and takes the electron for PSII. Hydrogen protons (H+) and oxygen byproducts are released. Oxygen is produced when water is split in the light dependent reactions, cycle 1. NOT from CO_2 in the light-independent reactions, cycle 2.

Alright! We've made ATP and NADPH. The energy carried within each molecule can now be used by the cell for important functions. But what if we want to store that energy for a cloudy day? Then we make sugar!

Chapter 13: Light Independent Reactions

Cycle 2: Light independent reactions. Cycle 2 actively takes place in the stroma, the spaces between the thylakoid stacks. These reactions can work day or night.

REMEMBER: This is also called the Calvin cycle because it was worked out by Melvin Calvin many years ago. It should not to be confused with the Krebs Cycle, which is involved in the breaking down of sugar through cellular respiration.

Remember that two things are happening in the Cycle 2: It uses CO2 as material for synthesizing sugars, and it powers the cycle of reactions using ATP and NADPH made from Cycle 1 (the light dependent reactions).

Technically, the Calvin cycle itself doesn't actually make the 6-carbon sugar that you seen in the chemical equation. It makes a 3-carbon pre-sugar compound that can be joined later to make the 6-carbon sugar.

Essentially the Calvin cycle is a series of reactions that takes a base organic molecule and reshapes and modifies it until a pre-sugar compound is formed. Each step in the modification requires a specialized enzyme and energy to keep it going. This is a cycle because it is not only able to create a pre-sugar compound but also restore its original base molecule to repeat the process over again. Any spent ATP and NADPH, now ADP and NADP, is recycled back to be used by cycle 1.

Question 5:

What are the two main jobs of the Light Independent Reactions?

1. Use CO_2, Make NAPDH
   Making NAPDH is a job of the Light DEPENDENT Reactions
2. **Use CO_2, Use NADPH & ATP to make sugar**
   The carbon atom in carbon dioxide is used to make the 6-carbon sugar. NADPH and ATP provide the energy to drive the reactions.
3. Make ATP, Use NADPH & ATP to make sugar
   Making ATP is a job of the Light DEPENDENT Reactions

Chapter 14: Carbons of the Calvin Cycle

At this point, it's not so important that you know the details of the Calvin cycle. But to illustrate how this cycle is able to sustain itself so efficiently we'll focus on carbons that make up the base organic molecule. All enzymes have been generalized for simplicity. Let's follow the carbons!!

1. First we start with three carbon molecules made of five carbon atoms. A specialized enzyme activates to bind each 5-carbon compound with one CO2 molecule. This reaction initially results 6-carbon compounds that so unstable, it immediately splits into smaller 3-carbon compounds.
2. Six ATP and enzymes are used to stabilize the 3-carbon compounds
3. Six NADPH and enzymes are used to modify the 3-carbon compound into the pre-sugar compound.
4. One 3-carbon pre-sugar compound exits the cycle.
5. Finally through multiple reactions, 3 ATP and enzymes rearrange the remaining compounds back into the 3 (5-carbon compounds).

The cycle continues to repeat and every two 3-carbon pre-sugar compound is combined to make the full 6-carbon sugar. Remember, spent ADP and NADP are feed back into the light reactions to be reused.

Question 6:

If the leaf receives more light, the rate of photosynthesis will:

1. Stay the same
   The rate will stay the same IF there are no photosystems available to absorb light, or no enzymes to use the energy, or not enough reactants.
2. **Increase**
   More light means more photosystems in the ETC activate to absorb energy. More ATP and NADPH are created and more enzymes activate to create sugar.
   This will keep increasing until there no more photosystems available to absorb energy, or no more enzymes to create sugar, or no more CO_2 to provide carbon.
3. Decrease
   The rate will decrease IF the plant has already run out of reactants like CO_2 and H_2O and there is too much O_2 product built up in the system

Chapter 15: Sugar Application

Now that we made sugar, what does the cell do with it?

Store it! The plant makes cellulose in cell walls or turns sugar into starch like potatoes. Use it! Through cellular respiration that takes place in the mitochondria of the cell, the sugar can be broken down to bind a great number of ADP and P to make ATP for cellular function.

Chapter 16: Review 3

Let's Review. Light independent reactions actively take place in the stroma, the spaces between the thylakoid stacks. Essentially the Calvin cycle is a series of reactions that takes a base organic molecule and reshapes and modifies it until a pre-sugar compound is formed. The cycle continues to repeat and every two 3-carbon pre-sugar compound is combined to make the full 6- carbon sugar Any spent ATP and NADPH, now ADP and NADP, is recycled back to be used by cycle 1.

Question 7:

The Light Independent Reactions are called a cycle because:

1. **The reactions are repeatable**
   The base organic molecules used to make sugar are restored after each series of reactions. Allowing the cell to continuously make sugar.
2. The molecules move around in a circle
   While the molecules do move around in the stroma, the reactions do no move in a circle.
3. Hydrogen moves through the thylakoid membrane
   This does not influence the cyclical nature of the Light Independent Reactions

Chapter 17: What if there was no photosynthesis?

We play a part in photosynthesis too! Let’s look at the photosynthetic equation again. The food we eat comes from sugars stored in plants and through cellular respiration, our bodies’ covert the sugars into energy. We breath in oxygen given off by plants to survive and the CO_2 that we breathe out is used by plants is used to make more sugar. And we breathe in the O_2 byproduct from plants to live. We are part of a greater cycle that is dependent on each other.

So if you were to imagine a world without photosynthesis: No plants, no animals, no food for us!. No oxygen being released, so no breathable air! None of the CO_2 are breaking down. So the planet would turn into an oven as the gases would trap all the heat from the sun. More global warming!

So the next time you look at the leaves on a plant, remember photosynthesis! Think energy!

Sugar Rush! Board game

This is an interactive way to review the cyclical nature of the Calvin Cycle. The board game focuses on the carbons involved in the reactions, and it is recommended that the students view the Light Independent Reactions (Chapter 13) and Carbons of the Calvin Cycle (Chapter 14) sections of the DVD prior to playing the game. The graphic images in the DVD match the graphics used to illustrate the game.

Duration: 15 mins setup and game instruction
30 mins of game play

5 game sets are available
Up to 4 players can play each game set

Each game set includes a set of instructions but **it is highly recommended that you (the teacher) demonstrate the game play and rules for the students to reduce confusion.** The initial setup and explanation of the rules may be a little complicated, but once the students understand what to do the actual game play is simple.

A video instruction of how to play the game and the game rules are included on the Instructional CD.

Each player is in control of their own Calvin Cycle. The game pieces they are manipulating are the carbons of the base organic molecules that are used to make sugar. Each player is competing to be the first to make a full sugar molecule. Just like the real Calvin Cycle, the reactions yield only half of a whole 6-carbon sugar. Therefore, the player must complete the cycle twice and set aside two 3-carbon sugars in order to win.

Make the Connection:

The carbon game pieces each player uses in the board game are like the carbon molecules seen in the Photosynthesis Animation. The ATP and NADPH resources a player collects come from the Light Dependent Reactions.

In Lab 2: Reactions in the Dark!, the light patch seen after applying iodine to the treated leaf is the result of no starch production. This is because no ATP and NADPH resources were available to be used in the Calvin Cycle to make sugar. The CO_2 resources a player collects to add an additional carbon game piece, is like adding carbon to the base organic molecules used to make sugar. In Lab 3: Floating Leaf Disks, the baking soda (sodium bicarbonate) added to the water solution also acts like CO_2 to provide carbon for the leaf to activate the Calvin Cycle.

Box 1 contains 2 game sets:
8 Board game mats
8 Resource meters
2 Resource card holders
2 Game boxes

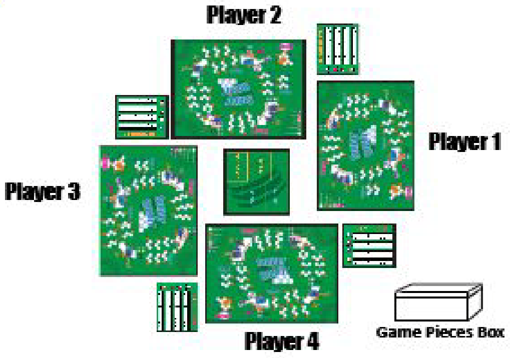
Box 2 contains 3 game sets:
12 Board game mats
12 Resource meters
3 Resource card holders
3 Game boxes

Please keep the game sets together!

Objective

Each player is in charge of their own Calvin Cycle and must be first to successfully modify their carbon molecules to create a sugar. Collect resources to **activate** enzymes that will move and modify the carbon molecules through each stage of the Calvin Cycle. Complete **TWO** revolutions of the Calvin Cycle to collect two pre-sugar molecules to make the winning sugar.

Setup



1. Setup the game boards so that each player faces the center.

2. Each player should have one game board and one resource meter

3. Everyone shares a card center and game piece box.

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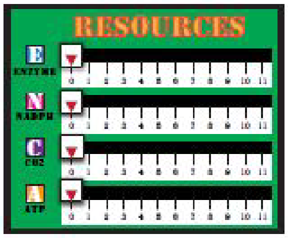
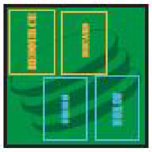
1. Each player has a resource counter. Place an arrow slider ▼ at zero on each resource meter for ATP, NADPH, CO2, and Enzymes.



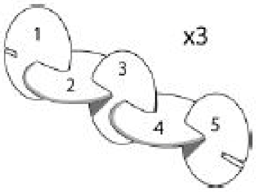
Resource Meter

2. Shuffle the RESOURCE and ACTION cards, and place them the Card Center labeled RESOURCE and ACTION.



Card Center

3. For each player: At Stage 1, connect 5 carbon pieces together to make a molecule and place it in the circular areas. Make three sets.



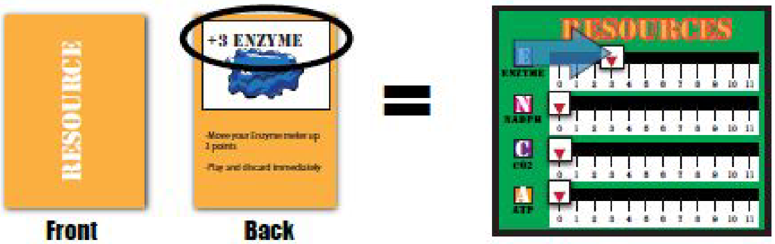
Stage 1 on Game Board

5. Each player: draw one ACTION card and SAVE IT in your hand.

6. Each player: draw one RESOURCE card and USE IMMEDIATELY. Move your respective resource meter up accordingly and place the card back into the pile.

Save it in your hand for now!

Use ALL RESOURCE cards IMMEDIATELY!



Front **Back**

Objective

Each player is in charge of their own Calvin Cycle and must be first to successfully modify their carbon molecules (purple game pieces) to create a sugar (glucose).

Collect resources to activate reactions that will allow you to modify and move your carbon molecules to each stage of the Calvin Cycle.

Set aside a pre-sugar molecule (3-purple pieces) at **Stage 3** and return your other molecules back to stage on.

Complete the cycle twice to make the winning sugar.

How to Play

Choose one person to go first. Each player takes a turn. **Each turn has 3 STEPS**

STEP 1 : Draw Cards

1. Draw one ACTION card and two RESOURCE cards.

2. Play the RESOURCE cards by moving your resource meter up accordingly and discard the cards immediately.

Save it for now!

Use and Discard immediately!

STEP 2 : Play Action Card

1. At the beginning you will have 2 ACTION cards in your hand.

2. Play an ACTION card or save it in your hand for the next turn.

3. Read the instructions on the card and discard after use.

4. **Only one ACTION card may be played per turn.** You may **save up to five action cards** in your hand, and the rest must be discarded.


Lose a Turn!

Pick any opponent to lose their next turn

-1 turn to opponent

-Play once and discard

Read the instructions carefully!

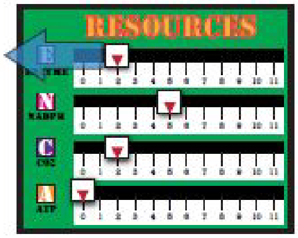
STEP 3 : Spend Resources

1. On the game board, each stage have specific resource requirements to cause a reaction.

2. If you meet the resource requirements to activate, move your resource meter down accordingly, and shift a string of carbon molecules to the next stage. (READ **STAGE RULES**!!!)

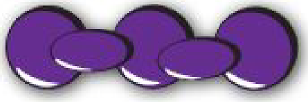
3. **All carbon molecule chains must be within one stage of each other.** (i.e. you cannot have part of your game pieces at stage 1 and stage 3 at the same time)

1 C
1 E



For Example:

1 C
1 E =



Resources required

To move ONE chain to the next stage*

X 3 =

1 C 1 C 1 C
1 E 1 E 1 E

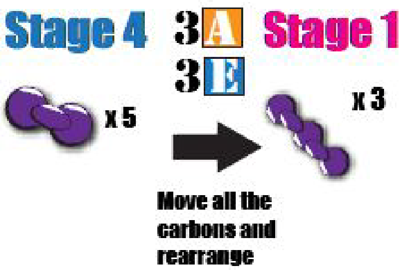
*exception from Stage 4 to Stage 1
Read STAGE RULES for details

Each Stage has specific rules and requirements.

Read the STAGE RULES carefully!

Stage Rules : Read Carefully!

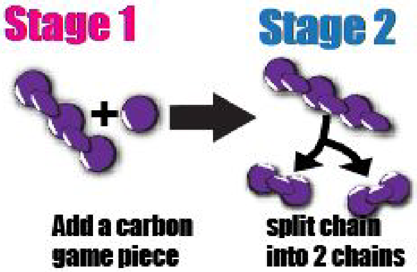
STAGE 1: 3A 3E



1. All carbon molecules start here and must end here.

2. From STAGE 4 to STAGE 1:
   Meeting the resource requirements moves ALL the carbon pieces at once! Rearrange your game pieces back into the three 5-carbon chains.

STAGE 2: 1C 1E X 3



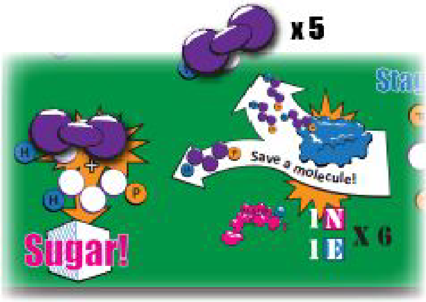
1. Add a carbon piece to EACH advancing 5-carbon molecule.

2. Immediately break apart the molecule into two, 3-carbon molecules.

STAGE 3: 1A 1E X 6

1. Meet the resource requirements to advance.

STAGE 4: 1N 1E X 6



Save a pre-sugar chain for the win!

1. **Remember to MOVE one 3-carbon molecule (pre-sugar) to the sugar-making corner.**

2. Move the remaing five 3-carbon mocules to Stage 4.

To Win

1. You must be the first to set aside two sets of pre-sugars (3-carbon molecules) by cycling through the Calvin Cycle **twice**. Thus, making sugar (glucose).

2. You must finally restore the cycle by moving the other carbon molecules back to Stage 1.

Laboratory Exercises

The suitcase comes fully equipped to perform the three labs for up to 28 students. Special equipment like hotplates, lamps, microscopes, or plants is available upon request to the STARS program.

STARS Website: http://www.swmed.edu/utsw/home/stars/index.html
STARS Contact Information: 1-800-81-STARS
STARSmail@UTSouthwestern.edu

Mention the photosynthesis suitcase in the email subject heading.

The following pages are the labs with teacher comments. Included in the appendix are student handout instructions for photocopying. A digital copy for printing is also available on the Instructional CD.

All lab question answers are highlighted in bold.

Lab 1: Stomata, Stomata!

Purpose: Review leaf stomata anatomy and explore the different examples of stomata grouping in plants that live in either dry or wet climates.

Suitcase Provisions:

- 7 bottles of clear nail polish
- 7 pairs of scissors
- Slide Box with slides
- 7 Rolls of clear plastic tape

Microscopes are available upon request from the STARS Program

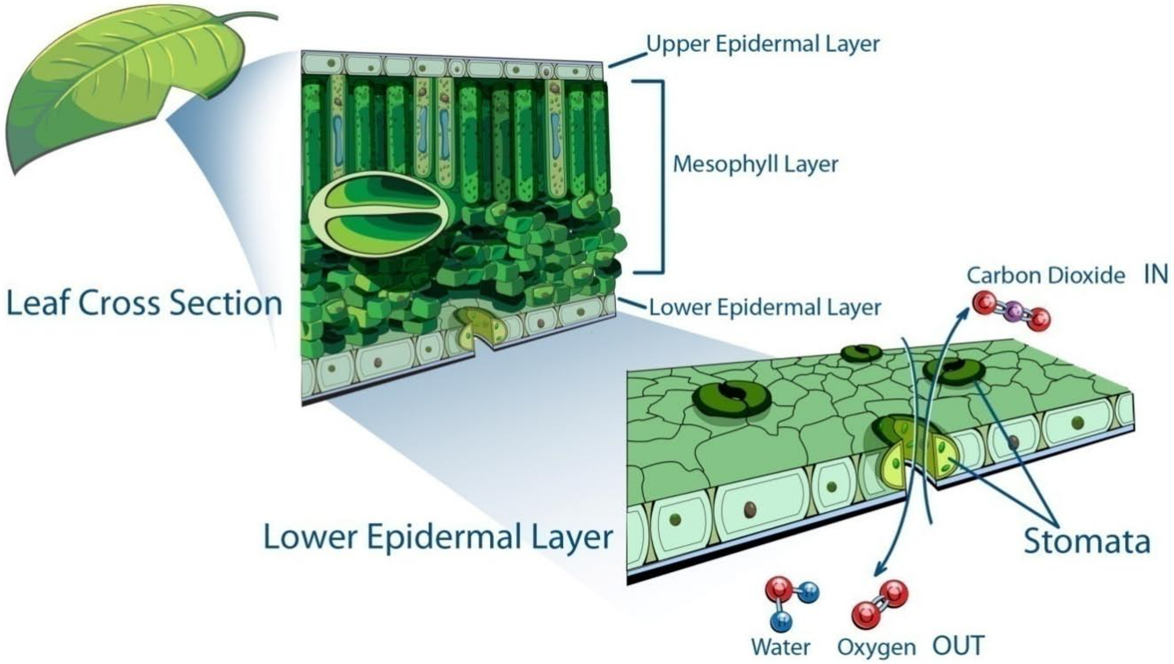
Pre-Lab Setup:

1. In the box labeled Lab 1: Remove nail polish bottles and place one bottle at each table.
2. Place one set of scissors and plastic tape at each table.
3. Set up one microscope at each table (if enough microscopes are available) or set up viewing stations around the room.
4. Included in the Lab 1 slide box are enough glass slides for each group. Extra slides are available in the suitcase.

Post-Lab Cleanup:

1. Dispose of any waste into the trash receptacle.
2. Make sure that the students clean each slide used and return them to the Lab 1 slide box.
3. Return nail polish, scissors, and plastic tape to their designated boxes labeled as Lab 1.

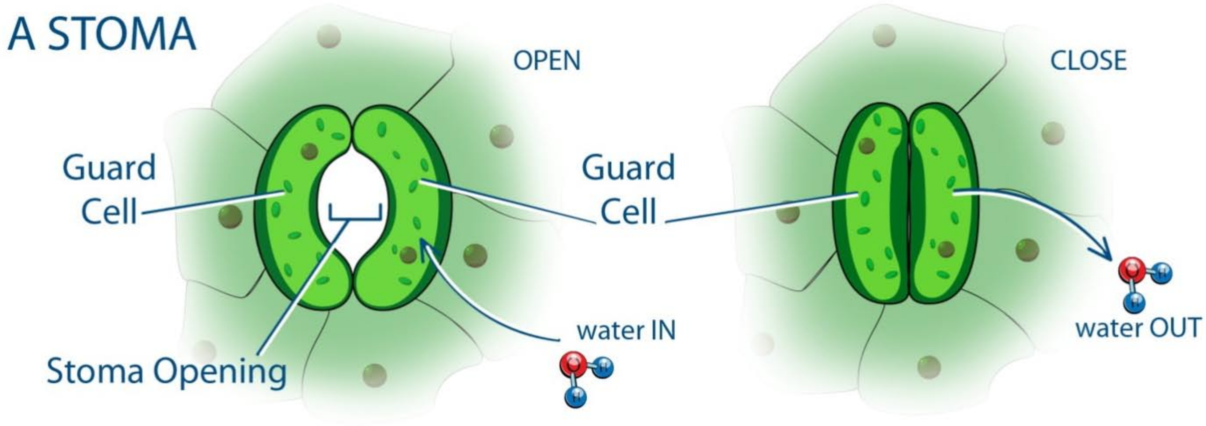
4. Place the boxes in the spaces diagramed on page **Error! Bookmark not defined.**, Suitcase Contents.



INTRODUCTION

Plants leaves have an outer layer of tissue called the epidermal layer that acts like skin to protect its internal structures. The epidermal layer contains specialized pores called stomata. Most stomata are located on the underside of leaves, or lower epidermis, so that they are protected from direct exposure to sunlight. Stomata are important for controlling the flow of gases like carbon dioxide, water vapor, and oxygen. The plant takes in carbon dioxide for photosynthesis and expels oxygen as a byproduct. Unfortunately, leaving the stomata pore open allows water vapors in the plant to escape to the outside. This process is called transpiration.

Water is vital for cellular respiration, supporting the plant structure, and cellular function.



A stoma (singular of stomata) has several parts: two jelly bean shaped cells called guard cells surround the pore opening. Guard cells expand by filling up with water to open the stoma, and contract by expelling water to close up the stoma again. They are the only cells in the epidermal layer that contain chloroplasts needed for photosynthesis.

Stomata are usually open during the day. If the plant is dehydrated or finished exchanging gases, the guard cells will close to prevent the loss of water. Plants that are adapted to different climates contain more or less stomata pores. Dry desert plants may contain fewer stomata, whereas wet climate plants contain more. If there are fewer stomata, less carbon dioxide is being taken in by the plant and that would decrease the rate of photosynthesis. Less photosynthesis means less sugar energy for the plant, which can slow plant growth. That's why desert plants tend to be smaller in size, while in contrast, jungle plants tend to be larger.

Teacher's Comment:

- Try to choose a plant that comes from wet climate (i.e. small ficus) and one that is from a dry climate (i.e. jade plant). The variation in stomata groupings will be more distinct for the students to see.

- An Inch Plant is essential because it provides excellent visualization of plant stomata without the need for slide preparation.

- Choose plants with leaves large enough that you can apply a dime sized coating of nail polish.

- Upon request, the STARS Program can provide plants for use.

ACTIVITY

Purpose: To view and compare stomata from several types of plants

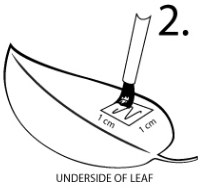
Materials:

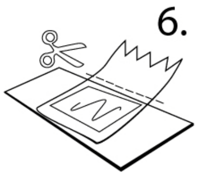
- 3 leaves (including an Inch Plant)
- Compound light microscope
- 3 microscope slides
- Clear nail polish
- Transparent tape

PROCEDURE

Part I: Preparation

1. Choose 1 Inch Plant leaf and 2 other plant leaves
2. Using the clear nail polish, apply a thick coat the size of 1 square centimeter on the underside of each leaf except the Inch Plant. You do not need to apply nail polish on the Inch Plant because its stomata are clearly visible under the microscope.
3. Allow the nail polish to dry on the 2 leaves.
4. Tape a piece of clear tape over the dried nail polish square.
5. Lift the tape gently to peel the nail polish from the leaf.
6. Tape the peeled impression to a microscope slide. Use scissors to trim away excess tape.
7. Repeat steps 4 -6 for the second plant.





Teacher's Comments:

If the nail polish was applied correctly, the slide should look like figure A. The inch plant stomata may be seen under the microscope without slide preparation and will look like figure B.

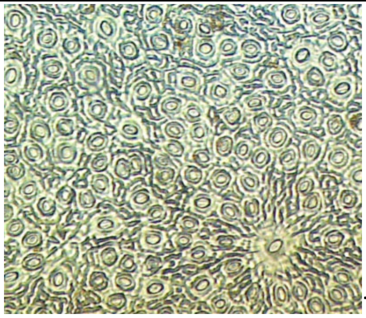


fig. A

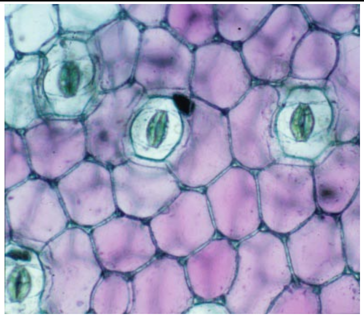


fig. B

Part II: Examination

8. Place the leaf slide under a light microscope at 400x magnification.
9. Search for areas with a large concentration of stomata. Draw what you see in the table below.
10. Count all the stomata in the microscopic field of vision and record the number in the table.
11. Move the microscopic field to a second area and record all the stomata you count. Repeat again.
12. Calculate the average number of stomata per microscopic field by adding all three count totals and dividing by 3. Record the number in the table.
13. Calculate the number of stomata per square millimeter by multiplying your average number by 8.
14. Repeat steps 8 -13 for the second and third plant. For the Inch Plant, place the underside of the leaf face-up on a slide and perform your examination.

DATA

	Leaf 1	**Leaf 2**	**Leaf 3**
Leaf Name			**Inch Plant**
Microscopic Field at 400x (Draw any visible stomata)			
Number of stomata Field 1			
Number of stomata Field 2			

	Leaf 1	**Leaf 2**	**Leaf 3**
Leaf Name			**Inch Plant**
Number of stomata Field 3			
Average number of stomata per field			
Average stomata per square millimeter			

ANALYSIS & CONCLUSIONS

1. Based on the average number of stomata per field calculated, which leaf had the most stomata? Why do think this is so?
   The wet climate leaf should have the most stomata. The wet climate means greater water moisture in the air. To prevent too much water from building up in the leaf cells, more stomata are needed to allow water to escape.

2. Explain how guard cells open and close stomata.
   Water rushes into the guard cells causing stomata to open. Water is let out to close the guard cells again.

3. Define transpiration.
   The escape of water vapors through the stomata opening.

4. Why would a wet climate plant allow for more transpiration to occur by having more stomata?
   The wet climate means greater water moisture in the air. To prevent too much water from building up in the leaf cells, more stomata is needed to allow water to escape.

5. Why does the lower epidermal layer have more stomata than the upper epidermal layer? Why do the stomata need protection from sunlight?
   Better protection from transpiration due to sunlight. The sun causes the water in cells to turn in water vapor and escape through the stomata. Too much water loss will cause the plant to dry out and die.

6. What gases move in and out of the leaf stomata? Name three.
   Carbon Dioxide, Oxygen, and Water Vapor

7. Name the parts that make up a stoma.
   Two guard cells

8. How can having less stomata in a leaf affect the overall growth of a plant?
   Less stomata can hinder the growth of a plant. Less water and carbon dioxide is able to enter the leaves, which reduces the resources available to drive photosynthesis. Less photosynthesis means less sugar available for plant growth.

Make the Connection

Stomata are important in regulating exchange of gases such as oxygen, carbon dioxide, and water vapor. These gases play a vital role in photosynthesis.
Make the connection of how these gases are used in the Light Dependent and Light Independent Reactions. Review these concepts using the Photosynthesis Animation.

Lab 2: Reactions in the Dark!

Purpose: To assess the varying amounts of starch produced in leaves exposed to light and leaves kept in the dark using the iodine-starch test.

Suitcase Provisions

- 8 beakers
- Petri Dishes
- 8 Metal Forceps
- 7 Iodine Droppers
- Alcohol
- 7 Scissors

Upon Request: (Can be added to the auxiliary suitcase)
  - Aluminum Foil
  - Aluminum Pans
  - 4 Hot Plates
  - Plants

Pre-Lab Setup

Place a plant with at least 28 leaves in a dark place or cover completely with a solid bag for 48 hours.

Day 1:

1. Place a pair of scissors on each table. Scissors can be found in the box labeled Lab 1 & 2.
2. Tear a 5 inch sheet of aluminum foil and place it on each table.
3. Bring plant out from dark.
4. Place box of paper clips next to plant for easy student access.
5. Have class complete Part I of the lab.
6. From auxiliary suitcase (if requested), remove lamps and clamp to a stand.
7. Expose the plants to full light for at least 24 hours.

Day 2:

1. Review lab safety when working with hot plates.
2. From auxiliary suitcase (if requested), remove hot plates (4) and set up stations around the classroom. Avoid setting up the plates in one area to prevent student congestion during the exercise.
3. From auxiliary suitcase (if requested), remove aluminum pans. Fill with water and place on hot plates.

4. In box labeled Lab 2: beakers, remove beakers. Fill with alcohol and place in the center of the water bath.
5. From boxes labeled lab 2, remove forceps, Petri dishes, and iodine droppers. Place each item on a table. There are enough supplies for 7 groups.

Post-Lab Clean Up:

Day 1:

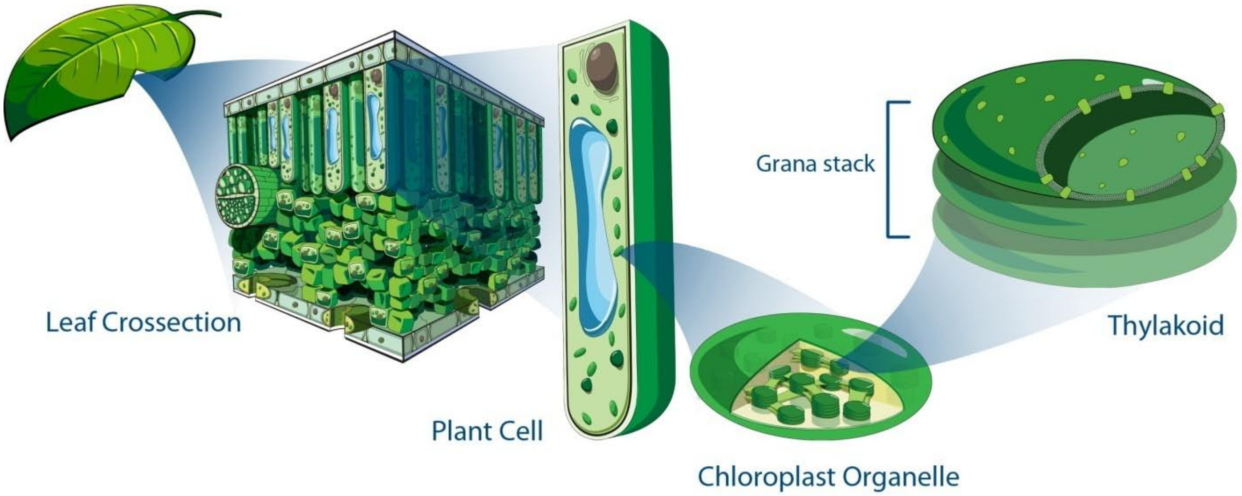
1. Clean scissors (7) and place back in the box labeled as Lab 1 & 2.

Day 2:

2. Rinse forceps (7) and Petri dishes, and return them to boxes labeled as Lab 2.
3. Rinse beakers (5) and return them to the box labeled as Lab 2 & 3.
4. Return iodine droppers (7) to box labeled as Lab 2.
5. Return any extra equipment to the auxiliary suitcase.
6. Place the boxes in the spaces diagramed on page **Error! Bookmark not defined.**, Suitcase Contents.

INTRODUCTION

When thinking about photosynthesis, one usually thinks of at least two things: plants and the sun. The sun provides the ultimate source of energy to living things. Autotrophs, such as plants, take energy from their surroundings (e.g. light) to produce energy-rich carbon compounds in the process known as photosynthesis. In most plants, photosynthesis takes place primarily in the leaves which are structured in such a way to aid the effectiveness of the process.

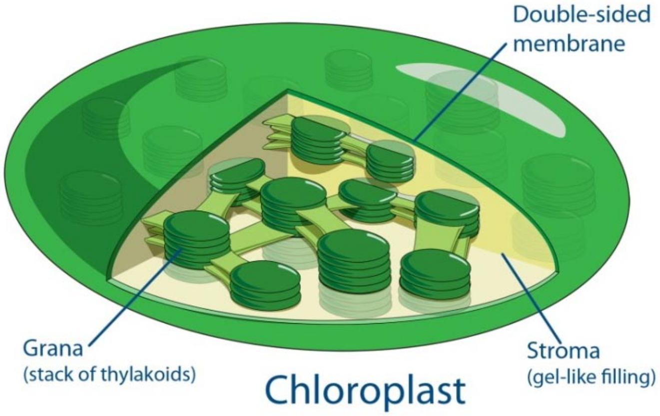


A leaf contains:

- Mesophyll tissue, which contains
    - Mesophyll cells, which typically contains
        ↳ 30-40 chloroplasts, of which the outside is enclosed by a double membrane and contain stacks of membranes on the inside called grana.

            - Grannum (singular form of grana) are made up of stacks of sac-like membranes, known as thylakoids
            - Stroma, a jelly matrix is around each grana

Photosynthesis directly involves the thylakoid and stroma membranes.

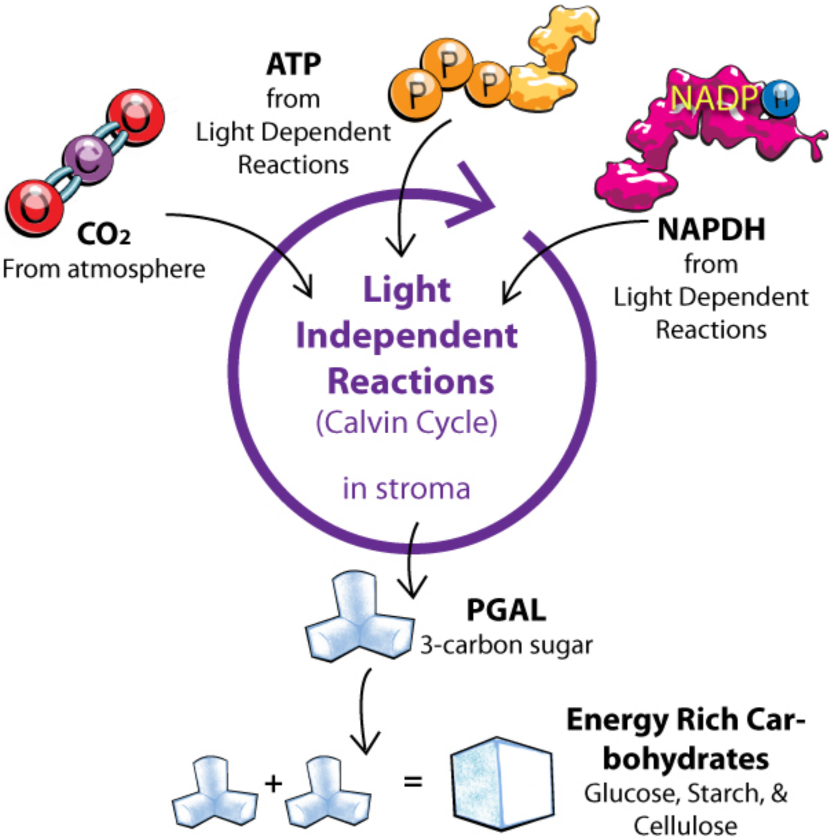


2 Types of Reactions

There are two main types of reactions that occur during photosynthesis: light dependent reactions (or light reactions) and light independent reactions(or dark reaction). Thylakoids membranes are where the light reactions take place. Light reactions produce products which are utilized in the dark reactions, which occur in a plant's chloroplast, specifically in the stroma.

The Dark Reaction

These reactions are also known as the Calvin-Benson cycle, Calvin's cycle, C3 cycle, light independent reactions and carbon fixation cycle. The general purpose of a dark reaction is to convert carbon dioxide and water into two trioses, phosphoglyceraldye (PGAL), and then into glucose using energy produced from the light reactions. Energy from the light reactions come in the form of ATP and NADPH.



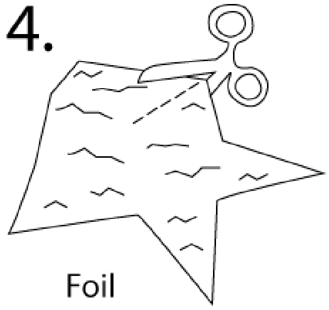
This cycle requires 6 carbon dioxide molecules to produce two molecules of PGAL, which are then combined into a single 6-carbon glucose. These glucose molecules are chemically combined to create long chains of starch and cellulose (carbohydrates). Plants typically store their energy in the form of starch. The stored energy is later consumed in various cellular activities. Heterotrophs can obtain this stored energy from eating plants.

ACTIVITY

Purpose: To assess the varying amounts of starch produced in leaves exposed to light and leaves kept in the dark using the iodine-starch test.

Materials:

- Plant that has been in the dark for 48 consecutive hours
- 1000 mL beaker
- 150 mL of ethanol in water bath
- Lugol's iodine in dropper bottle
- 4" strip of foil
- Scissors
- 250 mL beaker
- Hot plates
- Access to a plant light or fluorescent light source for 48 consecutive hours
- 200 mL tap water
- Petri dish bottom
- Forceps
- 2 Paper clips

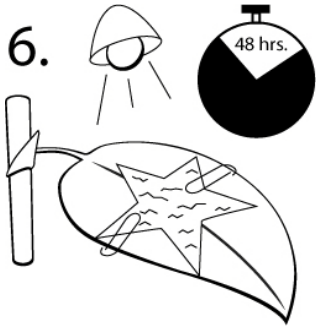


SAFETY ALERT to protect yourself and others

1. Wear goggles to protect your eyes and an apron to protect your clothes during part II of the activity.
2. When heating the alcohol, proceed with caution. As alcohol is flammable heat it by using a hot plate rather than an open flame.
3. Avoid contact with the plant/fluorescent light bulb when plugged in as they can produce heat.

PROCEDURE

PART I: Preparation



1. Read the introduction section of this activity and answer the pre-lab questions located on the student answer sheet provided.
2. Form a hypothesis of the iodine-starch test. Will there be more starch in the leaf surface exposed to light? Or will there be more starch in the leaf surface that was kept in

the dark?

3. Locate the leaf on the plant assigned to you by your teacher.
4. Using scissors, cut out your initials or other unique shape from the piece of foil. Cut the letters or shape out so that it covers most of the leaf surface.
5. Attach the foil cut-outs to the lead using paperclips.
6. Water and keep this plant in the light for 48 consecutive hours.

Teacher's Comments:

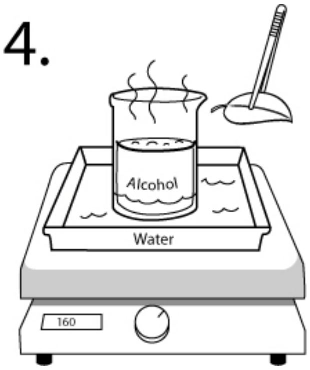
- 24 hours of light exposure is sufficient if you are planning to perform Part II by the next day.
- If you don't prefer to use foil, you can also use small stickers. However, make sure the stickers are fully opaque so that no light can get through.
- For the optimum results, use plants with leaves that are a solid green color.

PART II: Testing for the Presence of Starch

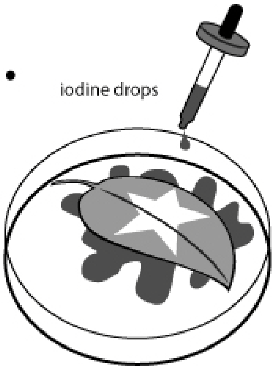
1. Put on goggles and an apron.
2. Obtain the leaf with your initials or shape.

   Remove your leaf from the plant by cutting it at the base of the petiole or the stalk of the leaf.

4.



6.



3. Your teacher has set up a water bath in a smaller beaker to heat the alcohol. Drop your leaf into the boiling water in the larger beaker and boil for 1 minute.
4. After 1 minute has elapsed, move your leaf into the smaller beaker which has alcohol in it using forceps. Observe what happens to the leaf's color.

5. When the color stops changing, use the forceps to remove the leaf from the alcohol. To remove the alcohol from the leaf, dip the leaf into the hot water bath in the larger beaker several times.
6. Place leaf into the Petri dish bottom and coat surface of the leaf with a layer of Lugol’s iodine solution.
7. After 1 minute has elapsed, pour off excess iodine solution on the leaf into the designated waste container.
8. Observe the leaf. Draw your observations on the student answer sheet.
9. Remove a second leaf from the plant which did not have any foil attached to it, by cutting it at the base of the petiole.
10. Repeat steps 1-9 using the second leaf.
11. Clean up your work space and return supplies to designated areas.

Teacher's Comments
After boiling the leaves in the alcohol and water, the leaves should look slightly transparent and light green.

Ideally, the leaf should look like the image #7 in Part II after the iodine treatment.

STUDENT ANSWER SHEET
PART I:
Pre-Lab questions:

1. Describe the difference between a heterotroph and an autotroph.
   Heterotrophs use organic carbon to grow, while autotrophs use the energy surrounding them to grow.

2. Name the two main events of photosynthesis.
   The light dependent reactions and the light independent reactions

3. Where in the plant does each of the two main events of photosynthesis occur?
   The light dependent reactions take place in the thylakoid membrane and the light independent reactions occur in the stroma of the chloroplast.

4. What are the 3 different inputs of the Calvin cycle?
   Carbon Dioxide, ATP, and NADPH.

5. What is the product of the Calvin cycle?
   A triose called PGAL.

6. How many molecules of each input is needed to form a single glucose molecule?
   Two molecules of PGAL are needed to form glucose.

7. Give three examples of energy rich end products of the Calvin cycle.
   Starch, Cellulose, and Glucose.

Hypothesis:

PART II:

Diagram of leaf with foil attached after boiling

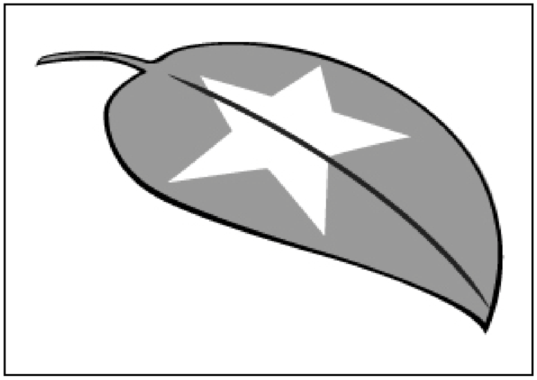
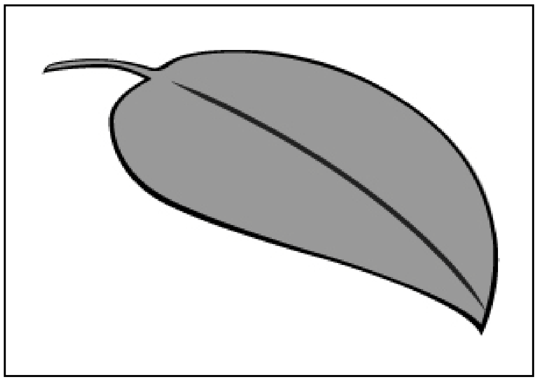


Diagram of no-treatment leaf



Analysis:

1. What are the similarities in the two leaves after they have been stained with iodine?
   The majority of both leaves are stained dark brown.

2. What are the differences in the two leaves after they have been stained with iodine?
   The area covered by the foil did not turn dark brown.

3. What portion of the leaves contain the most starch? Explain your answer.
   The dark portions of the leaf contain the most starch. These areas were exposed to sunlight and were actively making sugar. The control shows that areas with starch will stain dark with iodine.

4. Was the conclusion consistent with your hypothesis? If not, explain why.
   Yes

Conclusion:

1. What did you learn from repeating this experiment with the fully exposed second leaf?

   Learned how a unaffected leaf will react under the iodine test.

2. How do you know the Calvin cycle took place in the mesophyll cells underneath the foil attached to the first leaf?

   The area under the foil stained a light yellow in the iodine test, showing that some starch production activity was still happening.

3. The Luogol’s iodine solution tests for starch. One of the products produced by photosynthesis is glucose. What is the relationship between starch and glucose?

   Glucose is the simple base sugar molecule that can be formed into long chains of sugar called, starch.

4. Why does the iodine react differently to the various parts of the leaf?

   Iodine reacts differently depending of the varying levels of glucose in the leaf.

5. What is the relationship between the Calvin cycle and the light reactions?

   The Calvin Cycle uses the ATP and NAPDH produced in the light reaction to power its own reaction.

6. What is the chemical equation for the photosynthesis process?

   $6CO_2 + 6H_20 \rightarrow C_6H_{12}O_6 + 6O_2$

Make the Connection

The lab is a practical way to see that photosynthesis is taking place and that there is visual evidence, through the iodine test, that sugar was made.

Make the connection that the starch they tested for is a product from the Light Independent Reactions, or Calvin Cycle. You may review this concept using the Photosynthesis Animation and by playing the Sugar Rush! board game.

Lab 3: Floating Leaf Disks

Purpose: Observe the rate of rising leaf disks to calculate the net rate of photosynthesis.

Suitcase Provisions:

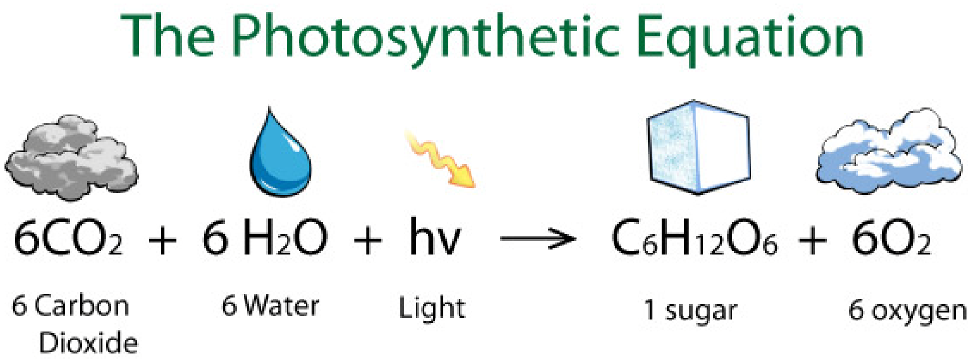
- Syringes
- Cups
- 7 hole punchers
- Mini pipettes
- Sodium Bicarbonate (Baking Soda)
- Beakers
- Timers
- Permanent Markers
- Plants available upon request
- Lights available upon request

Pre-Lab Setup

1. Prepare liquid detergent solution. Remove cups from bag labeled as Lab 3.
2. In a cup, squeeze a dime size amount of detergent and dilute with water.
3. Stir the cup to mix the solution, but don't stir too vigorously to prevent bubbles.
4. Set up several stations around the classroom.
5. Remove the container labeled Lab 3: Baking Soda and set up a bicarbonate station.
6. In bag the labeled Lab 3: Stopwatches (7), remove stopwatches and place on each table. Instructions to use the stopwatches are in the bag.
7. Remove beakers, mini pipettes, syringes, markers, and hole punches from the boxes and place one at each table.
8. From auxiliary suitcase (if requested), set up lamps on a stand.

Post- Lab Cleanup

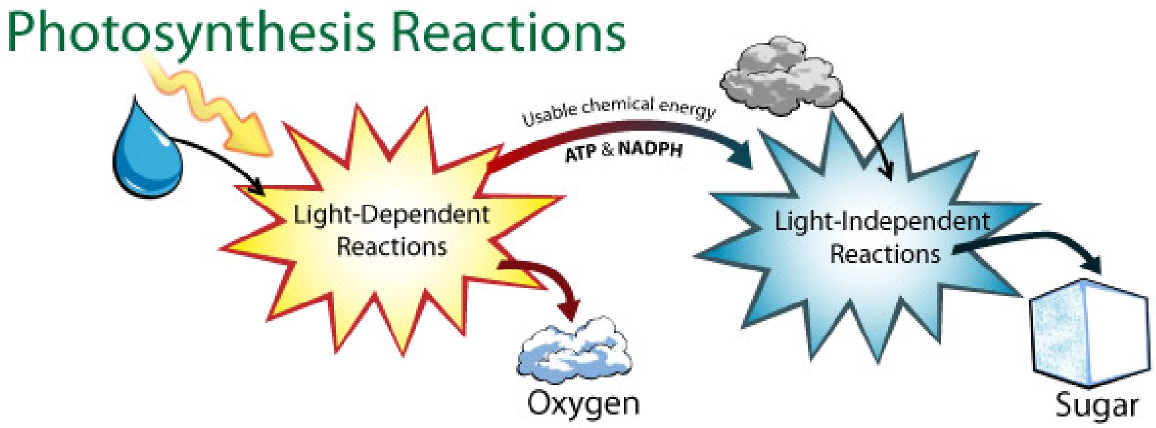
1. Dispose of any spent mini pipettes and cups
2. Rinse beakers and syringes (if reusable).
3. Please return beakers (5), syringes, markers (7), hole punchers (7) to their designated boxes.
4. Re-place boxes in the areas diagramed on page **Error! Bookmark not defined.**, Suitcase Contents.



INTRODUCTION

Photosynthesis is a two part process consisting of the light-DEPENDENT reactions, or light reactions, and light-INDEPENDENT reactions, or dark reactions. Photosynthesis takes place within the chloroplast organelles of plant cells.

Light Reactions: During exposure to sunlight, the light reactions activate to capture light rays and turn it into energy utilized in the dark reactions. During this process, water is consumed and oxygen gas is created as a byproduct. The oxygen is then released by the cell and creates air pockets inside the leaf structure.



Dark Reactions: Once energy is available from the light reactions, the dark reactions activate to create sugar for the plant. The reaction consumes carbon dioxide to help make sugar.
The plant collects carbon dioxide and gets rid of oxygen through stomata pores located on the underside of plant leaves.

IN THIS LAB:
Leaf disks usually float in water because of the air pockets between cells. However, if you fill the air spaces with solution, the density of the disks will

change and cause the disk to sink. The solution we will use in this lab includes sodium bicarbonate (baking soda), which acts as a carbon resource (like carbon dioxide) required for photosynthesis. When you expose the leaf disks to sunlight, photosynthesis will activate to consume the baking soda to make sugar and release oxygen into the leaf and create air pockets. The buoyancy, or ability to float, will change and the leaf disks will start to float again. The rate the disks rise is an indirect measurement of the net rate of photosynthesis.

ACTIVITY

Purpose: Observe the rate of rising leaf disks to calculate the net rate of photosynthesis.

Materials:

- Baking soda
- 300 mL of water
- Pipette
- Liquid soap
- Plastic syringe
- Beaker
- Leaf
- Single hole punch
- 2 clear plastic cups
- Timer
- Light source

Teacher's Comment:
Recommended plants to use: spinach, Ivy, Wisconsin Fast Plant Cotyledons. Avoid plants with hairy leaves. Oxygen bubbles might get caught on the hairs, skewing the results.

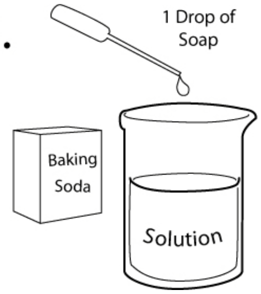
PROCEDURE

PART I: Preparation

Preparing the sodium bicarbonate solution and leaf disks

1. In a beaker, add 300 mL of water and 1/8 of a teaspoon of baking soda.
2. Fill a pipette with diluted liquid soap provided by the teacher.
3. Use the pipette to add 1 drop of diluted liquid soap to the beaker. The soap allows the solution to easily fill the air pockets in the leaf disks. Avoid soap bubbles.
4. Take a leaf and cut 20 or more disks using the hole punch. Avoid major leaf veins.

3.



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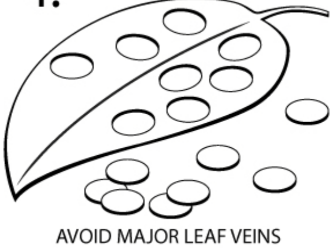
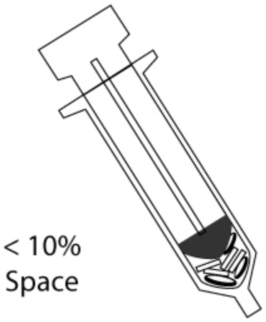


5. Set aside at least 10 disks for your control test.

Filling the leaf disks with baking soda solution

6. Remove the piston or plunger from the syringe and place 10 leaf disks into the syringe barrel. Replace the plunger being careful not to crush the leaf disks.
7. Push on the plunger until only a small volume of air and leaf disk remain in the barrel (< 10%).
8. Pull a small volume of sodium bicarbonate solution into the syringe. Tap the syringe to suspend the leaf disks in the solution.

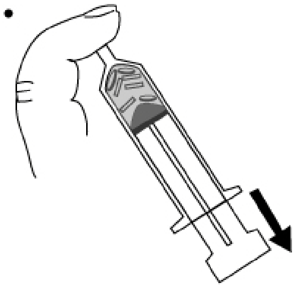
7.



8.

9. Holding a finger over the syringe-opening, draw back on the plunger to create a vacuum seal.
10. Hold this vacuum seal for about 10 seconds. While holding the vacuum, swirl the syringe so that the leaf disks will be suspended in the solution.

9.



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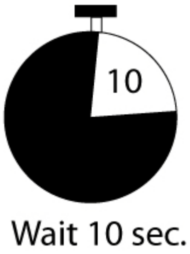


11.

Teacher's Comment:

Make sure to emphasize waiting for the full ten seconds before releasing the vacuum on the syringe.

11. Release the vacuum seal by lifting your finger off from the syringe-opening. The sodium bicarbonate solution will infiltrate the air spaces in the leaf causing the disks to sink.
12. You will probably have to repeat steps 9 - 11 several times in order to get the disks to sink. If you have difficulty getting your disks to sink after about 3 evacuations, it is usually because there is not enough soap in the solution. Try adding a few more drops of soap.

PART II: Examination

13. Pour the disks and solution into a clear plastic cup. Label the cup “with CO_2”.
14. Add the sodium bicarbonate solution in the cup to a depth of about 3 centimeters.
15. For a control, fill leaf disks set aside in step 4 with a solution of only water with a drop of soap (i.e. do NOT add baking soda to the solution). Fill the lead disks by performing steps 6-12. Label cup “H_2O only”.
16. Place your cups under the light source and start the timer.
17. At the end of each minute, record the number of floating disks in the table below.
18. Then swirl the disks to dislodge any that are stuck against the sides of the cups. Repeat step 17 until all of the disks are floating.

DATA

Minutes Elapsed	# of Disks Floating	
	With CO_2	H_2O only
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

ANALYSIS

Graph your data for leaf disks in each cup by the number of disks floating verses time elapsed.

Make a graph for with solution data and the control data.

QUESTIONS

1. Explain why there is a difference in the results for leaf disks with sodium bicarbonate (baking soda) and disks with H_2O only?
   The baking soda acts like CO_2 to provide carbon for photosynthesis to take place. The increase in oxygen byproduct from the photosynthetic reaction causes the leaf disks to rise. With water only, there is no available carbon for the leaf cell and as a result, the leaves don't rise.

2. What is the purpose of the syringe with plain water and leaf disks? Why do we need it?
   This syringe acts as the control for the experiment. It is the base line to which we can compare the data results from the bicarbonate solution filled leaf disks.

3. What is the visible evidence that photosynthesis is occurring?
   The leaf disks rise over time with exposure to sunlight.

4. What is the photosynthetic equation?
   $6CO_2 + 6H_20 \text{ -> } C_6H_{12}O_6 + 6O_2$

5. Which reaction stage does each of the products of photosynthesis get produced in?
   The product oxygen is created during the Light Reactions, while the product glucose is created during the Dark Reactions.

6. Where do leaf plants normally expel oxygen gas byproducts?
   Through the stomata openings.

7. If there was no light source for the plant, how would that affect photosynthesis? Would the leaf disks still float?
   No light would slow or stop photosynthesis. The leaf disks would not float.

8. What is the purpose of the baking soda, light source, and the chlorophyll in the leaf?
   The baking soda provides carbon needed in the dark reactions to make sugar. The light source provides energy to drive the photosynthetic process. The chlorophyll is the plant's tool to capture light energy so that it can be turned into chemical energy for the dark reactions and plant functions.

9. Where in the leaf is the stomata?
   Most stomata are located on the lower epidermis of the leaf. Some stomata may be found on the upper epidermis.

10. What actually causes the leaf disks to float?
    The leaf disks float when the light reactions activate to capture energy and oxygen byproduct is produced. These oxygen molecules start to accumulate in the spaces between leaf cells, causing the disk to increase in buoyancy and rise.

11. What causes the leaf disks to sink?
    Eventually the bicarbonate immediately surrounding the leaf disk is used up and the light-independent (dark reactions) come to a stop. The light dependent reactions also slow down, and the oxygen molecules built up start to escape the cells, causing the disk to sink.

Make the Connection

The gradual rise of the leaf disks is a clear indicator that photosynthesis is actively taking place, right in front of the student's eyes. This differs from Lab 2 where the students performed iodine tests looking for evidence that photosynthesis already took place. Make the connection of how the increase buoyancy in the leaf is due to the creation of oxygen, and that this is a byproduct of the light dependent reaction and the Electron Transport Chain. You can use the photosynthesis animation to review concepts starting at Chapter 6 (Where does it happen?).

Leaf Cell Model

This full 3-D model is a great hands-on tool for reviewing plant cell organelles. The model is fully detachable from the display stand and includes cut and uncut examples of all major organelles and plant cell structures.

You may use the model to quiz students on the different types of organelles and compare the differences between plant and animal cells. An image of all the labeled structures is included in this manual for your reference.

Note that the ribosomes displayed on the model are crafted to be individual circular clusters. However, they are painted inaccurately as bright orange streaks. This is apparent on the Rough Endoplasmic Reticulum close to the nucleus, and on the ribosomal cluster throughout the cytoplasm.

List of Structures and Definitions:

Cell Membrane - barrier that separates the outside environment from the interior of a cell.

Cell Wall - tough layer surrounding the cell membrane in plants. It acts as structural support and protection and also acts as a filtering mechanism. Note: animals do not have cell walls.

Cytoplasm - is the space enclosed within the cell membrane.

Chloroplast - organelle in plant cells that conduct photosynthesis.

Golgi Apparatus - organelle that processes and packages macromolecules like proteins after their synthesis and before they make their way to their destination.

Mitochondria - membrane-enclosed organelle that generates the cell’s supply of adenosine triphosphate (ATP).

Nucleus - membrane-enclosed organelle which contains a cell’s genetic material.

Nucleolus - made up of proteins and nucleic acids in a non-membrane bound structure that is located within the nucleus.

Ribosomes - small round particles in a cell that make proteins from amino acids.

Rough Endoplasmic Reticulum - organelle that forms an interconnected network within the cells. These have protein-manufacturing ribosomes on the surface. Attached ribosomes are not stable and constantly are being bound and released.

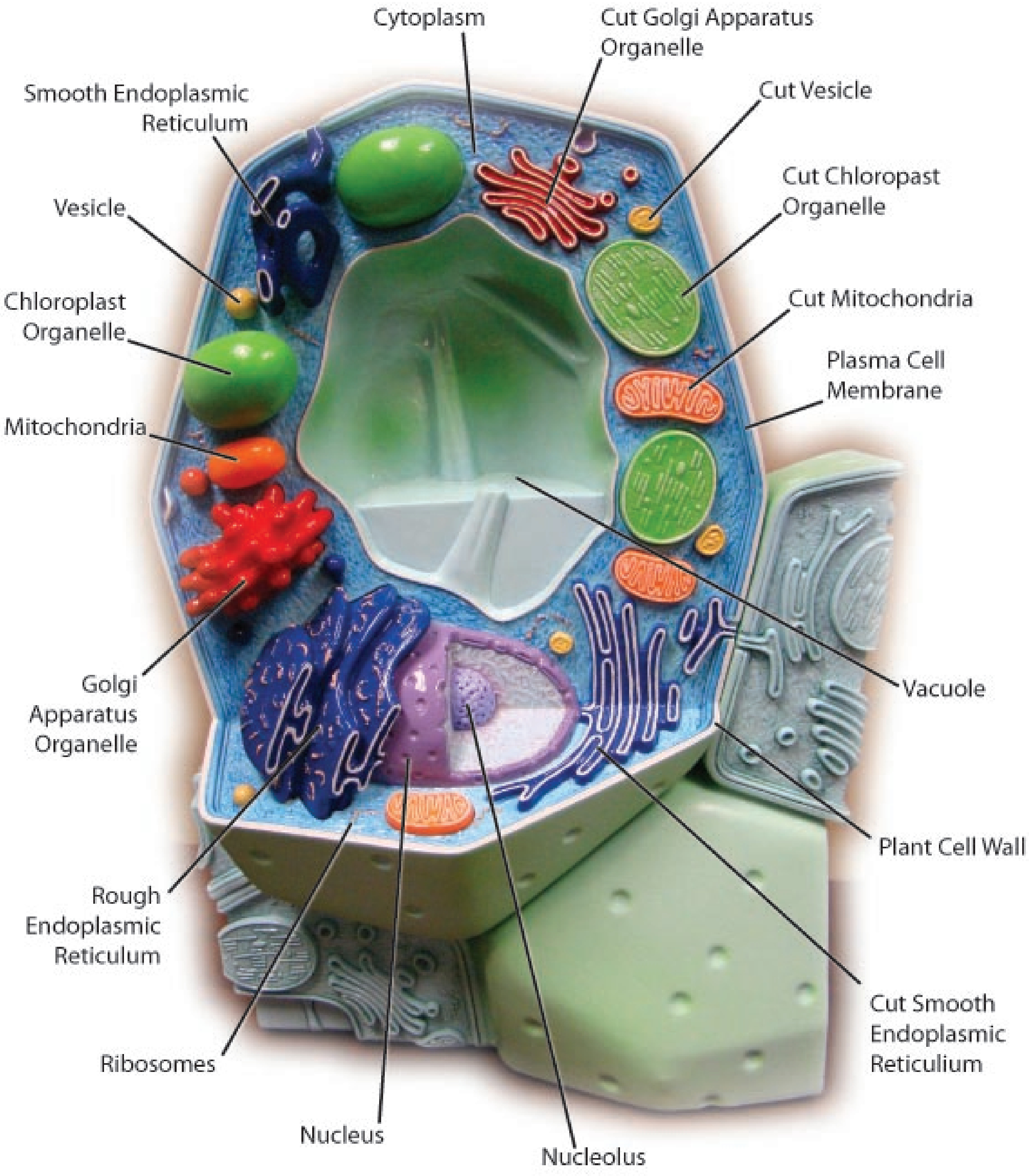
Smooth Endoplasmic Reticulum - organelle that forms an interconnected network within the cells. Utilized in several metabolic processes, including the metabolism of steroids. These are tubular in form and lack ribosomes.

Vacuole - membrane organelles which store inorganic and organic molecules like water or glucose. Formed by the fusion of multiple membrane vesicles.

Vesicle - small membrane-enclosed sac that stores and transports substances within a cell.

Plant Cell Model

Quick Reference Diagram



About and Acknowledgements

This Photosynthesis Science Suitcase was created by me, Derek Wu, as part of my graduate school thesis. I obtained a Bachelors of Science degree in Molecular Environmental Biology from the University of California, Berkeley. In addition, I obtained a Master of Arts in Biomedical Communication from University of Texas, Southwestern Medical Center at Dallas. I'm currently employed at Krames Patient Education in California.

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Appendix

The following versions are reproduced for student use.

Lab 1: Stomata, Stomata!

Lab 2: Reactions in the Dark

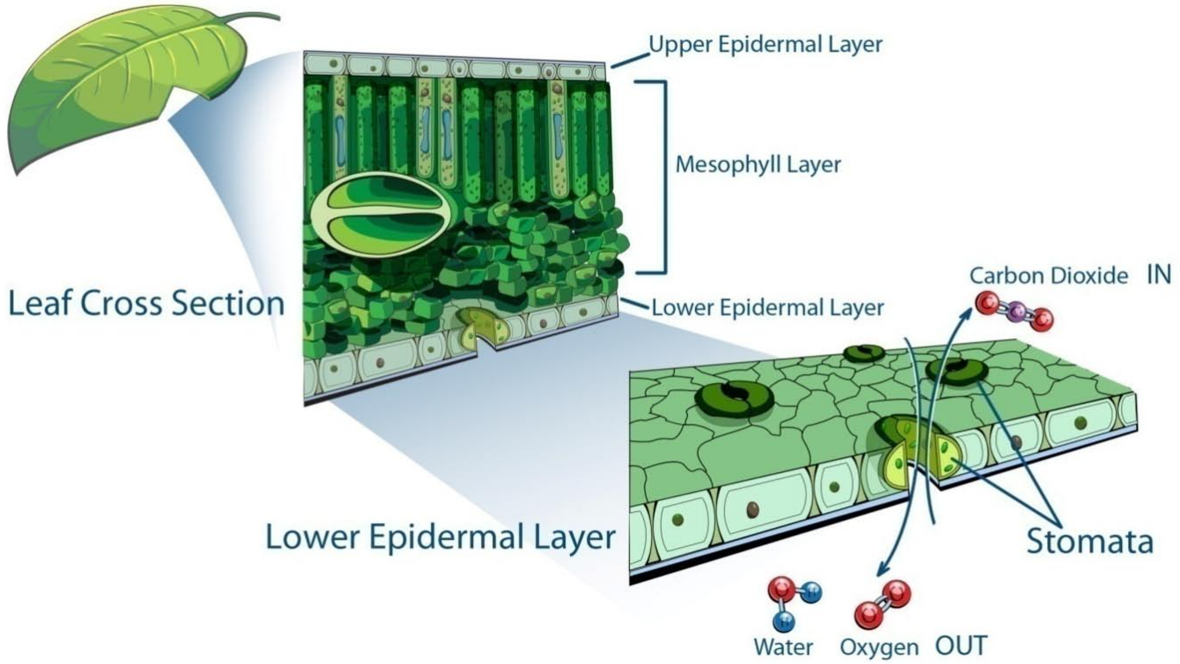
Lab 3: Floating Leaf Disks

Pre-Test: Magic Squares

Post-Test: Multiple Choice Test

Lab 1: Stomata, Stomata!

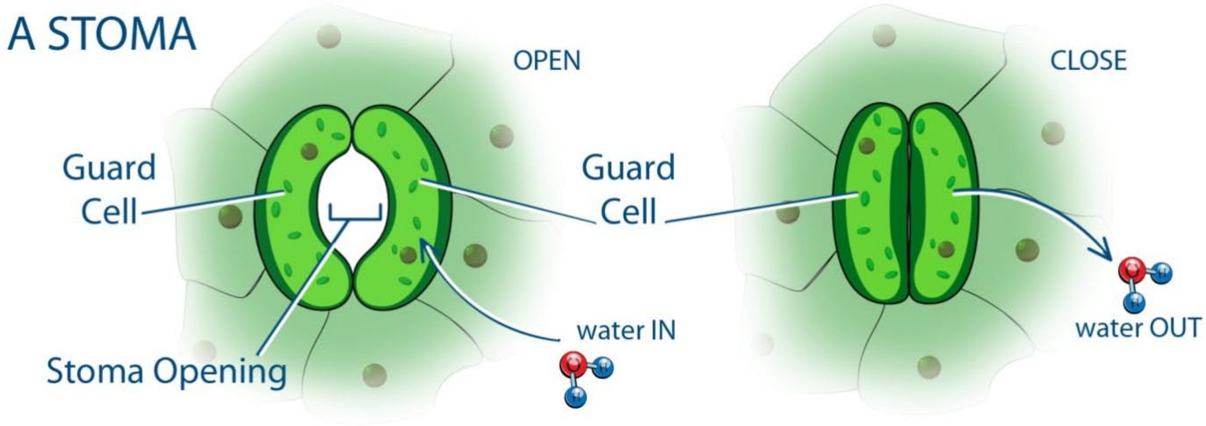
Purpose: Review leaf stomata anatomy and explore the different examples of stomata grouping in plants that live in either dry or wet climates.



INTRODUCTION

Plants leaves have an outer layer of tissue called the epidermal layer that acts like skin to protect its internal structures. The epidermal layer contains specialized pores called stomata. Most stomata are located on the underside of leaves, or lower epidermis, so that they are protected from direct exposure to sunlight. Stomata are important for controlling the flow of gases like carbon dioxide, water vapor, and oxygen. The plant takes in carbon dioxide for photosynthesis and expels oxygen as a byproduct. Unfortunately, leaving the stomata pore open allows water vapors in the plant to escape to the outside. This process is called transpiration.

Water is vital for cellular respiration, supporting the plant structure, and cellular function.



A stoma (singular of stomata) has several parts: two jelly bean shaped cells called guard cells surround the pore opening. Guard cells expand by filling up with water to open the stoma, and contract by expelling water to close up the stoma again. They are the only cells in the epidermal layer that contain chloroplasts needed for photosynthesis.

Stomata are usually open during the day. If the plant is dehydrated or finished exchanging gases, the guard cells will close to prevent the loss of water. Plants that are adapted to different climates contain more or less stomata pores. Dry desert plants may contain fewer stomata, whereas wet climate plants contain more. If there are fewer stomata, less carbon dioxide is being taken in by the plant and that would decrease the rate of photosynthesis. Less photosynthesis means less sugar energy for the plant, which can slow plant growth. That's why desert plants tend to be smaller in size, while in contrast, jungle plants tend to be larger.

ACTIVITY

Purpose: To view and compare stomata from several types of plants

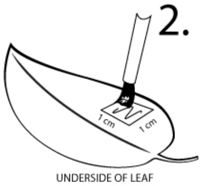
Materials:

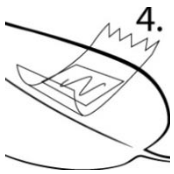
- 3 leaves (including an Inch Plant)
- Compound light microscope
- 3 microscope slides
- Clear nail polish
- Transparent tape

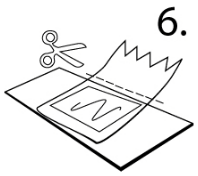
PROCEDURE

Part I: Preparation

1. Choose 1 Inch Plant leaf and 2 other plant leaves
2. Using the clear nail polish, apply a thick coat the size of 1 square centimeter on the underside of each leaf except the Inch Plant. You do not need to apply nail polish on the Inch Plant because its stomata are clearly visible under the microscope.
3. Allow the nail polish to dry on the 2 leaves.
4. Tape a piece of clear tape over the dried nail polish square.
5. Lift the tape gently to peel the nail polish from the leaf.
6. Tape the peeled impression to a microscope slide. Use scissors to trim away excess tape.
7. Repeat steps 4 -6 for the second plant.







Part II: Examination

8. Place the leaf slide under a light microscope at 400x magnification.
9. Search for areas with a large concentration of stomata. Draw what you see in the table below.
10. Count all the stomata in the microscopic field of vision and record the number in the table.
11. Move the microscopic field to a second area and record all the stomata you count. Repeat again.
12. Calculate the average number of stomata per microscopic field by adding all three count totals and dividing by 3. Record the number in the table.
13. Calculate the number of stomata per square millimeter by multiplying your average number by 8.
14. Repeat steps 8 -13 for the second and third plant. For the Inch Plant, place the underside of the leaf face-up on a slide and perform your examination.

DATA

	Leaf 1	**Leaf 2**	**Leaf 3**
Leaf Name			**Inch Plant**
Microscopic Field at 400x (Draw any visible stomata)			
Number of stomata Field 1			
Number of stomata Field 2			
Number of stomata Field 3			
Average number of stomata per field			
Average stomata per square millimeter			

ANALYSIS & CONCLUSIONS

9. Based on the average number of stomata per field calculated, which leaf had the most stomata? Why do think this is so?

10. Explain how guard cells open and close stomata.

11. Define transpiration.

12. Why would a wet climate plant allow for more transpiration to occur by having more stomata?

13. Why does the lower epidermal layer have more stomata than the upper epidermal layer? Why do the stomata need protection from sunlight?

14. What gases move in and out of the leaf stomata? Name three.

15. Name the parts that make up a stoma.

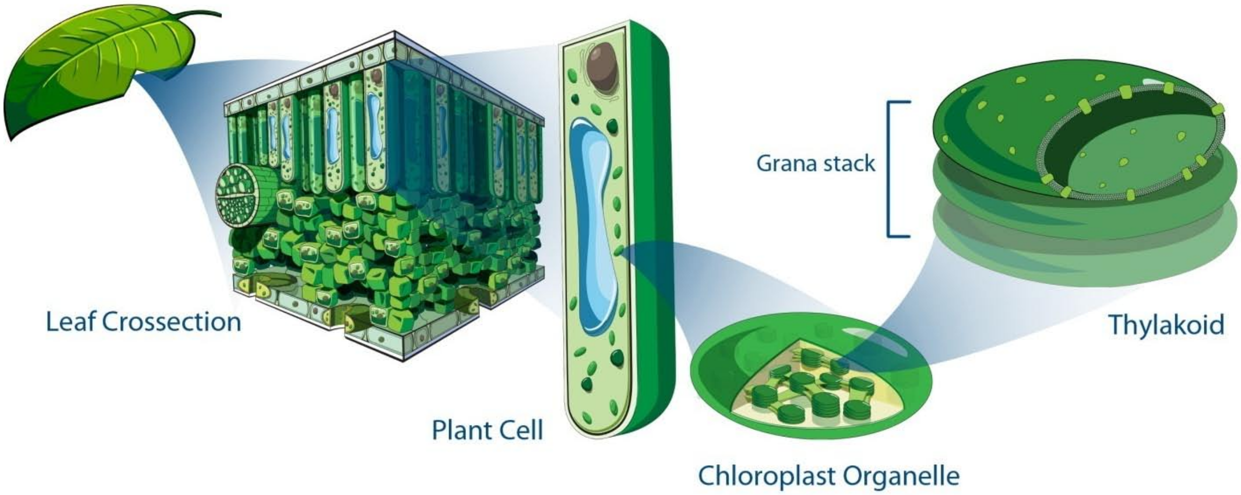
16. How can having less stomata in a leaf affect the overall growth of a plant?

Lab 2: Reactions in the Dark!

Purpose: To assess the varying amounts of starch produced in leaves exposed to light and leaves kept in the dark using the iodine-starch test.

INTRODUCTION

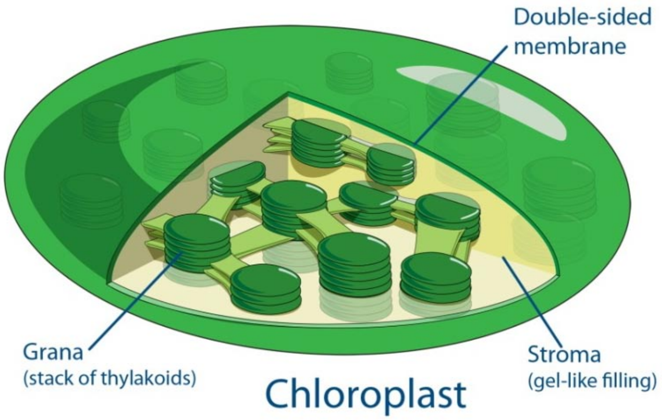
When thinking about photosynthesis, one usually thinks of at least two things: plants and the sun. The sun provides the ultimate source of energy to living things. Autotrophs, such as plants, take energy from their surroundings (e.g. light) to produce energy-rich carbon compounds in the process known as photosynthesis. In most plants, photosynthesis takes place primarily in the leaves which are structured in such a way to aid the effectiveness of the process.



A leaf contains:

- Mesophyll tissue, which contains
  - Mesophyll cells, which typically contains
    - ↳ 30-40 chloroplasts, of which the outside is enclosed by a double membrane and contain stacks of membranes on the inside called grana.
      - Grannum (singular form of grana) are made up of stacks of sac-like membranes, known as thylakoids
      - Stroma, a jelly matrix is around each grana

Photosynthesis directly involves the thylakoid and stroma membranes.

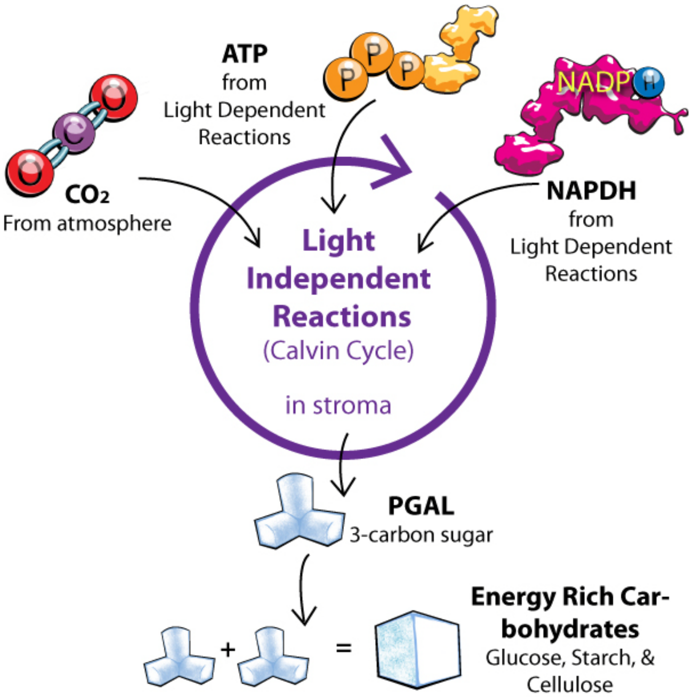


2 Types of Reactions

There are two main types of reactions that occur during photosynthesis: light dependent reactions (or light reactions) and light independent reactions(or dark reaction). Thylakoids membranes are where the light reactions take place. Light reactions produce products which are utilized in the dark reactions, which occur in a plant's chloroplast, specifically in the stroma.

The Dark Reaction

These reactions are also known as the Calvin-Benson cycle, Calvin's cycle, C3 cycle, light independent reactions and carbon fixation cycle. The general purpose of a dark reaction is to convert carbon dioxide and water into two trioses, phosphoglyceraldye (PGAL), and then into glucose using energy produced from the light reactions. Energy from the light reactions come in the form of ATP and NADPH.



This cycle requires 6 carbon dioxide molecules to produce two molecules of PGAL, which are then combined into a single 6-carbon glucose. These glucose molecules are chemically combined to create long chains of starch and cellulose (carbohydrates). Plants typically store their energy in the form of starch. The stored energy is later consumed in various cellular activities. Heterotrophs can obtain this stored energy from eating plants.

ACTIVITY

Purpose: To assess the varying amounts of starch produced in leaves exposed to light and leaves kept in the dark using the iodine-starch test.

Materials:

- Plant that has been in the dark for 48 consecutive hours
- 1000 mL beaker
- 150 mL of ethanol in water bath
- Lugol’s iodine in dropper bottle
- 4” strip of foil
- Scissors
- 250 mL beaker
- Hot plates
- Access to a plant light or fluorescent light source for 48 consecutive hours
- 200 mL tap water
- Petri dish bottom
- Forceps
- 2 Paper clips

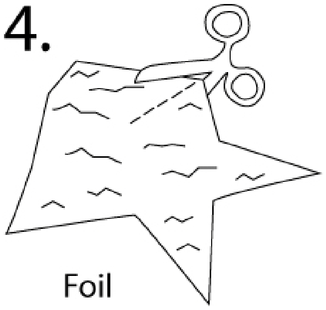
SAFETY ALERT to protect yourself and others

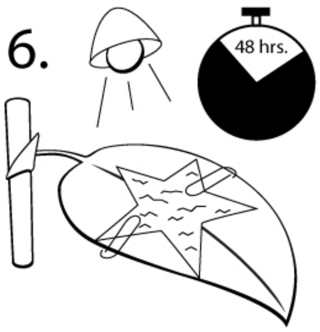
1. Wear goggles to protect your eyes and an apron to protect your clothes during part II of the activity.
2. When heating the alcohol, proceed with caution. As alcohol is flammable heat it by using a hot plate rather than an open flame.
3. Avoid contact with the plant/fluorescent light bulb when plugged in as they can produce heat.

PROCEDURE

PART I: Preparation

1. Read the introduction section of this activity and answer the pre-lab questions located on the student answer sheet provided.
2. Form a hypothesis of the iodine-starch test. Will there be more starch in the leaf surface exposed to light? Or will there be more starch in the leaf surface that was kept in the dark?
3. Locate the leaf on the plant assigned to you by your teacher.
4. Using scissors, cut out your initials or other unique shape from the piece of foil. Cut the letters or shape out so that it covers most of the leaf surface.
5. Attach the foil cut-outs to the lead using paperclips.
6. Water and keep this plant in the light for 48 consecutive hours.

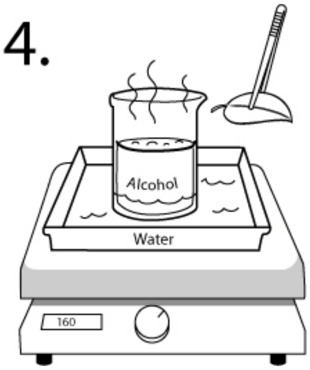




PART II: Testing for the Presence of Starch

1. Put on goggles and an apron.
2. Obtain the leaf with your initials or shape.
   Remove your leaf from the plant by cutting it at the base of the petiole or the stalk of the leaf.

4.



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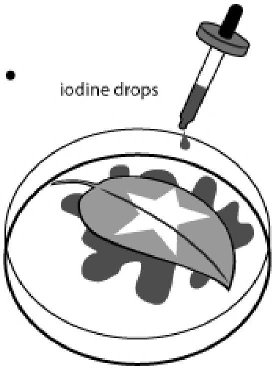


3. Your teacher has set up a water bath in a smaller beaker to heat the alcohol. Drop your leaf into the boiling water in the larger beaker and boil for 1 minute.
4. After 1 minute has elapsed, move your leaf into the smaller beaker which has alcohol in it using forceps. Observe what happens to the leaf's color.
5. When the color stops changing, use the forceps to remove the leaf from the alcohol. To remove the alcohol from the leaf, dip the leaf into the hot water bath in the larger beaker several times.
6. Place leaf into the Petri dish bottom and coat surface of the leaf with a layer of Lugol's iodine solution.
7. After 1 minute has elapsed, pour off excess iodine solution on the leaf into the designated waste container.
8. Observe the leaf. Draw your observations on the student answer sheet.
9. Remove a second leaf from the plant which did not have any foil attached to it, by cutting it at the base of the petiole.
10. Repeat steps 1-9 using the second leaf.
11. Clean up your work space and return supplies to designated areas.

STUDENT ANSWER SHEET
PART I:
Pre-Lab questions:

1. Describe the difference between a heterotroph and an autotroph.
2. Name the two main events of photosynthesis.
3. Where in the plant does each of the two main events of photosynthesis occur?
4. What are the 3 different inputs of the Calvin cycle?
5. What is the product of the Calvin cycle?
6. How many molecules of each input is needed to form a single glucose molecule?
7. Give three examples of energy rich end products of the Calvin cycle.

Hypothesis:

PART II:

Diagram of leaf with foil attached after boiling

Diagram of no-treatment leaf

Analysis:

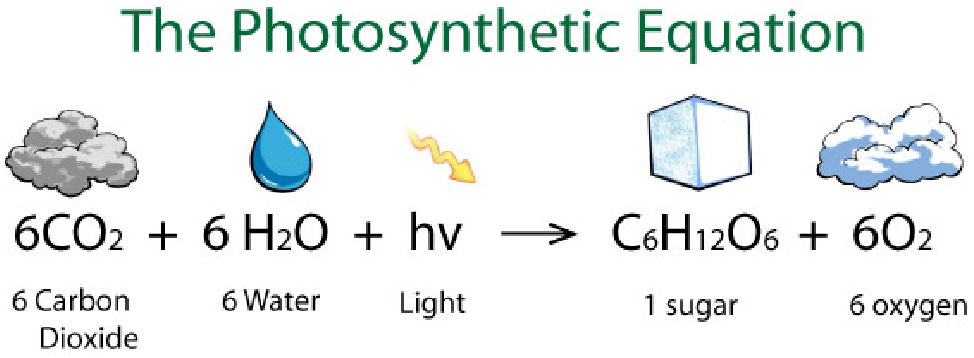
5. What are the similarities in the two leaves after they have been stained with iodine?
6. What are the differences in the two leaves after they have been stained with iodine?
7. What portion of the leaves contain the most starch? Explain your answer.
8. Was the conclusion consistent with your hypothesis? If not, explain why.

Conclusion:

1. What did you learn from repeating this experiment with the fully exposed second leaf?
2. How do you know the Calvin cycle took place in the mesophyll cells underneath the foil attached to the first leaf?
3. The Luogol's iodine solution tests for starch. One of the products produced by photosynthesis is glucose. What is the relationship between starch and glucose?
4. Why does the iodine react differently to the various parts of the leaf?
5. What is the relationship between the Calvin cycle and the light reactions?
6. What is the chemical equation for the photosynthesis process?

Lab 3: Floating Leaf Disks

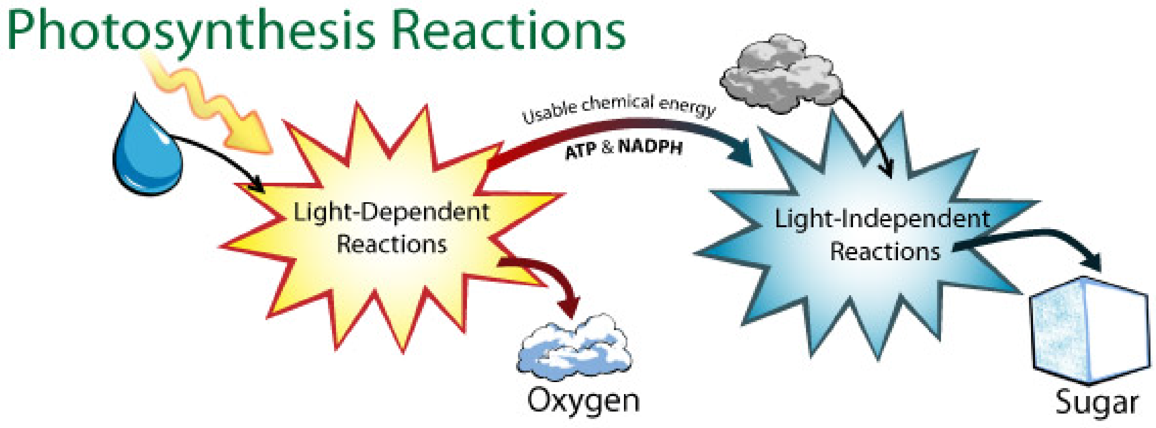
Purpose: Observe the rate of rising leaf disks to calculate the net rate of photosynthesis.



INTRODUCTION

Photosynthesis is a two part process consisting of the light-DEPENDENT reactions, or light reactions, and light-INDEPENDENT reactions, or dark reactions. Photosynthesis takes place within the chloroplast organelles of plant cells.

Light Reactions: During exposure to sunlight, the light reactions activate to capture light rays and turn it into energy utilized in the dark reactions. During this process, water is consumed and oxygen gas is created as a byproduct. The oxygen is then released by the cell and creates air pockets inside the leaf structure.



Dark Reactions: Once energy is available from the light reactions, the dark reactions activate to create sugar for the plant. The reaction consumes carbon dioxide to help make sugar.
The plant collects carbon dioxide and gets rid of oxygen through stomata pores located on the underside of plant leaves.

IN THIS LAB:
Leaf disks usually float in water because of the air pockets between cells. However, if you fill the air spaces with solution, the density of the disks will change and cause the disk to sink. The solution we will use in this lab includes sodium bicarbonate (baking soda), which acts as a carbon resource (like carbon dioxide) required for photosynthesis. When you expose the leaf disks to sunlight, photosynthesis will activate to consume the baking soda to make sugar and release oxygen into the leaf and create air pockets. The buoyancy, or ability to float, will change and the leaf disks will start to float again. The rate the disks rise is an indirect measurement of the net rate of photosynthesis.

ACTIVITY

Purpose: Observe the rate of rising leaf disks to calculate the net rate of photosynthesis.

Materials:

- Baking soda
- 300 mL of water
- Pipette
- Liquid soap
- Plastic syringe
- Beaker
- Leaf
- Single hole punch
- 2 clear plastic cups
- Timer
- Light source

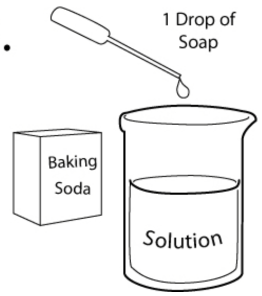
PROCEDURE

PART I: Preparation

Preparing the sodium bicarbonate solution and leaf disks

1.
2. In a beaker, add 300 mL of water and 1/8 of a teaspoon of baking soda.
3. Fill a pipette with diluted liquid soap provided by the teacher.
4. Use the pipette to add 1 drop of diluted liquid soap to the beaker. The soap allows the solution to easily fill the air pockets in the leaf disks. Avoid soap bubbles.
5. Take a leaf and cut 20 or more disks using the hole punch. Avoid major leaf veins.

3.



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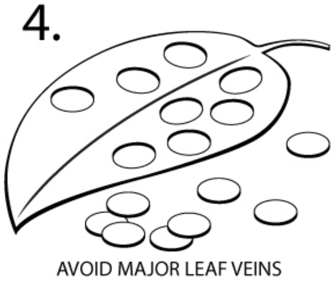
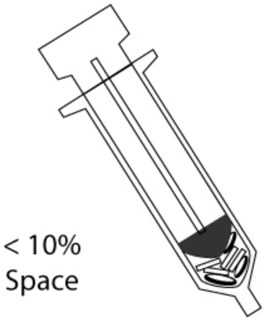


6. Set aside at least 10 disks for your control test.

Filling the leaf disks with baking soda solution

7. Remove the piston or plunger from the syringe and place 10 leaf disks into the syringe barrel. Replace the plunger being careful not to crush the leaf disks.
8. Push on the plunger until only a small volume of air and leaf disk remain in the barrel (< 10%).
9. Pull a small volume of sodium bicarbonate solution into the syringe. Tap the syringe to suspend the leaf disks in the solution.

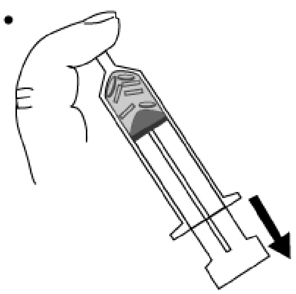
7.



8.

10. Holding a finger over the syringe-opening, draw back on the plunger to create a vacuum seal.
11. Hold this vacuum seal for about 10 seconds. While holding the vacuum, swirl the syringe so that the leaf disks will be suspended in the solution.

9.



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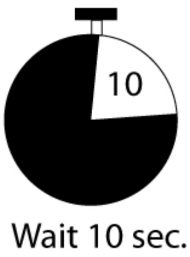


11.

12. Release the vacuum seal by lifting your finger off from the syringe-opening. The sodium bicarbonate solution will infiltrate the air spaces in the leaf causing the disks to sink.
13. You will probably have to repeat steps 9 - 11 several times in order to get the disks to sink. If you have difficulty getting your disks to sink after about 3 evacuations, it is usually because there is not enough soap in the solution. Try adding a few more drops of soap.

PART II: Examination

14. Pour the disks and solution into a clear plastic cup. Label the cup "with CO_2".
15. Add the sodium bicarbonate solution in the cup to a depth of about 3 centimeters.
16. For a control, fill leaf disks set aside in step 4 with a solution of only water with a drop of soap (i.e. do NOT add baking soda to the solution). Fill the lead disks by performing steps 6-12. Label cup "H_2O only".
17. Place your cups under the light source and start the timer.
18. At the end of each minute, record the number of floating disks in the table below.
19. Then swirl the disks to dislodge any that are stuck against the sides of the cups. Repeat step 17 until all of the disks are floating.

DATA
Record your data in the fields provided below.

Minutes Elapsed	# of Disks Floating	
	With CO_2	H_2O only
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

ANALYSIS

Graph your data for leaf disks in each cup by the number of disks floating verses time elapsed.

Make a graph for with solution data and the control data.

QUESTIONS

12. Explain why there is a difference in the results for leaf disks with sodium bicarbonate (baking soda) and disks with H_2O only?

13. What is the purpose of the syringe with plain water and leaf disks? Why do we need it?

14. What is the visible evidence that photosynthesis is occurring?

15. What is the photosynthetic equation?

16. Which reaction stage does each of the products of photosynthesis get produced in?

17. Where do leaf plants normally expel oxygen gas byproducts?

18. If there was no light source for the plant, how would that affect photosynthesis? Would the leaf disks still float?

19. What is the purpose of the baking soda, light source, and the chlorophyll in the leaf?

20. Where in the leaf is the stomata?

21. What actually causes the leaf disks to float?

22. What causes the leaf disks to sink?

Magic Squares!

Photosynthesis Pre Quiz

Question

A. The organelle in which photosynthesis occurs
B. Where is energy stored in ATP
C. Organism that makes its own food
D. Photosynthesis occurs in what organisms
E. Cells' usable source of energy
F. Reactants of photosynthesis
G. Organism that cannot make its own food
H. Structural formula for ATP
I. The organelle where aerobic respiration takes place
J. Process by which energy of glucose is released in the cell
K. Photosynthesis is separated into _(#) reaction cycles
L. Three elements needed for photosynthesis to occur
M. Tiny packet of light energy
N. Function of NADPH
O. Stored in plant cell walls and as starch
P. Products of photosynthesis
Q. The reactions where oxygen product is created
R. Photons are absorbed by this material
S. Where the light reactions take place
T. The reactions where carbon dioxide is split
U. Plant structure that allows the exchange of gases
V. The main cell layer where most photosynthesis occurs
W. What a stack of thylakoids is called
X. Protein structure that contains the chlorophyll pigments
Y. Number carbon dioxide molecules needed to make one glucose

Answer Choices

1. 2
2. In bonds between phosphate groups
3. Chlorophyll pigments
4. Mitochondria
5. 2 molecules
6. ATP
7. C6H12O6 + O2
8. Heterotroph
9. Granum
10. Energy carrier
11. Thylakoid membrane
12. Cellular respiration
13. Stomata
14. Water, carbon dioxide, and sunlight
15. Autotroph
16. A - P ~ P ~ P
17. Reaction Center
18. Glucose
19. Chloroplast
20. Light Dependent Reactions
21. Mesophyll
22. Photon
23. Plants and few microorganisms
24. Light Independent Reactions
25. 6CO2 + 6H2O + light

Add the answers up horizontally. Each row should add up to 65.

A	B	C	D	E	**= 65**
F	G	H	I	J	**= 65**
K	L	M	N	O	**= 65**
P	Q	R	S	T	**= 65**
U	V	W	X	Y	**= 65**

Photosynthesis Post-Quiz

1. What are the products of photosynthesis?
    a. Sugar and carbon dioxide
    b. Water and sugar
    c. Glucose and oxygen
    d. Water and carbon dioxide

2. There are ____ materials needed for photosynthesis to occur: ___________________
    a. 2, water and oxygen
    b. 3, light, carbon dioxide, and water
    c. 2, sugar and water
    d. 3, sugar water and oxygen

3. Photons are tiny packets of _____.
    a. Electrons
    b. Pigments
    c. ATP
    d. Light energy

4. Light reactions occur in the _____ membrane.
    a. Stroma
    b. Chloroplast
    c. Thylakoid disk
    d. Starch grains

5. Dark reactions occur in the _____.
    a. Stroma
    b. Starch grains
    c. Thylakoid disk
    d. Starch grain

6. There are ___stages(s) in photosynthesis.
    a. 1
    b. 3
    c. 2
    d. 4

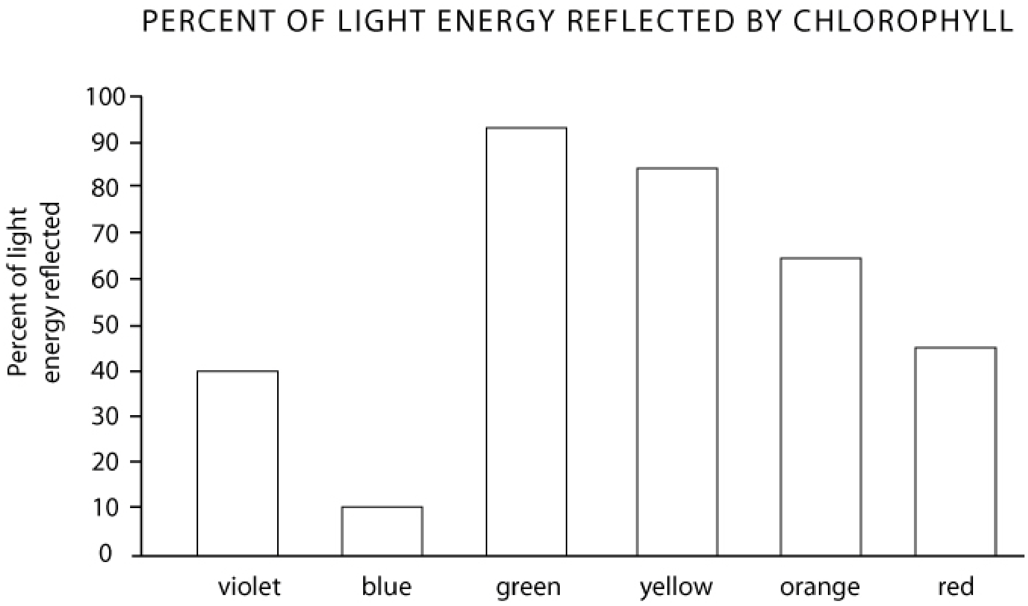
7. Light is captured from _____.
    a. Sunlight
    b. Pigments
    c. Photons
    d. Electrons

8. The source of oxygen(waste) comes from _____.
    a. Water
    b. Sugar
    c. Carbon dioxide
    d. oxygen

9. NADPH gets release into the _____, so that sugar can be made.
    a. Granum
    b. Stroma
    c. Thylakoid

10. Carbon Dioxide is split in the _____.
    a. Calvin cycle
    b. Photosystems
    c. Light Reaction

11. Photosynthesis takes place in the _____ organelle
    a. Thylakoid
    b. Chloroplast
    c. Chlorophyll


PERCENT OF LIGHT ENERGY REFLECTED BY CHLOROPHYLL

Use the bar graph, which shows the percentage of light energy reflected by chlorophyll, to answer the following questions. The graph was derived from the chlorophyll absorption spectrum.

12. Which color in this spectrum is most visible?

13. What is the approximate percentage of light energy reflected for this color?

14. What percentage of light energy absorbed does this represent?

15. If everything above 50 percent of light energy reflected is visible to the human eye, is the red light part of the mixture of colors seen in light reflected by chlorophyll?

16. ATP stands for
    a. Adenosine Diphosphate
    b. Alpha T-phosphorus
    c. Adenosine Triphosphate

17. The electron Transport Chain is used in _____.
    a. Calvin cycle, Photosystem II
    b. Photosystem I, Calvin cycle
    c. Photosystem II, photosystem I

18. NADPH is made in Photosystem ___ and used in the _____.
    a. I, Photosystem II
    b. II, Calvin cycle
    c. I, Calvin cycle

APPENDIX G:
Evaluation Survey

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:__________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9+4
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments: It seemed somewhat confusing at first. & Perhaps a short summary of each part of the game would make the start easier.

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:
We didn't look at the lab papers close enough to decide

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - ( ) Board Game
   - (✓) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments: I don't have a source of heat to do the floating leaf disk lab. (Limited lab supply)

2. Which component(s) is most effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments: I will have to use with students before answering this question

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9th
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   (✓) Animation
   (✓) Board Game
   (✓) Leaf Stomata Lab
   (✓) Floating Leaf Disk Lab
   (✓) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   ( ) Animation
   (✓) Board Game
   (✓) Leaf Stomata Lab
   (✓) Floating Leaf Disk Lab
   (✓) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   (✓) Animation
   ( ) Board Game
   ( ) Leaf Stomata Lab
   ( ) Floating Leaf Disk Lab
   ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:__________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9th
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments: More graphics of electron (motions) movements

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - ( ) Animation
   - (X) Board Game
   - (X) Leaf Stomata Lab
   - (X) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - ( ) Animation
   - (X) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? [✓ Yes] No
    a. If yes, what grader? 9-12
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree 1	Disagree 2	Neutral 3	[✓ Agree 4]	Strongly Agree 5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree 1	Disagree 2	Neutral 3	[✓ Agree 4]	Strongly Agree 5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree 1	Disagree 2	Neutral 3	[✓ Agree 4]	Strongly Agree 5

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree 1	Disagree 2	Neutral 3	[✓ Agree 4]	Strongly Agree 5

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree 1	Disagree 2	Neutral 3	[✓ Agree 4]	Strongly Agree 5

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - (✓) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9th and A.P. Bio level (11th & 12th)
3. Do you have access to a DVD player or a projector to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments: very nice showing the equation for photosynthesis! (example of oxidation-reduction)) but explain that losing an electron makes something more (+) so its oxidized & gaining the e- makes it more (-) so it reduces

"LEO" goes "GER" to remember

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments: great animations - lots of fun ones for the students to watch.

Glad you used the correct terminology also

[but what is "hv" in the equation?]

3. The Electron Transport Chain is effectively introduced in the animation.

< System is used by higher level texts

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

1) too much of a jump from structure of chloroplast to ETS - so either show the organelle & review or have something for students to preview. 2) too much molecular detail in ETS with photo systems for freshman level

Again, too much detail for freshman level but great for Honors or AP level

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

For light reactions

Comments: don't say "loses" an electron use the word donates ["losing" means it's ~~[illegible]~~ gone & that gives the wrong idea to students?]

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments: help visualize the process - like the "happy" molecules, also review portions are great

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	[✓ 4]	5

Comments: once we played the game it was easy to follow - sort of intuitive & the rules were easy & simple - does need to be demonstrated.

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments: but again the actual details are too much for freshman level

Personally I wouldn't say "Cycle 1" & "Cycle 2". This just confuses the issue.

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments: just a lot of fun in general even without learning about Calvin Cycle

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments: don't see too strong a clear of a connection

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments: match levels of instruction – freshman regulars are much different than AP seniors!

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments: really neat to see something new in this area.

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - ( ) Board Game
   - (✓) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9th or 10th
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree
1	2	3	4	5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	[✓ Neutral	Agree	Strongly Agree
1	2	3]	4	5

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree	Strongly Agree
1	2	3	4]	5

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?

   (✓) Animation
   ( ) Board Game
   ( ) Leaf Stomata Lab
   ( ) Floating Leaf Disk Lab
   ( ) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?

   (✓) Animation
   ( ) Board Game
   ( ) Leaf Stomata Lab
   ( ) Floating Leaf Disk Lab
   ( ) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?

   ( ) Animation
   (✓) Board Game
   ( ) Leaf Stomata Lab
   ( ) Floating Leaf Disk Lab
   ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9th
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments: Very difficult for 9th grade - explained well (I would not go into it w/ my low level students)

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments: like the pics & how chem. symbols enlarge

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments: not clear that all chains had to be at a certain stage before you can move any to next stage

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (X) Animation
   - ( ) Board Game (too hard for some of my kids)
   - (X) Leaf Stomata Lab
   - (X) Floating Leaf Disk Lab
   - (X) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - (X) Floating Leaf Disk Lab
   - (X) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - (X) Board Game more detail than I go into w/ my kids
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9 & 10
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	4	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	4	5

Comments: CO_2 : O_2 graphics are too similar which might be confusing. ?? Both look like clouds

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	4	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	5

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	5

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	4	5

Comments: Not sure about floating leaf disks. I think students would get frustrated w/ vaccum part.

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	4	5

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	4	5

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	5

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (X) Animation
   - (X) Board Game
   - (X) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - (X) Animation
   - ( ) Board Game
   - (X) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - (X) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:__________

2. Do you currently teach Biology? Yes [✓ No] 7th Science
   a. If yes, what grader? __________

3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No

4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - (✓) Board Game
   - (✓) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - (✓) Animation
   - (✓) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:__________
2. Do you currently teach Biology? [✓ Yes] No
   a. If yes, what grader? 9
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments: very good for honors biology laminate cards to be sturdier - include extra carbons in case they break

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments: Depends on graphics but looks like it will

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments: depends on animation - looks like it will

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments: but don't use hw

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments: not sure about 1st play (to do 1-3 on back page)

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments: My honors kids would love to play but don't know if we would have time to play — I should would try to juggle syllabus to make time for.

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments: would like student answer sheets in WORD so they can be answered electronically or interactive PDF (Acrobat 9?)

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments: if on different levels - regular/honors

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - ( ) Board Game
   - (✓) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - (✓) Animation
   - (✓) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:
w/ honors if time to complete game
need to get idea of play time (1 hour?)

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:__________
2. Do you currently teach Biology? Yes [✓ No]
   a. If yes, what grader? __________
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments: Students can easily understand; a little fast; Can you put in a slide for chapters?

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments: [redacted] Review component was nice but need review quizzes.

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	[✓ 2]	3	4	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - ( ) Board Game (Not Sure)
   - (✓) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - (✓) Animation
   - ( ) Board Game
   - (✓) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - (✓) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:____________
2. Do you currently teach Biology? Yes [✓ No]
    a. If yes, what grader? ____________
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
4. Do you have access to light microscopes for student use? [✓ Yes] No

Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments: Need to explain that you draw both cards each turn

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - (✓) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - (✓) Animation
   - (✓) Board Game
   - (✓) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

I will use this for exit level TAKS review w/ my 11th + 12th graders

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

Time is a factor

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

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2. Do you currently teach Biology? Yes [✓ No]
    a. If yes, what grader? ____________
3. Do you have access to a DVD player or a project to play a DVD in your classroom? [✓ Yes] No
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Please circle the number that most closely corresponds with your attitude toward the statement. Space for additional comments are available after each statement.

1. The graphics for the animation and board game are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

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Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

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1	2	3	4	[✓ 5]

Comments:

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Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
(✓) Animation
( ) Board Game
(✓) Leaf Stomata Lab
(✓) Floating Leaf Disk Lab
( ) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
(✓) Animation
( ) Board Game
( ) Leaf Stomata Lab
(✓) Floating Leaf Disk Lab
( ) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
( ) Animation
(✓) Board Game
( ) Leaf Stomata Lab
( ) Floating Leaf Disk Lab
( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT

SURVEY

Photosynthesis:

A Science Suitcase for 9th and 10th Graders

Please circle the answer that best applies to you.

1. Are you a: [✓ Teacher] Administrator Other:________
2. Do you currently teach Biology? Yes [✓ No]
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Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

2. The animation clearly explains the basic concepts of photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

3. The Electron Transport Chain is effectively introduced in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

good job ☺

4. The basic concept of the Calvin Cycle is understood in the animation.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

5. The graphical symbols are beneficial for remembering the Photosynthetic Equation.

Strongly Disagree	Disagree	Neutral	Agree	[✓ Strongly Agree]
1	2	3	4	[✓ 5]

Comments:

6. The board game instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

7. The board game is effective in depicting the cyclical nature of the carbon chains in the Calvin Cycle.

Strongly Disagree	Disagree	[✓ Neutral]	Agree	Strongly Agree
1	2	[✓ 3]	4	5

Comments:

8. The use of competition will keep students involved and interested in the game.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

9. The similar graphics in the animation and board game increases understanding of the basic Calvin Cycle.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

10. The lab instructions are clear and easy to follow.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

11. The diagram illustrations are beneficial to the lab instructions.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

12. The lab experiments are beneficial in teaching students about photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

13. The components of the suitcase are appropriate for the high school audience.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	[✓ 3]	[✓ 4]	5

Comments:

Honors and AP students

14. The components of the suitcase will enhance my current curriculum for teaching photosynthesis.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

15. The components of the suitcase will help students with the TEKS and TAKS.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

16. I would recommend this Science Suitcase to other teachers.

Strongly Disagree	Disagree	Neutral	[✓ Agree]	Strongly Agree
1	2	3	[✓ 4]	5

Comments:

Please mark all that apply.

1. Which component(s) would you most likely use in your classroom?
   - (✓) Animation
   - (✓) Board Game
   - (✓) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

2. Which component(s) is most effective?
   - ( ) Animation
   - ( ) Board Game
   - (✓) Leaf Stomata Lab
   - (✓) Floating Leaf Disk Lab
   - (✓) Dark Reactions Lab

Comments:

3. Which component(s) is least effective?
   - ( ) Animation
   - ( ) Board Game
   - ( ) Leaf Stomata Lab
   - ( ) Floating Leaf Disk Lab
   - ( ) Dark Reactions Lab

Comments:

THANK YOU FOR YOUR INPUT