Grades 2-3

Plant Power: Let's GrOw!

Instructor: Katie Beidler

Overarching Goal of Course: To explore photosynthesis from the molecule level up to the ecosystem level

Week 1: How plants make food (the building blocks of photosynthesis)

<u>Learning Objectives:</u>

- Explain the process of how plants produce their own food through photosynthesis
- Model the inputs and outputs of the photosynthesis reaction using Legos
- Illustrate the relationship between carbon dioxide and the sugars produced during photosynthesis

<u>Instructor Content:</u>

- All organic compounds needed for plant and animal growth (proteins, lipids, starches, sugars) are derived from the products of photosynthesis.
- Photosynthesis is the process by which plants transform water and carbon dioxide (a gas that is plentiful in the air) into carbohydrates (sugars and starches), using the energy of sunlight.
- Knowledge of the photosynthesis reaction
    - $6\ CO_2 + 6\ H_2O$ + Light energy $\rightarrow C_6H_{12}O_6$ (sugar) $+ 6\ O_2$
        - A chemical equation is a way to represent a chemical reaction using element symbols. Reactions occur when two or more molecules interact, and the molecules change. Chemical equations have two sides: the reactant side and the product side.
        - An element is a pure substance that has only one kind of atom in it. Atoms are the smallest units of matter and can be alone or together with other atoms. Examples of elements are – oxygen, iron and gold.
        - A molecule is a combination of atoms that are bonded together. The word comes from a Latin word meaning "little lump."

<u>Materials:</u>

- Handouts:
    - Plant Observation Journal.pdf
    - Building Blocks of Photosynthesis.pdf
    - Making Glucose Card.pdf
    - Glucose Layout Card.pdf
    - Photosynthesis Reaction Mat.pdf
    - Lego Photosynthesis Teacher Guide.pdf
- Blank paper, crayons, pens, markers
- Paper clips, black construction paper (two paper clips and one sheet of construction paper per student)
- Graham cracker boxes (one per table)
- Goldfish cracker containers (one per table)
- Coleus plants (one per student + one extra for every pair of students)
- Legos (for one pair of students)
    - 24—1 x 2 white bricks
    - 48—2 x 4 bricks
        - 36 red
        - 12 black

Week 1 Lesson Plan

Safety Precautions: None

9:15-9:30 AM
Activity as Students enter the room: Students will be given a coleus plant and a plant observation journal to record their plant observations from week to week. To keep track of their plant, students will be asked to write their name on a popsicle stick which will then be placed in the pot with the plant [Note: plants will need to be watered bi-weekly and kept in a sunny indoor location]. Students will be asked to make their first observation which includes a sketch of their plant and a brief description of how it looks (e.g., how many leaves does it have, what color are the leaves etc.).

9:30-10:00 AM
Engage (30 min): Students will be seated in groups of four. The table or desks students are sitting at should have boxes of snack crackers either Goldfish or Graham crackers. Instructor will begin with an icebreaker, go around the room and ask students to say their name and favorite snack food. Students, while working in pairs, will then be asked to investigate the common ingredients and nutrition facts for the different snack. Students will then be asked to write some of these ingredients on the white boards found around the room. As a class, we will discuss these ingredients in terms of the building blocks of nutrition required for humans and other animals to survive e.g., sugars (carbohydrates), oils (fats), proteins and vitamins. Students, in small groups of four, will then be asked to discuss things that plants need to survive. Instructor will use the following questions to begin the discussion:

- Do plants eat dirt?
- What do plants need to grow?
- Are the things plants need to grow, the same as what an animal needs to grow?

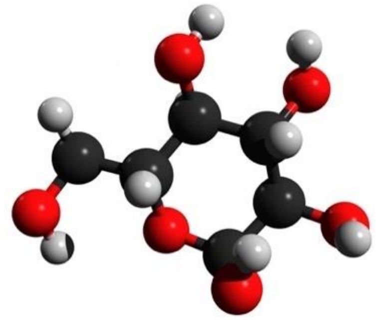
End the discussion by writing the list of what a plant needs to grow: water, carbon dioxide, and sunlight on the board. Show the following NOVA video to formally introduce the students to the process of photosynthesis: https://indiana.pbslearningmedia.org/resource/tdc02.sci.life.stru.photosynth/photosynthesis/

10:30-11:00 AM
Explore (30 min): In this Lego-based modeling exercise, students will learn how plants use CO_2 and H_2O to build glucose molecules ($C_6H_{12}O_6$). In this exercise, students will use different colored Legos to represent the elements involved in photosynthesis and illustrate how they are broken down and reassembled to create glucose. To get students familiar with the different elements involved in photosynthesis, the instructor will ask each student to hold up a carbon Lego (black 2 x 4 brick), in addition to a hydrogen (white 1 x 2 brick) and oxygen Lego (red 2 x 4 brick).

The instructor will write the chemical formulas for the following molecules on the board: CO_2, H_2O, $C_6H_{12}O_6$. Under each of the formulas, the instructor will ask students to write how many carbon (C), oxygen (O) and hydrogen (H) bricks they will need to make the Lego versions of the molecules. The instructor will then ask students to make a carbon dioxide (CO_2) molecule and are to hold it up once they are finished. Students will also make oxygen (O_2) and water (H_2O) molecules. After students are familiar with building the different Lego molecules, the instructor will write the reaction equation for photosynthesis on the board.

- $6\ CO_2 + 6\ H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6$ (sugar) + $6\ O_2$

In addition to writing the equation, students will be shown the following illustration of a glucose molecule (which has a ring-like structure):



Tell the students that for the remainder of the exercise they will be doing what plants do, making sugars using materials from the air around them and the sun for energy to make food for themselves. Students will work in pairs to assemble glucose molecules that we will then link together as a class to form starch and cellulose polysaccharides. Each pair of students will need copies of the following handouts: Building Blocks of Photosynthesis, Making Glucose Card, Glucose Layout Card and Photosynthesis Reaction Mat. Students should work independently and raise their hand when they need help.

11:00-11:30 AM
Snack Break: During snack break, students will illustrate photosynthesis on a white sheet of paper. Next, students will use the chemical equation that they just learned about and their own illustrations of what it would look like and will share them with the class.

11:30 AM -12:00 PM
Explain (10 min): To start the lesson, instructor will show the following TedEd video on photosynthesis:

- https://ed.ted.com/lessons/the-simple-but-fascinating-story-of-photosynthesis-and-food-amanda-ooten

After the video, instructor will explain that photosynthesis happens inside of leaves in structures called chloroplasts. Students will be asked what happens to a leaf when it is kept in the dark?

Elaborate (20 min): To elaborate on the connection between light energy and the products of photosynthesis (sugars), students will perform an experiment investigating what happens to the starches or sugars in their Coleus plant when the leaves don't have access to sunlight. This experiment will be completed during week two, but leaves need to be left in the dark for at least a week for the experiment to work. Students will be asked to cover one of the leaves of their plant with black construction paper. To avoid unnecessary damage to the leaf, students will cut a rectangular piece of black construction that can be folded to make a sort of envelope that the leaf will then be placed inside of. Students will use two small paper clips to clip the edges of the construction paper on either side of the leaf where it is attached to the stem. The plants should be kept near a window where they get plenty of sunlight for the next week. Students will make predictions about the class coleus experiment in their plant observation journals. In the last five minutes of class, students will be asked to make a prediction about the leaf that will be in the dark and the leaf that will be in the light. Also, they will predict which leaf will contain the most sugars after one week?

Week 2: Investigating photosynthesis at the leaf level (plant pigments)

Learning Objectives:

- Understand that leaves contain different pigments much like the colored markers and pencils we use in class.
- Learn the importance of chlorophyll in photosynthesis and the other pigments that are present, but not visible until leaves fall in the autumn.
- Illustrate the relationship between light and photosynthesis (i.e., with more light → there are more sugars in leaves due to increased rates of photosynthesis)
- Make a model of glucose using candy.

Instructor Content:

- Chloroplasts are the food producers of the cell and that these cellular structures are abundant in leaves. Chloroplasts work to convert light energy of the sun into sugars that can be used by cells. The entire process is called photosynthesis and it all depends on the chlorophyll pigment molecules in each chloroplast.
- Pigments are "molecules that absorb specific wavelengths (energies) of light and reflect all others." Pigments are colored: the color we see is the net effect of all the light reflecting back at us. From a biological standpoint, pigments are the natural coloring matter of plant or animal tissue. Historically, pigments derived from plants were used to color dyes and paints. Today, commercially produced paints and art supplies contain inorganic pigments made through chemical reactions such as oxidation. However, traditional plant-based dyes are still being produced on the IU Bloomington campus: https://soaad.indiana.edu/news/2018/2018-08-03-herald-times-online-rowland.html
- While chlorophyll is the primary pigment involved in photosynthesis, plants contain other pigments including carotenes (red, orange and yellow colored pigments) and anthocyanins (purple colored pigments). Plants look green because they contain more chlorophyll than the other accessory pigments listed above. In the fall during leaf senescence, plants recover the nutrients contained in leaves before they are shed. During this process known as leaf resorption, chlorophyll pigment molecules are broken down and recycled. Once the green chlorophyll pigments are gone, the other leaf pigments (the orange, yellow and red pigments) are now visible, hence the color of autumn leaves.
- Paper chromatography is a useful technique in the separation and identification of different plant pigments. In this technique, the mixture containing the pigments to be separated is first applied as a spot or a line to the paper about 1.5 cm from the bottom edge of the paper. The paper is then placed in a container with the tip of the paper touching the solvent. Solvent is absorbed by the paper and moves up the paper by capillary action. As the solvent crosses the area containing plant pigment extract, the pigments dissolve in and move with the solvent. The solvent carries the dissolved pigments as it moves up the paper. The pigments are carried along at different rates because they are not equally soluble. Therefore, the less soluble pigments will move slower up the paper than the more soluble pigments. This is known as developing a chromatogram.

Materials

- Handouts:
  - Tree Template.pdf
  - Photosynthesis Relay Race.pdf
  - Lollicule Template.pdf

- Paper, crayons, pens, markers, scissors
- Green construction cut into the shape of a leaf (one sheet per four students)
- Envelopes (two envelopes per four students)
- Flashlights (one per four students)

- Spinach Leaves (1 large package bought the night before and kept in the fridge until use)
- Hot plates (4)
- 50 mL Falcon Tubes with caps (1 per student). Prep falcon tubes on racks by adding 5mL of ethanol to each of the tubes.
- Pennies (1 per student)
- Beakers (four 250mL and six 600 mL)
- Petri Dishes (1 per student)
- 95% Ethanol (500 ml)
- Lugol's Iodine Solution (~20 mL in a bottle with dropper)
- Chemex square filters (1 per 10 students) coffee filters also work, but will need to be pressed flat)
- Hand lenses (1 per student)
- Rulers (1 per student)
- One bag of mini-marshmallows, black jellybeans or liquorice segments and red gummy candy or red hots (enough for every student to get 12 marshmallows, 6 black and 6 red candies)
- One box of toothpicks
- Gloves (1 pair per student)

Week 2 Lesson Plan

Safety Precautions: Boiling ethanol is dangerous and hot plates should be placed in the back of the room out of the way. Only the instructor should be allowed near the hot plates and should transfer the boiled leaves to petri dishes full of water before the students are allowed to view the leaves. Additionally, students will wear gloves while placing filter paper in the Falcon tubes.

9:15-9:30 AM
Activity as Student's enter the room: Students will be asked to make their second plant observation which includes a sketch of their plant and a brief description of how it looks (e.g., how many leaves does it have, what color are the leaves, etc.). Students will then be asked to think about the color of the coleus leaves and how they differ from other plants they have seen.

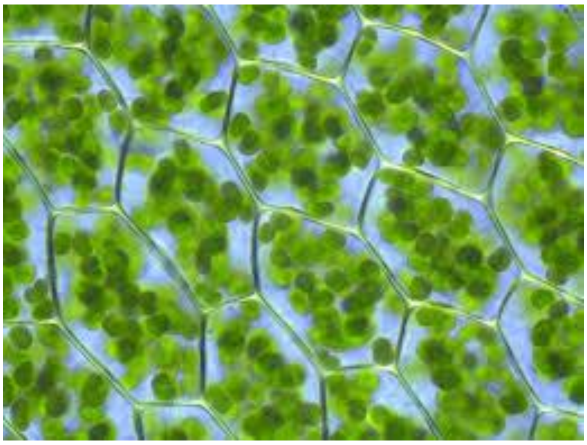
9:30-9:50 AM
Engage: Students will discover chlorophyll, a key ingredient in photosynthesis. In a simple activity, students will color with chlorophyll pigments. Instructor will use the following questions to begin the activity:

- Have you ever gotten grass stains on your clothes?
- Why does grass stain clothes?
- Why are plants green?

Students will be given 8-10 spinach leaves and will be asked to add leaves to make a chlorophyll rubbing or to press the leaves onto the paper to fill in the different tree templets using the green chlorophyll pigments. If students finish quickly, ask them to color in the branches of the tree with a brown colored pencil and to outline the shapes of leaves using a green colored pencil. After student's have finished filling in the tree template, the instructor will show the following Amoeba Sisters video to formally introduce chlorophyll pigments and chloroplasts: (note: this video includes some complex topics, but focus on the pigment discussion as week 4 will cover cellular respiration)

- https://www.youtube.com/watch?v=uixA8ZXx0KU

9:50-10:10 AM
Explore: Students will use hand lenses to observe the leaves of their coleus plant and to see if they can find the chlorophyll molecules. In order to see chloroplasts and the chlorophyll molecules that leaves contain, a microscope will be needed. To show students, instructor will use the microscope image on the next page. The instructor will point out the round structures in the squarish shaped plant cells- these are the chloroplasts. The chloroplasts look green because they contain chlorophyll molecules.



To explore plant pigments, students will carry a chromatography experiment to separate the pigments in both coleus and spinach leaves. Pairs of students will be asked to prepare two chromatography strips. Strips should be 1/8 of an inch (2cm) wide and 5 inches (13cm) long to fit inside of the falcon tubes (Pre-cut filter strips to the correct dimensions). The top of the strip can be folded over the side of the tube and secured in place by loosely putting the cap on (this will keep the strip in place and also help stop the ethanol from evaporating). The bottom of the strip will be covered in ethanol so that the ethanol absorbed by the paper will move up the paper by capillary action, taking the leaf pigments with it. After the spinach and coleus leaves are crushed onto filter paper, the pigments will be allowed to separate in 95% ethanol over the course of 20 minutes (during the snack break). Pre-label the tops of centrifuge tubes with a S (for spinach) or C (for coleus) as to not confuse the chromatography strips.

Plant Pigment Chromatography Experiment
Each student will be given a strip of filter paper and asked to draw a line in pencil (do not use ink, it will bleed in the ethanol and make it difficult to see the plant pigments). The pencil line should be half an inch (1.5cm) from the bottom edge of the filter paper. Ask students to write their initials on the very top of the filter paper. One student per pair will be asked to make a spinach rubbing on the line by rolling the edge of a penny over a spinach leaf, they should try to make the rubbing as thin as possible (try not to go below the line). Students should go over the line a couple times with the leaf to try to get as dark of an impression as possible. At the same time, the student's partner should do the same procedure with a coleus leaf (students might be hesitant to clip one of the leaves but tell them that new leaves will grow in a few days). Ask students to make predictions about which leaves contain green chlorophyll pigments and which leaves contain orange and yellow colored carotene pigments. Have them write their predictions on the board while the leaf rubbings on the filter paper dries. After the chromatography sheets (filter paper + leaf pigments) have been prepared, carefully place them in the correct tube and once the paper is in place, rest the lid on the top of the tube.

10:10- 10:40 AM snack break
During the snack break, show the following Magic School Bus episode to reinforce what the students have already learned about photosynthesis. https://www.dailymotion.com/video/x6vejxv

**During the break, the instructor should place 100 mL of ethanol into a 250mL beaker and place the 250mL beaker into a 600mL beaker half full of water. The 600mL beaker should then be placed on a hot plate. Ten minutes before the break is over, the hot plates should be turned on so that the ethanol can come to a boil over the course of the next 20 minutes. You will need one hot plate set up for the "light" coleus leaves and one for the "dark" coleus leaves. The experimental set-up can be viewed in the following video: https://www.youtube.com/watch?v=Z-ot7W7mkPU

10:40- 10:50 AM
Evaluate: Students will be asked to retrieve their chromatography paper and place it on a paper towel to dry. Once the paper is dry, ask the students to draw what the paper looks like in their plant observation journals. There should be chlorophyll pigments present in both the spinach and coleus leaves, even though the coleus leaf is purple. There should also be yellowish carotene pigments visible in the spinach leaf chromatogram.

10:50-11:20 AM

Elaborate: To elaborate on the connection between sunlight and plant sugars made during week one's photosynthesis lesson, students will complete their experiment testing for sugars (starch) in coleus leaves exposed to light vs coleus leaves kept in the dark under black construction paper. Students will use Lugol's solution to detect starches (comprised of sugars) in the different coleus leaves. The darker the leaf, the more starch can be detected. Before the Lugol's solution can be applied, the instructor needs to clear the purple and green pigments from the coleus leaves using boiling ethanol. Upon clearing, the leaves that had access to sunlight should turn a dark brown/ black color when the Lugol's solution is added. See following video protocol: https://www.youtube.com/watch?v=Z-ot7W7mkPU

Coleus Sugar Detection Experiment

The instructor should ask students to clip off the coleus leaf covered by the construction paper, as well as, an adjacent leaf that was exposed to sunlight (once again students might hesitate but reassure them that the leaves will grow back!). The instructor will carry the leaves to their respective hot plate stations (one for light leaves and one for dark leaves). While students are preparing leaves, the instructor will lay out paper towels on a back table and place open petri dishes on the paper towel so that the top and bottom of a petri dish are next to each other. Enough water will be added to coat the bottom of each petri dish. The instructor can either label the paper towel next to the petri dish with the leaf type (light vs. dark) or put the light leaf on the right and the dark leaf on the left. Students will then guess which was in the light / dark by how dark the leaf turns following the addition of the Lugol's solution.

Once leaves are placed in ethanol, they should turn white as chlorophyll pigments are soluble in ethanol (the ethanol in the beaker will turn a bright green color- more evidence that coleus leaves contain chlorophyll pigments). Using forceps, the white leaves should be carefully removed and placed into petri dishes to re-hydrate. Th should try to lay the leaves as flat as possible. Remember to set up the hot plates in the back of the room, as boiling ethanol is a potential hazard. Once the leaves have been removed from the ethanol, the hot plates can be turned off and the beakers of ethanol should be left to cool.

Students will gather around the table containing the petri dishes. The instructor will then add 5-10 drops of the iodine solution to each dish (enough to coat the leaf). Ask students which leaf is darker? Reveal that the darker leaf was the one that had access to the sunlight, because the leaf was able to use the energy from the sun to undergo photosynthesis and make sugars. Ask the students why the ethanol in the beaker is green? It is green because it contains chlorophyll pigments, the pigments that capture the sun's energy and eventually convert that energy into sugars.

11:30-11:50 AM

Evaluate: To reinforce the Lego modeling activity done in week one, students will build glucose or sugar molecules out of candy using the lollicule template handout. The black candies represent carbon atoms, the red candies represent oxygen atoms, and the marshmallows represent hydrogen atoms. The candy atoms should be held together using toothpicks in a glucose ring formation. Students will be able to build the glucose molecule using the template and what they learned last week. Instructor will explain that the toothpicks holding the candy atoms together represent chemical bonds which store energy. Students can eat their glucose molecule when they are done by breaking the bonds and absorbing the energy contained in the sugars!

11:50AM -12:00 PM

Photosynthesis Relay Race

**This lesson was developed by Ellen McHenry https://ellenjmchenry.com/photosynthesis-relay-race-game/

To review the formula for photosynthesis and allow students to expend energy, students will participate in a photosynthesis themed relay race. The instructions and materials for the race are found in the photosynthesis relay race handout. Instructor will need to prep construction paper leaves with in and out envelopes and cut out resource cards ahead of time.

Week 3: Investigating Photosynthesis at the plant level (the role of leaves, stems and roots)

Learning Objectives:

- Learn the function of different plant parts involved in photosynthesis and plant growth/reproduction.
- Identify different plant parts found in the grocery store and in a greenhouse as part of a botany scavenger hunt.

Instructor Content:

- Each part of a plant has a specific function important for the process of photosynthesis. For example, roots grow downward into the ground to anchor the plant and absorb the water and nutrients required for plant growth.
- The leaves of a plant contain chlorophyll, a chemical that gives leaves their green color. In the process of photosynthesis, chlorophyll converts sunlight into sugar to create food for the plant. While leaves come in a variety of shapes and sizes, most are flat—a property that helps maximize the surface area exposed to sunlight. Depending on what habitat a plant lives in, leaves might take on a different shape (for example the leaves of tropical plants vs succulent leaves from desert habitats).
- Stems serve as the pathway between roots and leaves. They are essentially tubes that pass liquids up and down to different parts of the plant. Stems are made of special cells that act as pipes. These pipes have a dual function: to bring down food produced by the leaves (through the phloem cells) and to bring up water and essential nutrients from the roots (through the xylem cells). In addition, stems hold the plant up and provide support, letting the leaves reach sunlight
- Some plants produce flowers that contain reproductive organs for the plant. When the flowers are pollinated, eggs inside the flower are fertilized and develop into seeds. Part of the flower then develops into a fruit that holds the new seeds.

Materials

- Handouts:
  - Plant Part Labels.pdf
  - Greenhouse Scavenger Hunt.pdf
- Paper, crayons, pens, markers
- 1 qt (32 oz) Ball Jars (one per pair of students)
- Tin foil (one roll)
- Miracle grow water soluble plant food (1/4 tsp per ball jar)
- Enough water to fill the ball jars up to the rim
- Cotton balls (one bag)
- Wooden dowels (one per group of four students)
- Stickers (12 per student)
- Clipboards (one per student)
- Common plant items found at the supermarket: broccoli, celery, spinach, carrots, sunflower seeds, popcorn, loose tea, beets, onions, herbs, oranges and grapes

Week 3 Lesson Plan

Safety Precautions: This week students will visit a greenhouse and will need to be chaperoned by at least one instructor per group of four students. Students will need to follow traffic safety rules while walking to the Jordan Hall Greenhouse.

9:15-9:30AM

Activity as Students enter the room: Students will be asked to make their third plant observation which includes a sketch of their plant and a brief description of how it looks (e.g., how many leaves does it have, are there new leaves growing back etc.) In addition to their coleus plants, there should be a coleus display plant with its roots exposed. These hydroponic plant jars should be prepared ahead of time. To prepare root jars, the instructor should wash the soil from the roots of the extra coleus plants. To prepare the jars, add 1/4th teaspoon of miracle grow plant food and 30 oz of water to each jar, then cover the jar with a layer of tinfoil. Poke a hole in the tinfoil and pass the roots of the coleus plant through the hole. Cotton balls can be placed around the stem to fill up the hole opening and keep the stem upright.

9:30-10:00 AM

Engage: To get students thinking about different plant parts and their function, the instructor will show the following video: https://www.youtube.com/watch?v=p3St51F4kE8

Supermarket Botany Exercise

The instructor will remind students that supermarket foods like carrots, asparagus, lettuce, oranges, and peanuts are actually edible roots, stems, leaves, fruits, flowers, or seeds. In the following supermarket botany activity, students will be asked to identify everyday foods as plant parts. The instructor will stimulate discussion with the following:

- "If you take a look around the produce section at a supermarket, you will find a wide variety of plants and plant structures. Lots of foods we eat every day—such as fruits, vegetables, and nuts—come from plants. In fact, we eat many different parts of plants such as roots, stems, leaves, fruits, and seeds. When we eat and digest plants, our bodies use the energy and nutrients that are stored in the plant cells. Carrots and sweet potatoes are thickened roots that we eat. Spinach and lettuce are examples of leaves that we eat. Asparagus, rhubarb, and potatoes are stems that we eat. Broccoli heads are actually flower buds that we eat. Interestingly, many foods that we call vegetables—like tomatoes, cucumbers, and peppers—are actually fruits because they contain seeds. In fact, the foods that we call fruits and vegetables are categorized somewhat arbitrarily: the term "vegetable" is merely a culinary term with no real scientific definition."

Prior to the start of the activity, instructor will need to place a variety of foods onto a table in the back of the room: broccoli, celery, spinach, carrots, sunflower seeds, popping corn, beets, onion, herbs, oranges and grapes. During the activity, students will be figuring out what part of the plant each item is from and moving that item to the correct location (a table with one of the following signs: roots, stems, leaves, fruit and seeds.

10:00-11:30 AM
Explore: Students will explore the different parts of plants by going on a botany scavenger hunt in the Jordan Hall Greenhouse. Students will be given a worksheet with various plant parts that they need to find. Instructor will check off their worksheet by adding a sticker to the box once they find the correct plant structure.

11:30AM-12:00 PM
Snack Break:
During the snack break, instructor will show the following Magic School bus episode to reinforce what the students learned about the different plant parts. https://www.dailymotion.com/video/x6o5sej

Week 4: Investigating links between photosynthesis and other cycles (transpiration & cellular respiration)

Learning Objectives:

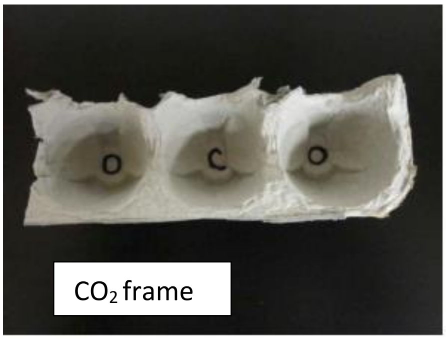
- Observe transpiration, the process by which a plant loses water through its stomatal pores.
- Investigate leaves up close to look for stomata, the structures responsible for gas and exchange and water loss.
- Understand that plants and animals can use that energy after breaking apart the sugar molecules through cellular respiration.
- Model the connection between molecules involved in photosynthesis and cellular respiration

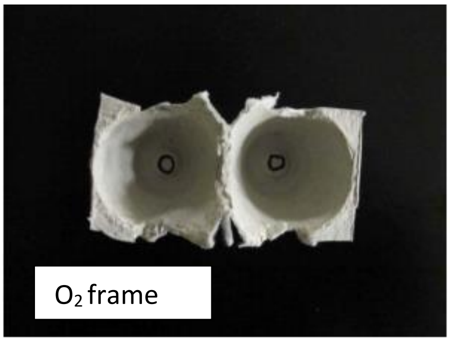
Instructor Content:

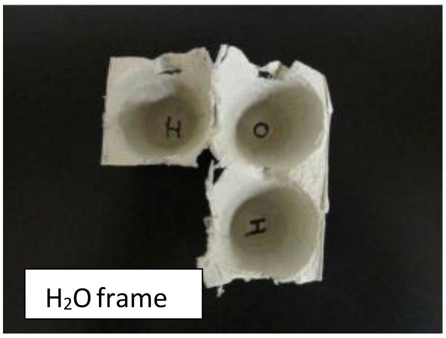
- Transpiration is the evaporation of water from plants. Most of the water absorbed by the roots of a plant, as much as 99.5%, is not used for growth or metabolism; it is excess water, and it leaves the plant through transpiration. Transpiration is very important for maintaining moisture conditions in the environment. As much as 10 percent of the moisture in the Earth's atmosphere is from transpiration of water by plants.
- Plants obtain the gases they need through their leaves. They require oxygen for respiration and carbon dioxide for photosynthesis. The gases diffuse into the intercellular spaces of the leaf through pores, known as stomata.
- Stoma (singular) or stomata (plural) are the pores on the surface of a leaf that modulates gas exchange between the plant and its environment.
- Many students believe that only animals carry out cellular respiration and plants only carry out photosynthesis; they do not understand that plants also need to carry out cellular respiration to provide ATP for cellular processes.
- All organisms, including plants and animals, break down simple sugars ($C_6H_{12}O_6$) into carbon dioxide (CO_2) and water (H_2O) to release energy. The cell uses the energy to build, repair, and reproduce cells in a process known as cellular respiration.
- Oxygen in the atmosphere is normally found in the form of O_2 (two oxygen atoms bonded together).

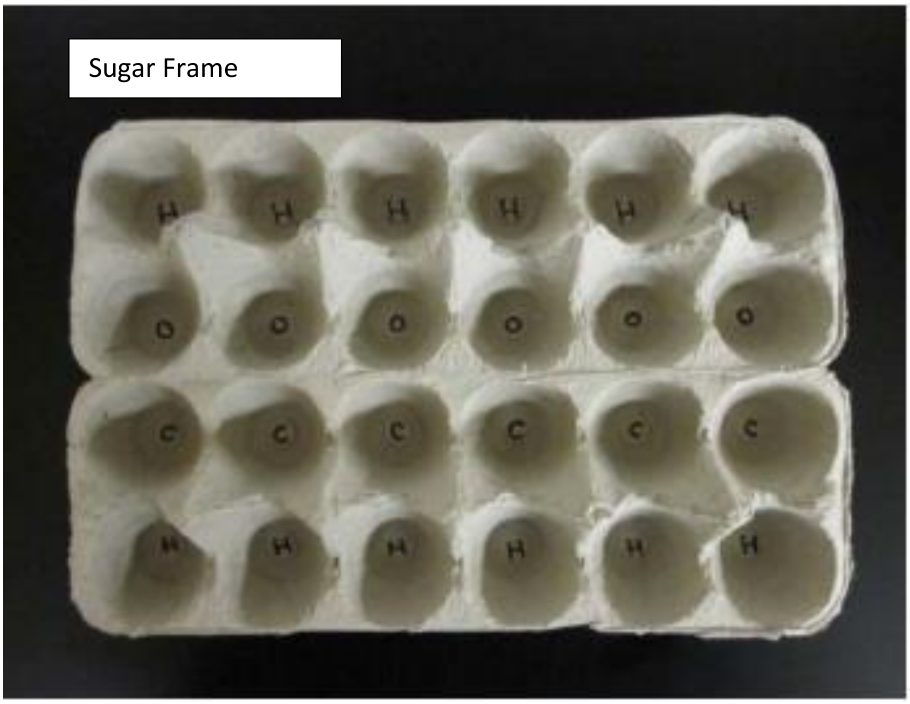
Materials

- Handouts
  - Photosynthesis and Respiration Instructions.pdf
- Paper, crayons, pens, markers and scissors
- Gallon Ziplock Bags (one per hydroponic plant jar)
- Masking tape
- Egg cartons (6 per group of four students)
  - To prepare the egg cartons for the modeling activity. Egg cartons will need to be cut apart into shapes (pictured below). These shapes will "frame" the molecules that students will assemble. Label the inside of each compartment to show what atom should be placed in it. Note that the shapes of the O_2,CO_2 and H_2O frames are roughly accurate; however, the shape of the sugar molecule is greatly simplified.
  - Each group needs 6 CO_2 frames
  - Each group needs 6 O_2 frames
  - Each group needs 6 H_2O frames
  - Each group needs one sugar frame









- Ping-pong balls (36 per group of four students)
  - These will represent carbon, hydrogen, and oxygen atoms. Use a sharpie to label the ping-pong balls. For each group of students, you will need 6 balls labeled “C”, 12 balls labeled “H”, and 18 balls labeled “O.”
- Plastic or paper energy tokens (24 per group of four students)
- Three signs, one that says “stomata”, one that says “stem”, and one that says “lungs”
- Small plastic tokens (48 per group)
- Microscope slides (one per student)
- Compound Microscopes with 10, 20 & 40x objectives (1 microscope per pair of students)
- Clear tape (one roll)
- Clear nail polish (one bottle per pair of students)
- Green leaves from a living plant (one leaf per pair of students)

Week 4 Lesson Plan

Safety Precautions: none

9:15-9:30 AM

Activity as Students enter the room: Students will be asked to make their fourth plant observation which includes a sketch of their plant and a brief description of how it looks (e.g., how many leaves does it have, what color are the leaves etc.).

9:30-9:50 AM

Engage: On each table there will be a coleus display plant with a plastic bag over top (the bag needs to be placed over the plant and sealed with layer of masking table at least four hours prior to the lesson). Students will be asked to think about why there is condensation or water on the inside of the bag and where this water could have come from.

Instructor will inform students that plants put down roots into the soil to draw water and nutrients up into the stems and leaves. Some of this water is returned to the air through holes in the leaves called stomata. Condensation forms, illustrating the process of transpiration, or the release of moisture to the atmosphere by plants. To review the water cycle and introduce the pores in plant leaves, instructor will show the following video: https://www.youtube.com/watch?v=ncORPosDrjI

9:50-10:30 AM

Explore: To explore how leaves take in gasses and expel water, students will go on a stomata hunt. Instructor will inform students that the pores in leaves that allow gas exchange are called stomata. To observe stomatal pores, students will be making stomatal impressions of leaf surfaces using nail polish and tape. These impressions can then be put onto slides and viewed with a compound microscope. Before starting the activity ask students to predict if there will be more stomata on the top or bottom of the leaf (usually there are more stomata on the underside or bottom of the leaf).

Looking Up and Down for Stomata

Students will be asked to work in pairs to prepare slides of stomatal impressions from the top and bottom of the same leaf. Each pair of students will prepare two slides, one slide with the impression of the top of the leaf and one with the bottom of the leaf. Students will need to label the slides with a sharpie with either a "T" or "B." Instructor will help students paint small swaths (about the size of a penny) of nail polish on the leaves. After the nail polish has dried, put a layer of tape over the nail polish (only clear tape will work). Students can then peel off the tape and stick it to a microscope slide. The slide will then be viewed under the microscope at 400x magnification. Students will count the number of stomata, in the field of view, for both slides. Students will also draw what they see from the microscope and label the things that can move in (CO_2) and out of the stomata (O_2 & H_2O).

10:30-11:00 AM

Modeling Photosynthesis

**This lesson plan was modified from the California Academy of Sciences
https://www.calacademy.org/educators/lesson-plans/modelling-photosynthesis-and-cellular-respiration

Instructor will explain that the classroom will represent a leaf, and that each table within the classroom will represent a cell within the leaf. Students will be working in groups of three or four to build a sugar molecule in their cell.

Prior to the activity Instructor will need to explain the materials and room layout:

- Each group will receive an empty sugar frame. Look at labels in the frame.
- Review what atom each letter represents. (C = carbon. H = hydrogen. O = oxygen.)
- Tell students the carbon atoms will be coming from carbon dioxide molecules (CO_2). Where is CO_2 found? (In the air.) How does CO_2 get into the leaf? (CO_2 in the air enters the leaf through the stomata.) Tell students that the classroom represents the leaf and the area outside the room represents the air surrounding the leaf. Open the door and place filled CO_2 molecules just outside.

- The hydrogen atoms will be coming from water molecules (H_2O). How does water get into the leaf? (It is drawn from the soil into the roots, up the stem, and into the leaf.) Place the filled H_2O molecules under the sign.
- Some of the oxygen atoms will come from CO_2 molecules and some from H_2O molecules.
- Show students the energy tokens. Explain that sugar molecules store energy. To represent this, students will have to pack an energy token under each atom in the sugar frame. Ask students where the leaves get this energy. (From sunlight.) Explain that plants convert energy from one form to another so that it can be stored in sugar molecules. Instructor will act like the sun and sprinkle the "light energy" tokens around the room.

Instructor will explain roles and rules:

- Students will have to work together within their groups to gather the things they need and put the sugar molecule together.
- Actions: Sugar molecules must be completed. As the materials are gathered, take atoms from the CO_2 and H_2O molecules and place them in the appropriate places in the sugar frame. Carbon dioxide molecules must be carried to the cell. Bring CO_2 molecules from the outside area to the table. Water must also be carried to the cell. Bring these molecules from the sink to the table. You have to get rid of empty frames. Students should then put frames back where they belong!
- Energy must be collected and converted into a usable form. Gather energy tokens from the table and pack an energy token under each atom in the sugar molecule. This represents the energy stored in the bonds within a sugar molecule.
- Atoms cannot be wasted. When you take apart a molecule, take all the atoms out of the frame. For example, you can't take the hydrogen out of the water frame and leave the oxygens in. Without the hydrogen, it's not a water molecule anymore.
- Leftover atoms go from the cell to the air. At the end of the activity, the only thing students should have on their table is the completed sugar molecules. Any leftover materials need to be taken out of the leaf and expelled into the air.
- Only fetch one thing at a time. You can split up the tasks, but still only one thing at a time!

11:00AM-11:30 AM

Snack Break: During the snack break, instructor will show the following Magic School bus episode to introduce topics that will be discussed next week (i.e., differences between producers, consumers and decomposers). https://www.dailymotion.com/video/x6vdozx

11:30-11:50 AM

Elaborate: Students will learn about how photosynthesis and cellular respiration are connected through an important relationship. This relationship is important because it enables life to survive as we know it. The products of one process are the reactants of the other. Before the snack break students-built sugar molecules by modeling the process of photosynthesis. Now students will break down sugar molecule to model the process of cellular respiration.

Modeling Respiration: Let's use some of the energy that they stored in their sugar molecules. Instructor will tell students that when cells break down sugar to access energy, they release CO_2 and water. However, there is a piece missing—they need to get something in addition to sugar to make this happen. Their task is to discover what that is and how to get it.

- Give groups empty CO_2 and H_2O frames. Tell them success is achieved when these molecules are complete and released into the air as byproducts. Give them time to break apart the sugar molecule, remove the energy tokens, and try to make the CO_2 and H_2O molecules. Leave the door (stomata) open and the oxygen atoms from earlier outside. Students will find that they need oxygen in order to complete the molecules and should figure out that they can get it from the "air" outside the leaf. The CO_2 and H_2O molecules should then be taken out of the stomata (released into the air.)

11:50AM -12:00 PM

Evaluate: Photosynthesis Relay Race (See Instructions from Week 2 on Page 7).

Week 5 Investigating Links Between Plant Life Cycles and Food Webs

Learning Objectives:

- Observe the different parts of flowers and learn their function in plant reproduction & seed production.
- Plant seeds and review what plants need to grow: soil nutrient, water and sun.
- Introduce the life cycle of a plant from a seed to fully-grown plant.
- Demonstrate that producers or plants are the base of food webs.
- Learn about different ways species can influence one another (e.g., connections between producers, consumers, decomposers and pollinators).

Instructor Content:

- A flower is the plant structure involved in reproduction. Flowers are attractive and appear in different colours and shapes to attract pollinators who help in pollen transfer.
- Producers are living organisms that make their own food and photosynthesis is the process by which producers obtain their energy from the sun and make food with that energy.
- Decomposers are the soil bacterium, fungus & invertebrates that decomposes organic material.
- Consumers are living organisms that cannot make food and have to consume producers.
- Producers, consumers and decomposers are linked to each other and their environment by the transfer and transformation of matter and energy which originates with the sun.

Materials

- Handouts:
    - Plant Life Cycle Handout.pdf
    - Tropical Food Web Id Cards.pdf
    - Tropical Food Web Script.pdf
- Paper, crayons, pens, markers and scissors
- Flowers in the Lily family (one stem per student)
- Small glass jars (one per pair of students)
- Pea seeds (soaked for 24 hours, two seeds per student)
- Small terracotta pots (one per student).
- Potting soil (two small bags)
- Newspaper and containers for the potting soil
- Watering can
- Ball of string
- Bamboo skewers (one per group of four students)
- Hand lenses (one per pair of students)
- Dissecting microscopes (4-40x; one microscope per pair of students)
- Small binder clips (one per student)

Week 4 Lesson Plan
Safety Precautions: none

9:15-9:30AM
Activity as Students enter the room: Students will be asked to make their final plant observations in their journals. In addition to coleus plants, instructor will put out jars of flowers on each of the tables. Casablanca Lilies and Alstroemerias (both are types of lilies) are easy to find in grocery stores and contain male and female plant parts. Student's will be asked to sketch the flower in addition to their coleus plants.

9:30-10:00 AM
Engage/ Explore: To engage the students in the day's lesson, they will be allowed to dissect a flower to explore the different parts of the flower and how they function in plant reproduction. Before dissection, instructor will show the following video: https://www.youtube.com/watch?v=djPVgip_bdU

Students will work independently to dissect flowers and discover the different structures. To aid in their observation, students will be given hand lenses, forceps and each table will have a stereoscope or dissecting microscope to help the students observe pollen. Following their observations, students will be asked about how plants reproduce and will brainstorm stages of the plant life cycle on the white board.

10:00-10:30 AM
Elaborate (20 min): Students will prepare pots and plant seeds to grow a pea plant. Students will fill pots two thirds of the way full of soil and then make a small hole with a bamboo skewer for each seed. Instructor will follow the guidelines on the back of the seed packet. The soil will need to be fairly wet to encourage germination.

Evaluate (10 min): Students will be asked to make a plant life cycle flipbook by cutting out the flash cards from the plant life cycle handout and putting them in the correct sequence. Once the cards are in the correct order, students will get their cards checked by the instructor and will be given a binder clip to make the cards into a flipbook. Once students finish their flipbooks and get them checked by the instructor, they can plant their own seeds!

10:30-11:00 AM
Snack Break: During the snack break, instructor will show the following Magic School Bus episode to introduce tropical ecology and the tropical food web that the students will be acting out.
https://www.dailymotion.com/video/x6o5wng

11:00-11:30 AM
**This activity was developed by Kathryn Gregory https://www.teacher.org/lesson-plan/food-chain-tag/
If the weather is nice, instructor may want to take students outside for the last two activities.
Explore: To explore the different roles of organisms in ecosystems, students will play food chain tag and act out a food web. Before building the food web, students will be asked to think about the different types of organisms that depend on plants (highlighting pollinators from earlier). Instructor can facilitate discussion by asking the following questions:

- Have you ever seen a wild rabbit in Bloomington?
- What do they think they eat? (plants)
- Do the rabbits have to be afraid of anything? Predators?
  - Students may answer foxes, mountain lions, birds. If students don't suggest it, suggest the Hawk.

The instructor should then draw a pyramid on the board that has 3 sections.

- In the bottom, biggest part of the pyramid, write producers. In the middle level of the pyramid, write primary consumers. In the top level of the pyramid, write secondary consumers.
- Ask students where they think the rabbit fits into this pyramid. The rabbit is a primary consumer and an herbivore because it eats only plants. Ask students where the food that rabbits eat should be. Plants go on the bottom level because they are producers.
- Ask students which animals belong in the top level. Hawks and foxes are carnivores and belong there along with other animals that eat plant eaters. Explain that the sun is also important because it gives energy to the producers (plants). You may wish to explain that there are also tertiary consumers that eat both omnivores and carnivores, like mountain lions that may eat the rabbits or the foxes.

Food Web Tag
Students will now play a tag-like game in which they will play the roles of hawks, rabbits, plants and sun.

- Instructor will assign about ½ the class to be plants. Plants keep their arms to their sides and try to avoid being "eaten" (tagged) by the rabbits.

    - If "eaten" by a rabbit, a plant converts to rabbit.
- The instructor should assign about ¼ of the class to be rabbits. They should put their hands to their heads like bunny ears and try to "eat" (tag) the plants and avoid being "eaten" by the hawks.
    - If "eaten" by a hawk, a rabbit converts to a hawk.
- The instructor should assign about ¼ of the class to be hawks. They run around waving their arms like wings and try to "eat" (tag) the rabbits and avoid being tagged by the sun.
    - If tagged by the sun, the hawks convert to plants.
- The instructor should assign one student to be the sun. The sun can tag the hawks and convert them back into plants. The sun does not have to have a hand motion, but all students should know who they are.
    - Explain that the sun is the most powerful of all. In this game, students will pretend that there is no water, and without water, animals will die of dehydration. After a long process, dead, decomposed animals eventually return to the soil and nourish plants. And the sun gives energy to these plants.

As a review:

- Hawks wave their arms like wings and hunt the rabbits and avoid the sun.
    - When tagged by the sun, turns into a plant.
- Rabbits make bunny ears on their heads, hunt the plants and avoid the hawks.
    - When tagged by a hawk, turns into a hawk.
- Plants keep their hands to their sides and avoid the rabbits and don't hunt anything.
    - When tagged by a rabbit, turns into a rabbit.
- The sun can only tag the Hawk, converting them to a plant.
    - The sun has no predators.

Rainforest food web activity

**This activity was developed by Kris Kelly http://smartsyandartsy.blogspot.com/2012/05/rainforest-cafe-field-trip.html

To model the connections among different types of organisms in a rainforest, students will build a tropical food web. To begin students will randomly pick an ID placard from a bowl. Students will be asked if their organism is a producer or consumer. Consumers will group together, and producers will group together. Now ask the students to mix themselves up and stand in a circle. The instructor will read the rainforest script and as each organism the ball of string will be unrolled the students will have to hold onto it. After the script is done the result will look like a spider web. Instructor will then talk about how all the animals and plants in the rainforest are connected, and depend on each other, and must remain in balance- not too many nor too few of any species. Then choose one animal or plant (student who is holding the string) and have him or her give 2 gentle tugs on the string. anyone who felt that tug, gives 2 short tugs, anyone who felt that tug gives 2 short tugs until the whole web has been affected. Then instructor will talk again about balance and how all that live in the ecosystem influence the others.