

# BUILDING LEAVES AND AN UNDERSTANDING OF PHOTOSYNTHESIS



by *Patty Littlejohn*

Through the years, the most difficult concepts for my students to grasp have been photosynthesis and cellular respiration. Photosynthesis is a little easier for them to understand because they start learning about it in elementary school. Cellular respiration, on the other hand, is completely unfamiliar and raises many questions. Where does it take place? How does a plant make food and in turn use the food to produce its own energy? Do animals carry on this process also? Isn't the respiratory system for breathing? Is this another name for the respiratory system?

To help students answer these and other questions, I decided to have them build a model leaf, plant cell, and animal cell (see photo above). This hands-on project allows students to see and manipulate the reactants and products of photosynthesis and cellular respiration. The materials are inexpensive (about \$40), easy to assemble, and reusable. They can be rolled up and stored in a cardboard tube and kept in your stockroom.

## *Making the most of the models*

When using these models, it is important to explain that they are simplified representations of actual objects. These particular models are conceptual models and physical models. They do not function as actual leaves or cells. Students manipulate the models to better understand the processes of photosynthesis and cellular respiration. The models demonstrate that the products of one process (photosynthesis) are the reactants of the second process (cellular respiration). The models also help students realize that

leaves and cells are three-dimensional structures. Figure 1 provides instructions for building the three models.

Once the models are completed, I lay them out in a hallway or other open space. I begin by having students determine which of the models represents the leaf. Then we peel back the epidermis (a layer of green sheeting) to reveal the chloroplasts. Next, we turn the leaf over to examine the stomata. Students will note that some of the stomata are open and some are closed. They are familiar with stomata from their microscopic examinations of lettuce and spinach and understand their role in regulating what enters and leaves the leaf. I reinforce the role of stomata by having students pass carbon dioxide molecules (poster board circles) through the stomata.

Next, I have students examine the vein (plastic tubing) that runs down the center of the leaf, delivering water to the leaf from the roots of the plant. The water (more poster board circles) inside the leaf is released from the vein through osmosis. This initial examination demonstrates that the reactants of photosynthesis—water, chlorophyll, and carbon dioxide—are available within the leaf.

We then turn the leaf back over to see where the process of photosynthesis takes place. Sunlight shining on the leaf triggers a chemical reaction among the carbon dioxide, water, and chlorophyll. The carbon dioxide (which enters the leaf through the stomata) and water (which enters through the vein) are represented by poster board circles within the model, but the chlorophyll is just assumed to be present within the chloroplast. The sun shines through the leaf hitting the chloroplast, water is present from the vein

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of the leaf, and carbon dioxide has entered through the stomata. The interaction of the sunlight, chlorophyll, water, and carbon dioxide produces oxygen ( $O_2$ ) and glucose ( $C_6H_{12}O_6$ ), which are represented by poster board circles. The oxygen passes out of the leaf through the stomata and the glucose is stored within the leaf.

When the students are working with the large leaf, we are manipulating the reactants and products of photosynthesis. From the large leaf we move to the giant plant and animal cell models to show how the products are used by each type of cell. I follow up by having students explain the process in their own words while manipulating the parts of the model.

Next, I place the plant and animal cell models on the floor beside the leaf. Students are asked to describe the differences between the two cells. The only organelles visible in the two cells are the nucleus, chloroplast (in the plant cell), and the mitochondria. We talk about the cell membrane (represented by the transparent vinyl layer) surrounding all cells that allows movement of materials into and out of the cell. The gaps in the stitching along the edge of leaf and animal cells allow for materials to be transferred in and out of the models.

Once photosynthesis has produced oxygen and glucose, two different things happen. The plant cell uses some of the glucose it produced in photosynthesis to carry on its normal activities. So, from the large leaf we move to the giant plant cell that contains mitochondria. Inside the mitochondria some of the oxygen and glucose just produced will be broken down for energy, and carbon dioxide will be released back into the air. If the cell produced more than it needs, the plant will store the excess glucose. When an animal consumes the plant, the glucose will diffuse through the cells of the animal along with oxygen that has been obtained through breathing. The mitochondria in the animal cell will break down the glucose and combine it with the oxygen to produce energy. Carbon dioxide will be released from the cells and will be picked up by the blood stream and taken to the lungs where it will be released back into the air. Water is also a product and will be used by the cell.

The students will use the circles representing carbon dioxide, oxygen, water, energy, and glucose to show these processes. The students will take the giant plant cell, put glucose and oxygen circles on one side of mitochondria, and show carbon dioxide, water, and energy on the other side. It is like our digestive tract. We take in many different foods, and the digestive process causes reactions that release a new set of materials.

The next step is to review the process of photosynthesis to demonstrate how the plant cell acts like a tiny factory that generates oxygen and glucose. The excess oxygen is



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Students working with the model plant cell.

released, and the excess glucose is stored in the cell and can be transferred to an animal that consumes the leaf.

We then focus on the muscle cell to show how glucose enters into the cell along with oxygen through the blood stream. Mitochondria in the cell use the reactants to release energy, water, and carbon dioxide. Next, we explore how carbon dioxide is diffused back into the blood stream, carried to the lungs, and released through respiration.

### Addressing the standards

In the middle school years students should start recognizing patterns and developing understanding about cells in living things. These students need to understand that cells carry on many functions in order to sustain life. Photosynthesis and cellular respiration are two processes that make it possible for plants and animals to continue transferring energy to all living organisms. Content Standard C of the National Science Education Standards denotes the importance of these concepts to a middle school student's understanding of life processes. *Benchmarks for Science Literacy* states that middle school students should know that matter is transferred from one organism to another repeatedly and between organisms. The process described above demonstrates this understanding and strongly supports the concept that almost all food energy comes originally from the Sun.

### Assessments

At the middle level, students should only be expected to recognize the reactants and products of photosynthesis and cellular respiration. I use several assessments to test student understanding when teaching with these models. For the first assessment, I print out each of the reactants and products of photosynthesis and equation symbols (Figure 2a) on separate sheets of paper. I then distribute the sheets to students and ask them to line up at the front

**FIGURE 1** Instructions for building a leaf, animal cell, and plant cell**Elements and compounds (for use with plant and animal cell models)****Materials**

- poster board, five different colors
- scissors
- marker

**Procedure**

1. Cut out 30 circles with a diameter of 10 cm of four different colors (white, yellow, light blue, and dark blue) of poster board.
2. Write *oxygen* on one side of the white circles and  $O_2$  on the reverse side. On the yellow circles write *carbon dioxide* on one side and  $CO_2$  on the other. On the light blue circles write *glucose* on one side and  $C_6H_{12}O_6$  on the other. On the dark blue circles write *water* on one side and  $H_2O$  on the other.
3. From the red poster board, cut diamond shapes 13.5 cm long to represent energy. Write *ATP* on one side and *energy* on the other. Middle school students do not study ATP, but hopefully they will remember the connection to energy when studying these processes in high school.

**Giant leaf****Materials**

- 1 green twin-size blanket
- 1 green twin-size sheet
- 2 sheets (approximately 2 × 2 m) of clear heavy-weight vinyl (shower curtain liners work well)
- 3 yards 1/4-inch plastic tubing
- permanent green marker
- craft glue

**Procedure**

1. Layer the four fabrics on top of one another as follows:  
Bottom layer: vinyl  
Second layer: blanket  
Third layer: vinyl  
Top layer: sheet
2. Use the marker to trace a leaf on one of the layers of vinyl. The leaf should be at about 2 m wide from tip to tip.

3. Use heavy-duty shears to cut out the leaf shape from the vinyl, then use it as a cutting template for the other layers.
4. Before relayering your leaf, use the marker to draw pairs of guard cells on the bottom layer of vinyl to create open and closed stomata about 24 cm long and 14 cm wide. The open stomata should resemble a pair of open lips and the closed stomata should resemble a pair of closed lips. Cover the vinyl with as many stomata as possible.
5. Draw capsule-shaped chloroplasts, each about 26 × 13 cm, on the other layer of vinyl. Again, fill the layer of vinyl with as many chloroplasts as possible. Tip: You can draw the stomata and chloroplasts on a sheet of paper, which can then be placed under the sheets of vinyl and traced.
6. Relayer the fabrics and sew them together along their outer edge. Your home economics teacher may be able to help.
7. Cut a window the size of a pillowcase in the center of the sheet to create a flap that students can raise up to view the chloroplasts.
8. On the stomata layer of vinyl, create a pore by cutting out the vinyl between the two guard cells that form each open stomata. This opening allows for the exchange of gases.
9. Thread plastic tubing between stitches down the center of the leaf between the blanket and stomata layers of the leaf. A hole needs to be cut in the sheet of vinyl to insert the tubing in one end. The tubing only needs to be glued in place at one end. It will extend 60 cm out the other end of the leaf. The tubing runs right down the middle of the leaf and continues out the end. The tubing represents the vein of the leaf.

**Plant cell****Materials**

- 2 square yards green cotton fabric
- 1 square yard gray felt
- 1 felt square (23 × 30 cm), any color
- 2 square yards clear heavyweight vinyl
- marker
- craft glue

**Procedure**

1. Use a 1.5 × 0.75 m piece of green cotton fabric as the background of the plant cell. I made the plant cell rectangular with rounded edges.
2. Cut five capsule-shaped mitochondria out of the gray felt, each approximately 34 cm long and 17 cm wide, and glue them to the green fabric background.
3. Cut a large circle out of any color of felt to represent the nucleus and glue it anywhere on the green background.
4. Cut the vinyl to fit the exact size and shape of the green cotton fabric.
5. Use a marker to trace capsule-shaped chloroplasts, each approximately 26 cm long and 13 cm wide, along the outer edge of the vinyl.
6. Sew the vinyl to the green felt, but do not create a continuous seal around the edge. Leave gaps in the stitching large enough to insert the circles representing the elements and compounds to model the semipermeability of the cell. Molecules of glucose, oxygen, water, and carbon dioxide move through these openings.

**Animal cell****Materials**

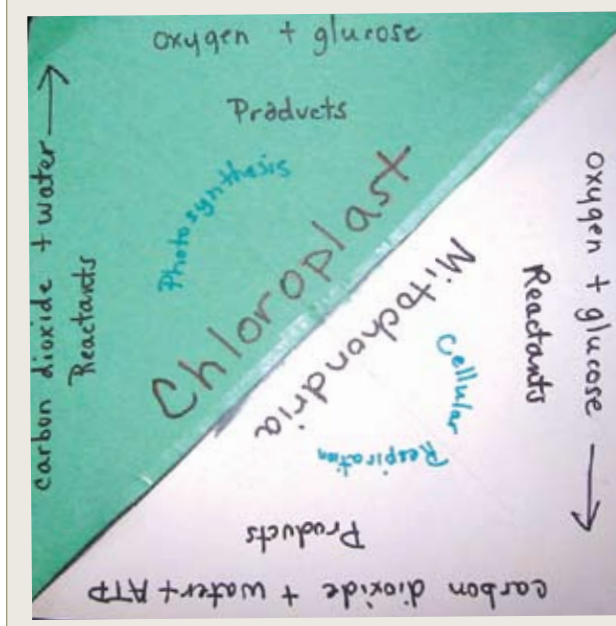
- 2 square yards pink felt
- 1 yard gray felt
- 1 felt square any color
- 2 yards clear heavyweight vinyl
- marker
- craft glue

**Procedure**

1. Use the pink felt as the background for the 1.75 × 0.45 m striated muscle cell.
2. Cut seven capsule-shaped mitochondria out of the gray felt and glue them to the pink background.
3. Cut a large circle 18 cm in diameter out of any color of felt to represent the nucleus and glue it anywhere in the cell on the pink felt background.
4. As with the plant cell, sew the vinyl to the pink background, and leave gaps in the stitching large enough to allow the model molecules of glucose, oxygen, and carbon dioxide to pass through.

**FIGURE 2 Card labels for equation activity**

- A. carbon dioxide, yields, water, chlorophyll, oxygen, sunlight, glucose, chloroplast, +, +
- B. carbon dioxide, yields, water, mitochondria, oxygen, ATP, glucose, cellular respiration, +, +, +

**FIGURE 3 Photo of P/CR square**

of the room to create the proper equation. I then distribute the reactants and products of cellular respiration (Figure 2b) to a second set of students and ask them to line up to create the proper equation. I have the two lines face each other so they can see the relationship between the two processes.

Another way I assess students is by asking them to create a foldable square that connects photosynthesis and cellular respiration (Figure 3). Students outline photosynthesis on a triangle of green paper and cellular respiration on a triangle of white paper. The two are then joined to form a square that creates a visual aid for understanding how the processes are related; specifically, that the reactants of one process are the products of the other process.

These models allow me to present a complex and abstract process to students in a concrete and hands-on way. Students really begin to understand photosynthesis and cellular respiration, which is documented by higher scores on the sections of our state test that focus on these concepts. ■