Photosynthesis and Cellular Respiration Role-Play

GRADE LEVELS 5th – 8th; California Content Standards for 5th
SUBJECTS Life Sciences
DURATION Preparation: 1 hour; Activity: 1 hour
SETTING Classroom

Objectives

In this lesson, students will learn:
1. that plants need carbon dioxide, water, and sunlight to carry out photosynthesis.
2. that photosynthesis produces sugar molecules that store energy.
3. that plants and animals can use that energy after breaking apart the sugar molecules through cellular respiration.
4. that plants exchange gasses through the stomata and land vertebrates exchange gasses through the lungs.

Materials

- egg cartons (6 per group)
- ping-pong balls (36 per group)
- “energy tokens” (24 per group)
- three signs, one that says “stomata”, one that says “stem”, and one that says “lungs”

Teacher Background

Photosynthesis is an essential process in plants. Through this process, energy from light is converted into a form that can be used by the plant. The energy is stored in sugar molecules. Animals (including humans) are not able to make this conversion, so we depend on plants to provide energy in a form that our bodies can use.

Plants take in water through the roots and carbon dioxide (CO₂) through the stomata. A pigment called chlorophyll, found in green parts of the plant such as leaves and green stems, captures energy from the sun. All three of these components—water, CO₂, and light—are required in order for photosynthesis to occur. Oxygen is produced as a waste product.

Cellular respiration is also an essential process, and takes place in all living things. Through this process, large molecules, such as the sugar molecules produced by photosynthesis, are broken down so that the energy stored within them can be used by the organism. Oxygen is required in order for this to occur, and CO₂ and water are produced as waste products.

Since both plants and animals do cellular respiration, they both need to take in oxygen from the air and release CO₂ and water into the air. In plants, this occurs through the stomata. In land vertebrates (like humans) this happens through the lungs. (Other animals have other methods, like gills, tracheoles, etc.)

In this activity, students will act out both processes (photosynthesis and cellular respiration), providing a tangible illustration of what components are needed for each process, as well as what
the waste products are. We recommend using the “Pondering Photosynthesis” and “Stomata Investigation” lessons first to prepare students for this activity.

Activity

**Preparation**

* Note that gathering and preparing these materials will be time-consuming the first time you do the activity, BUT all the materials can easily be stored and reused year after year.

1. Determine how many groups you will have. Each group will need 4 – 6 students. (If you are short on supplies, groups as large as 8 students could work.) You will need 36 ping-pong balls, 24 energy tokens, and 6 egg cartons for each group.
2. Prepare “energy tokens.” These should be small pieces of paper or cardstock (about 2 inches by 2 inches) with “L.E.” written on one side and the “C.E.” on the other side, as shown below:

   ![Energy Tokens](image1.jpg)

   (If you have access to a good double-sided printer, you can print the energy tokens included with this lesson plan instead of doing them by hand; however, depending on your printer’s alignment, it may not be possible to get the front and back to line up correctly.)

   Each group of students will need at least 24 energy tokens.
3. Prepare ping-pong balls. These will represent carbon, hydrogen, and oxygen atoms. Use a sharpie to label the ping-pong balls as shown below:

   ![Ping-Pong Balls](image2.jpg)
For each group of students, you will need 6 balls labeled “C”, 12 balls labeled “H”, and 18 balls labeled “O.”

4. Collect egg cartons. These will be used to structure the molecules that students will be constructing. Ask students to bring in egg cartons from home for several weeks before the activity to help collect enough. You will need 6 egg cartons for each group.

5. Prepare the egg cartons. You will need to cut the egg cartons apart into the shapes shown 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 O₂, CO₂ and H₂O frames are roughly accurate; however, the shape of the sugar molecule is greatly simplified.

Each group needs 6 CO₂ frames:

Oxygen in the atmosphere is normally found in the form of O₂ (two oxygen atoms bonded together). Each group needs 6 O₂ frames:
Each group needs 6 H₂O frames:

The sugar (glucose) produced by photosynthesis is made of 6 carbons, 12 hydrogens, and 6 oxygens. Each group needs one sugar frame:

**Part One: Photosynthesis**

**Introduction**
Ask students what plants need in order to do photosynthesis. Let them brainstorm ideas, then tell them they will discover the answer through this activity.

Set the stage:
- Explain that the classroom will represent a leaf. Hold up a leaf as an example. (If you can, use an edible leaf for this, such as lettuce or spinach.)
- Tell students that each table within the classroom will represent a cell within the leaf.
- Explain that the students will be working in groups to build a sugar molecule in their cell.
Photosynthesis and Cellular Respiration Role-Play

Explain the materials.

- First, review the difference between atoms and molecules. An atom is the smallest possible piece of a pure substance, like carbon or hydrogen. A molecule is made of two or more atoms bonded together. (If your students are not already familiar with this concept, spend a little time on it before starting the activity.)
- Give each group an empty sugar frame.
- Look at labels in the frame. Review what atom each letter represents. \( C = \text{carbon.} \ H = \text{hydrogen.} \ O = \text{oxygen.} \)
- Tell students the carbon atoms will be coming from carbon dioxide molecules \( (\text{CO}_2) \). \text{CO}_2 is a molecule found in the air. Ask students how \text{CO}_2 gets into the leaf. \text{(CO}_2 \text{in the air enters the leaf through the stomata.)}
- The hydrogen atoms will be coming from water molecules \( (\text{H}_2\text{O}) \). Ask students how water gets into the leaf. \text{(It is drawn from the soil into the roots, up the stem, and into the leaf.)}
- Some of the oxygen atoms will come from \text{CO}_2 molecules and some from \text{H}_2\text{O} 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. \text{(From sunlight.)}
- However, the energy in light is not in a form that can be used by a plant. Show students how to unfold the token from “light energy” \( (\text{L.E.}) \) and re-fold it as “chemical energy” \( (\text{C.E.}) \). Explain that plants convert energy from one form to another so that it can be stored in sugar molecules.

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. You may decide whether to assign a role to each student or to let the groups work out the process on their own.
- Actions:
  - Air must be carried to and from the cell. Ask students again how the air gets into the leaf. \text{(Through the stomata.)} Post a sign on the classroom door that says “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 \text{CO}_2 molecules and empty \text{O}_2 frames just outside. Students will bring the \text{CO}_2 molecules from the outside area to their table, and will take any leftover atoms or molecules from the table to the outside area.
  - Water must also be carried to the cell. Ask students again how water gets into the leaf. \text{(Through stems from roots, drawn from soil.)} Post a sign next to the classroom sink (if there is one; otherwise choose any location) that says “stem.” Place the \text{H}_2\text{O} molecules under the sign. Students will bring these molecules from the sink to the table.
  - Energy must be collected and converted into a usable form. Ask students again where the cell will be getting energy. \text{(From sunlight.)} The teacher will act as the sun and will sprinkle the energy tokens around the room. Students will gather energy tokens to the table and convert them from “light energy” into “chemical energy.”
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Converting energy tokens:

This token represents light energy.

To convert it, unfold it...

...turn it over...

...and refold. Now it represents chemical energy.

Summary of materials before photosynthesis:

The energy tokens (showing the “L.E.” side) should be scattered around the classroom.

The water molecules should be located below a sign reading “stem.”

The carbon dioxide molecules should be located outside of the door labeled “stomata.”

Empty oxygen frames should be located in the hallway, outside of the door labeled “stomata.”

Each group of students should have an empty sugar frame at their table.

Storing energy in the sugar molecule:

Pack an energy token under each atom of the sugar molecule by placing the token in the spot...

...and then placing the appropriate ping-pong ball atom on top of it. Repeat until the tray is full.
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❖ Making sugar:
  o As the materials are gathered, students must take atoms from the CO₂ and H₂O molecules and place them in the appropriate places in the sugar frame.
  o They must pack an energy token under each atom in the sugar molecule. This represents the energy stored in the bonds within a sugar molecule.

❖ Unused atoms:
  o Point out that when students take apart a molecule, they need to 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.
  o Tell students that at the end of the activity, the only thing they 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.

Procedure

Round one:
1. Once students are clear on what to do and where to find the materials, have them start building sugar molecules.
2. When each group has completed one sugar molecule, ask what was leftover? In other words, what waste product did the plant release? (Oxygen.)

Round two:
1. Take apart the sugar molecules and put all materials back in their original starting places.
2. Take away all the energy tokens. Tell the students the sun has gone down and no light is available. They must try to produce a sugar molecule without light, while still following all the rules. Do they think it’s possible?
3. Let them try. They will immediately realize they can’t do it without the energy tokens.
4. Reinforce the point: plants cannot do photosynthesis without light.

Round three:
1. Take apart the sugar molecules and put all materials back in their original starting places. Put the energy tokens back into play.
2. Close the door. Tell students the stomata have closed and no air is able to enter or exit the leaf. They must try to produce a sugar molecule with no air. Do they think it’s possible?
3. Let them try. They will quickly realize they can’t do it without the CO₂.
4. Ask students: why can’t plants do photosynthesis with the stomata closed? 
   (Because they need the carbon atoms from CO₂ molecules in the air.)

Round four:
1. Take apart the sugar molecules and put all materials back in their original starting places. Open the door.
2. Remove all the water molecules from the stem area. Tell students there is a
drought and there is no water for the plant to take up from the soil. They must try
to produce a sugar molecule without water. Do they think it’s possible?
3. Let them try. They will quickly realize they can’t do it without the H2O.
4. Ask students: why can’t plants photosynthesize without water? (Because they
need the hydrogen atoms from the H2O molecules.)

Round five:
1. Take apart the sugar molecules and put all materials back in their original starting
places. Put the water molecules back in the stem area.
2. This time let the activity run normally with all resources available. When
students have constructed their sugar molecules, have them keep it on their tables
for the next activity.
3. If desired, you can run this round as a race. Since students should now be familiar
and comfortable with the process, they can race to see which table can accurately
build a sugar molecule the fastest. The winners must have a complete sugar with
all the correct atoms, the correct number of energy tokens, and no waste atoms
leftover on the table.

Wrap-Up
❖ Ask students again: what do plants need in order to photosynthesize? They
should now be able to answer that air (specifically CO2), water, and sunlight are
all required for photosynthesis.

Part Two: Cellular Respiration

Introduction
❖ Tell students that they now need to use some of the energy that they stored in their
sugar molecules.
❖ This is a problem-solving task. Tell students that when cells break down sugar to
access energy, they release CO2 and water. (Give them empty CO2 and H2O
frames.) 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.

Procedure
Round one: plants
❖ Give them time to break apart the sugar molecule, remove the energy tokens, and
try to make the CO2 and H2O molecules. Leave the door (stomata) open and the
oxygen atoms from earlier outside.
❖ Students should find that they need oxygen in order to complete the molecules,
and should go get it from the “air” outside the leaf.
❖ The CO2 and H2O molecules should then be taken out the stomata (released into
the air.)
Round two: animals

❖ Reassemble the sugar molecules for this round and put all materials back in their starting places.
❖ Explain that animal cells need energy, and also get it by breaking apart sugar molecules. BUT animal cells can’t make their own sugars the way plant cells can. So where do animals get the sugar they need? *(By eating plants.)*
❖ Tell students that the leaf they are a part of is about to be swallowed by a hungry herbivore. *(If you used an edible leaf as a model earlier, pick up the leaf and eat it!)* Explain that the leaf is getting chewed up and digested. Then the sugar molecules that were contained within the leaf are passed to cells in the body.
❖ Take down the “stomata” sign and the “stem” sign. Tell students that the classroom now represents the teacher’s body. Each table is a cell within the teacher. The cells need to break apart the sugars to release energy so the teacher will have the energy to keep teaching. Just like in plants, the process will release CO₂ and water. What are they missing to make this happen? *(Oxygen.)* Where will the teacher get that oxygen? *(By breathing it in.)* Put a new sign over the door that says “lungs.”
❖ Now go through the respiration process again. This will be the very same process as it was for plants—the only difference is that oxygen enters through the lungs instead of the stomata. Students should bring oxygen in through the lungs (door) and release the CO₂ and H₂O produced in the process out through the lungs.

Wrap-Up

❖ If desired, discuss the terms *respiration* and *cellular respiration*. This can be confusing since they refer to different but related processes.
❖ The task students were doing at the tables—breaking apart sugar to release energy—is called *cellular respiration*. It’s a metabolic process—essentially a chemical reaction.
❖ The task of bringing O₂, CO₂, and H₂O molecules to and from the cell is called *respiration*. It’s not a chemical reaction, it’s simply the exchange of gasses (CO₂, H₂O, O₂, etc) between cells and the environment.
❖ The process of *cellular respiration* is exactly the same in plants and in animals.
❖ The process of *respiration* differs between plants and animals. In plants, gas is exchanged passively through the stomata. In land-dwelling vertebrates (like humans), gas is exchanged actively through the lungs. *(Other animals have other methods, like gills, tracheoles, etc.)*

Correlated California Content Standards

Grade Five

Life Sciences

2f. Students know plants use carbon dioxide (CO₂) and energy from sunlight to build molecules of sugar and release oxygen.
2g. Students know plant and animal cells break down sugar to obtain energy, a process resulting in carbon dioxide (CO₂) and water (respiration).