9 The Photosynthesis and Cellular Respiration Shuffle

INVESTIGATION • 1–2 CLASS SESSIONS

OVERVIEW

In this activity, students investigate photosynthesis and cellular respiration by organizing a series of images and statements and connecting this information to the carbon cycle. The activity includes an optional demonstration on making ginger ale to demonstrate fermentation, which will be referred to over the course of several activities.

KEY CONTENT

1. Photosynthesis is a cellular process through which organisms capture light energy from the sun and use it to generate and store energy.
2. Cellular respiration releases stored energy in glucose, allowing the organism to function.
3. Light is required for photosynthesis to occur, although parts of photosynthesis can happen in the absence of light.
4. Photosynthesis happens in the chloroplasts, which contain chlorophyll.
5. Only producers can perform photosynthesis.
6. Cellular respiration happens in the mitochondria and cytoplasm of cells.
7. Many organisms, including plants and plankton, perform oxygen-dependent cellular respiration.
8. Photosynthesis takes in light energy, carbon dioxide, and water, producing glucose and oxygen.
9. Cellular respiration takes in oxygen and glucose and produces carbon dioxide and water. Adenosine triphosphate (ATP) is also produced from cellular respiration.
10. The substances produced and consumed in photosynthesis and cellular respiration are complementary.

KEY PROCESS SKILLS

1. Students develop conclusions based on evidence.
2. Students make accurate interpretations, inferences, and conclusions from text.

MATERIALS AND ADVANCE PREPARATION

For the teacher

Transparency 9.1, "Kelp Forest Food Web"
Transparency 9.2, "Carbon Cycle"
Scoring Guide: UNDERSTANDING CONCEPTS (UC)
overhead markers*
2-liter plastic soda bottle with cap (optional)*
funnel, for food use only (optional)*
grater, for food use only (optional)*
1-cup measuring cup, for food use only (optional)*
¼-tsp measuring spoon, for food use only (optional)*
1-tbs measuring spoon, for food use only (optional)*
1 cup sugar (optional)*
1–2 tbs fresh ginger root (optional)*
1 lemon (optional)*
¼ tsp fresh granular baker's yeast (optional)*
cold water (optional)*

For each group of four students

set of 12 Photosynthesis & Cellular Respiration Shuffle paper strips

For each pair of students

computer with Internet access*

For each student

Student Sheet 9.1, "Photosynthesis and Cellular Respiration Diagram"
Group Interaction Student Sheet 2, "Developing Communication Skills" (optional)
Scoring Guide: UNDERSTANDING CONCEPTS (UC) (optional)

**Not supplied in kit*

If you plan to demonstrate making ginger ale, prepare the ingredients.

Masters for Scoring Guides are in Teacher Resources IV: Assessment.

Note: *Arrange for computers with Internet access for the day(s) students do this activity. Go to the* Science and Global Issues *page of the SEPUP website to access the simulation. You may want to bookmark this site for students. Make sure the browsers and supporting software are current and can properly run the simulation. If internet access is not available, Photosynthesis and Cellular Respiration cards are provided in the kit. Provide appropriate instructions for students, based on the simulation.*

TEACHING SUMMARY

Getting Started

- The class makes predictions about cellular respiration and photosynthesis.

Doing the Activity

- (UC ASSESSMENT) Students investigate and compare cellular respiration and photosynthesis

Follow-up

- (UC ASSESSMENT) Review the connections between the carbon cycle, photosynthesis, and cellular respiration.

BACKGROUND INFORMATION

In this unit, students learn about the most familiar type of cellular respiration, which is oxygen-dependent (aerobic) and occurs in many organisms such as macroscopic organisms, as well as microscopic plankton and other microbes. In general, cellular respiration is the metabolic process that releases stored chemical energy to make it available for cells to use. All organisms conduct some form of cellular respiration, but not all organisms require oxygen to do so. Many bacteria and archaea are lithotrophs, as opposed to organotrophs, meaning they rely on such inorganic materials as metal ions and sulfur as electron receptors for cellular respiration, instead of oxygen. Other organisms do not need the electron-transport chain; for example, yeast can obtain ATP strictly through fermentation without the electron-transport chain. Additionally, it is important to note that many organisms obtain oxygen without breathing. For example, many insects rely on diffusion to obtain intracellular oxygen.

Cellular respiration and photosynthesis have a direct link to ecosystem sustainability. Ecosystem collapse often begins with the removal of one or more species, which ultimately disturbs the balance between the carbon-containing compounds needed for cellular respiration and photosynthesis. As those two processes depend on each other, if the balance is disturbed long-term or permanently, the ecosystem is no longer sustainable. It is possible that another organism could fill the role of the species that was removed, but this often comes with a cascade of adverse side effects, such as happens with the invasive species that were studied in Activity 4, "Invasive Species."

GETTING STARTED

1 **Note:** Cellular respiration and photosynthesis are treated in more detail in the "Cell Biology: World Health" unit of this course.

Project Transparency 9.1, "Kelp Forest Food Web." Explain to students that this is a sample answer for the food webs they created in Activity 7, "Energy Flow Through an Ecosystem." Point out that this is one way to portray the food web, but not the only correct way. There are many possible versions, as they saw in Activity 7. Project Transparency 9.2, "Carbon Cycle." Have students identify where in the carbon cycle producers and consumers play a role.

2 After students read the introduction, ask them to predict where photosynthesis would occur in the kelp forest ecosystem, shown in Transparency 9.1, "Kelp Forest Food Web." As students offer answers, use an overhead marker to mark the organisms that perform photosynthesis (phytoplankton, giant kelp, acid kelp, and cyanobacteria). At this point students may not name all of these organisms. Because the class will revisit this diagram at the end of the activity, it is not necessary that they mark each organism or that you correct any incomplete or inaccurate answers. Then have students predict where in the kelp forest ecosystem cellular respiration would occur. Mark these organisms using a marker of another color.

Show students the video clip "Energy Flow in the Coral Reef Ecosystem," the link to which is on the *Science and Global Issues* page of the SEPUP website *(sepuplhs.org/sgi)*. Discuss how the energy flow in this ecosystem parallels that in the kelp forest ecosystem.

9 The Photosynthesis and Cellular Respiration Shuffle

1 IN THE PREVIOUS activity, "Moving Through the Carbon Cycle," you examined how carbon travels between reservoirs on earth. In this activity you will look more closely at how carbon and oxygen are continuously cycled by organisms and how these elements sustain both the organisms and ecosystems. You will examine what happens to carbon and oxygen at the cellular level.

Two fundamental cellular processes are cellular respiration and photosynthesis. **Cellular respiration** is the process by which cells release stored energy from sugars. **Photosynthesis** is the process in which producer cells use carbon dioxide, water, and nutrients to produce glucose and oxygen. Together these two processes make the carbon cycle possible, and move essential molecules through ecosystems.

All organisms in this community perform cellular respiration and some photosynthesize.

Challenge

2 ▶ How do carbon and oxygen cycle through the environment?

MATERIALS

FOR EACH GROUP OF FOUR STUDENTS
set of 12 Photosynthesis and Cellular Respiration Shuffle paper strips

FOR EACH PAIR OF STUDENTS
computer with Internet access

FOR EACH STUDENT
Student Sheet 9.1, "Photosynthesis and Cellular Respiration Diagram"

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3 Have students work on Student Sheet 9.1, "Photosynthesis and Cellular Respiration Diagram," in pencil, as they will be changing the diagram over the next few activities. Tell them to label the paths they think oxygen, glucose, carbon dioxide, and water take through the ecosystem. Students should make their best guess if they are unsure. Their diagrams will vary, and may not be accurate at this point. The purpose of the diagram is to allow them to revisit their ideas, learning, and misconceptions about photosynthesis and cellular respiration throughout this sequence of activities. This is a formative assessment opportunity for you to determine your students' current understanding of photosynthesis and cellular respiration. There will be opportunities to address errors and misconceptions later on in this unit.

If you intend to demonstrate fermentation (an optional component of this activity), set up a ginger ale mixture to ferment over the next several days. See the link on SEPUP's *Science and Global Issues* website *(sepuplhs.org/sgi)* for detailed instructions.

Procedure

3 1. Complete Student Sheet 9.1, "Photosynthesis and Cellular Respiration Diagram," as directed by your teacher.

4 2. Find the "Photosynthesis and Cellular Respiration Shuffle" animation on the *Science and Global Issues* page of the SEPUP website at *sepuplhs.org/sgi*. Sort the images based on what you already know about photosynthesis and cellular respiration, and on what you can see in the images.

3. When you have completed the animation, follow your teacher's instructions to record the results in your science notebook.

5 4. Obtain the Photosynthesis and Cellular Respiration Shuffle paper strips from your teacher.

5. With your group, lay all of the strips out on the table, and read each one aloud.

6. Sort the strips into two piles, one for cellular respiration and one for photosynthesis. If you are unsure about where any of the strips belong, lay them out next to where you will be working so that you can see them as you work.

7. Choose a stack to start with. Put the strips in the order in which you think the processes are happening.

8. Repeat Step 7 for the stack you have not ordered yet.

9. If you had any strips that you did not place, try to decide where they belong now that you have ordered the other strips.

10. Once you have all of the strips in order, compare your strips to the results from the animation, and make any adjustments in the order of the strips that you need to.

Note: There are more strips than animation images, and so more than one strip may fit with a single image.

6 11. Based on what you see in the animation and on the strips, write in your science notebook a short paragraph describing cellular respiration and one describing photosynthesis. Be sure you write in your own words, and do not just copy the strips.

DOING THE ACTIVITY

4 The simulation is on the *Science and Global Issues* website *(sepuplhs.org/sgi)*. As students work through the simulation, encourage them to look closely at the diagrams. In particular, they should note the directions of arrows, indicating if materials are entering or leaving an organism. In the photosynthesis diagrams, for example, water will be shown as entering an organism, while in cellular respiration it will be leaving the organism. This is a good opportunity for students to work on their communication skills by discussing with their partners the details of the diagrams and what they mean. You may wish to use Group Interaction Student Sheet 2, "Developing Communication Skills," which gives students suggestions for communicating well when in a group. Once they have completed the simulation students might print a screen shot so that they have a record for their student notebooks of the information from the simulation.

5 (UC ASSESSMENT) If students need assistance in ordering the paper strips, encourage them to look for clues within the statements. For example, any statement that contains the word "producers" would go in the photosynthesis stack. You also may want to tell the students that some of the steps essentially happen simultaneously, so their order is interchangeable. For example, "Sunlight hits the green parts . . ." and "Producer takes in carbon dioxide . . ." could be in reverse order and still be correct.

The correct orders for the strips are as follows:

Photosynthesis: K, G, J, D, B, I
(steps K and G can be reversed)

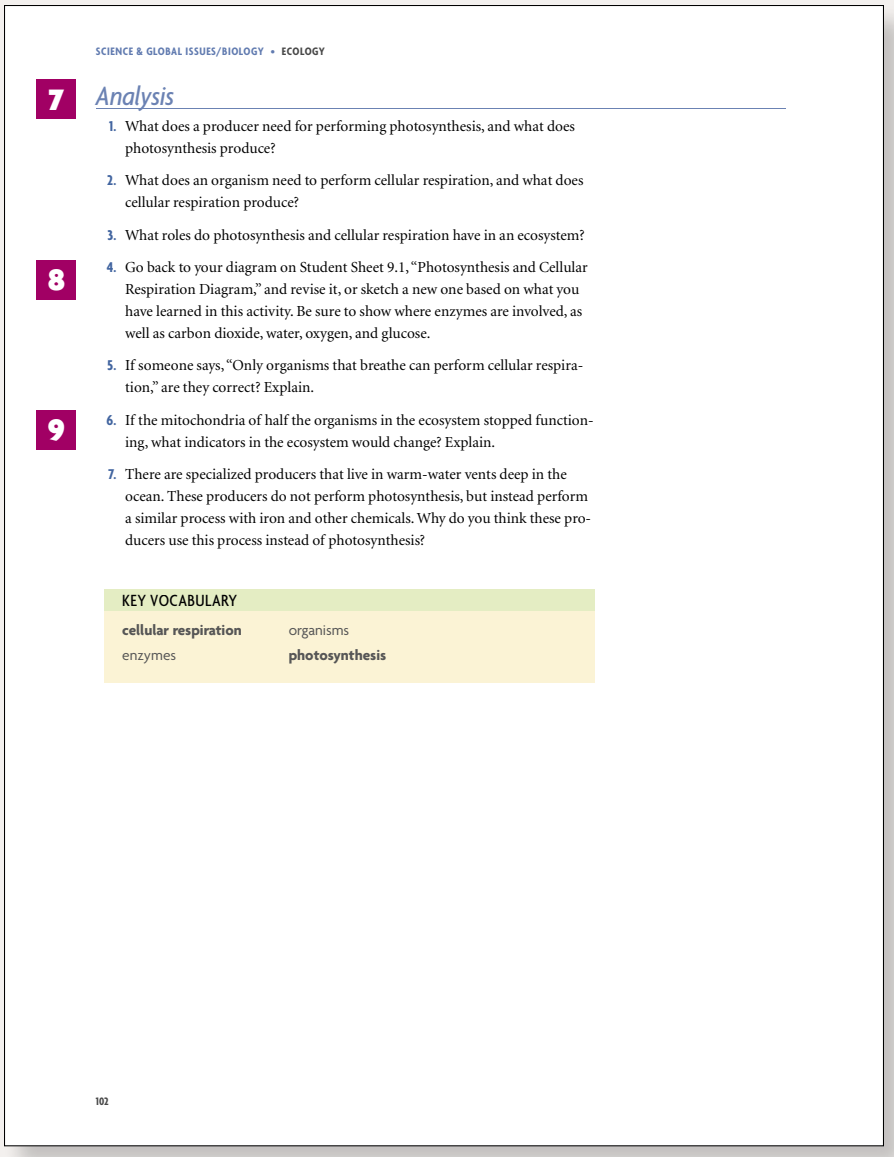
Cellular Respiration: E, A, F, C, L, H
(steps C, L, and H are interchangeable)

6 Students' written summaries should be brief—a short paragraph for each process. Encourage students to put the process into their own words as much as possible. Procedure Steps 5–11 are an opportunity for a UC ASSESSMENT using the UNDERSTANDING CONCEPTS Scoring Guide.

FOLLOW-UP

7 Using transparencies 9.1, "The Kelp Forest Food Web," and 9.2, "Carbon Cycle," review students' predictions from the beginning of the activity and correct or add to them as appropriate. Emphasize to the students that cellular respiration happens in the cells of many organisms in the presence of oxygen, including plants, phytoplankton, and bacteria, as well as animals. You may want to foreshadow the next activity by asking the students why they think organisms respire, and review the difference between breathing (taking oxygen into the body) and cellular respiration (the metabolic process for accessing energy for cells). Also, emphasize photosynthesis and cellular respiration's dependency on each other. If only cellular respiration occurred, all of earth's oxygen would eventually be used up.

8 (UC ASSESSMENT) Note that in Analysis Question 4 students revise their Photosynthesis and Cellular Respiration Diagrams. Ask students to volunteer to describe what kinds of changes they made on their diagrams, and what new information led them to correct any misconceptions they had at the beginning of the activity. Be sure to remind students that they will revisit these diagrams over the next several activities, and will add to them and further correct them as they work. Analysis Questions 3 and 6 are UC ASSESSMENT opportunities, asking students to connect cellular processes to overall ecosystem health.



SCIENCE & GLOBAL ISSUES/BIOLOGY • ECOLOGY

7 *Analysis*

1. What does a producer need for performing photosynthesis, and what does photosynthesis produce?
2. What does an organism need to perform cellular respiration, and what does cellular respiration produce?
3. What roles do photosynthesis and cellular respiration have in an ecosystem?
4. Go back to your diagram on Student Sheet 9.1, "Photosynthesis and Cellular Respiration Diagram," and revise it, or sketch a new one based on what you have learned in this activity. Be sure to show where enzymes are involved, as well as carbon dioxide, water, oxygen, and glucose. **8**
5. If someone says, "Only organisms that breathe can perform cellular respiration," are they correct? Explain.
6. If the mitochondria of half the organisms in the ecosystem stopped functioning, what indicators in the ecosystem would change? Explain. **9**
7. There are specialized producers that live in warm-water vents deep in the ocean. These producers do not perform photosynthesis, but instead perform a similar process with iron and other chemicals. Why do you think these producers use this process instead of photosynthesis?

KEY VOCABULARY

cellular respiration	organisms
enzymes	**photosynthesis**

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9 After students have completed the Analysis Questions, have a class discussion about Analysis Question 6. Depending on your students' responses, you may want to further clarify the connection between cellular processes and ecosystem health. Encourage students to discuss the same concept in terms of photosynthesis.

SAMPLE RESPONSES

1. Answers should contain the following information:

   A producer needs sunlight, carbon dioxide, and water. It also has to have chloroplasts with enzymes and chlorophyll. It produces oxygen and glucose.

   Students may also mention that producers need minerals or soil. It is important for students to understand that while plants and other producers may need minerals or soil to survive, these are not reactants in photosynthesis. **Note:** Phosphate is necessary for the formation of ATP from ADP (adenosine diphosphate), but this is not covered in detail in this activity.

2. An organism needs oxygen, glucose, and enzymes. They produce carbon dioxide, water, ATP, and heat.

3. (UC ASSESSMENT) Students' answers will vary. A correct and complete answer would include that photosynthesis and cellular respiration cycle oxygen, carbon dioxide, glucose, and water through the ecosystem. Photosynthesis and cellular respiration are also essential for the flow of energy in ecosystems.

   Sample Level-3 Response

   Photosynthesis and cellular respiration allow the carbon and oxygen that organisms consume and produce to be cycled through the ecosystem. They work together so that what is made from one process is used in the other. Without them the ecosystem would run out of carbon dioxide and oxygen, and everything would die.

4. Answers will vary. Their diagrams do not have to be entirely accurate at this point. Students will revise their diagrams as they complete additional activities in this unit.

5. The statement, "only organisms that breathe perform cellular respiration," is not correct. Oxygen has to get to the cells for cellular respiration to happen, but the oxygen can get there in many ways. Plants do not breathe, but they take in oxygen and perform cellular respiration.

6. (UC ASSESSMENT) Students' answers will vary. Students' choices of indicators will vary but may include a number of organisms in the ecosystem and the levels of oxygen and carbon dioxide. A correct and complete answer would explain that there would be a cascade of effects from the lack of cellular respiration. Students might suggest those organisms whose mitochondria stopped functioning would die due to the lack of cellular respiration.

   Sample Level-3 Response

   The mitochondria are where cellular respiration happens, so the organisms whose mitochondria stopped functioning would die right away. This would mean that the carbon dioxide levels would decrease, unless it was coming from another source. Eventually this would mean that there would only be half of the carbon dioxide needed for photosynthesis. Also, other organisms would die without the balance between cellular respiration and photosynthesis, unless they were able to get what they needed from neighboring ecosystems.

7. These producers would have to use something besides photosynthesis because there is no sunlight in the deep ocean.

REVISIT THE CHALLENGE

Students should understand that cellular respiration and photosynthesis cycle carbon through ecosystems. They should also know that the inputs and outputs of the two processes complement each other. The next several activities examine aspects of these processes, and the details of both are addressed in more depth in the "Cell Biology: World Health" unit of this course.