Teacher Guide: Cell Energy Cycle

Learning Objectives

Students will…

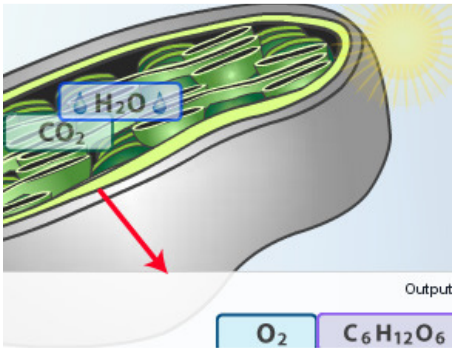
- Discover the reactants and products of the photosynthesis reaction.
- Balance the photosynthesis equation.
- Identify where in the cell photosynthesis occurs.
- Discover the reactants and products of cellular respiration.
- Balance the respiration equation.
- Describe the stages of cellular respiration.
- Compare the energy output of aerobic and anaerobic respiration.
- Explain how cellular respiration and photosynthesis are related.

Vocabulary

aerobic respiration, anaerobic respiration, ATP, cellular respiration, chlorophyll, chloroplast, cytoplasm, glucose, glycolysis, mitochondria, photosynthesis

Lesson Overview

All day long we breathe in and out, but why? Oxygen is a key reactant in cellular respiration, the chemical reactions that release energy from food. Without oxygen, we would not be able to produce enough energy to live. Cellular respiration and the complementary photosynthesis reaction are explored in the *Cell Energy Cycle* Gizmo.



The Student Exploration sheet contains three activities:

- Activity A – Students explore the process of photosynthesis.
- Activity B – Students explore the process of cellular respiration.
- Activity C – Students determine how photosynthesis is related to cellular respiration.

Suggested Lesson Sequence

1. **Pre-Gizmo activity** (10 – 15 minutes)
   Ask your students what animals and plants need to survive. What substances are found in the air we exhale, and how might these substances be useful to a plant? What substances produced by plants are helpful to the survival of animals? Could animals survive on Earth without plants? Could plants survive without animals?

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
   In many ways, cells can be compared to the structures and institutions that keep a city running. As students are working or just after they are done, discuss the following questions:
   - What two substances does a plant need for photosynthesis?
   - What are the products of photosynthesis?
   - What is the balanced equation for photosynthesis?
   - What two substances do animals and plants need for cellular respiration?
   - What are the two main stages of cellular respiration?
   - How does the energy produced by anaerobic respiration compare to the energy produced by aerobic respiration?
   - How is the equation for photosynthesis related to the equation for cellular respiration?

5. **Follow-up activity: Respiring yeast cells** (30 – 90 minutes)
   Yeasts are simple, unicellular fungi that are used to make bread and beer. When yeast undergoes aerobic respiration, they produce carbon dioxide gas. Bubbles of carbon dioxide in bread dough will cause the bread to expand as it is baked, giving it a fluffy texture. Yeast that undergoes anaerobic respiration will produce alcohol as a by-product.

   Several yeast experiments are described in the **Selected Web Resources** on page three of this document. Remember to follow all safety directions carefully.

   There are several other Gizmos that relate to the *Cell Energy Cycle* Gizmo. The *Photosynthesis Lab* Gizmo allows students to measure rates of photosynthesis, and *Plants and Snails* explores how photosynthesis and respiration are related. Links to these Gizmos can be found in the **Selected Web Resources**.

Scientific Background

Photosynthesis and cellular respiration are complementary processes. During photosynthesis, the energy of sunlight is used to combine carbon dioxide (CO_2) and water (H_2O) into glucose ($C_6H_{12}O_6$). Oxygen is released as a waste product of photosynthesis. The balanced chemical equation for photosynthesis is:

$$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$$

During respiration, organisms use oxygen to extract energy from the chemical bonds in glucose. The balanced chemical equation for cellular respiration is the reverse of the photosynthesis equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

The simple symmetry of these equations disguises the complexity of the processes involved. Cellular respiration, for example, takes place in three phases: *glycolysis*, the *Krebs cycle*, and the *electron-transport chain*.

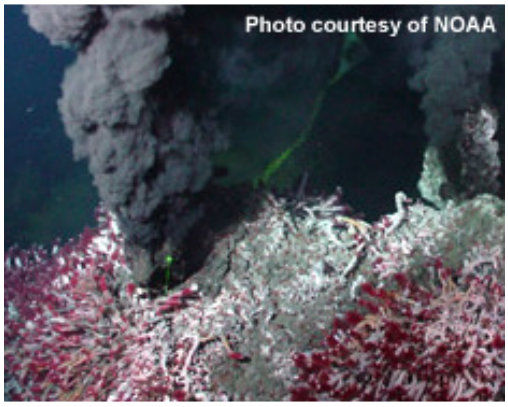
- Glycolysis occurs in the cytoplasm. A molecule of glucose ($C_6H_{12}O_6$) is broken down into two molecules of pyruvic acid ($C_3H_4O_3$) and two hydrogen ions (H^+). Glycolysis produces a net gain of two ATP molecules. (ATP, or adenosine triphosphate, is a molecule that is used as an energy source in cellular reactions.) No oxygen is required for glycolysis.

- The Krebs cycle (also called the *citrus acid cycle* or the *tricarboxylic acid cycle*) occurs in the mitochondria. The Krebs cycle is a series of eight enzyme-regulated reactions that break down pyruvic acid into carbon dioxide. The result is a variety of high-energy molecules: 6 NADH, 2 $FADH_2$, and 2 ATP.

- In the electron-transport chain (ETC), electrons from NADH and $FADH_2$ are transferred from one substance to another. In the process their energy is harvested to form ATP molecules. A total of 32 to 34 ATP molecules are formed in this process. At the end of the chain, the electrons combine with hydrogen ions and oxygen to form water molecules, which are released as a waste product along with the carbon dioxide.

Biology connection: Deep-sea vent communities

In 1977, a team of marine geologists was studying the sea floor near the 2,500-meter-deep Galapagos Rift zone. They weren't surprised to find plumes of hot water above the rift zone, an area where the ocean crust was splitting apart and new crust was forming from molten magma. What shocked the scientists were photographs of vigorous communities of tubeworms, crabs, snails, shrimp, and many other creatures living on the sea floor near the vents. How could these creatures thrive so far away from the energy of sunlight?



It turned out that the base of the food chain in these communities was a group of primitive bacteria, called *Archaea*, that obtain energy from the oxidation of hydrogen sulfides. This process, called *chemosynthesis*, produces enough biomass to support a strange and diverse community of organisms.

Selected Web Resources

Yeast respiration lab: http://serendip.brynmawr.edu/exchange/waldron/cellrespiration
Yeast lab: http://www.umsl.edu/~microbes/pdf/Swell%20Lab.pdf
Yeast fermentation: http://www.the-aps.org/education/k12curric/activities/pdfs/sullivan.pdf
Cellular respiration and fermentation: http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
Photosynthesis: http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookPS.html
Vent communities: http://en.wikipedia.org/wiki/Hydrothermal_vent

Related Gizmos:
Photosynthesis Lab: http://www.explorelearning.com/gizmo/id?395
Plants and Snails: http://www.explorelearning.com/gizmo/id?641