Connect and Collect: Photosynthesis in Minutes

MEASURE. ANALYZE. LEARN.™

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NSTA National 2019

St. Louis, MO

HANDS-ON ACTIVITIES

Photosynthesis and Cellular Respiration 2 ways

- Go Direct CO_2 Gas
- Go Direct SpectroVis Plus

Demo

Photosynthesis and Cellular Respiration

- Go Direct ODO

Photosynthesis and Respiration

(CO_2 Gas Sensor)

Plants make sugar, storing the energy of the sun into chemical energy, by the process of photosynthesis. When they require energy, they can tap the stored energy in sugar by a process called cellular respiration.

The process of photosynthesis involves the use of light energy to convert carbon dioxide and water into sugar, oxygen, and other organic compounds. This process is often summarized by the following reaction:

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

Cellular respiration refers to the process of converting the chemical energy of organic molecules into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:

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

All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP.

OBJECTIVES

- Use a CO_2 Gas Sensor to measure the amount of carbon dioxide gas consumed or produced by a plant during respiration and photosynthesis.
- Determine the rate of respiration and photosynthesis of a plant.

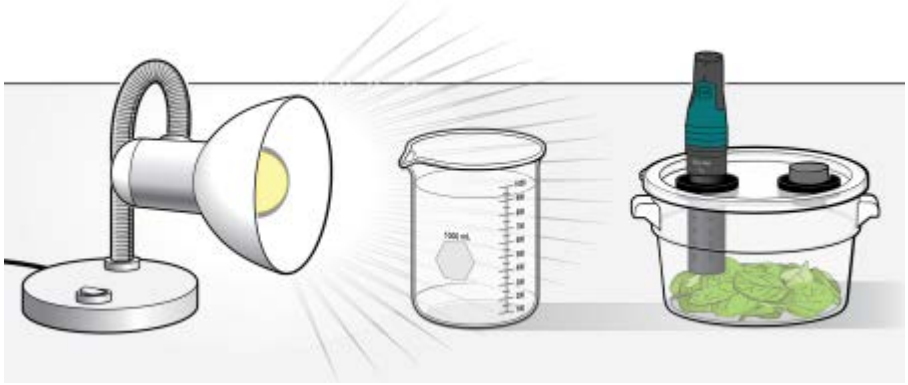

Figure 1

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct CO_2 Gas
BioChamber 2000
600 mL beaker
aluminum foil
lamp with bulb
#6 rubber stopper
spinach leaves
goggles

PROCEDURE

1. Wrap the BioChamber with aluminum foil so that no light will reach the leaves.
   a. Wrap the outside of the chamber with foil.
   b. Cover the lid with foil, poking the holes open to insert the sensor and the rubber stopper.
2. Cover the bottom of the chamber with a one centimeter layer of fresh, turgid spinach leaves.
3. Launch Graphical Analysis. Connect the CO_2 Gas Sensor to your Chromebook, computer, or mobile device.
4. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Rate to 15 samples/min and End Collection to 15 min. Click or tap Done.
5. Change the unit to ppt by clicking or tapping the CO_2 meter and choosing ppt from the Units menu.
6. Secure the lid on the chamber. Insert the CO_2 Gas Sensor into one the holes and the rubber stopper into the other.
7. Wait five minutes for the sensor to equilibrate, then click or tap Collect to start data collection. Data will be collected for 15 minutes.
8. When data collection is complete, determine the rate of respiration/photosynthesis.
   a. Click or tap Graph Tools, , and choose Apply Curve Fit.
   b. Select Linear as the curve fit. Click or tap Apply.
   c. Enter the slope of the line, *m*, as the rate of respiration/photosynthesis in Table 1.
   d. Dismiss the Linear curve fit box.
9. Make a heat sink by filling a 600 mL beaker with water.

10. Set up the lamp and heat sink as shown in Figure 1. **Important**: Do not turn the lamp on until instructed to do so.
11. Remove the aluminum foil from the respiration chamber.
12. Turn on the lamp.
13. Repeat Steps 8–10 to collect and analyze data for photosynthesis. **Note:** Data from the previous run will automatically be stored.
14. Graph both runs of data on a single graph.
    a. To display multiple data sets on a single graph, click or tap the y-axis label and select the data sets you want to display. Dismiss the box to view the graph.
    b. Use the displayed graph and Table 1 to answer the questions below.
15. Clean and dry the respiration chamber.

DATA

Table 1	
Leaves	Rate of respiration/photosynthesis (ppt/min)
In the dark	
In the light	

QUESTIONS

1. Were either of the rate values a positive number? If so, what is the biological significance of this?
2. Were either of the rate values a negative number? If so, what is the biological significance of this?
3. Do you have evidence that cellular respiration occurred in leaves? Explain.
4. Do you have evidence that photosynthesis occurred in leaves? Explain.
5. List five factors that might influence the rate of carbon dioxide production or consumption in leaves. Explain how you think each will affect the rate?

EXTENSIONS

1. Design and perform an experiment to test one of the factors that might influence the rate of carbon dioxide production or consumption in Question 5.
2. Compare the rates of photosynthesis and respiration among various types of plants.

Bio-Rad Algal Beads

Student instructions for Investigation #2 from the Bio-Rad® "Photosynthesis and Cellular Respiration for AP Biology Lab," adapted by Vernier Software & Technology for the Go Direct® SpectroVis® Plus Spectrophotometer.

MATERIALS

Chromebook, computer, or mobile device
Vernier Spectral Analysis app (for data collection)
Go Direct SpectroVis Plus
Bio-Rad Photosynthesis and Cellular Respiration Kit for AP Biology
three cuvettes with lids
aluminum foil
desk lamp
LED plant bulb
stopwatch or clock with second hand
Beral pipets
distilled water

PROCEDURE

1. Obtain and wear goggles.

2. Obtain two plastic Beral pipets, three cuvettes with lids and a small piece of aluminum foil.

    a. Mark one Beral pipet with **DI** (water), one with **A** (algae beads) and one with **C** (CO_2 indicator).

    b. Mark the lid of one cuvette **B** (blank).

    c. For the remaining two cuvettes, mark one lid with **T** (test) and one with **A** (algae beads).

3. Move algae beads into the cuvette marked **A**.

    a. Cut the Beral pipet marked **A** at the 100 µL mark diagonally to convert it into an algae transfer pipet.

    b. Use the algae transfer pipet to transfer 10 algae beads into the cuvette labeled **A**.

    c. Remove all liquid from the cuvette using the pipet marked DI.

    d. Place the cap on the cuvette.

4. Prepare the blank by filling the cuvette marked **B** with 2 mL distilled water. Seal the cuvette with a lid. **Note**: To correctly use a cuvette, remember:
    - Wipe the outside of each cuvette with a lint-free tissue.
    - Handle cuvettes only by the top edge of the ribbed sides.
    - Dislodge any bubbles by gently tapping the cuvette on a hard surface.
    - Always position the cuvette so the light passes through the clear sides.
5. Place 2 mL of CO2 Indicator in the cuvette marked **T**.
6. Launch Spectral Analysis. Connect the Go Direct SpectroVis Plus to your Chromebook, computer, or mobile device.
7. Select Absorbance *vs.* Concentration.
8. To calibrate the Spectrometer, place the cuvette labeled **B** in the Spectrometer and select Finish Calibration. **Note**: If necessary, wait for the Spectrometer to warm up before selecting Finish Calibration.
9. Set the optimum wavelength for examining the CO_2 Indicator solution.
    a. Place cuvette **T** in the spectrometer.
    b. The live graph will update with the spectrum of the sample. Note that one area of the graph contains a peak absorbance.
    c. Enter the desired wavelength of 550 nm in the box.
    d. Click or tap Done.
    e. In the Data Set 1 table, select Column Options.
    f. Enter **Duration** as the Name and **min** as the Units.
10. Start data collection. Take an absorbance reading for the cuvette marked **T**. **Note**: If any air bubbles form, gently tap on the cuvette lid to knock them loose.
    a. Place the cuvette in the spectrometer. Allow 10 seconds for the readings to stabilize, then click or tap Keep.
    b. Enter **0** for the time value.
    c. Use the pipet marked **C** to transfer the indicator solution from the cuvette marked T into the cuvette marked **A**.
    d. Replace the lid and gently invert several times to mix the algae beads with the indicator solution.
    e. Place the cuvette marked **A** in front of the desk lamp with the LED plant bulb.
11. Turn on the desk lamp.
12. Set a timer for 5 minutes.

13. After 5 minutes, use pipet **C** to transfer the indicator solution from cuvette **A** back to cuvette **T** and replace the lid. **Note**: If any air bubbles form, gently tap on the cuvette lid to knock them loose.
    a. Place cuvette **T** in the device. Allow 10 seconds for the readings to stabilize, then click or tap Keep. Enter the number of elapsed minutes for the time value.
    b. Remove the cuvette.
    c. Using pipette **C**, return the indicator solution to cuvette **A**.
    d. Place cuvette **A** in its original position in front of the lamp.
14. Repeat Step 13 every 5 minutes until 30 minutes have elapsed.
15. After 30 minutes, click or tap the Stop button. In the table, change the name of Dataset 1 to Light.
16. If there is sufficient time, proceed to Step 18.
17. Click or tap the Collect button. Select Create New Data Set.
18. Take an absorbance reading for cuvette **T**. **Note**: If any air bubbles form, gently tap on the cuvette lid to knock them loose.
    a. Place the cuvette in the spectrometer. Allow 10 seconds for the readings to stabilize, then click or tap Keep.
    b. Enter **0** for the time value.
    c. Use pipet **C** to transfer the indicator solution from cuvette T into cuvette **A**.
    d. Replace the lid and gently invert several times to mix the algae beads with the indicator solution.
    e. Wrap the cuvette marked **A** completely in aluminum foil and place it in front of the lamp.
19. Set a timer for 5 minutes.
20. After 5 minutes, use the pipet marked **C**, to transfer the indicator solution from the cuvette marked A back to the cuvette marked **T** and replace the lid. **Note**: If any air bubbles form, gently tap on the cuvette lid to knock them loose.
    a. Place the cuvette marked **T** in the device. Allow 10 seconds for the readings to stabilize, then click or tap Keep. Enter the number of elapsed minutes for the time value.
    b. Remove the cuvette.
    c. Using the pipette marked **C**, return the indicator solution to the cuvette marked **A**.
    d. Re-wrap the cuvette marked **A** with the aluminum foil and place it in its original position in front of the lamp.
21. Repeat Step 21 every 5 minutes until 30 minutes have elapsed.
22. After 30 minutes, click or tap Stop. In the table, change the name of Dataset 2 to Dark.

Photosynthesis and Cellular Respiration in Aquatic Plants

(Optical Dissolved Oxygen Probe)

Aquatic autotrophs such as plants and algae undergo photosynthesis and cellular respiration much like terrestrial plants. Atmospheric gases used in both processes dissolve in water and can be exchanged with autotrophic tissues.

Photosynthesis involves the use of light energy to convert carbon dioxide (dissolved in water in the form of carbonic acid, H_2CO_3) and water into sugar, oxygen, and other organic compounds. This process can be summarized by the following reaction:

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

Cellular respiration involves converting the chemical energy of organic molecules such as glucose into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:

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

Oxygen dissolves at the interface between the water and the air, and when aquatic autotrophs release oxygen as a byproduct of photosynthesis. This dissolved oxygen can be measured to determine whether aquatic plants are undergoing photosynthesis or cellular respiration under different light conditions.

OBJECTIVES

- Measure the concentration of dissolved oxygen in water using an Optical DO Probe.
- Determine the effect of light on the rate of photosynthesis in aquatic plants.

MATERIALS CHECKLIST

Chromebook, computer, or mobile device
Graphical Analysis 4 app
Vernier data-collection interface
Optical DO Probe
250 mL Nalgene bottle
1 L of aged tap water
aluminum foil
Stir Station, with ring stand post attached
Utility clamp
Stir bar
600 mL beaker
Lamp with LED plant bulb or halogen bulb
Java moss (*Vesicularia dubyana*) or Christmas moss (*Vesicularia montagnei*)

PROCEDURE

1. Set the switch on the Optical DO Probe to the mg/L setting. The switch is located on the box containing the microSD card.

2. Connect the Optical DO Probe to the data-collection interface, and then connect the interface to your Chromebook, computer, or mobile device. Launch Graphical Analysis.
   a. Set up the data-collection mode.
   b. Click or tap Mode
   c. Change End Collection to 15 min duration.
   d. Click or tap Done.

3. Obtain a golf-ball sized clump of java moss and gently place it in 250 mL Nalgene bottle along with a stir bar.

4. Fill the 250 mL Nalgene bottle with aged tap water, leaving approximately 2 cm of space at the top of the bottle.

5. Carefully wrap the bottle in aluminum foil, ensuring that the bottom surface of the bottle is flat enough to sit on a Stir Station. Leave space at the neck of the bottle for the Optical DO probe.

6. Place the bottle on the Stir Station and set it to stir at a medium speed.

7. Position the utility clamp on the ring stand post of the stir station above the bottle.

8. Insert the Optical DO Probe into the bottle. Stabilize it using the utility clamp, ensuring that it does not interfere with the stir bar. Wait for one minute.

9. Click or tap Collect to start data collection.

10. When data collection is complete, turn off the stir station.

11. Click or tap View, , and choose Apply Curve Fit. Record the slope of the line in Table 1.

12. Remove the Optical DO Probe from the water sample.

13. Remove the foil from the 250 mL Nalgene bottle.

14. Set up the lamp approximately 30 cm from the Nalgene bottle.

15. Place a 600 mL beaker of water between the lamp and the Nalgene bottle to act as a heat sink.

16. Turn on the lamp.

17. Repeat Steps 6–11.

DATA

Table 1	
Java moss	Rate of respiration/photosynthesis (DO mg/L/min)
In the dark	
In the light	

QUESTIONS

1. In the dark, was the rate value for DO a negative number? If so, what is the biological significance of this?

2. In the light, was the rate value for DO a negative number? If so, what is the biological significance of this?

3. Do you have evidence that cellular respiration occurred in aquatic plants? Explain.

4. Do you have evidence that photosynthesis occurred in aquatic plants? Explain.

5. List five factors that might influence the rate of oxygen production or consumption in aquatic plants. Explain how you think each will affect the rate.