122 - Photosynthesis

Supports PA STEELS Standards

- 3.1.6-8.F Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms

- 3.1.9-12.E Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy

Summary and Timing

Students use Vernier CO_2 sensors to answer the question, "Is my salad doing photosynthesis"? Students collect evidence by measuring the changes in CO_2 levels of spinach leaves in both light and dark chambers. The teacher must provide internet-connected devices for each student group to connect to the Vernier CO_2 sensors. Data is visualized using the free Graphical Analysis website. A class set (8 groups) of materials is included with the kit. Suggested timing - 1+ class periods.

Materials *Teacher Provided (view materials)

- Vernier CO_2 Gas Sensor (Bluetooth)
- Internet-connected student devices with Graphical Analysis web or desktop app*
- 250 mL reaction chamber
- Socks
- Lamp
- Ruler
- Forecps
- Spinach leaves

Safety

- The lamp may be hot; use caution and a heat sink as explained in the procedure to avoid damaging the sensors.

Guiding Questions/Phenomena

- Is my salad doing photosynthesis?
- How does the presence of light affect carbon dioxide levels in the reaction chamber?
- What evidence can we use to identify the process of photosynthesis? Respiration?

Credits and Document Version

This lab was adapted by B. Peckham and M. Dubaich in 2008 from the Vernier Photosynthesis lab. Additional updates by L. Bird and V. Stone (2025) for the Advancing Science program.

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Teacher Notes

- View a Vernier Bluetooth tutorial on YouTube.
- Use fresh spinach (from the grocery store produce section). Store the spinach in a cool place.
- This lab may be conducted as inquiry-based (pgs 3-4) or using the stepwise procedure (pgs 5-7).
- This experiment is a good opportunity to remind students that plants undergo both photosynthesis and respiration when light is present. Students should see a decrease in CO_2 over time in leaves that are exposed to light, as CO_2 is used up in the Calvin Cycle. Respiration may also occur, but photosynthesis will use CO_2 faster than it is produced by respiration. Students should see an increase in CO_2 over time in leaves that are kept in the dark. Photosynthesis cannot occur, but respiration continues, breaking down sugars and releasing CO_2 into the sealed chamber. Oxygen concentration would follow an opposite trend.

Sample Data and Suggested Answers to Questions for Stepwise Procedure

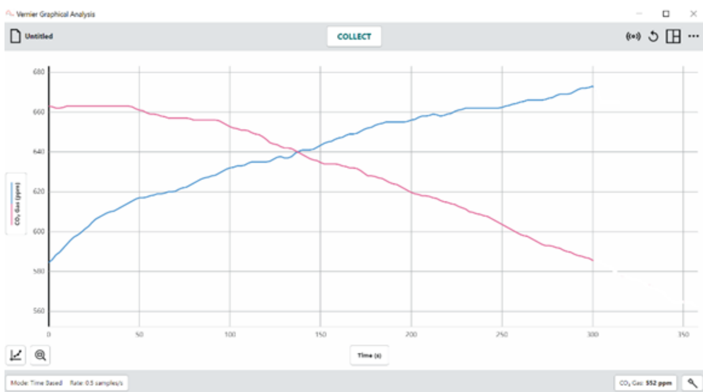

Figure 1. Screenshot of the completed graph, the blue line represents CO_2 production "in the dark" and the red line shows CO_2 consumption "in the light".

Treatment	Rate of Change (ppm/sec)	CO_2 is **produced** or **consumed**?
In the dark	*0.2013 ppm/sec*	*Produced*
In the light	*-0.335 ppm/sec*	*Consumed*

1. Student models should include a chamber, CO_2 sensor, spinach leaves, arrows may be used to indicate the flow of CO_2.
2. Was CO_2 produced or consumed in the dark? What process may have occurred inside the chamber to explain your results? *CO_2 was produced in the dark due to cellular respiration*
3. Was CO_2 produced or consumed in the light? What process may have occurred inside the chamber to explain your results? *CO_2 was consumed in the light due to photosynthesis occurring at a faster rate than cellular respiration resulting in a net decrease of CO_2*
4. List three factors that might influence the rate of CO_2 production or consumption of leaves. Explain how you think each will affect the rate. *Answers will vary but may include light color, light intensity, temperature, etc. Student responses to this question may be used to develop an inquiry-based lab to determine the effect of these factors on the rate of CO_2 production or consumption.*

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Inquiry Procedure

1. Ask the students if their salad does photosynthesis. Show the students the bag of spinach leaves purchased from the grocery store. Provide time for the students to discuss their predictions in small groups and then as a whole class. Most students say “no, their salad is not doing photosynthesis”, their reasons typically include: the plant has been picked and is now dead, or the leaf is disconnected from the roots so it can’t take in what it needs. Students may also note that no water is present - discuss that there is water in the spinach leaves - people wouldn’t eat a dried-out, crunchy spinach leaf.
2. Show the students the CO_2 sensor, explain that air from the room enters (diffuses) into the holes on the sensor tube and is then analyzed by the sensor to determine the amount of CO_2 in the tested environment. High school teachers may wish to share these additional details about the sensor operations: the sensor monitors the amount of infrared radiation absorbed by CO_2 to determine the level of gaseous CO_2.
3. Engage students in a conversation about the current CO_2 level in the room and the HVAC system, discuss how those levels might change throughout the day and why. Learn more about [indoor CO2 levels] and view a [chart relating CO_2 levels and human health].
    a. 400 ppm - approximate outdoor CO_2 value (fluctuates depending on various factors)
    b. 450 - 650 ppm - CO_2 levels in an empty classroom (or with just a few people)
    c. 700 - 1,000 ppm - CO_2 levels in an occupied classroom
    d. > 1,000 ppm - might indicate that the ventilation system is not operating properly
4. Show the students the 250 mL reaction chamber and place the sensor (hole side down) into the chamber. Discuss how we can run a controlled experiment inside the chamber to measure changing CO_2 levels. Show the students the remaining lab materials.
5. Provide time for the students to plan the experimental design in small groups. Students should sketch the experimental setup (create a model). Students can revisit their model/sketch throughout the investigation to add details as they collect evidence (such as the addition of light energy or the production/consumption of CO_2 gas).
6. Discuss the students' experimental design and agree on a class procedure. This is a good opportunity to discuss variables and the anatomy of a leaf (the photosynthesizing cells are on the top side). Students will typically design an experiment similar to the stepwise procedure provided at the end of this document. The teacher may need to modify the student’s procedure slightly to ensure the safety of the equipment and collect consistent data. Important procedure details to note include:
    a. The sensors must remain dry.
    b. The sensors must remain 15 cm from the light to protect them from heat damage.
    c. A heat sink should be placed between the light and the sensor to protect the sensor from heat damage.
    d. Use multiple leaves in the chamber to collect more reliable data.

   e. Run the "dark" part of the experiment first, leave the sensor in place, and finish with the spinach leaves exposed to light. This order allows CO_2 to build up in the chamber during the dark experiment before conducting the light experiment.
   f. The sensors take about 2 minutes to warm up. Collect data for at least 5 minutes; the first 1-2 minutes of data collection are often ignored due to the data lag caused by the gas diffusion process.
   g. The slope of the line is used to determine the rate of CO_2 production or consumption. Refer to the stepwise procedure below to learn how to use Graphical Analysis to calculate the slope of the line.
7. Students conduct the experiment and calculate the slope of the line.
8. Compile the student's data and calculate the class average. Use the class average to re-evaluate the question, "Is my salad doing photosynthesis?". Discuss the results and revise student models with the evidence collected from the experiment.
9. High school teachers may want to investigate these extensions:
   a. What errors or uncontrolled variables were present in our light/dark experiment? Revise and repeat.
   b. Does the distance from the lamp affect photosynthesis?
   c. Does the color of light affect photosynthesis?
   d. Do other items from the grocery store produce section do photosynthesis?

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Stepwise Procedure

1. Prepare the data collection equipment.
    a. Power on the Vernier Bluetooth sensor, and it will flash red.
    b. Go to https://graphicalanalysis.app/ with a Chrome browser or open the [Graphical Analysis](#) desktop app.
    c. Select “sensor data collection” (Figure 2).
    d. Select the Bluetooth device code that matches the ID code on the back of the sensor (Figure 3).
    e. Select “connect” and then “done”. The sensor will flash green when connected.
    f. If the sensor battery is low or your device does not have Bluetooth, use the USB cable to connect the sensor to your device.

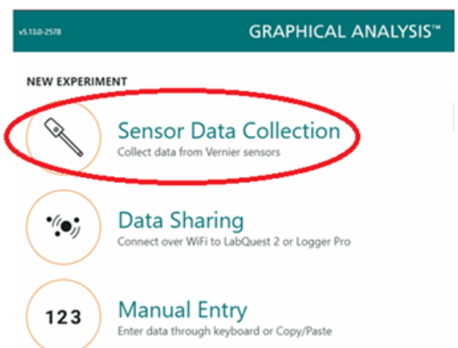

Figure 2. Select "Sensor Data Collection" to see a list of available Bluetooth sensors/probes.

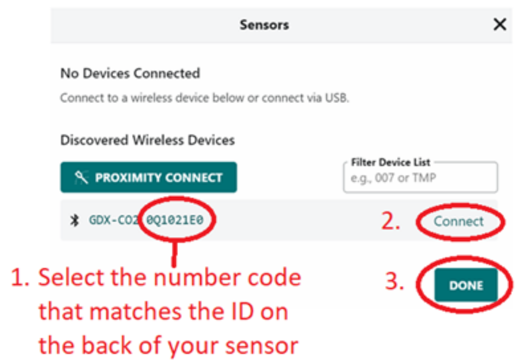

Figure 3. Select the number code that matches the ID on the back of your sensor/probe, click "connect", and then "done".

2. Set the data collection parameters,
    a. Click “mode: time-based” in the lower right corner of the app (Figure 4).
    b. Change the data collection settings to “rate” 0.25 samples/s and “end collection” after 300 s (Figure 5).

Figure 4. Click "mode: time based" in the lower left corner to set the data collection parameters for your experiment.

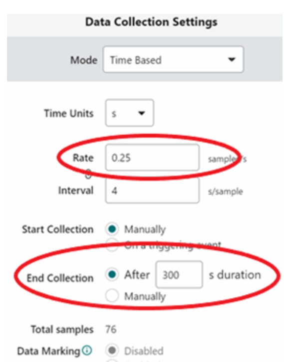

Figure 5. Data collection settings – rate = 0.25 samples/s and end collection after 300 seconds.

3. Prepare the lab materials (Figure 6).
    a. Gently place 3-5 spinach leaves in the 250 mL reaction chamber.
    b. Fill a lidded 250 mL reaction chamber with water. This will act as the heat sink.
    c. Place the reaction chamber with spinach leaves inside a sock.
    d. Insert the CO_2 sensor into the opening of the reaction chamber.
    e. Arrange the lamp, 250 mL reaction chamber, and heat sink (Figure 6). To avoid damaging the CO_2 sensor, make sure the lamp is 15 cm (6”) away from the sensor.
4. Begin the experiment.
    a. Turn on the lamp.
    b. Click “collect” to begin data collection. Turn off the lamp when data collection is complete. Data collection will automatically end at 300 seconds.
5. Analyze the data to find the rate of CO_2 change,
    a. Click and drag in the graph area to highlight the graph from 100 seconds to 300 seconds.
    b. Click the “graph options” button in the lower left.
    c. Choose “apply curve fit”, select “linear” from the drop-down menu, and then “apply”.
    d. Record “m”, the slope of the line, as the rate of change in your data table.
6. Remove the sock from the reaction chamber, but DO NOT remove the CO_2 sensor (Figure 7).
7. Repeat steps 4 and 5. To view both sets of data at the same time, click the y-axis label, and turn “on” the graphs for both sets of data.
8. Clean up. Remove the spinach leaves from the chamber and empty the heat sink.

Figure 6. Align the lab equipment as shown. Place the reaction chamber inside a sock to block the light from reaching the chamber. Place the reaction chamber with spinach leaves at least 15 cm from the light. Fill the culture flask (bottle with orange lid) with water and place it in between the lamp and the reaction chamber.

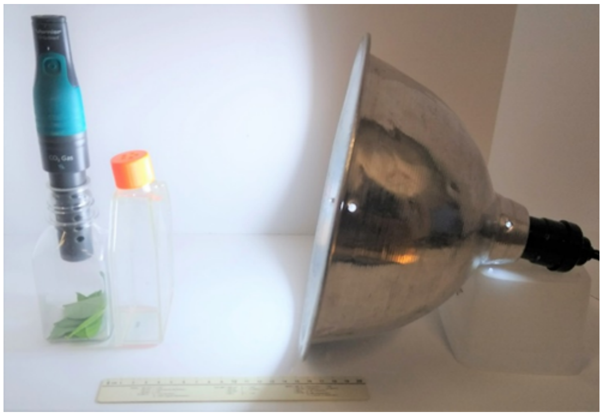

Figure 7. The sock is removed from the reaction chamber to run the "in the light" experimental treatment.

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Student Worksheet ____

Is my salad doing photosynthesis? Create a sketch to explain your prediction.

Data Table

Treatment	Rate of Change (ppm/sec) Parts per million per second	Carbon dioxide is **produced** or **consumed**?
In the dark Line color _______________		
In the light Line color _______________		

Questions

1. Revise your initial sketch to show how CO_2 levels changed during your experiment.
2. Was CO_2 produced or consumed in the dark? What process may have occurred inside the chamber to explain your results?
3. Was CO_2 produced or consumed in the light? What process may have occurred inside the chamber to explain your results?
4. List three factors that might influence the rate of CO_2 production or consumption of leaves. Explain how you think each will affect the rate.