Photosynthesis and Respiration

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (Logger *Pro*, Graphical Analysis 4, Spectral Analysis, LabQuest App, and EasyData). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Logger *Pro* versions of the experiments.

2. Different sensors can be used for this experiment. The sensors that can be used are: CO_2 (only), O_2 (only), or CO_2 and O_2 (together). All versions of the experiment can be found in the Electronic Resources. **Note**: The printed version of the book and the PDF of the entire book contain the CO_2 and O_2 (together) version of the experiment.

3. Plant material used must be fresh, moist, and turgid. Spinach leaves purchased from a grocery store work very well and are readily available any time of the year.

4. For best results, the spinach should be stored in a refrigerator or in a cooler. If kept cold, the spinach should produce good results for several days.

5. Each class period should use fresh spinach leaves directly from the refrigerator or cooler so the leaves stay as fresh as possible.

6. Before placing the spinach in the Biochamber, the leaves should be gently dried off with paper towels. Excess moisture on the leaves can cause condensation in the chamber, affecting the results.

7. The type of light bulb is very important for this experiment.
   - We recommend 12 W LED grow lights; they give the best results because they provide the correct wavelengths for photosynthesis and produce minimal heat energy.
   - 35 W halogen, flood-beam bulbs or standard 100 W incandescent bulbs can work. However, both bulbs radiate a lot of heat energy, which can affect the results.
   - 12-inch, fluorescent ring lamps work well because they fit nicely around the BioChamber 2000, bathe the leaves in light from all sides, and give off little heat energy. However, they can be difficult to obtain. Note that this type of bulb requires a ballast that screws into a plug-in socket adapter.

   For more information see **www.vernier.com/til/1519**

8. A heat sink is recommended to protect the spinach leaves no matter what type of light source you use. A 600 mL beaker can be used but a tissue culture flask filled with water makes a good heat sink because it is thinner, and will allow the leaves to receive much more light from the same lamp than a beaker.

9. The waiting time before starting data collection may need to be lengthened depending on the rate of gas production. You may wish to monitor the gas concentrations and start collecting data when the levels of gas begin to move in the correct direction. It may take up to 15 minutes under some conditions.

10. To extend the life of your O_2 Gas Sensors, always store the sensors upright. The box in which it was shipped provides a handy box to accomplish this.

11. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect your sensor.

12. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

ESTIMATED TIME

We estimate that setup and data collection can be completed in one 45-minute class period.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Developing and Using Models	LS1.A: Structure and Function LS1.C: Organization for Matter and Energy Flow in Organisms LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	Cause and Effect Structure and Function Energy and Matter Systems and System Models

SAMPLE RESULTS

Sample data for all versions of the student experiment are provided.

Using CO_2 and CO_2 Gas Sensors

Leaves	CO_2 Rate of respiration/photosynthesis (ppt/min)	O_2 Rate of respiration/photosynthesis (ppt/min)
In the dark	0.0112	–0.0724
In the light	–0.0179	0.2600

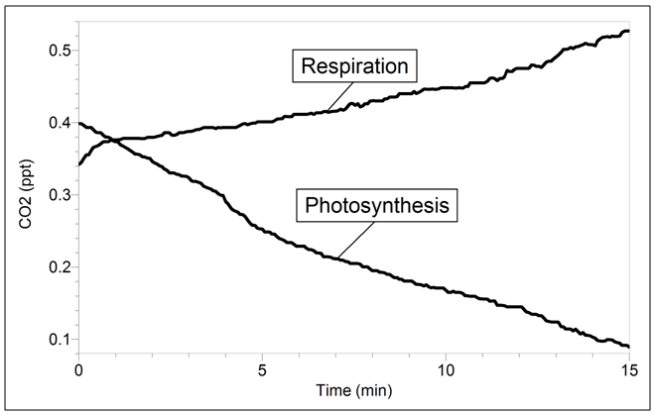

Figure 1

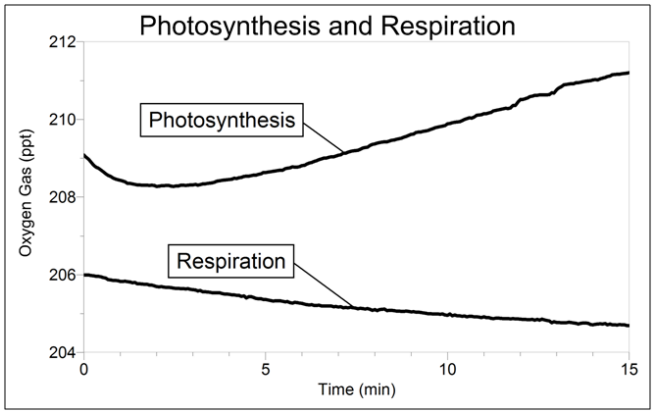

Figure 2

Using an O_2 Gas Sensor

Leaves	Rate of respiration/photosynthesis (ppt/min)
In the dark	–0.0844
In the light	0.2729

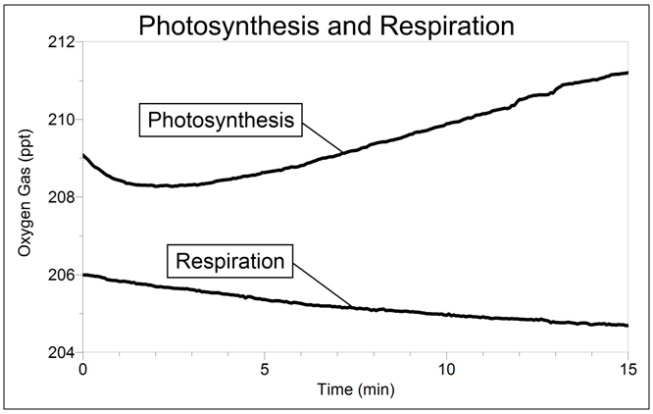

Figure 3

Using a CO_2 Gas Sensor

Leaves	Rate of respiration/photosynthesis (ppt/min)
In the dark	0.0177
In the light	–0.0202

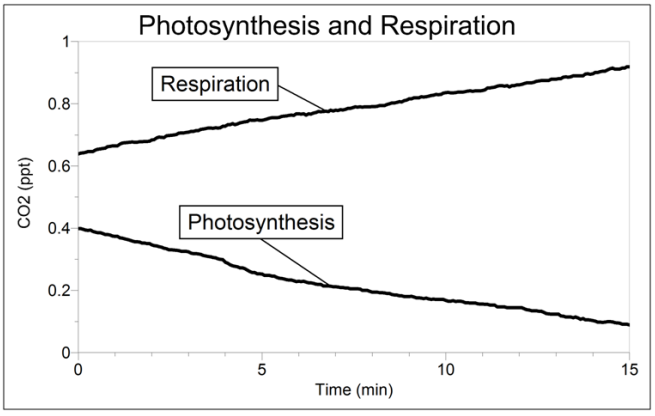

Figure 4

ANSWERS TO QUESTIONS

Using O_2 and CO_2 Gas Sensors

1. The CO_2 rate value for leaves in the dark was a positive number. The biological significance of this is that CO_2 is produced during respiration. This causes the concentration of CO_2 to increase, as sugar is oxidized and broken into CO_2, water, and energy.

2. The O_2 rate value for leaves in the dark was a negative number. The biological significance of this is that O_2 is consumed during cellular respiration. This causes the concentration of O_2 to decrease as glucose is oxidized for energy.

3. Yes, cellular respiration occurred in leaves, since O_2 decreased when leaves were in the dark and photosynthesis was not possible.

4. Yes, photosynthesis occurred in leaves, since O_2 increased when leaves were exposed to light.

5. Answers may vary. They might include:
   a. A greater number of leaves should increase the rate, since there are more chloroplasts to undergo photosynthesis and more cells to require energy through cellular respiration.
   b. A greater light intensity will increase the rate of photosynthesis. It may not affect the rate of cellular respiration, however.
   c. A cooler room may decrease both rates, as cellular metabolism decreases in cooler weather.
   d. Facing the top of the leaves toward the light should increase the rate of photosynthesis, since the chloroplasts are closer to the light source.
   e. If the plants overheat due to the heat from the lamp, they may wilt and stop functioning. This will decrease all rates.
   f. If there are too many leaves, diffusion may be restricted and prevent accurate readings. This may apparently decrease both rates.

Using an O_2 Gas Sensor

1. The rate value for leaves in the light was a positive number. The biological significance of this is that O_2 is produced during photosynthesis.

2. The rate value for leaves in the dark was a negative number. The biological significance of this is that O_2 is consumed during cellular respiration. This causes the concentration of O_2 to decrease as glucose is oxidized for energy.

3. Yes, cellular respiration occurred in leaves, since O_2 decreased when leaves were in the dark and photosynthesis was not possible.

4. Yes, photosynthesis occurred in leaves, since O_2 increased when leaves were exposed to light.

5. Answers may vary. They might include:
   a. A greater number of leaves should increase the rate, since there are more chloroplasts to undergo photosynthesis and more cells to require energy through cellular respiration.

b. A greater light intensity will increase the rate of photosynthesis. It may not affect the rate of cellular respiration, however.
c. A cooler room may decrease both rates, as cellular metabolism decreases in cooler weather.
d. Facing the top of the leaves toward the light should increase the rate of photosynthesis, since the chloroplasts are closer to the light source.
e. If the plants overheat due to the heat from the lamp, they may wilt and stop functioning. This will decrease all rates.
f. If there are too many leaves, diffusion may be restricted and prevent accurate readings. This may apparently decrease both rates.

Using a CO_2 Gas Sensor

1. The CO_2 rate value for leaves in the dark was a positive number. The biological significance of this is that CO_2 is produced during respiration. This causes the concentration of CO_2 to increase, as sugar is oxidized and broken into CO_2, water, and energy.

2. The rate value for leaves in the light was a negative number. The biological significance of this is that CO_2 is consumed during photosynthesis. This causes the concentration of CO_2 to decrease, as the CO_2 is converted into glucose.

3. Yes, cellular respiration occurred in leaves, since CO_2 increased when leaves were in the dark and photosynthesis was not possible.

4. Yes, photosynthesis occurred in leaves, since CO_2 decreased when leaves were exposed to light.

5. Answers may vary. They might include:
   a. A greater number of leaves should increase the rate, since there are more chloroplasts to undergo photosynthesis and more cells to require energy through cellular respiration.
   b. A greater light intensity will increase the rate of photosynthesis. It may not affect the rate of cellular respiration, however.
   c. A cooler room may decrease both rates, as cellular metabolism decreases in cooler weather.
   d. Facing the top of the leaves toward the light should increase the rate of photosynthesis, since the chloroplasts are closer to the light source.
   e. If the plants overheat due to the heat from the lamp, they may wilt and stop functioning. This will decrease all rates.
   f. If there are too many leaves, diffusion may be restricted and prevent accurate readings. This may apparently decrease both rates.