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Biology Essentials: Getting Started with Vernier

Experiments

Photosynthesis and Respiration

- Go Direct© CO_2 Gas Sensor

Enzyme Action: Testing Catalase Activity

- Go Direct Gas Pressure Sensor

Dissolved Oxygen in Water

- Go Direct Optical Dissolved Oxygen Probe

Workshop Presenter

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Vernier SCIENCE EDUCATION

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.

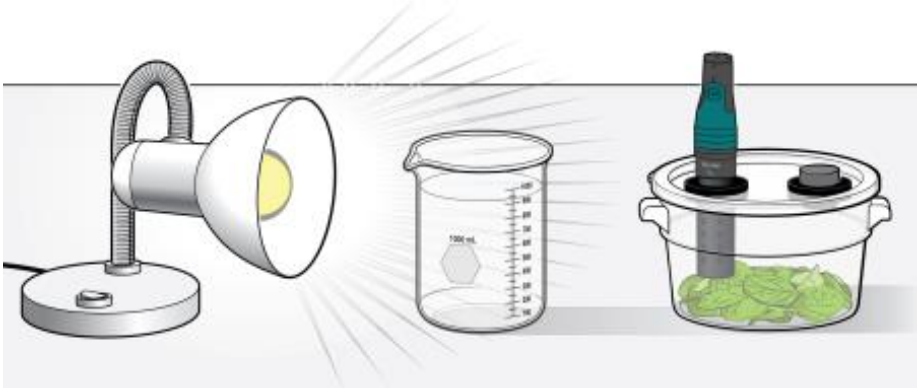

Figure 1

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 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 Options, , 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**: The previous data set is automatically saved.

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.

Enzyme Action: Testing Catalase Activity

(Gas Pressure Sensor)

Many organisms can decompose hydrogen peroxide (H_2O_2) enzymatically. Enzymes are globular proteins, responsible for most of the chemical activities of living organisms. They act as catalysts, as substances that speed up chemical reactions without being destroyed or altered during the process. Enzymes are extremely efficient and may be used over and over again. One enzyme may catalyze thousands of reactions every second. Both the temperature and the pH at which enzymes function are extremely important. Most organisms have a preferred temperature range in which they survive, and their enzymes typically function best within that temperature range. If the environment of the enzyme is too acidic or too basic, the enzyme may irreversibly denature, or unravel, until it no longer has the shape necessary for proper functioning.

H_2O_2 is toxic to most living organisms. Many organisms are capable of enzymatically breaking down the H_2O_2 before it can do much damage. H_2O_2 can be converted to oxygen and water, as follows:

$$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$$

Although this reaction occurs spontaneously, the enzyme catalase increases the rate considerably. Catalase is found in most living organisms.

A great deal can be learned about enzymes by studying the rates of enzyme-catalyzed reactions. The rate of a chemical reaction may be studied in a number of ways including:

- Measuring the pressure of the product as it appears
- Measuring the rate of disappearance of substrate
- Measuring the rate of appearance of a product

In this experiment, you will measure the rate of enzyme activity under various conditions, such as different enzyme concentrations, pH values, and temperatures. It is possible to measure the pressure of oxygen gas formed as H_2O_2 is destroyed.

OBJECTIVES

- Measure the production of oxygen gas as hydrogen peroxide is broken down by the enzyme catalase or peroxidase at various enzyme concentrations.
- Measure and compare the initial rates of reaction for this enzyme when different concentrations of enzyme react with H_2O_2.
- Measure the production of oxygen gas as hydrogen peroxide is broken down by the enzyme catalase or peroxidase at various temperatures.
- Measure and compare the initial rates of reaction for the enzyme at each temperature.
- Measure the production of oxygen gas as hydrogen peroxide is broken down by the enzyme catalase or peroxidase at various pH values.
- Measure and compare the initial rates of reaction for the enzyme at each pH value.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Gas Pressure
1-hole rubber stopper assembly
plastic tubing with Luer-lock fitting
10 mL graduated cylinder
250 mL beaker of water
three Beral pipettes
3% H_2O_2
600 mL beaker
enzyme suspension
three 18 × 150 mm test tubes
ice
pH buffers
test tube rack
thermometer
goggles

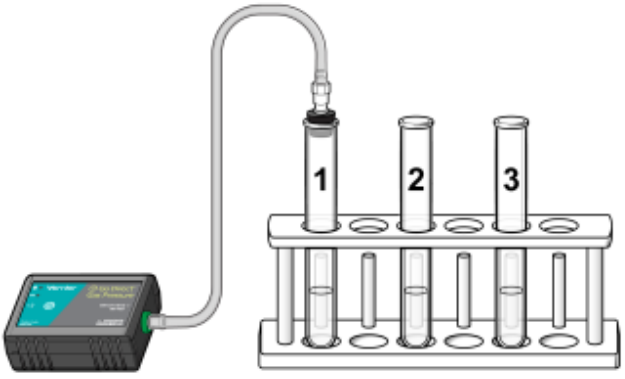

Figure 1

PROCEDURE

1. Obtain and wear goggles.
2. Connect the plastic tubing to the valve on the Gas Pressure Sensor.
3. Launch Graphical Analysis. Connect the Gas Pressure 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 0.5 samples/s and End Collection to 180 s.
   c. Click or tap Done.

Part I Effect of enzyme concentration

5. Place three test tubes in a rack and label them 1, 2, and 3.
6. Add 3 mL of 3.0% H_2O_2 and 3 mL of water to each test tube.
7. Initiate the enzyme catalyzed reaction. **Note**: The next steps should be completed as rapidly as possible.
   a. Using a clean dropper pipette, add 1 drop of enzyme suspension to test tube 1. **Note**: Be sure to not let the enzyme fall against the side of the test tube.
   b. Stopper the test tube and gently swirl to mix the contents. The reaction should begin immediately.
   c. Connect the free-end of the plastic tubing to the connector in the robber stopper as shown in Figure 2.
   d. Click or tap Collect to start data collection. Data collection will end after 180 s. **Note**: Monitor the pressure readings displayed on the screen. If the pressure exceeds 130 kPa, the pressure inside the tube will be too great and the rubber stopper is likely to pop off. Disconnect the plastic tubing from the Gas Pressure Sensor if the pressure exceeds 130 kPa.

Figure 2

8. When data collection has finished, disconnect the plastic tubing connector from the rubber stopper. Remove the rubber stopper from the test tube and discard the contents in a waste beaker.
9. Determine the rate of enzyme activity:
   a. Select the data in the most linear region of the graph.
   b. Click or tap Graph Options, , and choose Apply Curve Fit.
   c. Select Linear as the curve fit. Click or tap Apply.

d. Record the slope, *m*, as the reaction rate in Table 2.

e. Dismiss the Curve Fit box.

10. Find the rate of enzyme activity for test tubes 2 and 3:

    a. Add 2 drops of the enzyme solution to test tube 2. Repeat Steps 7–9. **Note**: The previous data set is automatically saved.

    b. Add 3 drops of the enzyme solution to test tube 3. Repeat Steps 7–9.

11. Display all three 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 only the data sets you want to display. Dismiss the box to view the graph.

    b. Use the displayed graph and the data in Table 2 to answer the questions for Part I.

Part II Effect of temperature

Your teacher will assign a temperature range for your lab group to test. Depending on your assigned temperature range, set up your water bath as described below. Place a thermometer in your water bath to assist in maintaining the proper temperature.

- 0–5°C: 400 mL beaker filled with ice and water
- 20–25°C: No water bath needed to maintain room temperature
- 30–35°C: 400 mL beaker filled with warm water
- 50–55°C: 400 mL beaker filled with hot water

12. Rinse the three numbered test tubes used for Part I. Fill each test tube with 3 mL of 3.0% H_2O_2 and 3 mL of water, then place the test tubes in the water bath. The test tubes should be in the water bath for 3 minutes before doing Step 13. Record the temperature of the water bath in the space provided in Table 3.

13. Find the rate of enzyme activity for test tubes 1, 2, and 3:

    - Add 2 drops of enzyme suspension to test tube 1. Repeat Steps 7–9. Record the reaction rate in Table 3.
    - Add 2 drops of enzyme suspension to test tube 2. Repeat Steps 7–9. Record the reaction rate in Table 3.
    - Add 2 drops of enzyme suspension to test tube 3. Repeat Steps 7–9. Record the reaction rate in Table 3.

14. Calculate the average rate for the three trials you tested. Record the average in Table 3.

15. Record the average rate and the temperature of your water bath from Table 3 on the class data table. When the entire class has reported their data, record the class data in Table 4.

Part III Effect of pH

16. Place three clean test tubes in a rack and label them pH 4, pH 7, and pH 10.
17. Add 3 mL of 3% H_2O_2 and 3 mL of each pH buffer to each test tube, as in Table 1.

Table 1

pH of buffer	Volume of 3% H_2O_2 (mL)	Volume of buffer (mL)
pH 4	3	3
pH 7	3	3
pH 10	3	3

18. Find the rate of enzyme activity for test tubes labeled pH 4, pH 7, and pH 10:
    - Add 2 drops of enzyme suspension in test tube pH 4. Repeat Steps 7–9. Record the reaction rate in Table 5.
    - Add 2 drops of enzyme suspension in test tube pH 7. Repeat Steps 7–9. Record the reaction rate in Table 5.
    - Add 2 drops of enzyme suspension in test tube pH 10. Repeat Steps 7–9. Record the reaction rate in Table 5.
19. Display all three runs of data on a single graph. Use the displayed graph and the data in Table 5 to answer the questions for Part III.

DATA

Part I Effect of enzyme concentration

Table 2

Sample	Reaction rate (kPa/min)
1 drops	
2 drops	
3 drops	

Part II Effect of temperature

Table 3	
Sample	Reaction rate (kPa/min)
Trial 1	
Trial 2	
Trial 3	
Average	
Temperature range: _____ °C	

Table 4: Class Data	
Temperature tested (°C)	Average rate (kPa/min)

Part III Effect of pH

Table 5	
Sample	Reaction rate (kPa/min)
pH 4	
pH 7	
pH 10	

PROCESSING THE DATA

1. Multiply your rate by 60 s/min to convert to kPa/min. Record the rates in Table 3.
2. For Part I of this experiment, make a graph of the rate of enzyme activity *vs*. enzyme concentration. Plot the rate values from Table 3 on the y-axis and the number of drops of enzyme on the x-axis.
3. For Part II of this experiment, make a graph of the rate of enzyme activity *vs*. temperature. Plot the rate values from Table 3 on the y-axis and the temperature on the x-axis.
4. For Part III of this experiment, make a graph of the rate of enzyme activity *vs*. pH. Plot the rate values from Table 3 on the y-axis and the pH on the x-axis.

QUESTIONS

Part I Effect of enzyme concentration

1. How does changing the concentration of enzyme affect the rate of decomposition of H_2O_2?
2. What do you think will happen to the rate of reaction if the concentration of enzyme is increased to 5 drops? Predict what the rate would be for 5 drops.

Part II Effect of temperature

3. At what temperature is the rate of enzyme activity the highest? Lowest? Explain.
4. How does changing the temperature affect the rate of enzyme activity? Does this follow a pattern you anticipated?
5. Why might the enzyme activity decrease at very high temperatures?

Part III Effect of pH

6. At what pH is the rate of enzyme activity the highest? Lowest?
7. How does changing the pH affect the rate of enzyme activity? Does this follow a pattern you anticipated?

EXTENSIONS

1. Determine the reaction rates of trials in Part I for each 30 second interval. What patterns do you see? What could explain the different rates you determined?
2. Different organisms often live in very different habitats. Design a series of experiments to investigate how different types of organisms might affect the rate of enzyme activity. Consider testing a plant, an animal, and a protist.
3. Presumably, at higher concentrations of H_2O_2, there is a greater chance that an enzyme molecule might collide with H_2O_2. If so, the concentration of H_2O_2 might alter the rate of oxygen production. Design a series of experiments to investigate how differing concentrations of the substrate hydrogen peroxide might affect the rate of enzyme activity.
4. Design an experiment to determine the effect of boiling the catalase on the reaction rate.
5. Explain how environmental factors affect the rate of enzyme-catalyzed reactions.

Dissolved Oxygen in Water

(Optical Dissolved Oxygen Probe)

Aquatic life depends upon oxygen dissolved in water, just as organisms on land rely upon oxygen in the atmosphere. Molecular oxygen is used by organisms in aerobic respiration where energy is released during the combustion of sugar in the mitochondria. Without sufficient oxygen, they suffocate. Some organisms, such as salmon, mayflies, and trout, require high concentrations of oxygen in the water. Other organisms, such as catfish, midge fly larvae, and carp can survive with much less oxygen.

Oxygen dissolves at the interface between the water and the air or when aquatic autotrophs release oxygen as a byproduct of photosynthesis. Abiotic factors including temperature and pressure influence the maximum amount of oxygen that can be dissolved in pure water. Biotic life also influences the amount of oxygen that is dissolved.

The quality of the water can be assessed with fair accuracy by observing the aquatic animal populations in a stream. Table 1 indicates the oxygen and temperature tolerance levels of selected animals based on known dissolved oxygen tolerances. If a stream has only species that can survive at low oxygen levels, it is expected to have low oxygen levels.

Table 1

Animal	Temperature range (°C)	Minimum dissolved oxygen (mg/L)
Trout	5–20	6.5
Smallmouth bass	5–28	6.5
Caddisfly larvae	10–25	4.0
Mayfly larvae	10–25	4.0
Stonefly larvae	10–25	4.0
Catfish	20–25	2.5
Carp	10–25	2.0
Water boatmen	10–25	2.0
Mosquito	10–25	1.0

OBJECTIVES

- Measure the concentration of dissolved oxygen in water using an Optical DO Probe.
- Determine the effect of temperature on the amount of dissolved oxygen in water.
- Apply the results to predict the effect of water temperature on aquatic life.

MATERIALS CHECKLIST

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Optical Dissolved Oxygen
two 250 mL beakers
100 mL beaker
polystyrene foam cup
1-gallon plastic milk container
hot and cold water
ice
goggles

PROCEDURE

1. Set up the Optical Dissolved Oxygen Probe to collect DO and temperature data.
   a. Launch Graphical Analysis.
   b. Connect the Optical Dissolved Oxygen Probe to your Chromebook, computer, or mobile device.
   c. Click or tap Sensor Channels. Select Temperature. **Note**: Leave DO Concentration selected.
   d. Click or tap Done.
2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Mode to Event Based.
   c. Change Event Mode to Selected Events.
   d. Select Average sensor reading over 10 seconds.
   e. Click or tap Done.
3. Click or tap Collect to start data collection.
4. Obtain two 250 mL beakers. Fill one beaker with ice and cold water. Place the polystyrene foam cup into the second, empty beaker.
5. Place approximately 100 mL of cold water and a couple small pieces of ice, from the beaker filled with ice water, into a clean plastic one-gallon milk container.
6. Seal the container and vigorously shake the water for a period of 2 minutes. This will allow the air inside the container to dissolve into the water sample.

Figure 1

7. Pour the water from the milk container into the polystyrene foam cup.
8. Place the shaft of the Optical DO Probe into the water.
9. Monitor the dissolved oxygen readings displayed on the screen. Give the dissolved oxygen readings ample time to stabilize (90–120 seconds).
10. When the readings have stabilized, click or tap Keep. **Important**: Do not remove the probe until the 10-second averaging period is complete.
11. Remove the probe from the water sample.
12. Pour the water from the polystyrene foam cup back into the milk container. Seal the container and shake the water vigorously for 1 minute. Pour the water back into the polystyrene foam cup.
13. Repeat Steps 8–12 until the water sample reaches room temperature.
14. Fill a second beaker with very warm water about 40–50°C. When the water in the polystyrene foam cup reaches room temperature, add about 25 mL of the very warm water prior to shaking the water sample.
15. Repeat Steps 8–12 until the water temperature reaches 35°C.
16. When all samples have been taken, click or tap Stop to stop data collection.
17. Record the dissolved oxygen and temperature readings in Table 2.
18. Create a single graph of dissolved oxygen *vs*. temperature to help you answer the questions.
    a. Click or tap View Options, , and choose 1 Graph.
    b. Plot dissolved oxygen concentration on the y-axis and temperature on the x-axis. To change what is plotted on each axis, click or tap the axis label and select the correct column.

DATA

Table 2	
Temperature (°C)	Dissolved oxygen (mg/L)

QUESTIONS

1. At what temperature was the dissolved oxygen concentration the highest? Lowest?

2. Does your data indicate how the amount of dissolved oxygen in the water is affected by the temperature of water? Explain.

3. If you analyzed the invertebrates in a stream and found an abundant supply of caddisflies, mayflies, dragonfly larvae, and trout, what minimum concentration of dissolved oxygen would be present in the stream? What maximum temperature would you expect the stream to sustain?

4. Mosquito larvae can tolerate extremely low dissolved oxygen concentrations, yet cannot survive at temperatures above approximately 25°C. How might you account for dissolved oxygen concentrations of such a low value at a temperature of 25°C? Explain.

5. Why might trout be found in pools of water shaded by trees and shrubs more commonly than in water where the trees have been cleared?