AP Biology Lab 12: Dissolved Oxygen and Primary Productivity

Driving Questions

What affects do temperature and light have on the dissolved oxygen content of water containing aquatic organisms?

- How does temperature effect dissolved oxygen concentration?
- What does the dissolved oxygen concentration of an aquatic ecosystem tell us about its primary productivity?
- How does light intensity affect the primary productivity of an aquatic ecosystem?

Background

Oxygen is necessary for the life processes of most organisms, including aquatic organisms. The abundance of available oxygen varies greatly between terrestrial and aquatic habitats. However, in both terrestrial and aquatic ecosystems, autotrophs like plants and green algae release oxygen gas as a byproduct of photosynthesis. The oxygen gas is then used by many organisms to create ATP through aerobic cellular respiration.

Approximately 21% of the atmosphere is composed of oxygen, whereas the dissolved oxygen (DO) concentration in water is only a fraction of 1%. The concentration of DO in a body of water is often used as a benchmark indicator of water quality because it suggests the number of producers in the ecosystem and the activity levels of the producers and consumers.

An ecosystem's primary production is the amount of light energy converted to chemical energy by autotrophs during a given time period. To measure the primary productivity of an aquatic ecosystem, one could attempt to measure the concentration of organic compounds produced by the autotrophs in a given time period. Since oxygen is a byproduct of photosynthesis, it is easier to use the concentration of DO as a measure of an aquatic ecosystem's primary productivity.

Gross primary production (GPP) is the total primary production by the autotrophs; it is the amount of light energy that autotrophs convert into chemical energy. Net primary production (NPP) is the amount of light energy that autotrophs convert to chemical energy minus the energy used by the autotrophs for cellular respiration (R). Net primary production is a very important measurement because it represents the amount of surplus organic material that will be available to consumers as food.

Respiratory rate is the rate at which energy is consumed through aerobic cellular respiration. Respiratory rate can be found by determining the amount of DO consumed by the autotrophs per unit area per given time. The relationship between GPP, NPP, and R is illustrated by the following equation:

$$GPP = NPP + R.$$

Materials and Equipment

For each student or group:

- Data collection system
- Water quality sensor with dissolved oxygen probe
- Fast-response temperature probe or stainless steel temperature probe
- Beakers (3), 250-mL
- Large vessel, to hold 1500 mL of algae
- Aquatic Productivity Bottles (1 set)
- Wash bottle
- *Chlorella* (or other green algae) culture, 1500 mL
- Ice water, 200 mL
- Warm water, 200 mL
- Room temperature water, 200 mL
- Fluorescent light source
- Wax pencil, or stickers and marker

Safety

Follow all standard laboratory procedures.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

Fill the Aquatic Productivity Bottles with algae culture, being careful to prevent any bubbles from remaining.	Measure the initial DO concentration of an algae culture.	After 24 hours, measure the DO levels; calculate the amount of cellular respiration, and net and gross primary production.	Label the bottles, place them into the five chambers and place the lid on top.	Incubate the bottles under a light source for 24 hours.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Note: If using a dissolved oxygen sensor instead of a water quality sensor, use the fast response temperature probe to avoid electrical interference. Do not use a dissolved oxygen sensor with a stainless steel temperature probe. The water quality sensor can be used with either temperature probe.

Part 1 – Measuring dissolved oxygen

Set Up: room-temperature water

1. ☐ Start a new experiment on the data collection system. (1.2)

2. ☐ Connect the dissolved oxygen (DO) sensor and the temperature sensor to the data collection system. (2.2)

3. ☐ Display Dissolved Oxygen (mg/L) and Temperature (°C) in a digits display. (7.3.1)

4. ☐ Do you think that the concentration of DO will be affected by temperature changes? If yes, do you think that it will rise at increasing or at decreasing temperatures?

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5. ☐ Obtain 200 mL of room temperature water (approximately 20°C) in a 250-mL beaker.

6. ☐ Place the temperature probe into the water.

7. ☐ Calibrate the DO sensor. (3.3)

Collect Data: room-temperature water

8. ☐ Begin monitoring data without recording. (6.1)

9. ☐ Measure the temperature of the room temperature water and record in Table 12.1.

10. ☐ Remove the temperature probe from the water.

11. ☐ Carefully place the DO probe into the water. The silver ring on the DO probe should be immersed in water, but the probe should not be touching the bottom of the beaker.

12. ☐ Measure the [DO] of the room temperature water while continuously stirring the DO probe.

13. ☐ When the DO levels have stabilized on the digits display, note the DO concentration.

14. ☐ Record your data in Table 12.1.

15. ☐ Rinse the DO probe with the wash bottle and return it to the storage bottle.

Set Up: cold water

16. ☐ Obtain 200 mL of ice cold water (approximately 0 °C) in a 250-mL beaker. There should be no ice in the water.

17. ☐ Place the temperature probe into the water.

Collect Data: cold water

18. ☐ Continue monitoring data without recording. (6.1)

19. ☐ Measure the temperature of the cold water and record the temperature in Table 12.1.

20. ☐ Remove the temperature probe from the water.

21. ☐ Carefully place the DO probe into the water. The silver ring on the DO probe should be immersed in water, but the probe should not be touching the bottom of the beaker.

22. ☐ Measure the concentration of DO in the cold water while continuously stirring the DO probe.

23. ☐ When the DO levels have stabilized on the digits display, note the DO concentration.

24. ☐ Record your data in Table 12.1.

25. ☐ Rinse the DO probe with the wash bottle and return it to the storage bottle.

Set Up: warm water

26. ☐ Obtain 200 mL of warm water (approximately 30 °C) in a 250-mL beaker. The temperature of the water should not exceed 45 °C.

27. ☐ Place the temperature probe into the water.

Collect Data: warm water

28. ☐ Continue monitoring data without recording. ◆(6.1)

29. ☐ Measure the temperature of the cold water and record the temperature in Table 12.1.

30. ☐ Remove the temperature probe from the water.

31. ☐ Carefully place the DO probe into the water. The silver ring on the DO probe should be immersed in water, but the probe should not be touching the bottom of the beaker.

32. ☐ Measure the concentration of DO in the warm water while continuously stirring the DO probe.

33. ☐ When the DO levels have stabilized on the digits display, not the DO concentration.

34. ☐ Record your data in Table 12.1.

35. ☐ Rinse the DO probe with the wash bottle and return it to the storage bottle.

Part 2 – Measuring the effects of light intensity on [DO] and primary productivity

In Part 2, you will be measuring the effects of varying light levels on the dissolved oxygen concentration of algae cultures. You will use the Aquatic Productivity Bottles to simulate the decrease in light that accompanies an increase in depth. To create this model of aquatic depth, you will expose bottles of algae culture to five different light levels: 100%, 75%, 50%, 25% and 0%. These percentages are based on the amount of light that reaches the 100% bottle.

Set up

36. ☐ Remove the temperature probe from the data collection system. You only need a digits display of dissolved oxygen concentration.

37. ☐ Obtain approximately 1500 mL of algae culture.

38. ☐ Begin monitoring data without recording. ◆(6.1) If necessary, calibrate the DO sensor. ◆(3.3)

39. ☐ Remove the DO probe from the storage bottle and carefully insert it into the culture. The silver ring on the probe should be immersed in the culture, but the probe should not be touching the bottom of the beaker.

40. ☐ Measure the concentration of DO of the algae culture while gently swirling the probe in the culture.

41. ☐ When the DO levels have stabilized on the digits display, note the DO concentration.

42. ☐ Record the data in Table 12.2.

43. ☐ Rinse the DO probe with the wash bottle and return it to the storage bottle.

44. ☐ You are going to expose the algae to differing amounts of light over the next 24 hours. The measurement that you just took is the initial concentration of DO. In what part of Table 12.2 do you think this measurement belongs? Is it the initial concentration of DO in the 100% bottle? The 50% bottle? All of the bottles?

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45. ☐ Why is it important to take this measurement before you expose the algae culture to the varying amounts of light?

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46. ☐ If your teacher has not already done so, label the bottoms of the five Aquatic Productivity Bottles with the percentages of light.

47. ☐ Fill the bottles, one by one, by completely immersing them in the large vessel of algae culture. While each bottle is submerged, shake it to ensure that all air bubbles have left the bottle and then place the cap on the bottle while it is still submerged.

48. ☐ Remove the capped bottle from the culture and dry it with a paper towel.

49. ☐ When all of the bottles are filled, place them into the cradle chambers, secure the lid on top. Place the bottles in the incubation area under a fluorescent light and allow them to sit undisturbed for 24 hours.

50. ☐ List the independent and dependent variables in this part of the experiment.

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Collect Data

51. ☐ After 24 hours, find your bottles, bring them back to your lab station, and remove the lid.

52. ☐ Display Dissolved Oxygen (mg/L) in a digits display. ◆(7.3.1)

53. ☐ Lay several paper towels onto the lab table. Starting with the 100% bottle, take the bottle out of the apparatus, place it onto the paper towels and carefully remove the cap.

54. ☐ Start data recording. ◆(6.2)

55. ☐ Remove the DO probe from the storage bottle and carefully insert it into the culture. The silver ring on the probe should be immersed in culture, but the probe should not be touching the bottom of the beaker.

56. ☐ Measure the concentration of DO of the algae culture while gently swirling the probe in the culture.

57. ☐ When the DO levels have stabilized on the digits display, stop data recording. ◆(6.2)

Note: Try not to introduce any air bubbles into the solution during data collection.

58. ☐ Record the data in Table 12.2.

59. ☐ Rinse the DO probe with the wash bottle in between each bottle. Return the probe to the storage bottle when finished.

60. ☐ Repeat this procedure with each of the remaining four bottles (75%, 50%, 25%, and 0%).

61. ☐ Gather class data and record in Table 12.2.

62. ☐ Net productivity is the amount of light energy converted to chemical energy minus the energy used for respiration. Which bottles would you use to calculate net productivity?

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63. ☐ Gross productivity is the total amount of light energy is converted into chemical energy. Which bottles would you use to calculate gross productivity?

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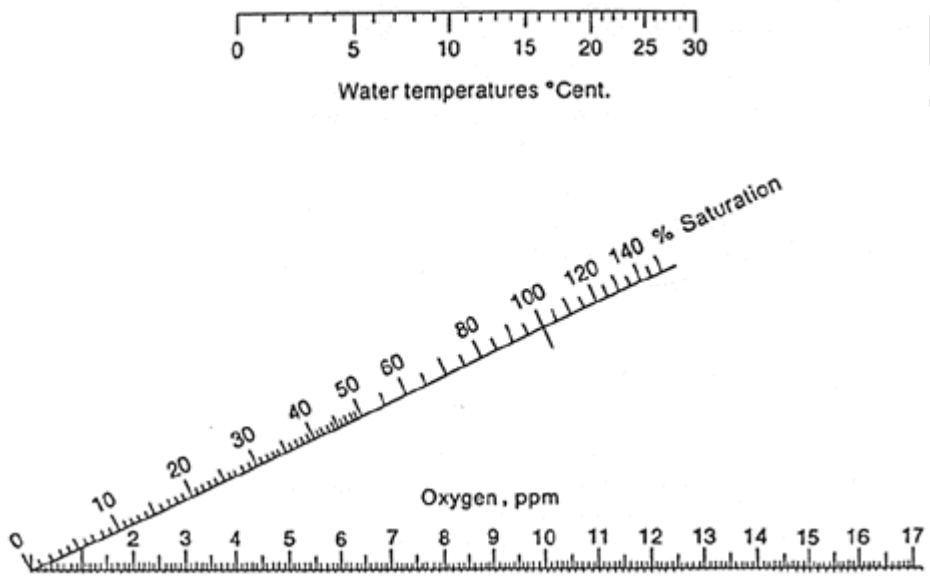
Data Analysis

1. ☐ Use the nomogram in the figure below to estimate the percent oxygen saturation of the water sample at each of the three temperatures. To do this, line up the edge of a straight edge or ruler to the temperature of the water on the top scale and the [DO] that you measured at that temperature on the bottom scale. The ruler will pass over the middle scale at the estimated percent saturation. Record this value in Table 12.1.



Nomogram of oxygen saturation

2. ☐ Gather class data and enter in Table 12.1.

3. ☐ Calculate the respiration rate (R) for your group's algae solution. *R* equals the total amount of dissolved oxygen consumed in the bottle that received no light (0% bottle), since there was no photosynthetic activity in that bottle. So:

R = Initial DO concentration – Final DO concentration (0% bottle).

4. ☐ Record your group's respiration rate in Table 12.3.

5. ☐ Collect class data and record class average of respiration in Table 12.3.

6. ☐ Calculate the net primary productivity (NPP) of the algae in each of your group's bottles.

NPP = Final [DO] of bottle – Initial [DO] of bottle

7. ☐ Record your group's net primary productivity for each of the bottles in Table 12.4.

8. ☐ Collect class data, calculate the average, and record this data in Table 12.4.

9. ☐ Calculate the gross productivity of the algae in each of your group's bottles.

GPP = *NPP* of bottle + *R*

10. ☐ Record your group's gross primary productivity for each of the bottles in Table 12.4.

11. ☐ Collect class data, calculate the average, and record in Table 12.4.

Table 12.1: Dissolved oxygen at varying temperature

	Temperature (°C)	**Group Data: [DO] (mg/L)**	**Class Average: [DO] (mg/L)**	**Group Data: [DO] from nomogram (% saturation)**	**Class Average: [DO] from nomogram (% saturation)**
Room Temp.					
Cold					
Warm					

Table 12.2: Dissolved oxygen at varying light intensity

Bottle	**Group Data: Initial [DO] (mg/L)**	**Class Average Initial [DO] (mg/L)**	**Group Data: Final [DO] (mg/L)**	**Class Average Final [DO] (mg/L)**
100%				
75%				
50%				
25%				
0%				

Table 12.3: Total amount of aerobic cellular respiration (R)

	Group data	**Class Average**
Initial [DO] (mg/L)		
Final[DO] 0% Bottle (mg/L)		
Respiration Rate (*R*) (mg/L)		

Table 12.4: Net primary production (NPP) and gross primary production (GPP)

Bottle	Group Data: GPP (mg/L)	Group Data: NPP (mg/L)	Class Average: GPP (mg/L)	Class Average: NPP (mg/L)
100%				
75%				
50%				
25%				
0%				

Analysis Questions

1. The change in DO concentration in the 0% bottle during the incubation period is a measure of respiration. Why is this particular bottle used to calculate respiration rate?

2. What is the relationship between temperature and the solubility of gases like oxygen in solution? Use evidence from part 1 to support your claim.

3. What is the relationship between temperature and the % saturation of a solution? Use evidence from part 1 to support your claim.

4. **Compare the NPP and GPP of the five bottles and make a statement about the relationship between light intensity and photosynthetic activity. Use evidence from your experiment to support your claim.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Design an experiment that would test the effects of varying pH on dissolved oxygen concentration and the productivity of an aquatic ecosystem.**

2. **What are some adaptations that aquatic organisms have that allow them to adapt to the very low dissolved oxygen concentration in aquatic ecosystems?**

3. **When this experiment is conducted with pond water instead of pure algae solutions, results can vary greatly. Explain why pond water might respond differently to varying light intensity than pure algae solution.**

4. At 22°C a solution contains 4.8 mg/L of DO and is at 53% saturated. The same solution at 29°C contains 4.4 mg/L of DO and is 56 % saturated. Explain why increased temperature decreases the solubility of a gas in solution but increases the percent saturation of a solution.

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following is the best definition of net primary productivity?

- **A.** The amount of oxygen produced by plants and algae.
- **B.** The amount of oxygen used by plants and algae.
- **C.** The total primary production in an ecosystem.
- **D.** The amount of light energy converted to chemical energy by autotrophs during a given time period.
- **E.** The amount of light energy converted to chemical energy by autotrophs during a given time period minus the amount used by the autotrophs in respiration.

2. When comparing photosynthesis and respiration, which of the following statements is true?

- **A.** Carbohydrates are produced in respiration, but not in photosynthesis.
- **B.** Oxygen is produced in photosynthesis, but not in respiration.
- **C.** Oxygen is produced in respiration, but not in photosynthesis.
- **D.** Water is produced in photosynthesis, but not in respiration.
- **E.** Carbon dioxide is produced in photosynthesis, but not in respiration.

3. A scientist studying the oxygen concentration in sealed chambers containing cultured plant cells finds that when the chambers are illuminated, the concentration of oxygen increases. However, when the chambers are kept in the dark, the concentration of oxygen decreases. Why does the oxygen concentration decrease when the chamber is kept in the dark?

- **A.** Plant cell mitochondria consume oxygen by aerobic respiration.
- **B.** Plant cell chloroplasts run the photosynthetic pathways backwards to consume oxygen.
- **C.** Plant cell chloroplasts switch their structure and function and become mitochondria.
- **D.** The chambers are not properly sealed and oxygen is leaking out.
- **E.** The cultures in the chambers must be contaminated with some animal cells, since only animal cells consume oxygen.