LAB TWELVE DISSOLVED OXYGEN AND AQUATIC PRIMARY PRODUCTIVITY

OVERVIEW

1. In Exercise 12A your students will measure and analyze the dissolved oxygen (DO) concentration in water samples at varying temperatures.
2. In Exercise 12B they will measure and analyze the primary productivity of natural waters or lab cultures using screens to simulate the attenuation (decrease) of light with increasing depth.

TIME REQUIREMENTS

Exercise 12A requires 45 minutes.

If time and your interest and expertise permit, you could conduct this lab during a field trip to a lake, river, or bay. A supplement to this lab includes the Winkler technique and necessary materials (see page 85 in this teacher's manual).

Exercise 12B requires 30 minutes for Day 1 and 45 minutes for Day 2.

STUDENT MATERIALS AND EQUIPMENT

Exercise 12A

Setup for Each Pair or Group of Students	Amount Needed
kit to determine DO content of water*	1
fresh water at 0–5°C, at 20°C, or 30°C (use a different temperature for each group)	100 mL
additional 300-mL Biological Oxygen Demand (BOD) bottle to accompany kit	1
thermometer	1
aluminum foil	1

Exercise 12B

Setup for Each Pair or Group of Students	Amount Needed
kit to determine DO content of water*	1
lake, pond, or sea water, or algal (*Chlorella*) culture	500 mL
additional 300-mL Biological Oxygen Demand (BOD) bottles to accompany kits	7
aluminum foil	enough to wrap 1 BOD bottle
plastic window screens, approximately 5″ x 5″**	17
rubber bands	4–8
marking pen and labeling tape	1

* Kits for measuring dissolved oxygen are available from many supply companies.
** Screens can be obtained from a hardware store.

The approximate light attenuation characteristics for layered screens are listed below:

Percent Light	*# of Screen Squares*
100%	0
65	1
25	3
10	5
2	8

PREPARATION SUGGESTIONS

Exercise 12A:
Set up water samples of different temperatures well before class to allow for oxygen equilibration. Consider using a demonstration of opening 2-liter bottles of seltzer water or soda that are at different temperatures. The warmer bottles will lose much of their carbonation upon opening.

Exercise 12B:
Be certain to place the light source far enough away from the experimental bottles to avoid overheating them. (A good check is to hold your hand by the bottles in front of the light to detect heat. Your hand should not be warm.) An alternative would be to use a heat sink or a clear container of water between the light source and the experimental bottles.

EXERCISE 12A: Dissolved Oxygen and Temperature

SAMPLE RESULTS

Depending on the testing procedure you use, the dissolved oxygen may be measured in parts per million (ppm) or milligrams per liter (mg/L) or milliliters per liter (mL/L). You should be able to make conversions between each of these with the following information (where .698 mg/mL, or .7 for simplicity, represents the ratio between the mass of O_2 and the volume it occupies at STP):

$$\text{ppm } O_2 = \text{mg } O_2/\text{L}$$

$$\text{mg } O_2/\text{L} \times 0.698 = \text{mL } O_2/\text{L}$$

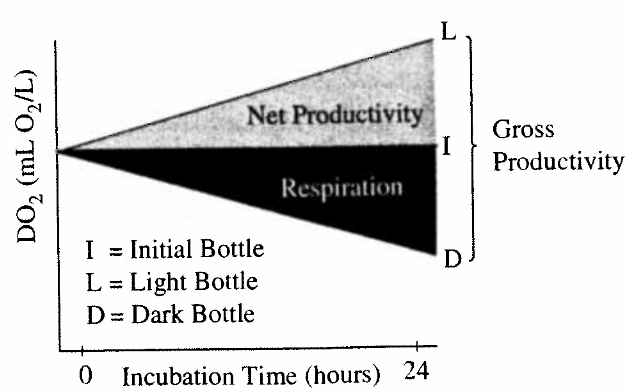
From this you can also calculate the amount of carbon fixed in photosynthesis as follows (where .536 mg C/mL O_2 represents the ratio between a given mass of C fixed in sugar and the volume of O_2 released during that fixation):

$$\text{mL } O_2/\text{L} \times 0.536 = \text{mg carbon fixed/L}$$

Note: A lake becomes eutrophic when mg carbon fixed/L = 85.

Figure 12.3 (from page 140 in the student manual) is useful in illustrating the changing concentrations of oxygen.

Figure 12.3: Light-Dark Bottle Method to Determine Gross Productivity



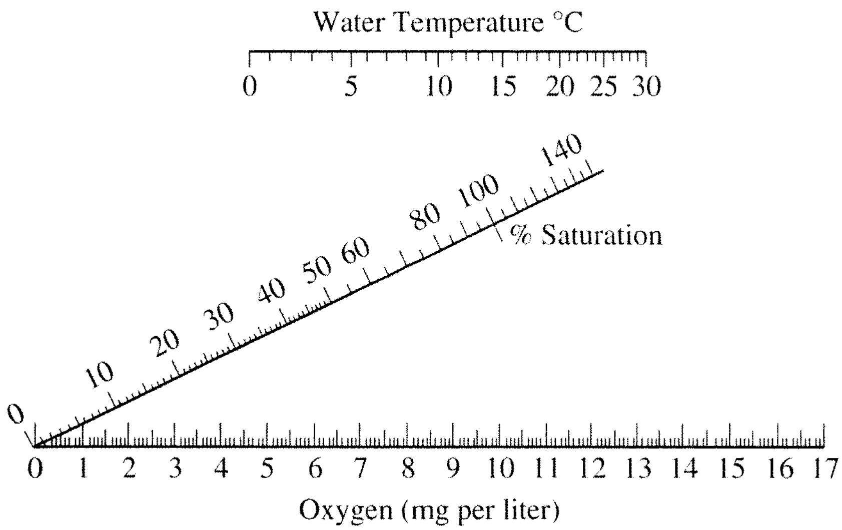
L – I = Net Productivity
I – D = Respiration
[illegible]

Questions

(from pages 143–144 in the student manual)

1. Rate of O_2 production
   Rate of CO_2 uptake
   Rate of carbohydrate or biomass
2. For each milliliter of oxygen produced, 0.536 milligrams of carbon is assimilated.
3. The relationship is an inverse one. As the temperature in a liquid rises, the amount of gas that remains dissolved in the liquid decreases. The most oxygen-rich water is shallow, rapidly moving, and cold. At 4°C, water can hold approximately 19% oxygen.
4. Will vary with class data.
5. Water is much thicker than air. This means that the gill muscles must work much harder to move water over the gills' surfaces. Another factor is that water holds much less oxygen (5 to 10 milliliters per liter) than does air (200 milliliters per liter).
6. You would expect a higher DO reading in the stream water in comparison to the lake water. As the stream moves over rocks in the stream bed, the tumbling action oxygenates the water. Also, the shallowness of the stream means that more water comes in contact with the atmosphere, thus increasing the amount of oxygen carried in the water.
7. The DO at 7:00 a.m. would be lower than the DO at 5:00 p.m. The DO would have been reduced greatly by respiration by all organisms (not just phototrophic organisms) throughout the night and morning, while the low levels of light early in the morning would not produce as much DO through photosynthesis as would be produced by the light of increasing brightness later in the day.
8. A. At a particular temperature, only a fixed amount of oxygen could be dissolved in a given volume of water. Since the volume of water is greater, the amount of oxygen dissolved in the water would be greater. (The slightly larger surface area in B at the air/water interface would allow a slightly greater rate of diffusion from the atmosphere into the water, but this difference would be insignificant compared to the difference attributable to the volume of water.) Over the course of a day, the fish would use up the DO in both containers, and the one with more surface area (B) would better sustain the fish. The term "oxygen available" depends on time. Initially, container A would have more; over time, B would have "more available" due to more surface area.
9. Eutrophication is the increase in concentration of nitrogen, phosphorus, and other nutrients in bodies of water. Nitrogen and phosphorus tend to be limiting nutrients in natural bodies of water (nitrogen tends to be limiting in marine and estuarine ecosystems, while phosphorus tends to be limiting in freshwater ecosystems). By increasing the amounts of these nutrients in bodies of water, the types of organisms that are most successful or that have the greatest biomass change. These changes affect the entire ecosystem. The most common effect is for there to be tremendous blooms of algae. These algae produce large amounts of oxygen during the day, but respiration by the algae at night often depletes the DO to zero at night. In addition, dense growths of algae at the surface may shade out the waters beneath, limiting the primary productivity and causing anoxia in the underlying waters. The algae often eliminate (through competition) the natural food of herbivores in the ecosystem.

Figure 12.2: Nomogram of Oxygen Saturation
(from page 139 in the student manual)



EXERCISE 12B: A Model of Productivity as a Function of Depth in a Lake

SAMPLE RESULTS

Table 12.4: Class Data—Mean Productivity
(from page 142 in the student manual)

# of Screens	% Light	Gross Productivity*	Net Productivity*
0	100	*0.15*	*0.06*
1	65	*0.15*	*0.06*
3	25	*0.13*	*0.04*
5	10	*0.10*	*0.01*
8	2	*0.06*	*-0.03*

Respiration*
0.09

Note: These data will be highly dependent on the source of the culture.

* mLO_2/L/hr