

BIOLOGY 1240: BIOLOGY LABORATORY  
FALL SEMESTER — 2001

LAKE PHOTOSYNTHESIS  
LAB INSTRUCTOR TEACHING GUIDE

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## LAKE PHOTOSYNTHESIS LAB: INSTRUCTOR GUIDE

### Introduction

This guide is intended to give help to biology lab instructors in the lake photosynthesis lab exercises. The usual philosophy of teaching for the labs applies here.

### Overall Objectives of the lake photosynthesis lab

We want the students to learn (1) General: reason about models that fit data; understand the effect of light on photosynthesis (2) Specific: (a) to understand a model of light saturation during photosynthesis; (b) calculate total lake photosynthesis, (c) convert units for lakes, (d) measure light levels, (e) understand the compensation point as it relates to depth and incident light levels.

### Section 2: Guessing the Effect of Light

The students are to draw a few curves to make definite their qualitative expectations for the effects of light on photosynthesis.

### Learning Objectives

(1) distinguish among possible curves for the light-photosynthesis relation, (2) reason why some curves are unlikely

### Discussion

1. Call on all groups for input, taking part of the solution from each.
2. If one group is way off base, don't ignore or berate: put their diagram up separately.
3. You will get curves increasing to a maximum, possibly in an S shaped (sigmoid) curve. An S-shaped curve is possible, but it depicts a process that **accelerates** at low light. This suggests that at low light, higher arrival rates of photons produce more oxygen, than at lower arrival rates. (The **slope** of the curve is increasing when light levels are low.) This is a **positive feedback** effect: higher light levels cause the system to become more efficient.
4. The non-S-shaped curve depicts continuously decreasing slope as light levels increase. But at low light levels, the increase with light is nearly linear. This is consistent with the verbal hypothesis that as photon arrival rate increases the capacity of biochemical system to process photons is reduced. (This is the opposite of the S-shaped curve.) The reason is that time is required for the biochemical machinery to convert light, water, etc into sugars: ATP, enzymes, and substrates all have to move in space (albeit, small dimensions) to coincide for the reactions to take place.  
An analogy that connects with the next lab on Holling disc equation: Big Macs arrive at a low rate 1/8hr, could you eat all of them at that rate? (yes). What about 2/8hr? 10/8hr? Is your ability to consume Big Macs increasing or decreasing as arrival rates increases?
5. Argue them away from thinking it may be linear.

6. If students suggest photoinhibition as a possible curve (curve bends over at high light), do not discourage it. Rather, make this a positive point, but indicate that we are going to assume that this does not occur. Emphasize that the models are approximations and do not always apply over all light levels.
7. It is not necessary to have concensus here. Just list the possibilities.

### Section 3: Performing the Experiment

#### Learning Objectives

(1) See that high light intensity increases photosynthesis rate, (2) understand the concept of experimental treatment applied to light levels, (3) understand why sodium bicarbonate is needed.

#### Discussion

There is nothing to discuss here unless there were problems. If a group's experiment failed, this is a wonderful opportunity to apply the scientific method: eliminate possibilities. Get the class as whole to discuss it. Otherwise, make sure the class data is on the board.

### Sections 4 and 5: Guessing the Equation

This is the challenging part of this lab exercise.

#### Learning Objective

(1) Understand that drawing a single curve through data means that departures from the curve is experimental noise, (2) apply math modeling concepts by guessing an equation that corresponds to a curve.

#### Discussion

After the students struggle with Section 4 in which they are supposed to create an equation, reconvene the class and work them through Step 4. This has the actual model on it. Please read this presentation, because it differs a bit from what I did in class.

Equation for Curve

Develop the equation after you scale the photosynthesis data to go from 0.0 to 1.0 (rather than the maximum value they found in their experiments). After you have that equation, scale the equation by  $O_{\max}$ .

Work through the mini-quizzes with the class.

## Sections 6 and 7: Estimating $b$

### Learning Objectives

(1) More work with logs. (2) More fitting data to equations

### Discussion

This is straight-forward, just apply the log rules. You can't get estimates for all parameters, so we'll "eyeball"  $O_{\max}$  and use that to get  $b$ .

First, isolate  $e^{-bI}$  by itself on one side of the equals sign.

$$\begin{aligned} O &= O_{\max} (1 - e^{-bI}) \\ \frac{O}{O_{\max}} &= 1 - e^{-bI} \\ e^{-bI} &= 1 - \frac{O}{O_{\max}} = \frac{O_{\max} - O}{O_{\max}} \end{aligned}$$

Next, take the natural log of both sides:

$$\ln(e^{-bI}) = \ln\left(\frac{O_{\max} - O}{O_{\max}}\right)$$

Finally, apply the laws of the natural logs:

$$-bI = \ln(O_{\max} - O) - \ln(O_{\max})$$

And re-arrange to make this look like an equation for straight line:

$$\begin{aligned} \ln(O_{\max} - O) &= \ln(O_{\max}) - bI \\ (y &= b + mx) \end{aligned}$$

As hard as it may be to believe, this is an equation for a straight line.  $\ln(O_{\max} - O)$  is the dependent variable,  $\ln(O_{\max})$  is the intercept,  $I$  is the independent variable,  $-b$  is the slope.

Then apply it to the class data.

## Section 8 and 9: Solving the Lake Problem

In Section 8, the students try to discover a plan for solving the problem by breaking it into pieces.

### Learning Objectives

(1) Solving an integration problem by breaking the lake into pieces. (2) Putting 2 equations together to solve the problem.

### Discussion

Conceptually, solving the problem is easy. We have an equation for light with depth and we have an equation for photosynthesis with light. We step through a 1 meter by 1 meter water column calculating light and photosynthesis. The total for the column is the sum of all the small pieces (see figure)

**Section 10: Solved Problems****Discussion**

The answers are self-explanatory, so the students can do these outside of class. You can suggest that they try them on their own and email you questions. Or, you can do them in class if time is available.

**Step 9: Homework**

To you by Tuesday AM.