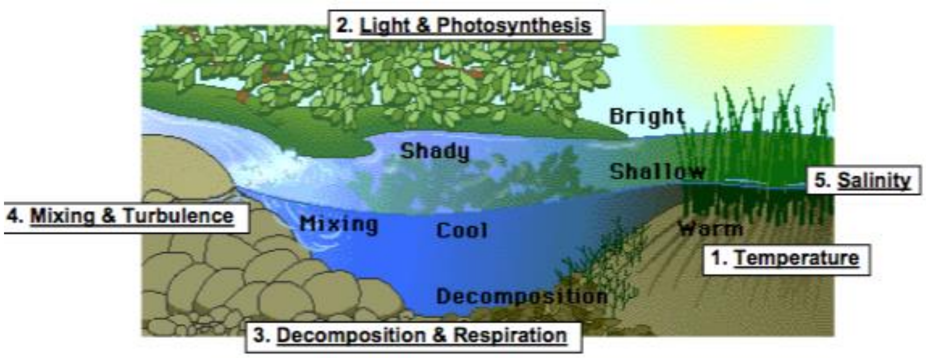
Dissolved Oxygen, Primary Productivity and Energy Dynamics Activity

Introduction: DO is often used as an indicator of water quality. You have probably read or seen news reports of fish kills that have been linked to sewage spillage. Aquatic microorganisms metabolize the sewage, using up DO. As DO levels drop, fish cannot acquire the oxygen they need, and they die. DO concentration is expressed in parts per million (ppm) or mg/L. Desirable fish species such as trout and perch require a minimum of 8 mg/L dissolved oxygen to survive. Less-desirable fish such as carp can survive at dissolved oxygen levels as low as 2 mg/L. Below 2 mg/L, only invertebrates such as sludge worms and mosquito larvae can survive. How does oxygen enter the water?

Purpose: In this activity, you will analyze the factors that can affect DO availability and productivity in a lake when depth is the variable.

Prior Knowledge: How do you think the following factors affect the availability of oxygen in a pond or lake?



a) Temperature____
b) Light____
c) Decomposition____
d) Mixing/Turbulence____
e) Salinity____

Lab Bench Activity: Dissolved Oxygen and Aquatic Primary Productivity

Go to: http://www.phschool.com/science/biology_place/labbench/lab12/intro.html

1. Why must oxygen be dissolved in an aquatic environment?

2. What two variables are you looking at in this lab?

Click "Next" read the Key Concept and click "next concept"

3. Oxygen is essential for ______________________________ in most organisms.
4. List the five factors that affect the amount of oxygen dissolved in water. State how the factor affects the amount of oxygen.
   a.
   b.
   c.
   d.
   e.

Click "Next concept"

5. Which environment has the greater concentration of dissolved oxygen: salt water or fresh water?
6. Which environment has the greater concentration of dissolved oxygen: warm water (31°C) or cool water (18°C)?
7. Which environment has the greater concentration of dissolved oxygen: a clear pond or a pond with a heavy algal mat? Explain.

Click "Next concept"

8. Define: Primary productivity
9.
   - Gross productivity
   - Net productivity

10. We cannot measure gross productivity directly because respiration, which uses up oxygen and organic compounds, is always occurring simultaneously with ____________________________ — but we can measure it indirectly. How do we do this?
    a.
    b.
    c. How does this allow us to calculate gross productivity?

Click "Next concept"

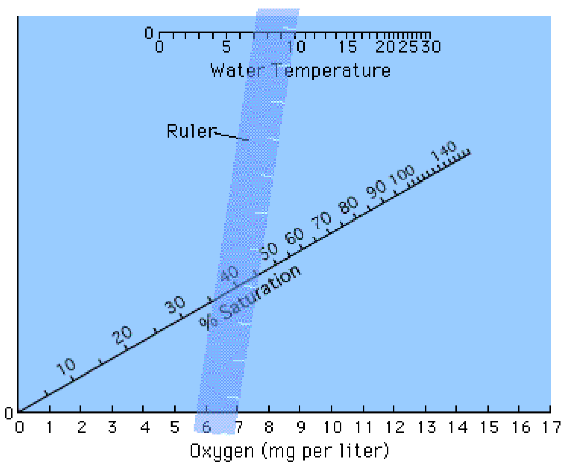
11. The equation for photosynthesis is:

12. Because this lab focuses on dissolved _____, we don't include _____ in our discussions. However, don't forget that _____ plays a major role in both photosynthesis and cellular respiration.

13. Primary productivity can be measured in three ways: Circle the one that we will use in this lab.
    a.
    b.
    c.
14. Do you understand why this measurement will reveal primary productivity? Explain.

Watch the Bozeman video: AP Biology Labs 12-Dissolved Oxygen to learn about the Winkler titration Method. This is the method that would be used to get the data you are working with.

Click "Next" Using the Nomograph below answer questions 15 and 16.



15. What is the percent oxygen saturation for a water sample at 10°C that has 7 mg O_2/l?
16. What is the percent oxygen saturation for a water sample at 25°C that has 7 mg O2/l?
17. Which holds more dissolved oxygen? Hot or cold water

Click "Next"

18. The amount of light available for photosynthesis ______________ off sharply with ___________ depth in an aquatic environment. You model this condition by wrapping water-sample bottles with increasing layers of screen.
19. What photosynthetic organism is used in this lab?
20. What are the percentages of light that you are working with in this lab? _______, _______, _______, _______, _______, ________.

Click “A closer look”

21. What two things are happening to the O2 in the initial light bottle?

Click “A closer look”

22. What two things are happening in the dark bottle?

Click “A closer look”

23. What two things are happening to the O2 in the light bottles?

Click “Next”

24. On the first day of the laboratory, you measure the amount of ___________ present in your original sample. You then measure the amount of __________ present after _____________ of ____________________ and ______________________ under the light conditions in each bottle.

    1. The aquatic sample must be rich in ___________________ _________________________ — water that is so algae-rich it appears green is good for this activity.

Click “Next”

Initial DO –

Dark DO = ______________________

Light DO –

Dark DO = ______________________

Light DO –

Initial DO = ______________________

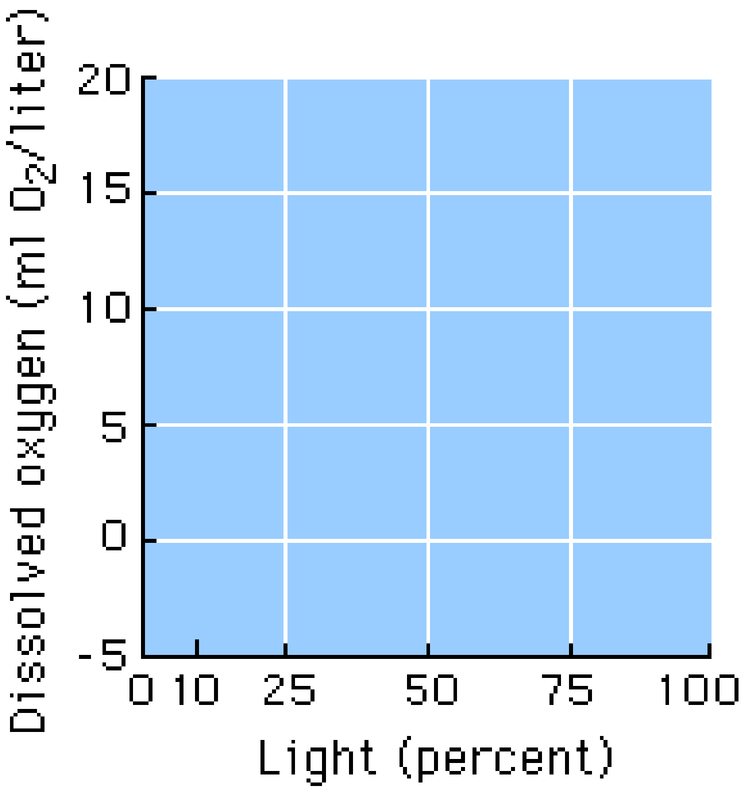
Click “Next”

A biology student inadvertently removed all the screens and labels from the water-sampling bottles before he measured the amount of dissolved oxygen. When he tested the unidentified bottles, he obtained the results shown below.

The initial oxygen reading for this water was **4 mg O_2/l.** Based on the results predicted by the hypothesis that light increases productivity, enter the letter of the bottle that corresponds to each light percentage. Then complete the rest of the table and graph the **gross and net** productivity for this data.

Fill in the table using the information from the sample problem.

Amt of light (%)	Letter of bottle	Amount of dissolved O2 (mg/l)	Gross productivity (mg/l)	Net productivity (mg/l)
0				
2				
10				
25				
65				
100				



Click "Self_Quiz". Take the quiz and click "Check Your Answers" Take a screen shot and email to me (mrs.naber@gmail.com) or print out and attach to this packet.

Energy Dynamics Lab

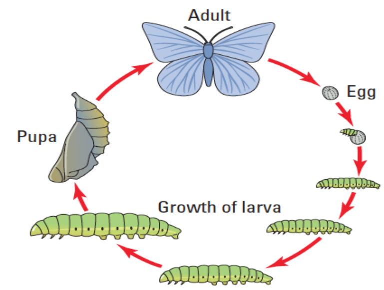


Figure 1. Butterfly Life Cycle

■■Background

Almost all life on this planet is powered, either directly or indirectly, by sunlight. Energy captured from sunlight drives the production of energy-rich organic compounds during the process of photosynthesis. These organic compounds create biomass**. The net amount of energy captured and stored by the producers in a system is the system's net productivity. Gross productivity is a measure of the total energy captured.**

In terrestrial systems, plants play the role of producers. Plants allocate that biomass (energy) to power their life processes or to store energy. Different plants have different strategies of energy allocation that reflect their role in various ecosystems. For example, annual weedy plants allocate a larger percentage of their biomass production to reproductive processes and seeds than do slower growing perennials. As plants, the producers are consumed or decomposed, and their stored chemical energy powers additional individuals, the consumers, or trophic levels of the biotic community. Biotic systems run on energy much as economic systems run on money. Energy is generally in limited supply in most communities. Energy dynamics in a biotic community is fundamental to understanding ecological interactions.

■■Learning Objectives

- To explain community/ecosystem energy dynamics, including energy flow, net primary productivity (NPP), and primary and secondary producers/consumers
- To demonstrate understanding of mathematical analyses in energy accounting and community modeling by calculating biomass and NPP, using data from a model system based on Brassica plants and butterfly larvae.

■■ Estimating Net Primary Productivity (NPP) of Fast Plants

Primary productivity is a **rate** — energy captured by photosynthetic organisms in a given area per unit of time. Based on the second law of thermodynamics, when energy is converted from one form to another, some energy will be lost as heat. When light energy is converted to chemical energy in photosynthesis or transferred from one organism (a plant or producer) to its consumer (e.g., an herbivorous insect), some energy will be lost as heat during each transfer.

In terrestrial ecosystems, productivity (or energy capture) is generally estimated by the change in biomass of plants produced over a specific time period. Measuring biomass or changes in biomass is relatively straightforward: simply mass the organism(s) on an appropriate scale and record the mass over various time intervals. The complicating factor is that a large percentage of the mass of a living organism is water — not the energy-rich organic compounds of biomass. Therefore, to determine the biomass at a particular point in time accurately, you must dry the organism. Obviously, this creates a problem if you wish to take multiple measurements on the same living organism. Another issue is that different organic compounds store different amounts of energy; in proteins and carbohydrates it is about 4 kcal/g dry weight and in fats it is 9 kcal/g of dry weight).

A. Pre-Lab: Thinking through the processes
(ALL ANSWERS ON DATA SHEETS)

1. **Label** each arrow on the diagrams with appropriate terms to describe energy flow for each situation.

B. Using Sample Data to estimate NPP for Fast Plants

A team of students started 40 Wisconsin Fast Plants from seed. After growing them for 7 days under a regimen of 24 hours of light a day, the team randomly selected 10 plants. The plants were carefully pulled, with their roots. After washing the soil from the roots and blotting the plants, the team found the wet mass of all 10 plants.

Wet mass of 10 plants (Day 7) = 34.5g

The team then took the 10 plants and placed them in a drying oven at 200°C for 24 hours. They then found the dry mass of the 10 plants.

Dry mass of 10 plants (Day 7) = 7.6g

1. **Calculate** the percent of the team's plants that was actually biomass.

2. Note how much of the plant's total mass is *actually* biomass, and how much is water. Remembering that each gram of dry biomass is equivalent to 4.35 kcal of energy, **do the following calculations**:

a. How much energy (in kcal) is found in 10 plants that are 7 days old?
b. What is the average amount of energy that is in 1 plant that is 7 days old?
rate).
c. What is the **NPP per day per plant** for the 7-day-old plants?

3. The team repeated the procedure above on Day 14 and Day 21. **Use the data** they obtained to fill in the data table by making all appropriate calculations. BE CAREFUL to make the proper adjustment for the different number of days.

Wet mass of 10 plants (Day 14) = 62.5g
Dry mass of 10 plants (Day 14) = 15.1g

Wet mass of 10 plants (Day 21) = 91.1g
Dry mass of 10 plants (Day 21) = 25.3g

4. **Complete** the Class NPP Data table for this exercise. Your team's data will go in the empty column as "Team 1." **Find** the Average NPP for each time period, and **graph** that result in the graph provided.

Suggest a reason(s) to explain the pattern of NPP over time.

C. Using Sample Data to estimate Energy Transfer from Producers to Primary Producers

In this part of the lab, teams used Brussels Sprouts as their producers and cabbage butterfly larvae as the primary consumers.
Refer back to the E/Biomass diagram for butterfly larvae you filled out in Pre-Lab #2.
Thinking point: How you would calculate the **secondary productivity** and the amount of energy **lost to cellular respiration**?

Known values (energy contained):
plant 4.35 kcal/g   larvae 5.5 kcal/g   frass 4.75 kcal/g

1. **Suggest** a reason(s) why plants, larvae and frass might contain differing amounts of energy.

2. The team of students made a "brassica barn" by placing Brussels sprouts in an aerated container with 10 caterpillar larvae that were 12 days old. Before assembling the barn, students weighted both the sprouts and the larvae.

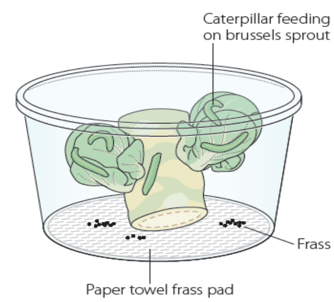


Figure 4. Brassica Barn

> Wet mass of Brussels sprouts = 30g
>
> Wet mass of 10 larvae = 0.3g

After 3 days, the team re-weighed the sprouts and larvae.

> Wet mass of Brussels sprouts = 11g
>
> Wet mass of 10 larvae = 1.8g

A drying oven was then used to find the biomass of the larvae, the remaining Brussels sprouts, and the frass.

> Dry mass of Brussels sprouts = 2.2g
>
> Dry mass of 10 larvae = 0.27g
>
> Dry mass of frass from larvae = 0.5g

Use the data above to complete the table in your answer packet.

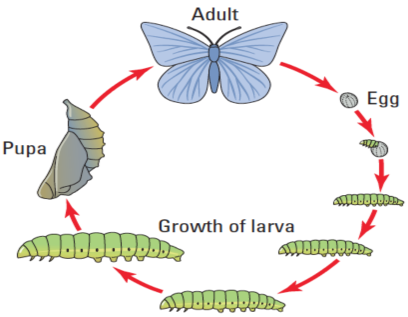
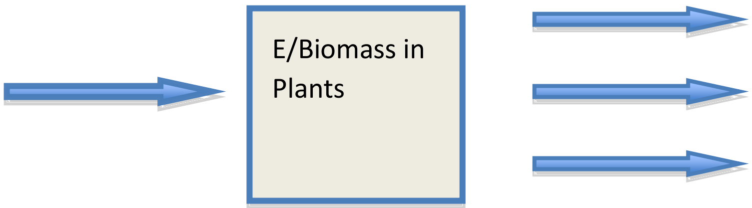


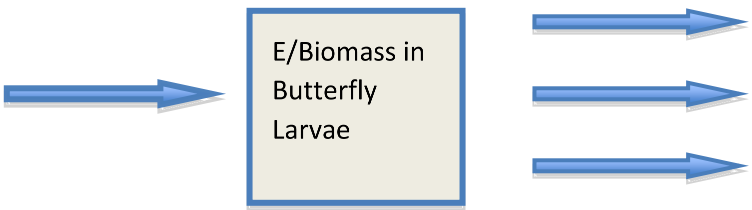
Figure 1. Butterfly Life Cycle

<u>Data Tables</u>: Energy Dynamics Lab

A. Pre-Lab: Thinking through the processes

1. Label each arrow with appropriate terms to describe energy flow for the situation indicated.





B. Using Sample Data to estimate NPP for Fast Plants Data *Show work!*

1. Percent biomass:

2a.

2b.

c. NPP per day per plant:

3. Data Table (Team 1)

Age in Days	Wet mass (10 plants)	Dry mass (10 plants)	Percent biomass	Energy content (total)	Energy content (per plant)	NPP in kcal per day per plant
7						
14						
21						

4. Data NPP Table (Class Data)

Time (days)	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Class Mean
7		0.43	0.47	0.44	0.46	0.44	
14		0.49	0.51	0.50	0.49	0.52	
21		0.55	0.54	0.55	0.53	0.51	

Comment on any pattern seen in graph. **Suggest** a reason(s) to explain the pattern of NPP over time.

PART C: Using Sample Data to estimate Energy Transfer from Producers to Primary Producers

1.

2. Table of Energy/Biomass Flow from Plants to Butterfly Larvae

	Day 1	**Day 3**	**3 day finals, etc.**
Wet mass of Brussels sprouts			Grams consumed _____________
Plant % biomass (calculate for Day 3)	Same as Day 3		
Plant energy (wet mass X % biomass X 4.35 kcal)			Kcals consumed per 10 larvae _____________
Plant energy consumed per larvae	X	X	Kcals consumed per 1 larvae ______________
Wet mass of 10 larvae			Gms gained __________
Wet mass per individual			Gms gained per larvae __________
Larvae % biomass	Same as Day 3		
Energy production per individual (individual wet mass X % biomass X 5.5 kcal/g)			Kcals gained per larvae ________
Dry mass of frass from 10 larvae	X	X	
Frass energy (frass mass X 4.75 kcal/g)	X	X	
Energy of frass from 1 larva	X	X	
Respiration: how much of total energy consumed was lost to respiration?	X	X	