L. Haines

Energy Dynamics Lab "Dry" Version

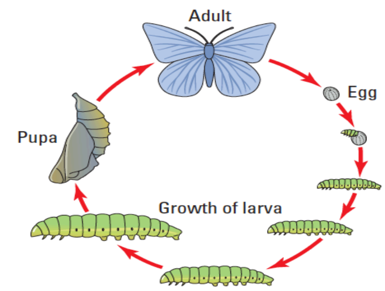

Figure 1. Butterfly Life Cycle

■■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.

■■ Part I: 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. Define the following terms:
- gross primary productivity
- net primary productivity
- secondary productivity

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

B. Procedures: 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). 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. Procedures: 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. With your group, discuss 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.

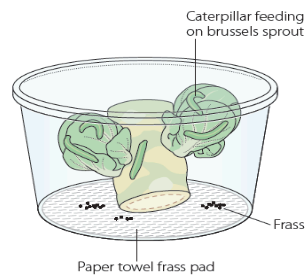

Figure 4. Brassica Barn

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.

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.

D. Complete the exercise by answering the Summary Questions *thoughtfully*.

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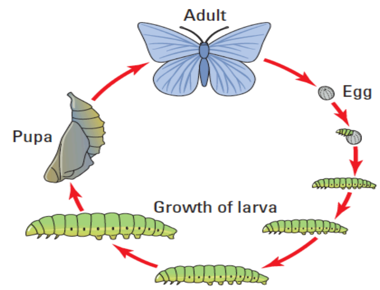


Figure 1. Butterfly Life Cycle

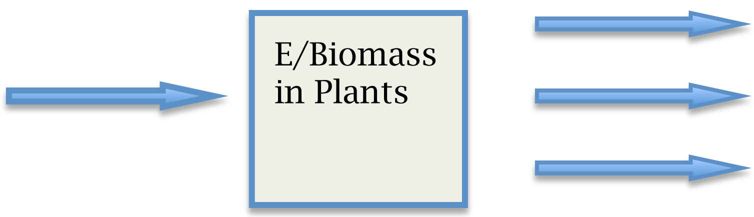
Data Tables: Energy Dynamics Lab “Dry” Version

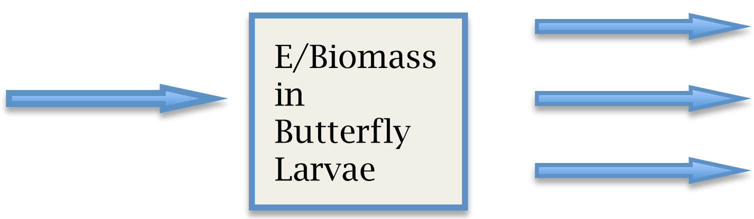
A. Pre-Lab: Thinking through the processes
1. Define the following terms:
- gross primary productivity

- net primary productivity (NPP)

- secondary productivity

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





B. Procedures: Using Sample 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.

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PART C

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	

Part D: Summary Questions

1. State the conclusions from this investigation in no more than three sentences.

2. Construct a diagram modeling the results of this investigation (similar to earlier diagrams). Label all arrows using actual data (numbers) from investigation.

3. Suggest a biological question raised by this investigation. Describe how your team would perform a new investigation to answer this question.