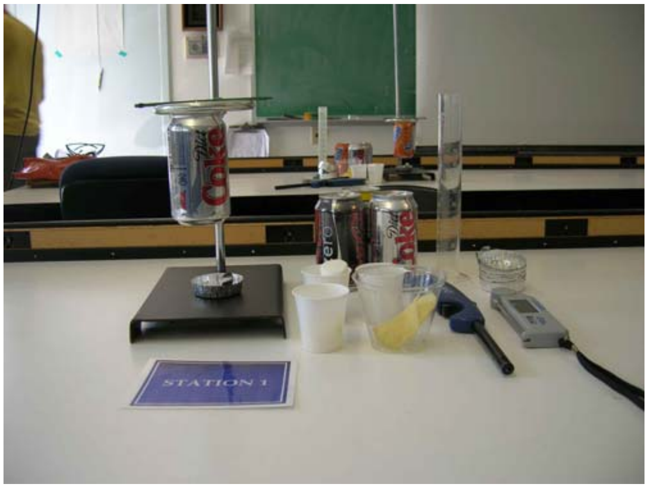
SMS 491/EDW 472
Spring 2008

Energy and Food Webs

Station 1. Class Activity – Homemade Calorimeter (modified after "Burning" Calories http://bioweb.usc.edu/courses/2004-fall/documents/bisc150-lab_burningcal.pdf)

Materials (per group):

- Homemade calorimeter (small soda can and wood/glass rod)
- Digital thermometer
- Lighter
- Graduated cylinder (100 ml)
- Aluminum weighing boats
- Ring stand
- Scale
- Food to burn (e.g., cashews, marshmallows, chips)



Experiment:

1. Of the 2 food items you will be testing, predict which one will have more Calories. Discuss your prediction with your group.
2. Obtain a weigh boat and food item. Record the initial weight (W_i = food item + weigh boat).
3. Measure out 100 ml of water and pour it into the soda can. Measure the initial temperature of the water (T_i).
4. Place the weigh boat + food item on the ring stand base. Ignite the food item.
5. As soon as the item catches fire, lower the can so it rests just above the flame.
6. Once the item has finished burning, use the thermometer to carefully stir the water and measure the final temperature (T_f). **Caution! The can & water will be hot!**
7. Allow the burnt food item to cool then weigh the remnants (W_f = food item + weigh boat).
8. Repeat steps 1-7 for each food item. Make sure you use a new soda can and fresh water for each repetition of the experiment. Record data in the table provided.

Food Item	Weight (Mass) of Food (g)			Temperature of Water (°C)		
	Initial Weight (W_i)	Final Weight (W_f)	Mass of Sample Burned ($\Delta W = W_i - W_f$)	Initial Temperature (T_i)	Final Temperature (T_f)	Change in Temperature ($\Delta T = T_f - T_i$)

Determine Calories of the food items:

By measuring the change of temperature of a known volume of water, you can calculate the amount of energy in the food because the heat gained by the water will equal the heat lost by the food item.

$$Q_{\text{heat lost by food}} = Q_{\text{heat gained by water}}$$

$Q_{water} = (m)(c)(\Delta T)$; m = mass of water (grams; 1g = 1ml)

c = specific heat capacity of water = 1 calorie/g °C

ΔT = change in temperature (°C)

Food Item	Energy or calories (cal)	Calories (Cal) or kilocalories (kcal)	Cal/g

Actual Cal/g: cashew = 160 cal/28.3g = 5.63 Cal/g; Sun Chip = 140 Cal/28g = 5 Cal/g

Questions:

1. Based on the results of your experiment, how many Calories per gram (Cal/g) were in each food item (1 Cal = 1000 cal = 1 kcal)? Did your predictions in (1) hold true?
   Answers will vary.

2. How well does the Calorie content you calculated compare to what is listed on the package? Were you able to determine the entire Calorie content of each item? If differences exist, what may account for these differences? How are some of the sources of energy "loss" in the experiment similar to those observed in nature (e.g., biological processes)?

   A calorimeter can be used to measure the chemical potential energy in food. A combustion reaction releases chemical energy stored in the molecules of fuel in the form of heat. This reaction raises the temperature of the surrounding objects. If the reaction is the system, and everything is the surroundings, then energy in the form of heat is transferred from the system to the surroundings. However, not all of the potential energy in food is available to do work (see from our experimental calorimeters, a lot of heat is lost and not all of material is burned). Some of the energy went in to heating the soda can, some to heat the water, and a lot was "lost" to the surrounding environment. This is similar to nature in that it reinforces the 1st and 2nd Laws of Thermodynamics, which state that no energy conversion is 100% efficient and that any energy that is lost from the system (calorimeter) is gained by the surrounding environment. What we observed was more of an "open" system, rather than a "closed" system created with a "real" bomb calorimeter. But we can apply what we observed and the lack of efficient energy transfer in our experimental calorimeters to how energy moves through ecosystems (food chains and webs in particular).

   In the context of food webs, the available or usable energy than can be transferred from one trophic level to the next is limited because of this lack of energy transfer efficiency. The transfer of energy in food webs or from

one trophic level to another is only 10% efficient. When food is ingested, some of the potential energy is lost from the "system" as waste (non-digestible), some is lost as heat, some is used for general body maintenance, and some of the assimilated energy is used for growth (biomass). As we stated previously, the energy isn't lost, it is still in the "system" or environment, but it isn't readily available as biomass to pass on to higher trophic levels. This "loss" of useable energy limits the length of food chains.

3. How could you improve the experimental design so the results would be more consistent with the packaged values?

   Try to decrease the "loss" of heat to the surrounding environment by creating more of a closed system. Add an outer can or something that could help insulate the soda can and water.

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2. Energy Transfer in Ecosystems
(Modified after "The Root Beer Activity" from the Utah State Office of Education
http://www.usoe.k12.ut.us/curr/science.sciber00/8th/energy/sciber/ecosys.htm)

Materials:

- Candy (1000g)
- 4 large beakers (4 trophic levels/organisms)
- Scale

Instructions:

1. Put 1000g of candy in the first beaker, this represents the amount of available energy. Note: you can either use this as a demonstration in front of the class, or use students as volunteers to represent each trophic level or organisms in a food chain.
2. Now pass 10% of the candy (hint: you can use the scale) or "available energy" to the first trophic level or empty beaker. What trophic level does this represent?
3. Repeat the process for the remaining trophic levels.

4. Why aren't there food chains that support an infinite number of links?
   There isn't enough energy available at higher trophic levels to support a large abundance or populations of organisms.

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3. Class activity – Production/grazing/predation game (from Farallones Marine Sanctuary Association; http://www.farallones.org/documents/education/FoodWeb.pdf)

Materials (per group):
Get game materials from http://www.farallones.org/documents/education/FoodWeb.pdf
6 pages of each trophic level, copied onto colored paper
Stopwatch (1 per group)

Activity:

1. Divide class into groups of 4, and assign each person to a trophic level.
   Nutrients – required for photosynthesis – white (stopwatch duty)
   Primary producers – diatoms - green
   Primary consumers/Grazers – Krill - yellow
   Secondary consumers/Predators – Whales - blue
2. Round Rules:
   - Each round lasts exactly 5 minutes.
   - To begin, lay down the 6 nutrient sheets on a desk.
   - Use the start time and production rate for each trophic level from the chart below.
   - The **start time** is the time at which a trophic level begins growing (start laying down cards).
   - The **production time** is the combination of the feeding, growing, and reproduction rates. It is the time interval between laying cards down.
   - For example in Round 1, primary producers lay down 1 card at the beginning (T = 0), then **subsequently** lay down 1 card every five seconds for the entire 5 minutes. Krill have a time lag of 10 seconds (T = 10), and lay down one card every 10 seconds. Whales start after 20 seconds (T = 20), and lay down 1 card every 30 seconds.
   - Each card represents an abundance of organisms that consumes the abundance of one card of their prey (the lower trophic level). So place cards only over their prey or lower trophic level. Do not overlap cards of the same color. Diatoms (green) lay down their cards on the nutrient sheet. Krill (yellow) on top of diatoms (green) and whales (blue) on top of krill (yellow).
   - Note: when a card is showing, those organisms are alive, feeding, and reproducing. Once a card has been covered up, the organisms have been eaten and are dead (**stop playing**). If a trophic level cannot feed (i.e., lay down cards) because no prey (lower trophic level) cards left uncovered, then that trophic level has crashed (**stop playing**). Record the time when your level crashed!

		Round 1		Round 2		Round 3		Round 4	
Trophic Level	Card Color	start time	production rate	start time	production rate	start time	production rate	start time	production rate
Diatoms	green	0	5	0	5	0	5	0	2
Krill	yellow	10	10	20	3	10	15	10	5
Whales	blue	20	30	25	20	20	10	20	10

Questions:

1. What is the abundance of each tropic level at the end of the game for all four rounds? Which levels are growing at the end of the game for all four rounds?

   Round 1 is a steady state system. All levels are producing at a rate slower than the trophic level below them. The diatoms have the highest (fastest) rate at 1 card every 5 seconds, the krill are the middle with a rate of 1 card every 10 seconds, and the whales are the lowest (slowest) at a rate of 1 card every 30 seconds. Round 2 is a primary producer limited system. The krill are producing at a faster rate than the diatoms, so the diatoms go extinct first and then the other levels crash afterwards. Round 3 is limited by the whales. The whales begin producing before the krill have had time to get going. The diatoms continue to grow through the whole round. Round 4 is limited by nutrients. The diatoms use up the nutrients before the round is over. The krill and whales continue to feed, but the diatoms do not reproduce anymore.

2. Round 1 is in a steady state system. Compare the production rates of the trophic levels. Predict what would happen to the diatoms and whales if this game were to run for another 5 minutes?

   The production rate in Round 1 is increased from one trophic level to the next. If this round continued, the diatoms would crash first because they would run out of nutrients.

3. Why did all the trophic levels crash on Round 2? What are two ways a steady state could be restored for Round 2?

   Diatoms were eaten, so they could not reproduce (lay another card down), then the krill ran out of food, then the whales. The whales survived longer because their production rate was so much slower than the other levels. Krill were eating at a faster rate than the diatoms were photosynthesizing and growing.

   Steady state could be restored in Round 2 by increasing the rate of the diatom production (lowering the rate to below one card per 3 seconds to one card per 2 seconds) or by decreasing the rate of krill production (making the production rate at one card every 6 seconds).

4. What limits the growth of the diatoms in Round 3? What would happen to the diatoms and whales if the game were to run another 5 minutes?

The growth rate of diatoms in Round 3 is limited by nutrients. If this game were to last longer, the krill and whales would go extinct because they would run out of food.

5. What are some of the assumptions and limitations of this model (activity)?

For this model, it is assumed that the feeding rate, reproduction rate, and growth rate are all one rate. In reality, this is not true. The assumptions surrounding when a tropic level crashes are not realistic. This model is limited in predicting the relationships between feeding rates and reproductive rates of different trophic levels. This model is emphasizes the relationship between trophic levels.

		Round 1		Round 2		Round 3		Round 4	
Trophic Level	Card Color	crash time	number of cards	crash time	number of cards	crash time	number of cards	crash time	number of cards
Diatoms	green	-	31	0:44	0	-	60	2:23	45
Krill	yellow	-	20	0:45	8	0:20	0	-	30
Whales	blue	-	10	3:05	8	0:30	1	-	29

		Round 1		Round 2		Round 3		Round 4	
Trophic Level	Card Color	crash time	number of cards	crash time	number of cards	crash time	number of cards	crash time	number of cards
Diatoms	green								
Krill	yellow								
Whales	blue								