Energy Pipeline

Objective: Students will explain why energy dissipates at each trophic level and relate the role of each trophic level to ecosystem dynamics.

Materials: Dried beans, bucket labeled "Used-Up Calories," zip-lock baggies, metabolism cards, bowls or small containers (5 for each pair of students), 6 small paper cups, 3" x 5" cards (one per pair of students), bell or whistle, and Total Growth chart.

Background: In every ecosystem, the biotic and abiotic components are linked by energy flow and material cycling. Each trophic level within an ecosystem is defined according to its major role at each level (producers, consumers, and decomposers). The trophic level that ultimately supports all others consists of producers or autotrophs, plants that use sunlight to make organic compounds (sugars) which provide energy for metabolic processes and growth. All other organisms are heterotrophs, consumers that are unable to make their own food. Either directly or indirectly, plants support nearly all forms of animal life, including humans. The primary consumers of plants are the herbivores, the secondary consumers that eat herbivores are the carnivores, and the tertiary/quaternary consumers may be carnivores or omnivores.

Energy flow through the ecosystem determines the trophic relationships. Because energy is lost at each level, each successive trophic level contains less energy, less organic material, and fewer numbers of organisms. As a rule, about 90% of the available energy for any trophic level is lost through heat, movement, and other metabolic activities. Only about 10% (on average) is available for transfer to the next level. For this reason, food chains tend to be short. When animals consume most of their food from a secondary or tertiary level, the transfer of energy is less efficient that it is when they consume at the primary level. There are relatively few top predators in an ecosystem because of this considerable loss of energy between levels. As much as a million calories in plant material may be needed to support 1,000 calories stored by a secondary carnivore.

Purpose: To demonstrate some of the complex trophic interactions resulting from the flow of energy throughout ecosystems.

Procedure:

1. Each student pair will receive a set of five metabolism cards representing the energy use of either plants (autotrophs), primary consumers (herbivores), or secondary consumers (carnivores). One student pair will represent the sun and will not receive a set of metabolism cards. The sun pair needs two cups to carry seeds.
2. Non-sun pairs – place one metabolism card in each of the five bowls.
3. Sun pairs – hand out 10 seeds (in a cup) to each plant pair. Each seed represents sunlight containing one calorie of energy. Continue filling and handing out cups of 10 seeds or "calories" to each plant pair that requests one.
4. Plant pairs –
    - Sort the "calories" in your bowls as indicated by the metabolism cards.
    - Once all 10 "calories" have been placed in the proper bowls, ask the sun pair to supply another 10 "calories."
    - Continue distributing seeds, 10 at a time, in your bowls until you have accumulated 10 "calories" in the "growth" bowl.
    - You are now large enough to be "eaten" by the herbivores. Place the 10 calories from the "growth" bowl into a baggie and hand it to one of the herbivore pairs. The seeds in the other bowls should now be discarded in the bucket labeled "Used-Up Calories."
    - Record one tally mark on your 3" x 5" card for each baggie produced.
    - Request additional "calories" from the sun pair and continue sorting and producing bags until the end of the round.
5. Herbivore pairs –
    - Taking one baggie at a time that is received from plant pairs, sort the "calories" in your bowls as indicated by the metabolism cards until you have accumulated 10 "calories" in the "growth" bowl.
    - Place the 10 "growth" bowl calories in a baggie and hand it to the carnivore pair. The seeds in the other bowls should now be discarded in the bucket labeled "Used-Up Calories."
    - Record one tally mark on your 3" x 5" card for each baggie produced.
    - Continue sorting and producing bags until the end of the round.

6. Carnivore pair – take the first bag received from one of the herbivore pairs and sort the 10 "calories" in your bowls as indicated by the metabolism cards. *As soon as the final stone from this first bag is placed, signal the end of the round.*
7. The moment the signal is given for the end of the round, all pairs stop and count the total number of baggies produced and record results on the class data table.

   For herbivore and plant pairs:

   Growth Calories = # of baggies produced times 10 (each baggie contained 10 "calories")

Data Table and Observations

Total Growth Chart

Organism Type	**Round 1**	**Round 2**	**Round 3** (optional)	
	Growth Calories	Growth Calories	Growth Calories	Nutrients
Carnivore				
Herbivore				
Plant				
Bacteria (optional)				

Analysis Questions: Answer the questions in complete sentences making sure to incorporate the question into the answer.

1. Using the organism types above, create a food chain. Give the trophic level for each organism type. Make sure that arrows indicate the direction of energy transfer.
2. How are the growth calories distributed among the trophic levels? What caused the difference?
3. What are some of the ways energy is used up at each trophic level?
4. Where did the plants acquire their energy?
5. Why were there no limits on the amount of "calories" given to plants? How are plants limited in the real world?
6. What would happen to the number of bags needed for the entire system if the carnivore had been allowed to "grow" to full size? That is, how would the numbers have changed if the round had been allowed to continue until 10 "calorie" seeds had accumulated in the carnivore growth bowl?
7. Why are food chains often short?
8. Could a lower trophic level pass all of its calories directly to a higher level? Why or why not?
9. Given the same initial amount of "calories," how could an organism transfer more calories to the next level and still survive? What consequences would such changes have for the survival of an organism or species?

Adapted from "Project Wild K-12 Curriculum and Activity Guide," by the Council for Environmental Education, 2007.