ENERGY FLOW THROUGH ECOSYSTEMS

How does energy flow through ecosystems? Energy flows through ecosystems in one direction from photosynthetic organisms to herbivores to carnivores to decomposers. Through this activity students will learn terms associated with ecosystems. Students will correlate the volume of water in a container to the amount of energy available at different trophic levels of a food chain. This is a great activity to conduct with students outdoors; however it can be done indoors.

Concept: Energy flows through ecosystems in one direction from photosynthetic organisms to herbivores to carnivores and decomposers. The total energy found in organisms from one trophic level in a food chain is available to organisms in the next trophic level as only a portion of energy consumed is stored as organic matter; the rest is utilized in metabolic processes or transformed into heat.

Content Background Information Required: No background information required. Please watch the demonstration video to get a better idea of how to conduct this lab with students, including tips for setting up the lab.

Student Objectives:
- Students will assess the dependence of all organisms on one another and the flow of energy and matter within an ecosystem
- Students will gain an understanding of the flow of energy in ecosystems
- Students will learn components of a food chain and arrange them according to energy flow
- Students will practice skills associated with measuring liquids
- Students will compare the quantity of energy in the steps of an energy pyramid

Materials:
- Containers for holding and collecting water (Could be buckets or trays)
- Paper or Styrofoam cups
- Graduated Cylinders or Measuring Cups

Lesson Preparation:
1. Review terms associated with ecosystems.
2. Review K20 Alt instructional video under the demonstration video section
3. Review websites on resources section of this lesson

Setting up the activity: This activity involves setting up containers in a line so students can simulate a water bucket brigade. Students will be passing water from cup to cup down a line until they reach the end where they will dump the remaining water in the last cup into a container. Students will do this in a small group or with a partner for one minute. The goal is for students to calculate the efficiency with which they transfer water from the first container to the last container. There will be a loss of water that occurs in the transfer process because the cups students will be using to transfer water will have holes in them. This lab can be a little messy. It might be the perfect opportunity to take students outdoors to conduct this lab. However, as you can see in the demonstration video it can be accomplished inside. The overall goal of this activity is for students to make connections between the loss of water and the loss of energy that occurs naturally in an ecosystem from trophic level to trophic level. Watching the demonstration video will allow you to have a better idea of how to set this lab up and how to conduct it with students.
Lesson Procedures:

Introduction-Exploring The Concept

- Begin by setting up the containers for the water transfer and explaining to students that they will be transferring water in a bucket brigade down a line.
- They will be given one minute to transfer as much water from the first container to the last container. They must use the cups they are given to transfer the water. (Give each group of students the 4 cups. Have them label the cups 1-4 and use a sharpened pencil to put the following holes in the cups. Each of the cups will come to represent a trophic level in food chains in ecosystems during a discussion that can be lead with students after they have completed the activity.
  - Cup 1 = 1 hole
  - Cup 2 = 1 hole
  - Cup 3 = 2 holes
  - Cup 4 = 3 holes
- Give one group 3 cups instead of 4. This group will be representing a food chain with three trophic levels instead of 4. The data this group collects can be used in a discussion with the entire class later. The class can analyze any differences in the data collected between the group who had 3 cups and the groups who had four cups. The group with 3 cups should follow the labeling and hole punches below:
  - Cup 1 = 1 hole
  - Cup 2 = 2 holes
  - Cup 3 = 3 holes
- Students must be able to calculate how much water they dipped out of the first container in one minute and they must be able to calculate how much water they ended up with in the last container after one minute. (Allow them to think about this and see if they can come up with a way to accomplish these two tasks. The demonstration video shows that students used graduated cylinders to measure how much water would fit in one full cup and then they kept count of the number of times they dipped a cup full of water from the first container in one minute. They multiplied the number of cups they dipped by the amount of water that fit in one cup to calculate the total amount of water they dipped out of the first container. To determine how much water they ended up with in the last container they carefully measured the water with a graduated cylinder. If you do not have graduated cylinders you can use measuring cups.)
- Students will conduct this activity a total of 3 times and complete student handout 1.
  - To calculate the efficiency of water transfer:
    - Efficiency = Volume of water in end container (mL) / Volume taken from beginning container (mL) x 100
- Have a copy of the student handout available on the board so students can write the data they collect on the board. Have students complete student handout 1 to include all of the classroom data from the activity.
The picture to the left may give you a better idea of how this lab can be set up and completed. This student is dipping his cup #1 in the first container, which is full of water. He will then transfer the water from cup #1 into cup #2 which is in his left hand. The gray tray under his left hand is being used to catch water coming from the holes in cup #2. He will then transfer the water in cup #2 to his partner who is holding cup #3 and they will continue the water transfer until they reach the final container.

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**Student Handout 1 “Example”**

**Data Table:**

<table>
<thead>
<tr>
<th>Group</th>
<th>Trial 1 Volume taken from first container</th>
<th>Trial 1 Volume in final container</th>
<th>Efficiency of water transfer</th>
<th>Trial 2 Volume taken from first container</th>
<th>Trial 2 Volume in final container</th>
<th>Efficiency of water transfer</th>
<th>Trial 3 Volume taken from first container</th>
<th>Trial 3 Volume in final container</th>
<th>Efficiency of water transfer</th>
<th>Average Efficiency of water transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Once students have completed the data table with information begin a discussion with students in which they can begin to think about the comparison between the loss of water from the activity and the loss of energy in ecosystems from trophic level to trophic level.

**Explaining the Concept:**

- Ask students what they notice about the data they collected. They may discuss that there was a considerable amount of water lost from the first container to the last. They may notice that the efficiency for the group that had 3 cups may be higher than the groups who had four. We want them to take away from the activity that water was lost from the first container to the last in the process of transference. *Students are practicing observations, interpretation, and communications skills while they look at the data and try to give it order and make sense of it.*

- Once students have analyzed the data on the board you can begin to have students make the connections between the activity they just completed and how energy is transferred in ecosystems by asking students to label each of their cups the following:
  
  - Cup 1 = Grass
  - Cup 2 = Field mouse
  - Cup 3 = Snake
  - Cup 4 = Hawk

  For the group with three cups they can label them:
  - Cup 1 = Grass
  - Cup 2 = Field mouse
  - Cup 3 = Snake

- Ask students what their cups now look like with these labels. What do their cups represent? *Students may say a food chain or a food web. You could ask them if they know the difference. If they don’t, you could facilitate one of the extension ideas from the HQ documentation of this lesson in the virtual classroom. If students mention ecosystem that’s great too.*

- Once students have made the connection that their cups represent a food chain or make some reference to it, ask students to think about the activity they just did with the water and to look at their newly labeled cups and think of the water as being energy transferred among the components of their food chain.

  - Do you think there is any comparison between water lost in the activity and energy lost in ecosystems or food chains?
  
  - *We want students to realize that energy is lost to the environment when organisms consume other organisms in an ecosystem.*

- When students are finished discussing energy loss and its comparison to the water lost in the activity you can lead them through a discussion to answer the questions in student handout 2.
1. An **ecosystem** is a functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area.

2. The transfer of food energy from plants to one or more animals in a linear sequence is known as a **food chain**.

3. An organism that uses light energy or energy stored in chemical compounds to make energy-rich compounds is known as an **autotroph**.

4. An organism that cannot make its own food and feeds on other organisms is called a **heterotroph**.

5. **Producers** use sunlight to make food.

6. **Herbivores** obtain food from photosynthetic organisms.

7. **Carnivores** eats meat in the form of other animals.

8. **Decomposers** break down and release nutrients from dead organisms.

10. **Trophic Levels** are the energy levels or steps in a food chain or food web.

9. How does energy flow through an ecosystem? Energy flows through ecosystems in one direction from photosynthetic organisms to herbivores, carnivores, and decomposers. The total energy found in organisms from one trophic level in a food chain is not available to organisms in the next trophic level. It’s important that students make these connections from the discussion and from the activity.

11. Is the amount of energy in each trophic level the same in a food chain? Explain

   Yes, we want students to restate that energy is lost from trophic level to trophic level in an ecosystem which includes a food chain.

   The diagram to the left is an example of an energy pyramid which may help students visualize trophic levels a little better. You can draw it on the board and explain to them that approximately 10% of energy is passed on to the next trophic level. This fact will be important for students in answering EOI style questions in student handout 3.
Food Chain Activity:

The following activity can be used to reinforce the concept of a food chain and the terms associated with it.

- Give each group of students a different example of a food chain and ask them to organize the organisms, define their role (producer, consumer [herbivore, omnivore, carnivore] or decomposer) and describe the energy transfer across the system.
- If students are unsure which organisms consume which organisms, have them do some research on the internet to figure it out. Remind them that the category the organism fits in is determined by what organism they consume.
- Have students present their finding to the class in a presentation.
- Here is a great website that reviews terms associated with food chains and includes animation:
  

![Food Chain Activity Diagram](image)

During this activity ask students what they know about predator-prey relationships and how it applies to any of the food chains they are trying to organize.

- Predators expend energy in trying to capture their prey
- The reward of gaining the prey is that the predator gains energy
The following questions are Biology I EOI practice questions pertaining to the concepts of energy in ecosystems and components of ecosystems.

**Which statement about energy in an ecosystem is correct?**
- A Producers store about 90% of the energy contained in an ecosystem.
- B Producers transfer about 10% of their energy to primary consumers.
- C Primary consumers transfer 90% of their energy to secondary consumers.
- D Primary consumers store about 10% of the energy contained in an ecosystem.

B is the correct answer.

**Which characteristic determines whether an organism is a producer, a consumer, or a decomposer?**
- A how it moves
- B how it reproduces
- C how it obtains food
- D how it maintains homeostasis

C is the correct answer

**Which statement correctly describes how energy flows among the above organisms in a prairie food chain?**
- A Energy flows from the coyote to the rabbit to the grass.
- B Energy flows from the grass to the rabbit to the coyote.
- C Energy flows from the rabbit to both the coyote and grass.
- D Energy flows from both the grass and the coyote to the rabbit.

B is the correct answer and this is an example of depth-of-knowledge question of 1.

**An energy pyramid for an ecosystem is shown below.**

<table>
<thead>
<tr>
<th>Energy Pyramid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
</tr>
<tr>
<td>Level 2</td>
</tr>
<tr>
<td>Level 3</td>
</tr>
<tr>
<td>Level 4</td>
</tr>
</tbody>
</table>

The producers in the ecosystem produce 25,000,000 kilocalories per year. How much energy is most likely available to the organisms in Level 2 of the pyramid?
- A 250,000 kilocalories per year
- B 2,500,000 kilocalories per year
- C 25,000,000 kilocalories per year
- D 250,000,000 kilocalories per year

The correct answer is B, because level 1 represents producers and they pass on about 10% of their energy to the next level.
A disease has greatly reduced the number of night snakes present in a desert ecosystem.

Which population would increase as a direct result of the decrease in the night snake population?

A. the red-tailed hawk population  
B. the boring weevil population  
C. the yucca moth population  
D. the wood rat population

The correct answer is D and this is an example of a depth-of-knowledge question 2.

Which energy pyramid accurately represents the amount of energy at each level of this food web?

A. Grass  
   Grasshoppers  
   Mice and skunks  
   Owls  

B. Grass  
   Grasshoppers  
   Mice and skunks  

C. Grass  
   Grasshoppers and mice  
   Skunks  
   Owls  

D. Grass and Grasshoppers  
   Mice  
   Skunks  
   Owls  

The correct answer is C, it’s the only one that has only producers at the very bottom level and this is an example of a depth-of-knowledge question 2.
Extensions or Applications for this lesson:

Modifications:
This lesson can be conducted indoors or outdoors and may be adapted by having students use five and six cups to do the bucket brigade to see how that changes the data collected. With five and six cups students can explore the concepts of primary, secondary, and tertiary consumers, where consumers eat other consumers.

This lesson can be conducted with one group of two students if a full class will not be participating. The most effective way to accomplish this activity with one group of students collecting data is by having the group do the activity with 4 cups, then 3 cups then analyzing the data collected and organized from that.

Highly Qualified Extension For Professional Development Points (See HQ Section of this lesson for more information):

Extension activity:
Many topics can be introduced to students as extensions to this lesson. They can learn about the nitrogen cycle, the carbon cycle, the water cycle, and photosynthesis, and make connections between each of those topics and the information they gained about ecosystems in this lesson.

- Assign one of the topics to students and have students explore the following processes in groups of two or in teams.
  - Students can research the processes in pairs and present their findings to the rest of the class through a power point presentation or poster presentation.
  - Students can research the processes in teams and develop a game or activity to conduct with the class.

Website resources for the cycles and photosynthesis are available under the resources section of this lesson. Students should be able to make connections between their topic and its connection to living organisms in ecosystems and discuss that in their presentation or game or activity they develop.

- Nitrogen Cycle = The cycle of the element nitrogen through ecosystems. Organisms need nitrogen in order to synthesize amino acids and protein. Nitrogen is taken up from the soil by plants in the form of nitrate and converted to plant protein.
- Carbon Cycle = All living organisms are made up of carbon-containing molecules: carbohydrates, proteins and lipids. The carbon cycle encompasses all of the reactions that enable living organisms to use carbon to build tissues and release energy.
- Water Cycle = The cycle by which water evaporates from soils, vegetation, oceans and other bodies of water; accumulates as water vapor in clouds; returns to the Earth, oceans and other bodies of water as rain and snow; and runs off as river flow, through the soil or an aquifer.
- Photosynthesis = The process by which green plants make carbohydrates such as sugar, using water, carbon dioxide, and sunlight.

Once you have conducted the, “energy flow through ecosystems”, lesson, and go to the HQ section of this lesson to submit answers to a few questions to gain professional development points towards building a house in Biology Sciences. Additional professional development points can be gained by developing and conducting the extension lesson idea discussed above.
PASS Objectives: Biology I

Process and Inquiry Standards:
- Observe and Measure
  - 1.1, 1.2, 1.3
- Interpret and Communicate
  - 4.1, 4.2, 4.3, 4.5
- Inquiry
  - 6.1

Content Standards and Objectives:
- The Interdependence of Organisms
  - 4.1, 4.2
- Matter, Energy, and Organization in Living Systems
  - 5.1, 5.2

PASS Objectives: Middle School Science

Process and Inquiry Standards: 6th, 7th, & 8th grade science
- Observe and Measure
  - 1.1, 1.2, 1.3
- Interpret and Communicate
  - 4.1, 4.2, 4.3, 4.5
- Inquiry
  - 5.1, 5.2, 5.3, 5.4

Content Standards and Objectives: 6th grade science
- Populations & Ecosystems
  - 4.1, 4.2

Alternative Credit for students who are not enrolled in Biology I:

English credit suggestions:

- Through the extension activity students could receive credit in English for giving a speech through a presentation
- Students could gain English credit for writing an essay about the impact of humans on living organisms in ecosystems