



CREATING CHAINS AND WEBS TO MODEL ECOLOGICAL RELATIONSHIPS

OVERVIEW

This hands-on activity supports the HHMI short film *The Guide* and the 2015 Holiday Lectures on Science: *Patterns and Processes in Ecology*. Students will identify producers and consumers in the savanna ecosystem of Gorongosa National Park in Mozambique. Using a set of “Gorongosa cards,” they will then create a food chain to show the flow of energy in that system, introduce an ecological force or disturbance (e.g., fire), and predict how that force would impact energy flow. Lastly, students will construct a more complex model of the flow of energy by depicting multiple relationships in a food web and again make a prediction about the impact of introducing an ecological force.

KEY CONCEPTS AND LEARNING OBJECTIVES

- All organisms need energy to survive that they obtain from their environment, including by eating other organisms.
- Ecosystems are dynamic, experiencing shifts in population composition and abundance and changes in the physical environment over time, which affect stability and resilience of the entire system.
- Ecological forces or disturbances can have natural or anthropogenic causes.
- An ecosystem can be represented by different types of models, each of which may have different strengths and drawbacks.

Students will be able to

- Classify organisms based on their roles in the transfer of energy in an ecosystem.
- Create a model (e.g., a food chain) showing feeding relationships among organisms.
- Evaluate different models that depict relationships among organisms in a community.
- Predict how ecological forces or disturbances may impact their models and justify their claim with evidence.

CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (November 2013)	MS-LS2-1, MS-LS2-4, MS-LS2-2, HS-LS2-1, HS-LS2-2, HS-LS2-4, HS-LS2-6
AP Biology (2012-13)	2.A.2, 2.A.3, 2.C.2, 2.D.1, 2.D.3 4.A.5, 4.A.6, 4.B.3, 4.B.4, 4.C.3
IB Biology (2009; 2016)	5.1.4, 5.1.5, 5.1.6, 5.1.7, 5.1.8, 5.1.10, 5.1.11, 5.1.12; 4.1, 4.2, C.2, C.3

KEY TERMS

producer, consumer, herbivore, carnivore, omnivore, energy flow, primary consumer, secondary consumer, tertiary consumer, quaternary consumer, rule of 10 percent



Food Chains and Webs

TIME REQUIREMENTS

This lesson is designed for 2 50-minute class periods including watching the 34-minute short film *The Guide* in class. To save time, you may wish to have your students watch the film at home.

SUGGESTED AUDIENCE

This activity is appropriate for middle school life sciences and general high school biology.

PRIOR KNOWLEDGE

Students should know that predators eat prey and that most organisms have multiple sources of food. They should also be aware that the sun is the primary source of energy for all but a few unique ecosystems. Light energy is converted to a more usable source of energy by plants, or primary producers.

MATERIALS

Each group of students will need:

Gorongosa cards (24 total)

Paper and pencil (or white boards and markers) for indicating arrows for energy flow

PROCEDURE

1. Watch (or assign student to watch at home) the HHMI short film *The Guide* to see the context for the activity.
2. Divide the students into working groups and provide each group with a complete set of Gorongosa cards.
3. Students can work with their cards on tables, desks, or other workspace and record written answers on the worksheet provided.

TEACHING TIPS

- The Gorongosa food web cards are offered in two formats. If you can print double-sided, then use that file and cut the cards accordingly. If you can only print single-sided then use that file and cut and fold the cards so that they are double-sided with an image on one side and text on the other.
- Students often reverse the direction of the arrow to show that an animal is eating a plant or other animal rather than using the arrow to show the direction of energy flow. You might want to remind students of that relationship.
- Prior to watching the film, you might want to pose the question “What good are small animals?” like E.O. Wilson does during his Gorongosa visit. Likewise, after the film you might ask students to recall why Gorongosa was able to experience successful restoration despite most large animals being hunted or removed from the landscape.
- If you would like students to make several food chains or webs, you might consider having the students represent arrows on sticky notes for easy recombination. Or have students use white boards as a placemat so arrows can be drawn and erased quickly.
- You might also prompt a discussion of what regulates population sizes at different trophic levels. Populations of organisms at lower trophic levels are commonly regulated by predation, whereas organisms at higher trophic levels may be regulated by prey availability and/or may be more sensitive to habitat disruptions.



6. Ecosystems include both biotic (living) and abiotic (nonliving) components that can influence food chains. In this activity, the abiotic components are referred to as an ecological force or disturbance. Choose one of the disturbance cards, read the information provided, and then make a prediction about how it might impact the food chain you created above.

Answers will vary. Example below is based on a food chain of plant → insect → shrew → serval.

Ecological Force (list the title)	Describe four ecosystem impacts noted in the card	Predict how these impacts would affect each trophic level
Drought	<p>Rains stop during July-September and lakes and rivers dry up.</p> <p>Competition for nutritious vegetation.</p> <p>Animals may need to travel more, using precious energy to find food rather than for growth and reproduction.</p> <p>Scarce water is concentrated at a few water holes where animals gather in large numbers.</p> <p>Animals may experience changes in the nutritional value of their food and the frequency of their eating. This could lead to hunger and weakness, making some animals more prone to diseases, parasites, and predators.</p>	<p>Producer: <u>Plants</u> might stop growing since they can't get enough water; some plants might die off.</p> <p>Primary consumer: <u>Insects</u> that rely on green plants would face stiffer competition as nutritious plants become scarce. Their numbers may decrease.</p> <p>Secondary consumer: <u>Shrews</u> might switch their prey or expand their hunting ranges to gather enough food. This could make them more prone to exposure to predators.</p> <p>Tertiary consumer: <u>Servals</u> might actually have an easier time finding shrews to eat at first, but over time, if the shrew population dwindles, the servals might need to switch their prey or expand their hunting territory, using precious energy to hunt.</p>

7. Not all disturbances have negative consequences for all trophic levels. In one or two sentences, describe a possible benefit that one trophic level in your food chain may gain from the disturbance you selected.

Answers will vary but should be consistent with logic from each student's food chain.

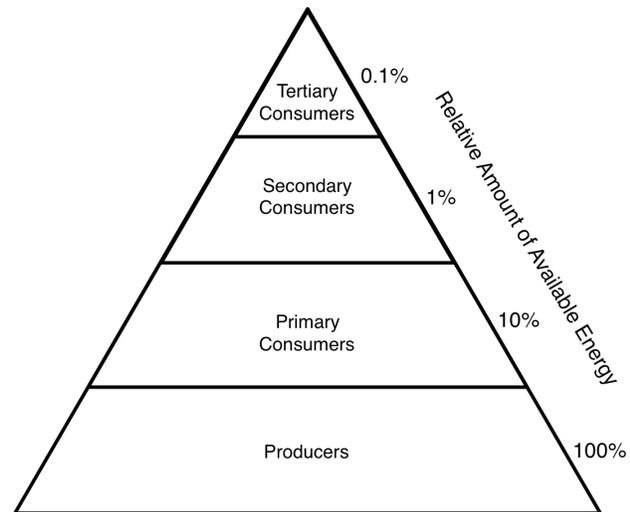


Part 2: Quantifying energy flow and the rule of 10 percent

Three hundred trout are needed to support one man for a year. The trout, in turn, must consume 90,000 frogs, that must consume 27 million grasshoppers that live off of 1,000 tons of grass.

-- G. Tyler Miller, Jr., American Chemist (1971)

Only a small fraction of energy available at any trophic level is transferred to the next trophic level. That fraction is estimated to be about 10 percent of the available energy. The other 90 percent of the energy is needed by organisms at that trophic level for living, growing, and reproducing.



This relationship is shown in the energy pyramid above. It suggests that for any food chain the primary producer trophic level has the most energy and the top trophic level has the least.

8. Why is a pyramid an effective model for quantifying energy flow?

The pyramid shape shows a hierarchy but also relative amounts at each level.

9. Place the organisms from your original food chain on the pyramid provided below.

10. Using the rule of 10 percent in energy transfer, record the species names for each trophic level and the amount of energy available at that level if your producer level had 3,500,000 kilocalories of energy/area.

Organisms filled in will vary, but amounts for each trophic level, starting at the bottom of the pyramid, should be 3,500,000 kilocalories, 350,000 kcal, 35,000 kcal, 3500 kcal.

11. In one or two sentences, describe how the available energy may affect the population sizes of organisms at different trophic levels.

Students should observe that since the energy available at each trophic level decreases, the populations of animals at higher trophic levels will be smaller than the populations at lower trophic levels. For example, many warthogs can support relatively few lions.

Part 3: Creating a food web

Food chains are simple models that show only a single set of energy-transfer relationships, but many organisms obtain energy from many different sources and in turn may provide energy to several different consumers. A food web illustrates all these interactions and is a more accurate model of how energy moves through an ecological community.

12. Starting with your original food chain (question 5), add another plant and four more animal cards to construct a food web that shows how energy flows from producers through primary consumers, secondary consumers, tertiary consumers, and possibly a quaternary consumer. When



making your food web, you can have more than one arrow leading to and from each organism. Draw a version of your food web below.

Answers will vary.

13. In one or two sentences, describe any patterns you notice in the relationships between trophic levels.

Possible answers could include that the lion has more prey species that provide energy to it than the serval and the fish eagle has even fewer. Insects provide energy to several species.

14. Now choose and read a different disturbance card and predict its impact on your food web. Complete the table below:

Ecological Force (list the title)	Describe four ecosystem impacts noted in the card	Predict how this impact would be seen in your food web
Fire	<p>Grasslands depend on fires to release nutrients and remove old, dead, dry grasses above ground, prompting new, green growth.</p> <p>Woody shrubs and trees will not spread into grassland areas.</p>	<p>Producers: Grassland plants will flourish, but woody vegetation might decline.</p> <p>Primary consumers: Insect, impala, zebra, and buffalo populations would increase. More green and nutritious grasses will increase food for grazing animals big and small. Browsers like the impala may not have as many woody shrubs to eat but switch to more grasses.</p> <p>Secondary consumers: Warthogs and shrews will have more insects to eat.</p> <p>Tertiary consumers: Servals will have more shrews to eat. Their numbers may increase. Lions will also have more prey. Their numbers may increase.</p>

15. Describe whether some trophic levels benefit from the disturbance while others do not. If humans caused the disturbance, was it negative or positive for each trophic level in the food chain?

Answers will vary, but students should grasp that negative impacts at one trophic level might act as positive impacts on lower trophic levels. In ecology, this is called a trophic cascade.

Part 4. Model evaluation

In science, models are used to represent explanations and predications. The food chain, food web, and energy pyramid are all models that show feeding relationships and allow us to make predictions. Compare and contrast the strengths and weaknesses of each model by filling in the table below.



Food Chains and Webs

Model	List two things this model is useful for illustrating or predicting	Identify one feature that this model lacks or one that could lead to a misconception
Food chain	<p>Possible answers:</p> <ol style="list-style-type: none"> 1) Identifies levels and easy to see relationship 2) Trophic levels easily identified 	Does not show that animals eat more than one thing; very simple
Energy pyramid	<ol style="list-style-type: none"> 1) Shows hierarchy of trophic levels 2) Relative amount of energy or organisms is indicated by space of pyramid level for each trophic level 	Does not show that animals eat more than one thing; very simple
Food web	<p>Possible answers:</p> <ol style="list-style-type: none"> 1) Multiple feeding relationships depicted. 2) Consumers that are specialized (limited prey choices) versus more general consumers (multiple prey choices) can be depicted. 	<p>Trophic levels not as easily observed.</p> <p>The hierarchy shown in previous models might not be as easily maintained in a food web. Some prey might appear physically higher than their predator(s), making it look like it is a higher trophic level.</p>

16. Select the model that you think is most effective in representing relationships among organisms in the Gorongosa ecosystem and justify your choice in two or three sentences.

One possible answer is that the food web best represents the relationship in Gorongosa, as it allows for multiple prey species for the second- and third-level consumers. This is more realistic, as most carnivores eat more than one prey animal. Some carnivores might have a preferred prey species but will switch prey depending on conditions and availability.

AUTHORS

Written by Kim Parfitt, Central High School, Cheyenne, Wyoming
 Edited by Mark Nielsen, PhD and Bridget Conneely, HHMI

Field Tested by Rebecca Tishkoff, Ezra Academy, Woodbridge, CT; Yvonne Alexander, Hopkins Junior High, Fremont, CA; Kimberlie Forgey, Sacred Heart Preparatory, Atherton, CA; Phyllis Robinson, St. Andrew's Episcopal School, Potomac, MD; Laura Julien, Lancaster High School, Lancaster, OH; David Knuffke, Deer Park High School, Deer Park, NY; Mark Little, Broomfield High School, Broomfield, CO; Rachel Badgett, Asbury High School, Albertville, AL; Turtle Haste, Desert Ridge Middle School, Albuquerque, NM; Kelly Holtzman, Oconomowoc High School, Oconomowoc, WI; Dr. Beth Kunze, Downingtown East High School, Exton, PA; Laura Dinerman, Sherwood High School, Sandy Spring, MD; Elaine Shute, Seneca Valley High School, Germantown, MD; Sunita Meyers, Loyola School, New York, NY; Chris Monsour, Tiffin Columbian High School, Tiffin, OH; Jeannie Cuervo, Cleveland High School, Cleveland, TN; Shannon Thomas, Twinsburg High School, Twinsburg, OH; Mary-Elizabeth Quan, Ray Wiltsey Middle School, Ontario, CA; Luisa McHugh, William Floyd Middle School, Moriches, NY; Angela Armstrong, Rockland High School, Rockland, MA; Tara Shepherd, John Taylor Collegiate, Winnipeg, Manitoba; Kimberly Saltsburg, Westminster High School, Westminster, MD