I. Wolves in Yellowstone National Park

Early in the twentieth century, humans eliminated wolves from Yellowstone. In the late twentieth century, humans brought wolves back to Yellowstone. How did these changes in the wolf population affect other animals and plants in Yellowstone? To answer this question, watch The Habitable Planet, Ecosystems, Unit 4 (http://www.learner.org/courses/envsci/unit/text.php?unit=4&secNum=1), beginning at 13 minutes and 40 seconds and ending at 22 minutes and 37 seconds.

These graphs summarize recent trends in the numbers of wolves and elk in the Northern Range in Yellowstone.

1. Why did the number of elk decrease after 1995?

2a. Based on these graphs, estimate the maximum population size for wolves.

2b. Estimate the minimum population size for elk.

2c. Notice that the number of wolves is much lower than the number of elk. What is one possible explanation for this difference?

3. After 1995, the growth of willows increased in some parts of Yellowstone. What is one possible explanation for this trend?

We will return to these questions after you have learned more about food webs and trophic pyramids.

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1 By Drs. Ingrid Waldron and Lori Spindler, Dept Biology, University of Pennsylvania. © 2019. This Student Handout and the Teacher Preparation Notes with instructional suggestions and background information are available at http://serendipstudio.org/sci_edu/waldron/#ecolfoodweb
II. Food Chains and Food Webs

**Trophic** refers to eating or nutrition. In a typical trophic relationship, one organism eats all or part of another organism. A **food chain** summarizes a sequence of trophic relationships within an ecosystem.

In this diagram of a food chain, each arrow points from an organism that is eaten to an organism that eats it.

4. Fill in the blank food chain with an example from the video about Yellowstone.

There is another type of food chain that doesn’t begin with living plants.

5. Think about a forest where trees lose their leaves each fall and trees sometimes die. What happens to the dead leaves and trees?

**Decomposers** get their nutrition from dead organic matter. Decomposers include bacteria and fungi (e.g. mushrooms) which secrete digestive enzymes and absorb digested molecules from the dead organic matter.

This flowchart shows a food chain that begins with dead organic matter, with an example from Yellowstone.

6. If you visited Yellowstone, you would not notice this food chain. Why not?

7. Match each item in the top list with the best match or matches from the bottom list.

*Producer ___*
*Primary consumer ___ ___*
*Secondary consumer ___ ___*
*___ a. an organism that consumes primary consumers*
*___ b. an organism that consumes producers*
*___ c. an organism that makes its own organic molecules from small inorganic molecules (e.g. uses photosynthesis to make sugars from CO₂ and H₂O)*
*___ d. includes some carnivores and Protista*
*___ e. includes herbivores*
In real biological communities, the trophic relationships are much more complex than a simple food chain. These more complex trophic relationships are summarized in a **food web**.

This figure shows a small part of a food web. Notice that the food web contains multiple food chains.

8. Use asterisks to mark the organisms in one food chain in this food web.

Most of the organisms in this food web can be classified in one of these **trophic levels**:
- producers
- primary consumers
- secondary consumers.

9. Draw a rectangle around the producers in this food web. Circle the primary consumers.

Not all organisms fit in a single trophic level. You may have heard of omnivores which eat both plants and animals. A more general category is a **trophic omnivore** which is any animal that eats organisms from more than one trophic level.

10. Explain why the hawk in the above food web is a trophic omnivore.

- Your teacher will give you a deck of cards that you will use to create a Yellowstone food web. To begin, draw the boxes in this chart on your lab table or on the large paper provided by your teacher. Each box should be the size specified or a little larger, so it will be big enough for the relevant cards.

- Find the cards for the producers and dead organic matter in your Yellowstone deck. Put these cards in the appropriate boxes.
➢ Put the cards for the primary consumers and the decomposers in their boxes. Draw an arrow to show each trophic relationship listed on the cards.
➢ Use the remaining cards to put secondary consumers in their box and the cards for the trophic omnivores in appropriate places outside the boxes. Draw an arrow to show each trophic relationship.

11. After your teacher has checked and approved your food web, draw a diagram of the food web on a separate sheet of paper. Include the categories, the names of the organisms, and the arrows.

12. Some scientists distinguish between a **green food web** that begins with producers and a **brown food web** that begins with dead organic matter. In your Yellowstone food web, draw a circle around the brown food web. (Do not include organisms that are part of both the brown and green food webs (e.g. robins).)

13. Your Yellowstone food web may look complex, but a complete Yellowstone food web would be much more complex. Many more types of organisms live in Yellowstone, including more than 1000 different kinds of plants and more than 1000 different kinds of insects. Humans are also part of the Yellowstone food web, since human hunters kill thousands of elk when they migrate out of Yellowstone Park during the colder months. Add humans to your food web.

14. Most organisms have more trophic relationships than the few that are shown on each card. Also, some of the trophic relationships shown are much more important than others. For example, Yellowstone wolves eat many elk and few beavers. Draw fatter arrows from elk to wolves and from elk to humans to represent the importance of these trophic relationships.

Even though your food web is incomplete, it can help us predict and understand important ecological phenomena.

A **trophic cascade** occurs when a change in the population of a predator not only affects its prey population, but also has indirect effects on another population in the ecosystem. In this flowchart, each arrow represents a negative effect of one population on the size of another population.

15a. Fill in the blanks, using the example from page 1.

15b. Draw a curved arrow with a (+) to show the indirect effect of predators in this trophic cascade.

16. Explain how changes in the wolf population could produce the following trends.
   • After wolves were eliminated from Yellowstone, the number of beaver colonies decreased.
   • After wolves were reintroduced to Yellowstone, the number of beaver colonies increased.
   (Hint: Beavers use tall willows for food and building dams.)
III. Carbon Cycle and Energy Flow

Organisms are made up primarily of carbon-containing organic molecules and water. If you eat an apple or a hamburger, you are consuming carbon-containing organic molecules from a plant or an animal. Your body needs these organic molecules for two purposes:

- to provide energy for biological processes
- to make your body’s own carbon-containing organic molecules.

17. The biosphere, with all of the Earth’s organisms, receives a continuous inflow of energy from the sun. In contrast, the biosphere does not receive an inflow of carbon atoms. What are some possible reasons why life in the biosphere needs an inflow of energy, but does not need an inflow of carbon atoms?

To better understand why the biosphere needs an inflow of energy, but does not need an inflow of carbon atoms, we will begin by reviewing photosynthesis, cellular respiration, and biosynthesis.

Photosynthesis

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6 CO₂ + 6 H₂O → C₆H₁₂O₆ + 6 O₂

Sunlight → Chemical energy + heat
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The upper box shows changes in how the atoms are organized in molecules, and the lower box shows the associated energy changes.

18a. Circle the organic compound (glucose) that is produced by photosynthesis.

18b. Explain how photosynthesis illustrates the general principle that matter is neither created nor destroyed in biological processes.

Cellular Respiration

Some of the sugar molecules produced by photosynthesis are used for cellular respiration.

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C₆H₁₂O₆ + 6 O₂ → 6 CO₂ + 6 H₂O
~29 ADP + ~29 P → ~29 ATP + ~29 H₂O

Chemical energy → Chemical energy + heat
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19. The main function of cellular respiration is to produce ATP. Why do cells need ATP?

20. Use photosynthesis and/or cellular respiration as examples to illustrate the following general principles.

- Energy is neither created nor destroyed in biological processes, but energy can be transformed from one type to another.
- During energy transfers and transformations, some of the input energy is transformed to heat energy.
Biosynthesis
Some of the sugar molecules produced by photosynthesis are used for biosynthesis, which produces all the different organic molecules that make up an organism. For example, multiple glucose molecules are combined to make the polymer cellulose, which is used to make plant cell walls.

Photosynthesis and cellular respiration play crucial roles in the **carbon cycle** where carbon atoms cycle between CO₂ in the air and organic molecules in living organisms or dead organic matter.

21a. The B arrow shows CO₂ entering a plant. How do the carbon atoms in CO₂ become carbon atoms in organic molecules in the plant?

21b. How do the carbon atoms in organic molecules in a plant become carbon atoms in organic molecules in an animal?

22. The A arrows show CO₂ leaving plants, animals and decomposers. How do the carbon atoms in the organic molecules of plants, animals and decomposers become carbon atoms in CO₂?

23a. The C arrow shows defecation and/or death. Add another C arrow to show part or all of the plant dying and becoming available to decomposers.

23b. What problems would occur if there were no decomposers?

24. Explain how a carbon atom in a giraffe could eventually end up as a carbon atom in a tree.
25a. This chart shows part of the carbon cycle. Describe the processes involved in the carbon cycle by labeling each of the four thick arrows with one or more of the following terms: biosynthesis, cellular respiration, digestion, eating, and/or photosynthesis.

25b. Follow these directions to show the through-flow of energy in the above chart.
- Draw and label a dashed arrow to show the inflow of energy in the form of sunlight.
- Circle the arrow which shows chemical energy moving from one trophic level to the next.
- Draw and label dashed arrows to show that each of the biological processes produces heat, which leaves the organisms and ultimately is radiated out to space.

26. How can the sun’s energy be transformed to provide the energy that a giraffe uses to move? Be specific about the multiple steps that are required.

27a. How can life continue in the earth’s biosphere without an inflow of additional carbon atoms?

27b. Explain why life in the earth’s biosphere needs a continuous inflow of energy.
IV. Trophic Pyramids

28. The average American consumes almost 2000 pounds of food each year. Obviously, we do not gain 2000 pounds of weight each year! What happens to all the weight of the food we eat? Where do the atoms in the food molecules go?

The biomass of an organism is the mass of all the organic molecules in the organism. Researchers have analyzed the rate of biomass production at different trophic levels in a forest food web in New Hampshire. They found that:

- The producers (e.g. maple trees) had a much higher rate of biomass production than the primary consumers (e.g. caterpillars). (See the flowchart below.)
- Much of the biomass produced by the trees and other producers was not eaten by primary consumers; instead much of this biomass became dead organic matter (e.g. dead leaves and branches).
- Much of this dead organic matter was consumed by decomposers (fungi and bacteria).

29. Add to the above flowchart to show three reasons why the rate of biomass production for primary consumers was much smaller than the rate of biomass production for producers.

The graph below shows that the rate of biomass production for the producers in the forest was five times bigger than the rate of biomass production for the primary consumers plus decomposers (1000 vs. 200 g/m²/year).

30. Draw a bar that shows the rate of biomass production that you would expect for secondary consumers, and explain your reasoning.
The information in the graph you just completed is often displayed in a **trophic pyramid** like this one. (Tertiary consumers eat secondary consumers. Trophic omnivores are included with tertiary and secondary consumers.)

![Trophic Pyramid Diagram]

31. Scientists sometimes use the general estimate that the rate of production of biomass at one trophic level is ~10% of the rate of production of biomass at the just lower trophic level. Use this 10% estimate to calculate the rate of production of biomass at each consumer trophic level in this trophic pyramid.

The trophic pyramids considered thus far represent the relative rates of biomass production. Some trophic pyramids show the relative numbers of organisms at each trophic level.

32a. Which would you expect, based on the trophic relationship between wolves and elk?
   a. approximately 10 times as many elk as wolves
   b. approximately the same number of elk and wolves
   c. approximately 10 times as many wolves as elk

32b. Explain your reasoning.

32c. In the 21st century, there have been approximately 100 times as many elk as wolves in Yellowstone. What is one possible reason why there is only one wolf for every 100 elk, instead of one wolf for every 10 elk? (Hint: Check your Yellowstone food web.)

33a. Erin and Pat each had a lunch with a similar amount of biomass. Erin had a hamburger and Pat had a baked potato, so they were consuming biomass from different trophic levels. In comparison to the amount of land required to produce Pat’s potato, how much land do you think is required to produce Erin’s hamburger?
   a. 10% as much land to produce the hamburger
   b. the same amount of land to produce the hamburger and the potato
   c. 10 times as much land to produce the hamburger

33b. Explain the reasoning that supports your answer.