What am I?

A Game Connecting Mathematics and the Environment

by John Mighton, Founder of JUMP Math

www.earthrangers.org

Teacher's Guide: Intermediate level

Lesson 2: *Classification in Biology*

Introduction

In the last lesson your students learned how to sort shapes according to their geometric properties. In this lesson they will learn how biologists sort animals according to what they eat (or where they derive their energy). Knowing which animals and plants a particular animal depends on to survive can help scientists protect the animal and make sure that it is not harmed by human activities.

A food chain, or food web, is a diagram that shows which plants or animals are eaten by the animals in a particular habitat. There is a great deal of interesting mathematics in a food web, and understanding these mathematics will allow your students to understand in-depth how pollution, loss of habitat and climate change harm plants and animals.

Tell your students that since they are now all experts at asking good questions to solve a puzzle, you will give them a chance to solve some puzzles about nature. Solving these puzzles will help them learn to think like scientists. And when they can think like scientists, they will discover for themselves how their actions affect the environment, and they will see how much power they have to protect the plants and animals of the world.

Food Chains and Food Webs

As a warm-up activity, post a selection of animal cards from BLM 3 on the board and ask your students to discuss how they might sort the animals. In thinking about the properties of the animals, students might ask the following type of questions:

Does the animal have legs? If so, how many?
Does the animal have wings?
How does the animal move? Does it run, crawl, swim, or fly?
Where does the animal live?
What type of body covering does it have?
Is the animal's body segmented (like an ant's or grasshopper's)?
Does the animal have a backbone? (Animals with backbones are called vertebrates and ones without are called invertebrates.)

After your students have had a chance to discuss these questions, remind them of one thing that all animals have in common: they must eat food to survive. Food gives animals the energy they need to grow, move, and reproduce.

Biologists are scientists who study animals and plants. Biologists can learn a great deal about an animal by finding out what kinds of things it eats.

Place the following animal cards on the board and draw arrows between them as shown:

Tree → Caterpillar → Frog → Fish → Snowy Owl

(Note: In the diagram the animal names are arranged horizontally to save space, but you should place the cards on the board in a column vertically, with the plant at the bottom. The cards are fairly small so you can create food chains that have a number of animals in them. Students at the back of the classroom may not be able to read the labels on the cards, but they should be able to recognize the animal on a card by its silhouette. To help students recognize the cards from a distance, let them see them up close first so they can become familiar with the names of the animals. You might want to laminate the cards so that they are easier to use, and so you can reuse them later).

Tell your students that the diagram you created is called a food chain. A food chain shows which plants or animals are eaten by the various animals in a habitat. In a food chain, the arrows always point from the food to the animal that eats the food. Leave the food chain on the board while your students help you with the following activity:

Place the cards below on the board in the order shown. Ask your students if they can arrange the cards in a column and create a food chain by drawing arrows to show which animals eat which food.

Question 1: **Tree Robin Caterpillar Great Horned Owl**
Answer: **Tree → Caterpillar → Robin → Great Horned Owl**

Question 2: **Grasses Mouse Grasshopper Barn Owl Snake**
Answer: **Grasses → Grasshopper → Mouse → Snake → Barn Owl**

Ask your students whether the three food chains have anything in common. Students might notice that each chain starts with a plant and ends with an owl. Tell your students that many food chains end with animals that are not owls, but very few start with an animal rather than a plant. Ask your students whether there could be a food chain where an animal is at the bottom and a plant appears above an animal. Your students may be surprised to learn that plants do sometimes eat animals! The venus fly trap, for instance, eats insects by trapping them in leaves that have long spines along their edges that form a cage when the leaf closes. Once the insect is trapped, the leaf releases a chemical that dissolves the insect, thus allowing the plant to digest its prey. (Students might do a research project on the types of plants that eat animals.)

Tell your students that you put an owl at the top of each food chain for a reason. Scientists can learn a great deal about a habitat (a habitat is a place where animals live) by studying what owls eat. Owls eat a great variety of small animals, including insects, reptiles, birds, and mammals like mice and rabbits. Since owls don't have teeth, they can't chew their food the way we chew ours. (Most birds that eat animals larger than insects shred their prey with their beaks, because this helps them digest the food). Some owls, like the barn owl, don't even do this: they swallow their prey whole! This means that owls usually digest less of what they eat than other birds. They regurgitate the parts of their prey they can't digest in balls called "owl pellets." If you pull open an owl pellet, you can sometimes find the entire skeleton of a mouse or a shrew inside. Because owls eat so many different kinds of animals, scientists can get a good idea of the types and numbers of animals that live in a particular habitat by examining the owl pellets.

Owls are amazing hunters. The barn owl, for instance, has special feathers that reduce the noise it makes when it flies so it can hover silently above its prey. It also has extremely acute hearing so it can hunt in the dark just by listening for the movements of its prey. (You might encourage your students to do a research project on owls and their importance in their habitats.)

Biologists call plants "producers" because they absorb the energy of the sun and store it in a form that animals can digest. Animals are called "consumers" because they use up or consume the energy that is stored in plants. In a food chain you can usually find three types of animals: animals that only eat plants, which are called herbivores; animals that eat other animals, which are called carnivores; and animals that eat both plants and animals, which are called omnivores. Since carnivores depend on herbivores to survive and herbivores eat plants, all animals (including humans) depend on plants to survive. That is why it is so important to protect the forests, meadows, and grasslands of the world and why it is important to grow plants in a way that doesn't harm the environment.

Mix up the cards below and tell your students that there is an omnivore in the food chain they can make with the cards. So, once they have made the food chain, they will have to add an extra arrow from the plant to the omnivore.

Grasses → Grasshopper → Mouse → Snowy Owl

The level at which an animal occurs in a food chain has environmental significance, so biologists created special names for each level. Herbivores are called primary consumers, while animals that are one level above primary consumers are called secondary consumers. Then there are tertiary consumers, quaternary consumers, and so on. (It is rare for a food chain to have more than five levels, for a reason that will be explained later). An animal can be a consumer at several levels in a habitat. For instance, in the food chain above, the mouse is both a primary and a tertiary consumer.

Ask your students to identify the producers, consumers, herbivores, omnivores, and carnivores in the food chains above, as well as the primary, secondary, and tertiary consumers.

Draw your students' attention to the first food chain that you made for the snowy owl. Tell them that you are going to create a more complicated structure called a food web by adding animals to the food chain. Place the flower, butterfly, dragonfly, and duck cards on the board. Ask your students to make a food chain leading up to the snowy owl beside the first food chain, and then ask them to add any arrows they think might connect the food chains. The answer is shown in Figure 1. Then place the grasses, grasshopper, and mouse cards on the board and ask the students to repeat the exercise. The resulting diagram is shown in Figure 2. Tell your students that any diagram which combines several food chains is called a food web.

Figure 1

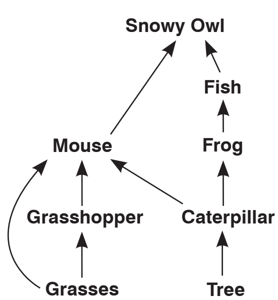
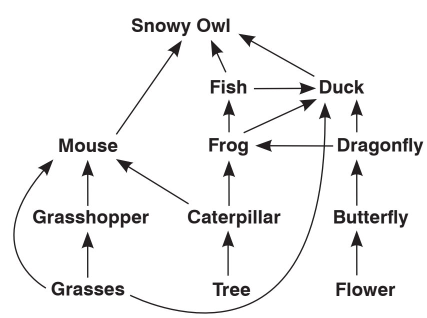


Figure 2



Tell your students that there is a great deal of interesting mathematics in the food web. Ask: What does the number of arrows that point away from a particular animal tell you? (How many animals in the web eat the animal) What does the number of arrows that point to the animal tell you? (How many animals are eaten by the animal) How many animals eat the caterpillar? (Two) How many animals are eaten by the duck? (Three) Which two animals eat the most animals? (The duck and the snowy owl) How many animals are omnivores? (Two: the mouse and the duck) Ask a number of questions of this sort to give students a chance to demonstrate their understanding of the web.

Knowing how many arrows point to and away from an animal in a food web can tell you how important the animal is in a habitat. An animal with many arrows pointing away from it provides food for many other animals. And an animal with many arrows pointing towards it can perform an important function by controlling populations of animals that might otherwise become too numerous and destroy the habitat. Caterpillars, for instance, would kill a great many trees if they weren't eaten by the animals that are directly above them in the web. (Ask your students which animals in the web keep the population of caterpillars in check). But caterpillars are important themselves as they provide food directly or indirectly for so many other animals. In a natural habitat, all of the animals and plants play a role in maintaining the health of the habitat.

Another important mathematical feature of a food web is called a "path." To find a path, start at one of the organisms on the web and move along any arrow in the direction in which it points. (You are not allowed to move backwards along an arrow; all paths lead upwards). If you follow a set of one or more arrows in a row, you will have found a path in the web. Ask a student to identify a path from the grasses to the snowy owl by naming the animals along the path. Ask another student to find a different path from the grasses to the snowy owl. (Paths are considered different as long as one of the paths has at least one different organism on it, so paths that are different may still overlap. For instance, “grasses, grasshopper, mouse, snowy owl” and “grasses, mouse, snowy owl” are different paths.) How many paths are there from the flower to the snowy owl altogether? (There are four) From which plant are there the least number of paths to the snowy owl? (There are three paths from the grasses, and four paths from both the tree and the flower).

The length of a path is the number of organisms you encounter as you move along the path. For instance, the path “caterpillar, mouse, barn owl” has length 3, since there are 3 animals along the path. Ask students to count the length of several paths on the web. Then ask: How long is the longest path from a plant to the snowy owl? (There are two paths of length 6; for instance, flower, butterfly, dragonfly, frog, duck, fish, snowy owl). How long is the shortest path? (There are two paths of length 3). What is the most common path length? (5) For a real challenge: What fraction of the total number of paths are of length 6? (From this fraction students can see that long paths are relatively rare).

Ask your students to think about how paths might be important in a food web. If you follow all the paths that lead upwards from an organism, you will find all the animals that derive the energy that they need to survive from that organism. How many animals in the web derive energy from the frog? (Three: the fish, the duck, and the snowy owl). How many derive energy from the caterpillar? (Five: the frog, the fish, the mouse, the duck, and the snowy owl). From which animal do the greatest number of animals derive energy? (The caterpillar). From which plant do the greatest number of animals derive energy? (The tree) You might point out to your students that the relations of interdependence in a habitat are even more complex than those they can see from the web. For instance, plants also depend on animals to survive: flowers, for instance, depend on bees to spread their pollen, and trees depend on animals like squirrels and chipmunks to spread their cones, nuts, and seeds.

From the web, students can begin to see how human activities affect the environment. They can see, for instance, how many animals are harmed when trees are cut down or grasslands are destroyed. They can also see how pollution and poisons spread through a habitat. Farmers spray pesticides on crops to control insects like caterpillars and grasshoppers. The chemicals in pesticides are stored directly in the body of an animal that eats the pesticide, but they are also stored in the body of a second animal that eats the first, in the body of a third animal that eats the second, and so on. So the chemicals in pesticides, which can be harmful to humans as well as animals, work their way upward along any paths in the web. How many animals in the web are affected if a caterpillar or a grasshopper eats a plant that has been sprayed with pesticides? Your students should see that all but one of the animals are affected, because every animal can be reached from a path that starts from the caterpillar or the grasshopper!

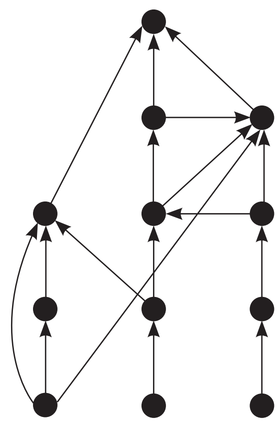
Let your students know that the length of the path in a food chain has another important environmental implication. At each level in the food chain, much of the energy of the sun that is stored in plants is lost. In the next lesson they will learn to estimate how much energy is lost and about the environmental consequences of this loss.

Let your students know that food chains are an example of a very important structure that mathematicians call a “directed graph.” Directed graphs have many applications in mathematics as well as in computer science, business, and in the sciences in general. To make a directed graph from a food chain, just replace each animal card with a dot (called a “vertex”). The arrows on the graph are called “edges” or “directed edges.” (See below for an example).

A directed graph can represent many things besides a food chain. It can represent a set of airline routes (the dots represent cities and the arrows show which cities you can fly between) or links between websites (the dots represent websites and the arrows show which websites are connected to other websites by links) or the order of a set of tasks (the dots represent the tasks and the arrows show the order the tasks must be done in).

Put several food webs on the board and allow your students to practise drawing directed graphs from the food web. The directed graph for the snowy owl food web in Figure 2 is shown below. (If your students find this exercise hard, start with very simple food webs).

Figure 3



End the lesson by playing the game from the previous lesson but using the animal cards rather than the shape cards. Put a selection of animal cards on the board, arranged in a food web, and ask students to identify the animal you are thinking of by asking questions. Students should ask questions that are based on the food web and on the terms and concepts they learned in the lesson. For instance, if you use the food web for the barn owl from Figure 2, they might ask: Are you thinking of a producer? A consumer? A herbivore? A carnivore? An omnivore? An animal that is both a primary and a tertiary consumer? An animal that derives its energy from a dragonfly? An animal that is eaten by two other animals? And so on.

As a warm-up game you might try using the food web below. You might also ask students to draw a tree diagram to sort the animals. An example is shown in Figure 5. (Note: The properties in the tree diagram are some of the properties students might use in their questions).

Figure 4

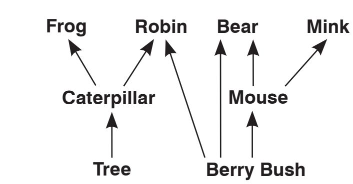
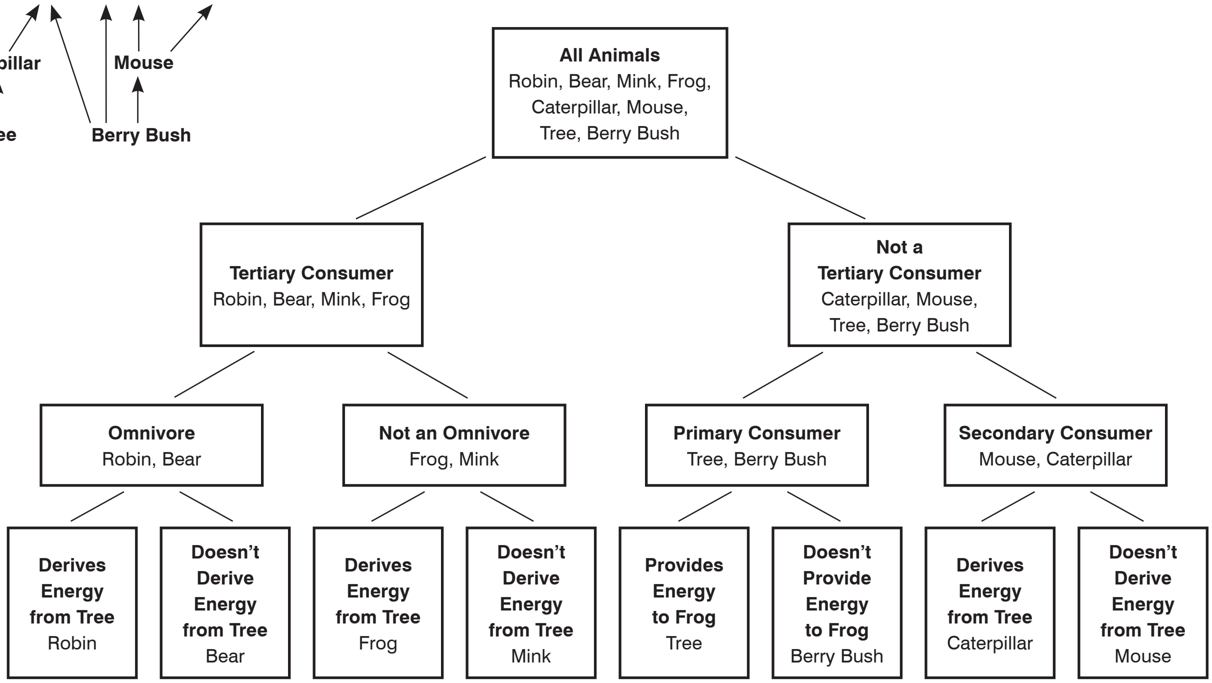


Figure 5



Tell your students that now that they understand some of the mathematics of food webs, they are ready to start applying their knowledge. In the next lesson they will look more deeply at how directed graphs can be used to understand the environment and will learn about things they can do at home and at school to help protect plants and animals.

