Activity 3 Energy Flow in Ecosystems

GOALS

In this activity you will:

- Infer the loss of energy in the form of heat from the human body.
- Relate the laws of thermodynamics to the transfer of energy in a food chain.
- Calculate the energy lost at a given level in a food web.
- Explain the significance of a pyramid of biomass, a pyramid of numbers, and a pyramid of energy.

What Do You Think?

Heat stroke is caused by a failure of the heat-regulating mechanisms of the body. It can be caused by heavy exercise combined with hot and humid conditions.

- **Where does the heat in the body come from?**

Write your answer to this question in your *Active Biology* log. Be prepared to discuss your ideas with your small group and other members of your class.

For You To Do

As you work through this activity, consider whether there is any relationship between events like heat stroke and the heat that is stored and lost at each link in a food web.

1. Read through the steps of the activity.
   a) What are you investigating in this activity?
   b) Predict what you think will happen to the water temperatures in the containers.

2. You can now follow the steps to conduct the experiment. Put 600 mL of water in each of three containers. The temperature of the water should be 10°C. You may have to add ice. Remove the ice when the temperature gets to 10°C.
3. Have one student put one hand into the water in container A. Have that student put the other hand into the water in container B. In container A, move the fingers rapidly in the water. Do not move the hand in container B. Keep one hand moving and the other hand still for five minutes.
4. Another student will hold a thermometer in the water in container A. Read the temperature once each minute for 5 minutes.

a) What is the purpose of stirring the water?

b) Record the temperatures in the chart.

Clean up any spilled water immediately.

Minutes	Temperature Container A (moving hand)	Temperature Container B (still hand)	Temperature Container C (no hand)
1			
2			
3			
4			
5			

a) Record the temperatures in a chart similar to the above.

5. A third student will hold a thermometer and read the temperatures in container B. Also, stir the water in this container using the stirring rod.

Wash your hands after completing the activity.

6. A fourth student will hold a thermometer in container C. Stir the water in this container. Read the temperature once each minute for five minutes.

a) Why did you have a container that you did not put your hand in?

b) Record the temperature readings in the chart.

7. Make a line graph of the temperature readings for the three containers. You will have three lines on the same graph.

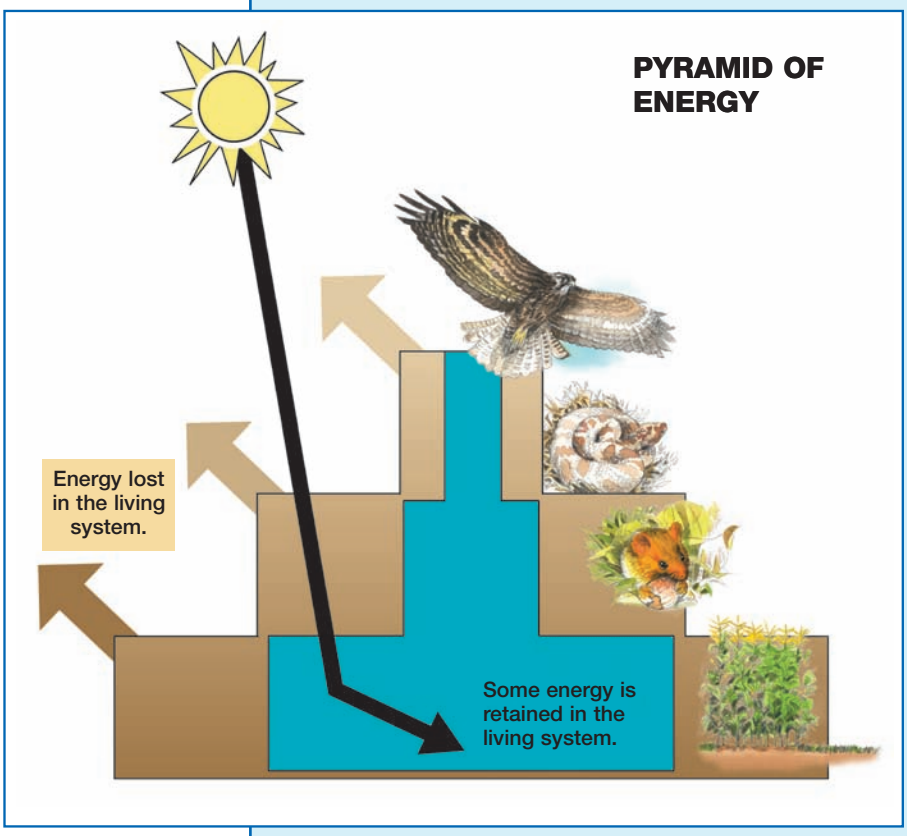
a) In container B, you held your hand in cold water without moving it. What happened to the temperature? Does this data support your prediction?

b) In container A, you exercised your hand. How did the temperature of the water change? Do your data support your prediction?

BioTalk

Pyramids of Mass and Energy

One of the most important abiotic factors that affects relationships in a community is energy. Organisms in an ecosystem are tied together by the flow of energy from one organism to another. The food chain that exists when a herbivore eats a plant and a carnivore eats a herbivore depends on the energy entering the community in the form of sunlight. Without the Sun, there would be no green plants, no herbivores, and no carnivores. (There are a few ecosystems that get their energy from another source.)



The size of a community, therefore, is limited by the amount of energy entering it through its producers. The total amount of chemical energy stored by photosynthesis is the gross primary productivity of the community. Much of that energy is used by the producers to grow and to maintain themselves. The remaining energy, which is available to the consumers as food, is the net primary productivity of the community.

The transfer of energy from producer to primary consumer to secondary consumer, and so on in a food web must follow the laws of **thermodynamics**.

The first law of thermodynamics states that although energy can be transformed, it cannot be created or destroy. Some energy from the Sun is transformed into a form that can be used by living organisms. However, if energy is not destroyed, what happens to it? Why is it necessary to keep adding energy in the form of sunlight? That is where the second law of thermodynamics comes into play. It states that in any energy transformation some energy is lost from the system in an unusable form.

Usually this is in the form of heat. In this activity, you actually measured the temperature increases that resulted from the heat loss from the human body. You noted that with exercise, the heat loss was even greater than without movement.

Among living beings, the transfer of energy in food from "eaten" to "eater" is really quite inefficient, and of course a great deal of the food does not get eaten at all. From grass to sheep the loss is about 90 percent.

It takes about 10 kg of organic matter in the grass to support one kilogram of sheep.

Bio Words

thermodynamics: the study of energy transformations described by laws

Bio Words

pyramid of living matter: a pyramid developed on the basis of the mass of dry living matter at each trophic level

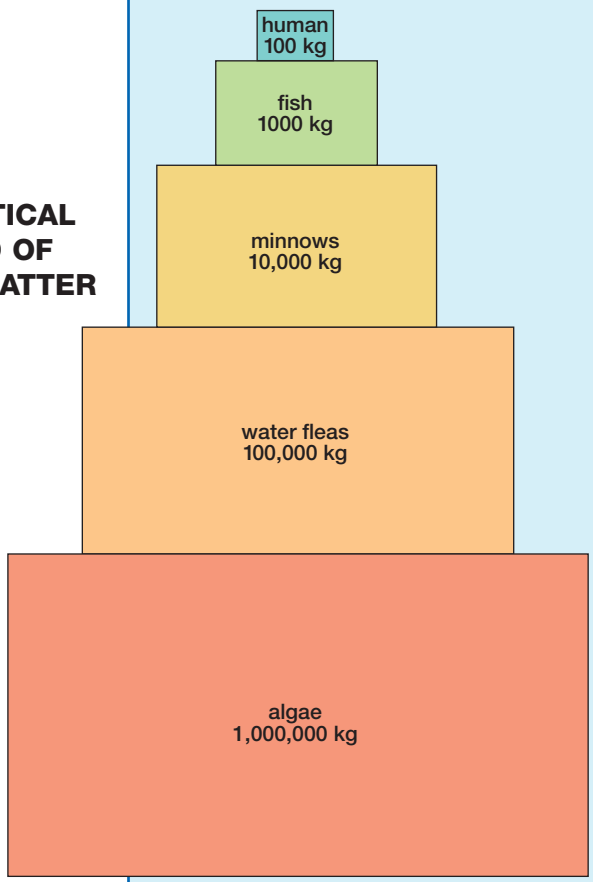
pyramid of energy: a pyramid developed on the basis of the energy at each trophic level

trophic level: the number of energy transfers an organism is from the original solar energy entering an ecosystem; the feeding level of one or more populations in a food web

For the sake of simplification, assume that each consumer lives entirely on one kind of food. Then a person on a lake might live entirely on a given type of fish, for example. To support one kilogram of this person it takes about 10 kg of fish, 100 kg of minnows, 1000 kg of water fleas, and 10,000 kg of algae. This information in graph form is called a **pyramid of living matter**. Mass is a measure of the amount of matter in an object. Because much of the mass of living organisms is water, the producers first must be dried for a truer estimate of their mass when constructing a pyramid of matter. The pyramid shows that the amount of matter is greatest at the producer level.

It is possible to measure the amount of energy available at each level. The **pyramid of energy** that results from graphing these values also

THEORETICAL PYRAMID OF LIVING MATTER



Humans have relied on fish as a source of food throughout history. Most of the fish protein was provided by species caught in the wild.

shows that the energy available is greatest at the producer level and steadily decreases at the other levels. Each step in the pyramid is called a **trophic level** (energy level). Because energy is lost at each transfer, the steps in a pyramid of energy are limited. Usually, there are no more than about five trophic levels in a food chain.

It is also possible to construct a pyramid of numbers by counting the number of organisms in a food chain. Although the largest number of organisms is usually found at the base of the pyramid, this is not always the case. For example, in a meadow there will be many more grass plants than there will be grasshoppers. However, a single tree can sustain many caterpillars.

Reflecting on the Activity and the Challenge

In this activity, you observed the loss of heat from the human body. You then related that to the loss of energy at each step of a food chain. You learned that the further you go up a food chain, the less energy is available. As part of your challenge you are expected to explain how energy flows through an ecosystem. You should also consider how the flow of energy is affected in the environmental issue that you have chosen.

Biology to Go

1. What is the relationship, if any, between the heat energy stored and dissipated at each link in a food web and the heat energy responsible for a heat stroke?
2. In the activity, the student who kept his/her hand in the water may have begun to shiver. Why do you suppose this happened?
3. Explain how the transfer of energy in a food chain follows the laws of thermodynamics.
4. Why is there a limit to the number of trophic levels in an energy pyramid?
5. Why is a pyramid of numbers not always a good example of the flow of energy through a food chain?

6. An energy pyramid illustrates the energy lost at each level of a food web. In general, each level of the pyramid has only 10% of the energy at the level below it. If the producer level (the lowest level) has 10,000 kilocalories available for the rest of the food web, how much energy is available for the other three levels?
7. An energy pyramid illustrates a great loss of energy as you go up the pyramid. When humans eat meat, they act as a top-level consumer. A steer eats a small amount of corn which contains 10 kilocalories. If you were to eat the same amount of corn you would get the same amount of energy from it as the steer. How much energy would you get from that small amount of corn if you ate some hamburger from that steer? Before you calculate this answer think about how this energy pyramid differs from the energy pyramid in the previous questions.

Inquiring Further

Biological amplification

What does biological amplification mean? Use the example of dichloro diphenyl trichloroethane, or DDT, to illustrate how biological amplification and food chains and energy pyramids are related.

The peregrine falcon is a bird of prey at the top of the food chain. As a result of biological amplification, falcons ingested high levels of the pesticide DDT. Falcons contaminated with DDT did not lay eggs or produced eggs with shells that broke.