

ENERGY FLOW THROUGH LIVING SYSTEMS

reflect

Enter the word “domino” as a search term on the Internet; you can find some amazing domino runs. You can make your own by setting up a series of dominoes in a line. When you push the first domino in line, it falls into the next domino, which falls into the next one, and so on down the line. One push starts a chain reaction that results in the whole trail of dominos falling.



One push, and a trail of dominos falls.

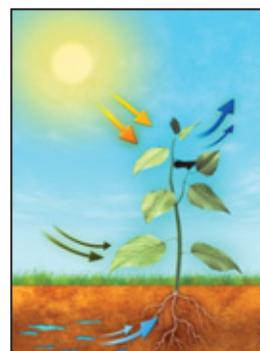
How is a domino trail helpful in describing the movement of energy through living systems?

Energy flows through living systems.

When you push on the domino at the start of a trail, you can see the energy from your push being transmitted from one domino to the next. Your push represents the energy that started the run. This energy moves along the line as each domino topples into the next.

Energy also moves from a starting point through living systems in a one-way direction. This movement is described as a *flow*. The Sun is the major starting point for most of the living things on Earth. A small percentage of organisms use sulfur compounds from volcanic sea vents deep in the ocean as their source of energy. Instead of using sunlight in photosynthesis, these organisms use chemicals to aid in *chemosynthesis*. They make their own food just like in photosynthesis.

Let's focus on the major pathway that energy takes on Earth. It begins with light energy from the Sun. Green plants convert solar energy into chemical energy using photosynthesis. Chemical energy refers to the bonds between atoms in molecules like glucose ($C_6H_{12}O_6$). Photosynthetic organisms are known as *producers* because of their role in this type of energy conversion. They use energy from the Sun to produce their own food. This food is simply a source of energy that organisms can store for later use.

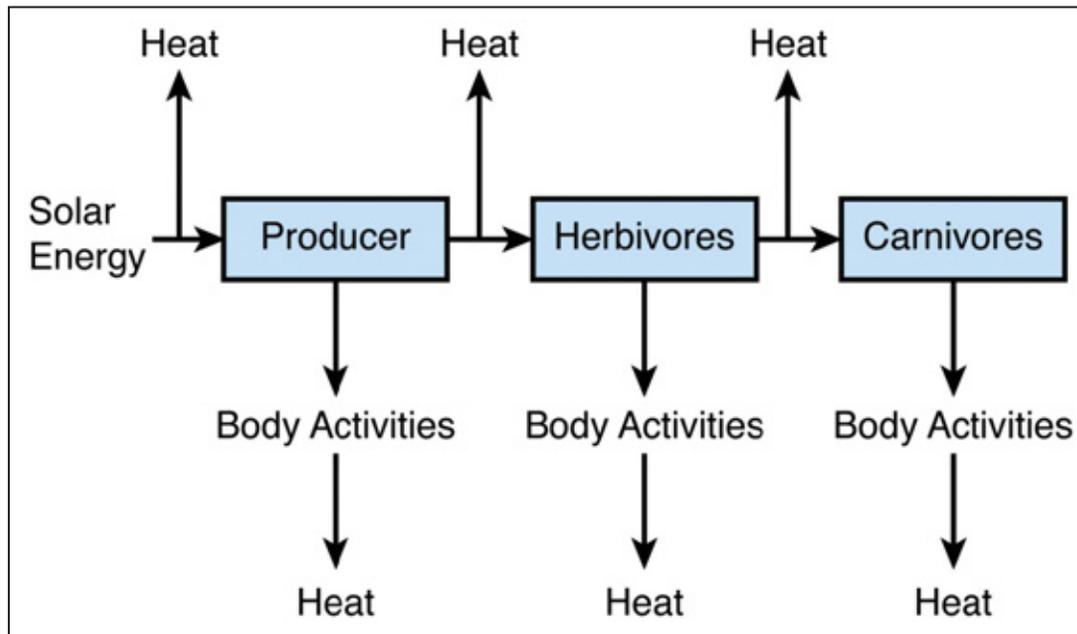


During photosynthesis, green plants use energy from the Sun to convert carbon dioxide and water into sugar molecules.

Each organism on Earth must take in energy from its environment to stay alive. The cells of all living things need constant inputs of energy so they can carry out the metabolic functions necessary to remain alive, grow, and reproduce. Producers provide a source of chemical energy for organisms that eat them. The organisms that use plants as a source of food are known as *herbivores*. Organisms that eat—or *prey on*—herbivores are called *carnivores*.

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The diagram below shows the overall flow of energy through living things. At each step, the transfer of energy involves a loss of energy in the form of heat and body activities. For example, when you exercise you get hot. The heat you feel in your body results from the energy transfers that happen when you move. When you sweat, your body expends energy to cool itself down.



look out!

Energy may be lost in living systems as it flows through them. However, this energy is not lost completely from the universe. All energy within the universe can be accounted for at any time. This is because the total amount of energy in the universe is constant. Energy is never created and never destroyed. Energy is only converted from one form into another. As energy moves between living things, some energy—in the form of heat—is lost. This *thermal energy* escapes into the environment and is no longer useful to organisms, but it is not destroyed.

A food chain shows how energy flows from one organism to another.

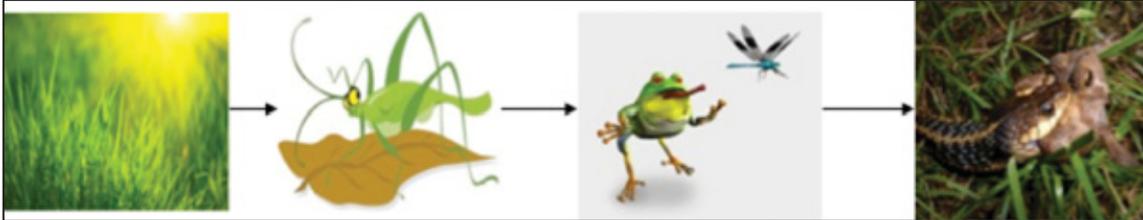
In general, energy flows from the Sun to producers and then to consumers. The path is linear as the energy present in one step is transferred to the next. You can find specific examples of this pathway in an ecosystem.

For example, suppose you observed a grassland ecosystem. There, you would see grass and scattered trees growing in a field. The grass and trees are producers that use sunlight to carry out photosynthesis. Grasshoppers are herbivores that live in grassland ecosystems. They get energy by eating grass and leaves.

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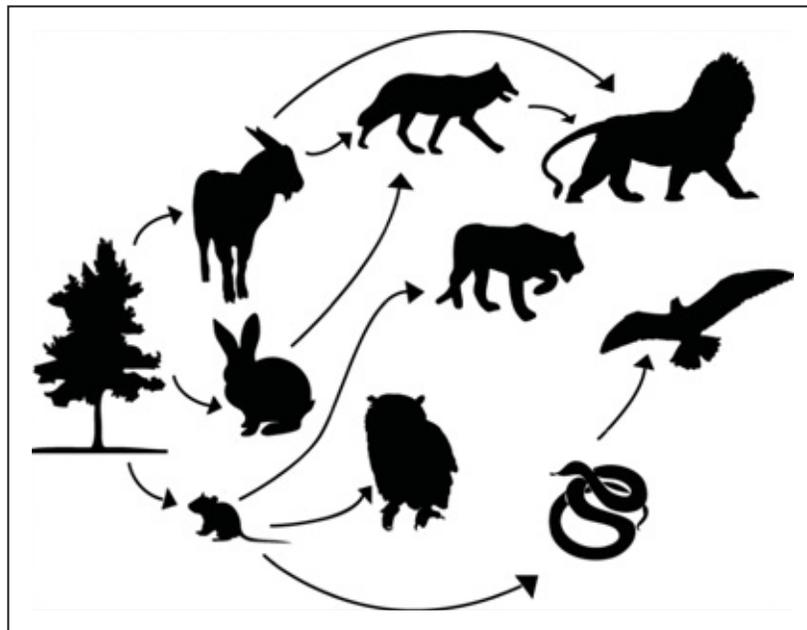
Another transfer of energy occurs when a frog preys on a grasshopper. Later, another energy transfer occurs when a snake captures and eats the frog. We can represent the path of energy flow in this scenario using the following flowchart:



A food chain is a specific path of energy transfer within an ecosystem. In this food chain, energy flows from the Sun to grass to a grasshopper to a frog to a snake. What organism could be the next step in this food chain?

A food web represents the interconnected food chains within an ecosystem.

There are many food chains in any given ecosystem. Any one organism often plays a role in several food chains. All of the food chains, with their many interconnections in an ecosystem, make up a *food web*. A portion of the food web for the grassland ecosystem discussed above could be diagrammed as follows:



The arrows in a food web indicate the direction of energy transfer. Within one food web are many food chains. For example, you can see in the food web shown on previous page that the mouse is part of three food chains. It eats plants and is eaten by cougars, owls, and snakes.

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An energy pyramid shows the distribution of energy within an ecosystem.

So far we have looked at ecosystems with an emphasis on the direction of energy flow. So far we have looked at ecosystems while emphasizing the direction the energy flow, but what do we know about the amount of energy within an ecosystem? How is the amount of energy distributed?

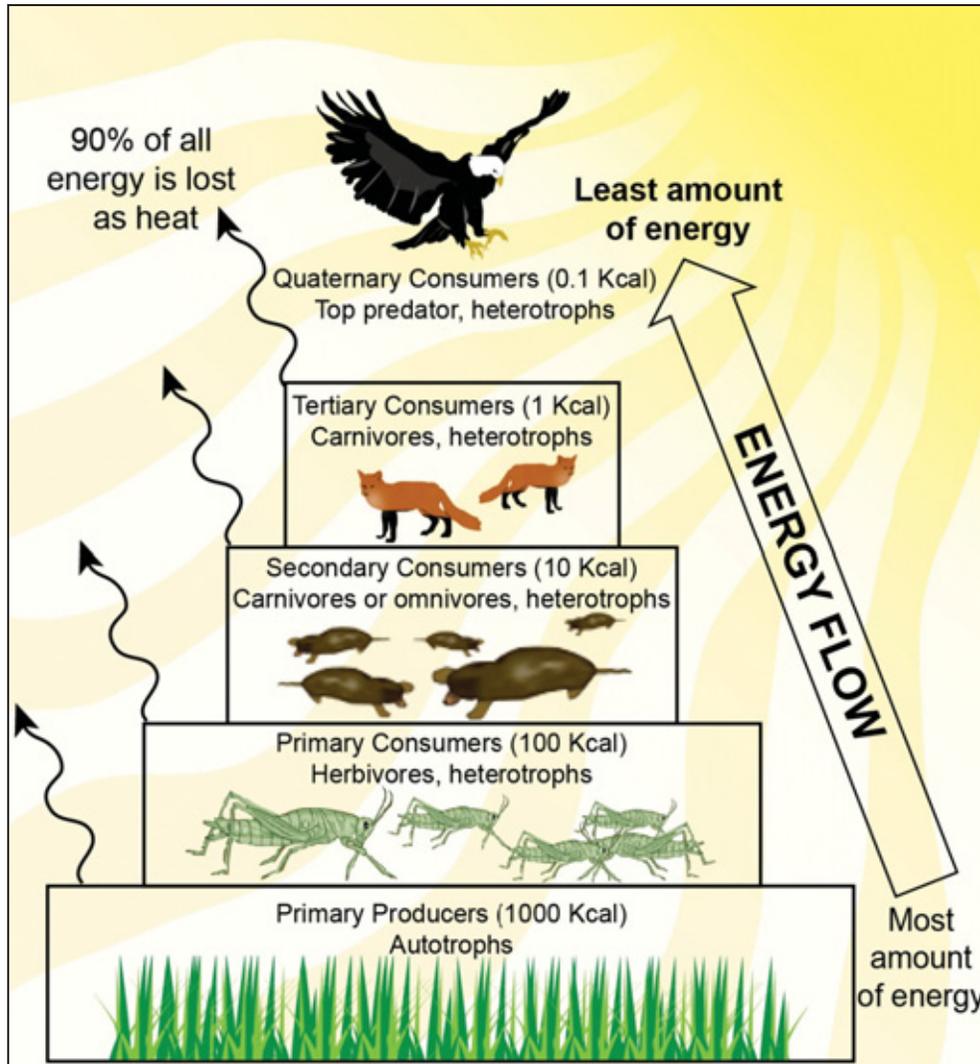
In order to answer these questions, we need to classify and define specific energy levels within an ecosystem. These levels are called *trophic levels*. Producers represent the first trophic level. Producers are sometimes also referred to as *primary producers*. Herbivores, or *primary consumers*, represent the second trophic level. Primary consumers feed on producers. Carnivores, or *secondary consumers*, represent the third trophic level. Secondary consumers feed on primary consumers. *Tertiary consumers* and *quaternary consumers* make up the last two trophic levels. (*Tertiary* means “third level,” and *quaternary* means “fourth level.”) Tertiary consumers feed on secondary consumers. Likewise, quaternary consumers feed on tertiary consumers. (Tertiary and quaternary consumers are also carnivores.)

Earlier, we briefly talked about how the amount of energy changes as it is transferred from one organism to the next. Recall that some energy is given off to the environment as heat during transfers. Because some energy is lost as heat during and between energy transfers, the amount of energy retained in living organisms decreases as you move up through each trophic level. In other words, less energy is available for consumers at each level of the energy pyramid. Specifically, only about 10% of the total energy at one trophic level is passed on to the next higher trophic level. For example, if 1000 kilocalories of energy are present at the primary producer level, one-tenth of this energy, (about 100 kilocalories) is passed to the primary consumers in the next level. Even less energy is available for secondary, tertiary, and quaternary consumers.

The diagram on the next page uses box sizes to represent the amount of energy present at each trophic level. The largest box at the bottom contains the primary producers. The next largest box contains the primary consumers. Secondary consumers are next, followed by tertiary consumers. At the top is the smallest box, representing the quaternary consumers. Altogether the stacked boxes make up a pyramid called an *energy pyramid*. An energy pyramid represents both the distribution of energy and the direction of energy flow within an ecosystem.

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This energy pyramid contains several terms you may not recognize. Primary producers are also called *autotrophs*. The prefix *auto-* means "self." (An *autobiography* is a book you write about yourself.) The root *troph* comes from a Greek word meaning "nourishment." So, an *autotroph* is something that nourishes, or feeds, itself by producing its own food. All consumers are *heterotrophs*. The prefix *hetero-* means "other." So a *heterotroph* is something that feeds itself by eating other things.

look out!

Decomposers, such as mushrooms and bacteria, are consumers because they break down the bodies of dead organisms. This recycles matter for future organisms to use. Decomposers do not occupy a specific trophic level of an energy pyramid. Instead, they extract energy from dead organisms throughout the pyramid.

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what do you think?

Biomass is the mass of matter in living things. Like the quantity of energy in an ecosystem, the quantity of biomass in an ecosystem can be represented as a pyramid. How do you think the specific trophic levels are organized within the biomass pyramid? Do you think biomass increases or decreases as you go from producers to consumers? To help you answer these questions, try to sketch a biomass pyramid.

Everyday Life: Where are humans located in an energy pyramid?

Think about the foods you eat. If you are like most people, you eat a variety of foods. These include fruits and vegetables, which came from producers. You may also eat beef, chicken, and fish, which are consumers. People who eat both meat and plant-based foods are *omnivores*. People who eat only plant-based foods call themselves *vegetarians*, and are classified as *herbivores*.

Omnivores move back and forth between several different trophic levels because of the variety of foods they eat. This makes omnivores primary, secondary, tertiary, and quaternary consumers. People who have vegetarian diets occupy only the lowest consumer trophic level because they eat only producers. Vegetarians are only primary consumers.

What do you know?

The following images (A, B, and C) show three different organisms. Place each organism in the correct place in the energy pyramid on the next page. Use an arrow to indicate how energy would flow between these organisms. Use additional arrows to indicate where energy might be removed from living organisms as heat.

Image A: Deer

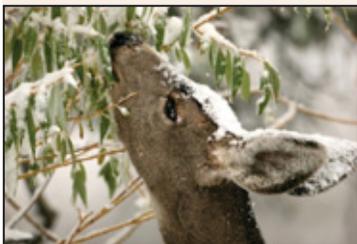


Image B: Wolves



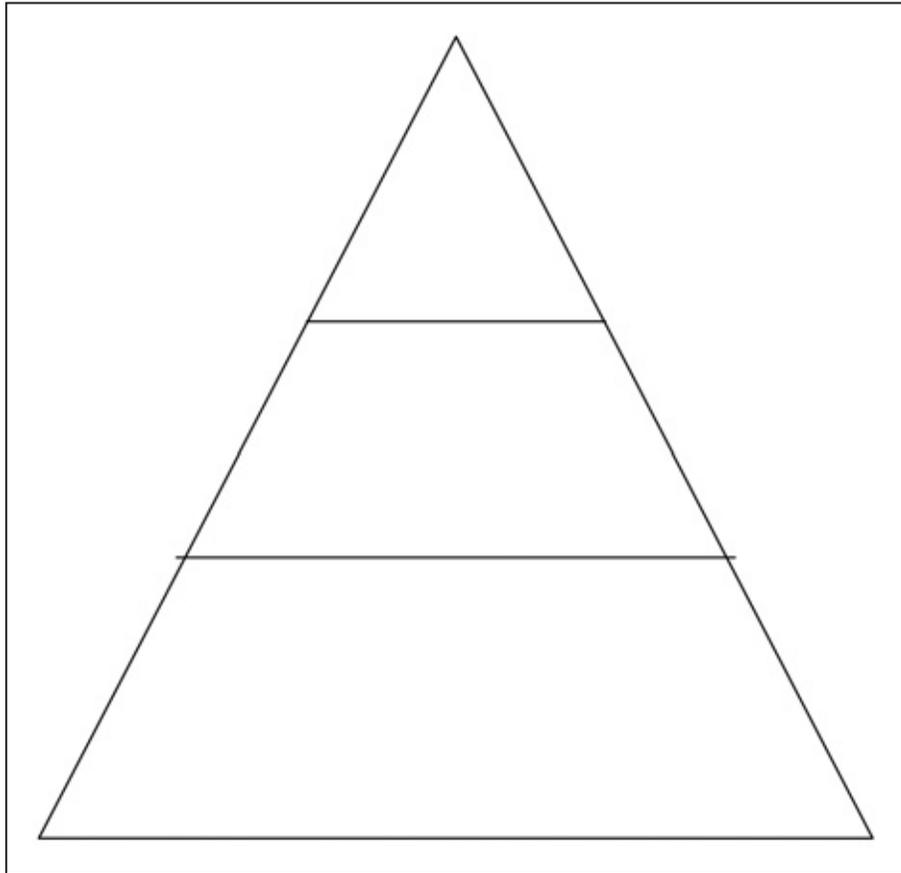
Image C: Tree



- Label each level as producer, primary consumer, etc.
- Label each organism as autotroph/heterotroph
- Show how much energy passes up to each level
- Show how much energy is LOST at each level
- Draw a food chain to show the flow of energy.
- Include at least 4 other organisms to make your food chain into a food web.

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Energy Pyramid:



connecting with your child

Food Webs and Energy Pyramids in Marine Ecosystems

This companion focuses on *terrestrial ecosystems*, that is, ecosystems on land. To help students learn more about food webs and energy pyramids, have them carry out research in the library or on the Internet to find examples of food webs in *marine ecosystems*, that is, ecosystems in water, including oceans, lakes, rivers, ponds, and wetlands. Have your child use the information he or she collects to draw a detailed food web showing specific marine organisms and their relationships to one another. Your child will then take this information, construct an energy pyramid, and label the trophic levels with the names of the organisms that occupy them.

Here are some questions to discuss with your child:

- What organisms carry out photosynthesis in this marine ecosystem?
- What organisms would be considered primary consumers in this marine ecosystem?
- What organisms are secondary consumers?
- What organisms are at the tops of the food chains in this marine ecosystem?