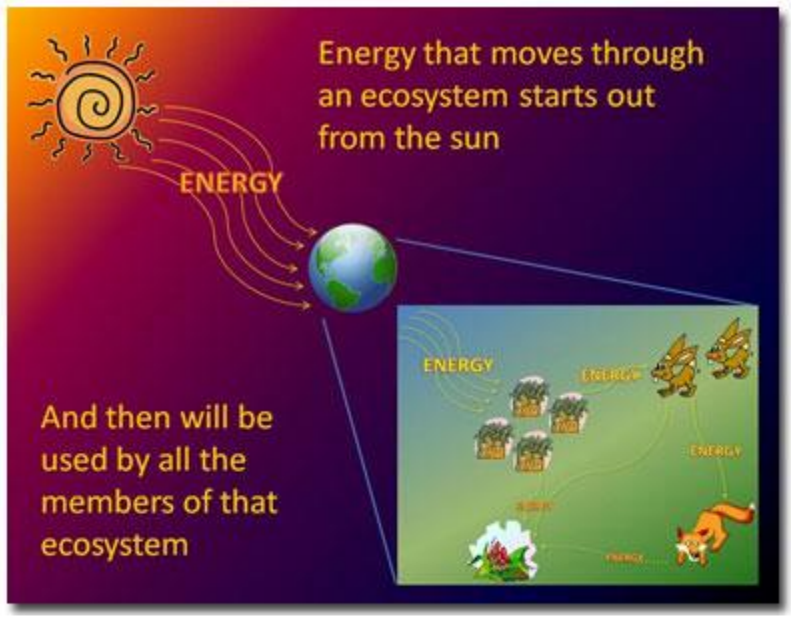
Food Webs: Energy Moving through Ecosystems

Everything Needs Energy

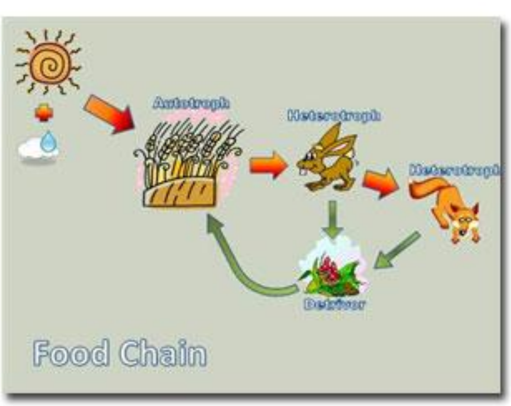
What powers the Earth? Where do we get the energy needed for survival? The answer is, of course, the sun. How does the energy from the sun get to us in a form that we can use for food? There is a law in physics called the conservation of energy law. It states that the total amount of energy in an isolated system remains constant over time. This law means that the total amount of energy received from the sun, as well as the energy stored in the Earth, is all there is on the Earth. We cannot create more. This energy, however, can be converted into different forms that various living things can use. The Earth receives energy daily from the sun in the form of sunlight. Plants use photosynthesis to turn this energy into simple sugars that plants can use to feed themselves. Animals, on the other hand, cannot turn sunlight into food for themselves. Animal cells don't have chlorophyll and don't photosynthesize. So animals have to get energy from other sources, such as plants or other animals. With this information, we have the basic map of how energy flows in an ecosystem.

Background

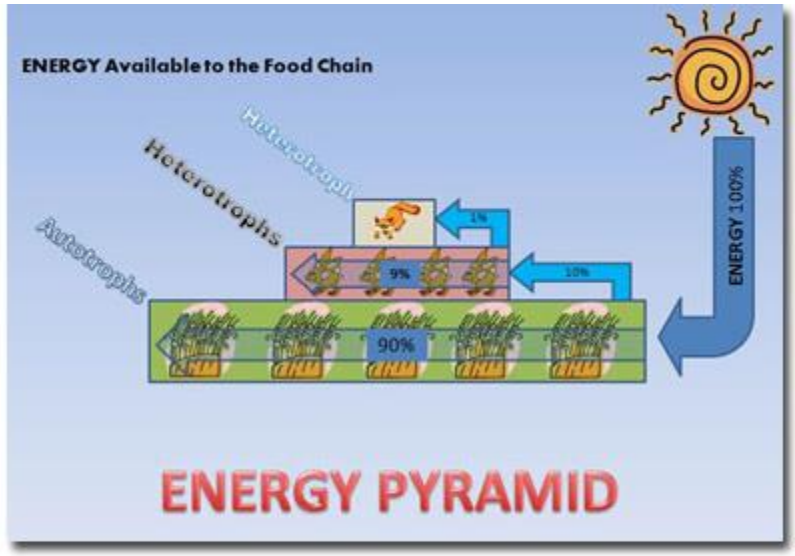
To best understand how energy starts out as sunlight and then eventually ends up in an animal, we need to figure out how the energy transfers from one organism to another. Everything in the natural world is connected. Animals rely on plants to convert sunlight into simple sugars that animals can use for energy. Plants rely on microbes to breakdown dead organic matter to give them the nutrients that the plants need to survive. Plants, animals, and microbes need air and water for respiration. This interdependency is known as an ecosystem. An ecosystem is the interaction of a group of living organisms (animals, plants, and microbes) with nonliving things (air, water, and minerals).



There are ecosystems all over, of all sizes, from vast deserts to tiny ponds. The interaction of living organisms and nonliving things requires energy. To see how energy flows through an ecosystem, scientists look at food webs. What is a food web? By definition, a **food web** is a multitude of interconnected trophic interactions. So what is a trophic interaction? Organisms within an ecosystem can be classified as autotrophs, heterotrophs, or detrivores. Interactions of organisms in different classes are trophic interactions. An **autotroph** is an organism that manufactures its own food from raw inorganic materials like plants and algae. Many times, we call autotrophs producers, because they produce their own food and food for others. A **heterotroph** cannot manufacture its own food; like animals and some microorganisms, it obtains its energy and nutrients by eating plants, other animals, or their dead remains. Heterotrophs are called consumers, because they receive their energy by taking it from others. A **detrivore** is a decomposer. Decomposers, such as bacteria and fungi, feed on waste and dead matter and convert them to inorganic chemicals that can be recycled as mineral nutrients. Autotrophs, heterotrophs, and detrivores within ecosystems rely on one another for food. This is considered trophic interaction. For example, grass (autotroph) growing in a field is eaten by a rabbit (heterotroph). The rabbit is eaten by a fox (heterotroph). Finally, leftovers from the fox and rabbit are decomposed by a mushroom (detrivore). Each step in this example is called a **trophic level**, where organisms are interacting with one another. The combination of these trophic interactions is called a **food chain**. After all of the trophic interactions within an ecosystem are unified, they become known as **food webs**.

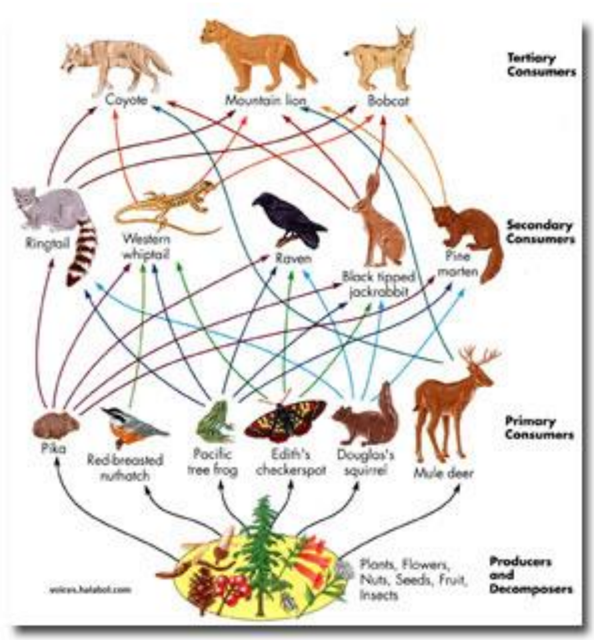


Is There Enough Energy to Go Around?



As plants use energy from the sun to produce energy for themselves, they also provide energy for other animals. The sun's energy "flows" through a food chain from the plants to animals. Throughout a food chain, each trophic level requires a portion of energy in order for the organisms to sustain themselves. Ecologists have figured out that about 90% of the energy is kept on that trophic level, which means only 10% of the energy is available for the next trophic level (CRMO 2013).

To show how this works, we use an energy pyramid (like the one to the right), showing the requirements of our food chain. Looking from the top of a food chain down, how much energy does it take for the top heterotroph to survive? In our example, our hypothetical fox needs four rabbits to make it. Now, if we have two foxes, how many rabbits would we need? The answer is eight. All of these rabbits require a bunch of grass and other plants to get the energy they need. We need a lot of nutrients, sunlight, and water to feed all that grass. If there is not enough energy going through the food chain, the top consumers (heterotrophs) will not be able to survive



We have seen the energy demands from our example food chain. However, this is just one simple example in a much more complex real-world scenario. When we take a bunch of food chains and put them together to make a food web, creating a more real-world scenario, we can see how the demand for energy and other resources will become extremely complicated (like the example to the left).

Activity

This activity was adapted from an activity by the Missouri University of Science and Technology, Science Education and Quantitative Literacy Program (SEQL 2004).

Objective

In finding out how energy flows through ecosystems, scientists use modeling. Scientists use modeling, because, in most cases, modeling and computer simulations are much cheaper, faster, and more practical than manipulating actual ecosystems. Computer modeling also allows for mistakes to be made, without any real-world impacts. Computers and other devices allow scientists to study different aspects of the world to give us answers to difficult questions. Scientific modeling is a way of figuring out what is happening or might happen.

This activity is a model and one that can be done without a computer. All of the parts in this model are portraying various aspects of a food chain. During this activity, we will observe how energy flows through an ecosystem. We will also be able to ask and answer questions about how the amount of available energy and resources affect organisms in an ecosystem. This activity is a model and one that can be done without a computer. All of the parts in this model are portraying various aspects of a food chain. During this activity, we will observe how energy flows through an ecosystem. We will also be able to ask and answer questions about how the amount of available energy and resources affect organisms in an ecosystem.

Materials

- 10 packs of 100 beans/marbles/paper dots or something that can be counted easily
- 18 index cards

Procedure

The first part of any model is to set parameters. A parameter is basically a rule that we need to follow throughout the model. For this model, we are going to set parameters for all of the organisms in the food chain.

- Parameters:
  - Energy for this model is represented by the packets of beans/marbles/paper dots. One packet of ONE HUNDRED beans/marbles/paper dots is enough to support ONE GRASS PLANT.
  - TWENTY beans/marbles/paper dots are required for one RABBIT to survive.
  - THRITY beans/marbles/paper dots are required for one FOX to survive.
  - TEN beans/marbles/paper dots are required for one FERRET to survive.
- On each index card, designate a member of the food chain as follows:
  - 1 sun
  - 10 grass plants
  - 5 rabbits
  - 1 fox
  - 1 ferret.
- On a table top, lay out the sun card, the 10 grass plant cards, the five rabbit cards, and the fox card. Place all of the packets around the sun.
- Take packets from the sun, and give one packet to each grass plant. We know that 90% of the energy from the sun is used by the plant. Have each grass plant keep 90 beans/marbles/paper dots in its packet, and remove 10 beans/marbles/paper dots.
- Have each rabbit try to obtain 10 [*note: 20 is intended here*] beans/marbles/paper dots from plants.
  - Did all the rabbits survive?
  - Is there extra energy?
- We know that 90% of the energy from plants is used by the rabbits and that 10% is available to the foxes. Have each rabbit keep 18 beans/marbles/paper dots (90%), and make two beans/marbles/paper dots (10%) available to the fox.
- Have the fox try to obtain 30 beans/marbles/paper dots from the rabbits.
  - Were there enough rabbits for the fox to be supported?
  - How many more rabbits will the food chain need to support one more fox?
  - How many more grass plants are needed to support that many more rabbits?
- We know that a fox can't survive in this food chain. So let's try a ferret, which only requires 10 beans/marbles/paper dots to survive. Run the model again but with the ferret.
  - Does the ferret survive?
  - What if we had three ferrets? Would they survive? How many rabbits would we need to support three ferrets?
  - What if we had a mountain lion, which requires 56 beans/marbles/paper dots from either foxes or rabbits to survive? How many rabbits and foxes would we need? How many plants would we need?

Entire introduction, activity plan, questions, and additional information retrieved on August 10, 2015 from: *http://www.portageinc.com/community/pp/foodwebs.aspx*

Questions

1. Will there need to be more grass and other plants for the fox to survive?
2. Do you think that the fox could get its energy from someplace else besides rabbits?
3. Why are fewer organisms found as you move up a food chain?
4. What would happen to other organisms if the rabbits left the area?
5. What if we had more rabbits and fewer grass plants in the food chain?
6. Why do you think that there are rarely more than five levels in a food chain?
7. Define an omnivore. How would an omnivore fit into our food chain?

Something to Think About

Yellowstone National Park had no wolves for close to 70 years after they were exterminated. Over those years, the Yellowstone ecosystem had adapted to not having its top predator around. As a result of the absence of wolves, the elk population increased, and beaver and moose populations decreased. Upon the reintroduction of wolves in Yellowstone in 1995-1996, elk populations decreased, and beaver populations increased (Nature 2007).

When the elk population increased, they needed more plants, and energy, to survive. Elk eat aspens, cottonwoods, and willows. Beaver also eat these plants, but with the increased elk eating their food, beavers were unable to obtain enough energy to survive. Also, with fewer beavers, there were fewer beaver ponds, which are important to moose. Upon the reintroduction of wolves, the elk population decreased, which allowed for more food (energy) for beavers and more habitat for moose.

Food for Thought

We say in our discussions and experiment how the food web is built on relationships. Each relationship is important to the overall flow of the system. In our case, we looked specifically at energy. How might this model be used in other real world applications? (Think finance, manufacturing, or almost any capital business organization). In any system in which there is an input and an output, we can modify this model to show the interdependent relationships between each level of the system. This is a very powerful tool to understanding how the world works.

Definitions

Autotroph - An organism that manufactures its own food from raw inorganic materials like plants and algae.
Detrivore – A decomposer, such as a bacterium or fungi, that feeds on waste and dead matter and converts them into inorganic chemicals that can be recycled as mineral nutrients.
Ecosystem - An interaction of a group of living organisms (animals, plants, and microbes) with nonliving things (air, water, minerals).
Food chain – A linear sequence of links made up of different trophic levels.
Food web - A multitude of interconnected trophic interactions, or food chains.
Heterotroph – An organism, such as an animal or plant, that cannot manufacture its own food, so the organism obtains its energy and nutrients by eating plants, other animals, or their dead remains.
Trophic level - Where organisms are interacting with one another creating interactions.

References:

- CRMO, 2013, http://www.nps.gov/crmo/forteachers/activity-4b.htm, "Activity 4B: Craters Ecosystems," The National Park Service, Craters of the Moon.
- Nature, 2007, In the Valley of the Wolves,http://www.pbs.org/wnet/nature/episodes/in-the-valley-of-the-wolves/introduction/212/.
- SEQL, 2004, seql.mst.edu/2004/institute/presentations/Rahaman1.doc, "Energy floe in Ecosystems: A lesson for presentation to fellow teachers," Missouri University of Science and Technology: Science Education and Quantitative Literacy Program.