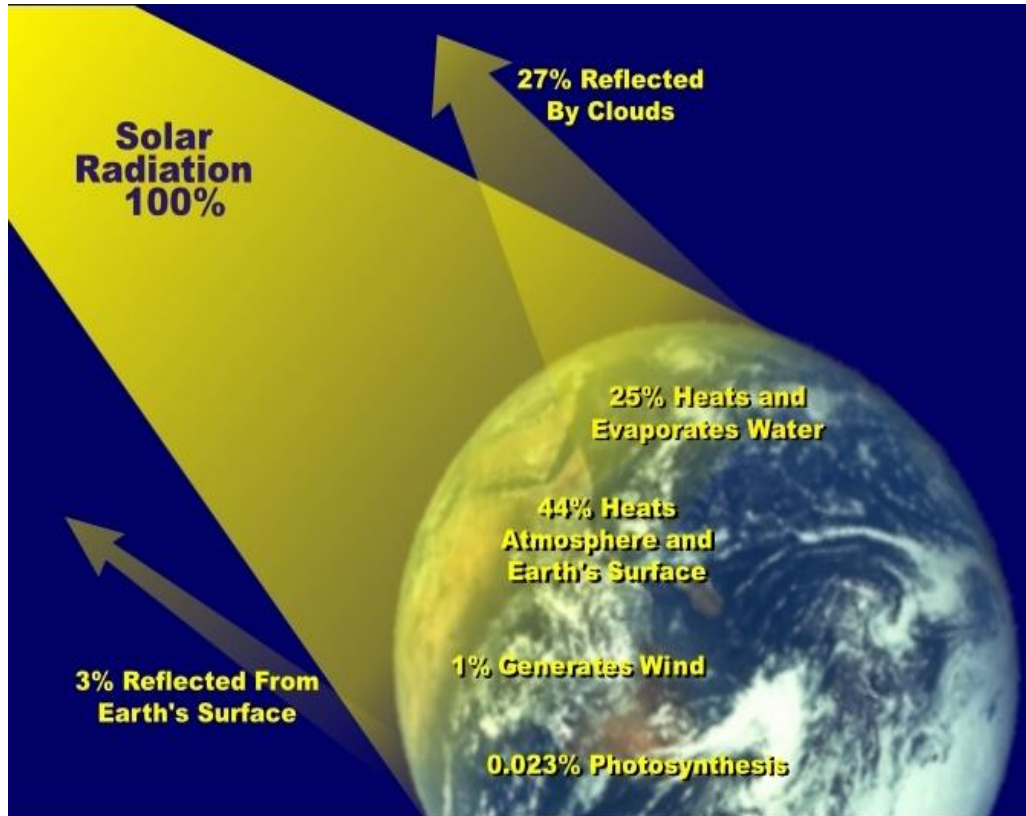


Energy Flow Through an Ecosystem:

The vast majority of life on Earth depends on sunlight as its source of energy. Of all the radiant energy that reaches the earth, some of it penetrates the earth's atmosphere to the Earth's surface, but only a small quantity is used to drive the process of photosynthesis. Consider the following image! About how much of the energy that reaches the earth is actually used in photosynthesis?



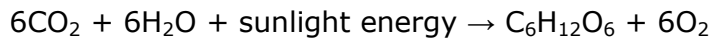
Albedo Effect:

The actual amount of energy that reaches the surface of the Earth is affected by the albedo effect of clouds and dust particles in the atmosphere. **Albedo** is a measure of the amount of light reflected from an object. Albedo is normally expressed as a decimal value representing the percentage of light reflected.

For example, clouds have an average albedo about .27 so about 27% of the sun's energy is normally reflected by clouds back to space. On a clear day, more light would be able to penetrate to the Earth's surface and as a result a greater amount of photosynthesis should occur.

Photosynthesis, a biological process, uses the energy of sunlight to manufacture sugar, which serves as the universal food for life. Oxygen produced as a product of photosynthesis is released into the environment.

The formula for this reaction is:



- where CO_2 represents carbon dioxide
- H_2O represents water
- $\text{C}_6\text{H}_{12}\text{O}_6$ represents the sugar molecules (carbohydrate)
- and O_2 represents oxygen

As you can see from the formula, the energy that had originally come from the sunlight is transferred to the molecules of sugar, ($\text{C}_6\text{H}_{12}\text{O}_6$), as indicated in the equation above. The sugar serves as the source of energy for nearly all life on Earth. The energy stored in the sugar is passed from the plants to other organisms when the plants are consumed as food. This passage of food from producer to various consumers in turn is known as a food chain.

If the community has a great deal of biodiversity, there will be several organisms that can feed on more than one type of food resource, and as a result there would be several possible food chains. All of the possible food chains together make up a food web. Each step in the food chain is called a **trophic level**. Consider the following simple food chain with four trophic levels:

Corn → Mouse → Snake → Hawk

Notice that the pathway of energy flow in the food chain/web always begins with a producer. Producers are also known as **autotrophs** because they make their own food. The mouse, snake, and hawk are consumers. Consumers are called **heterotrophs** because they can not make their own food. Heterotrophs must obtain their nutrients from the organisms they eat. There are many levels of consumers. The mouse is considered a **primary consumer** (or **first order consumer**) because it feeds directly on the plant. A primary or first order consumer is also called an **herbivore**. The snake is considered a **secondary consumer** (or **second order consumer**) and is called a **carnivore**. The hawk that feeds on the snake is an example of a **tertiary consumer** (or **third order consumer**). In this example the hawk is also considered the **top carnivore** since there are no carnivores that feed on it. The hawk is considered to be at the top of the food chain.

Although the hawk is the top carnivore in this example, it is not actually the **final consumer**. Consider what happens when the hawk or any other member of the food chain dies! The final consumers in any food chain/web are the **decomposers**. Decomposers are organisms of decay, that make use of wastes and remains of dead organisms.

Corn → Mouse → Snake → Hawk → Decomposers

To release the energy stored in the sugar, organisms carry out a metabolic process known as **cellular respiration**. The energy released during cellular respiration is what enables organisms to carry on their life processes such as movement, growth, and reproduction. The process of cellular respiration does transfer energy from the food to the organism for carrying life processes, but also releases heat which cannot be used any further. Heat energy is lost on a continuous basis from all living things.

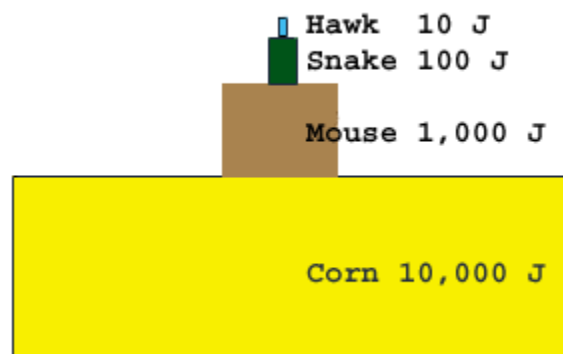
The transfer of energy from one trophic level to the next is never 100% efficient since each organism must utilize some of the energy to support its own existence.

An ecosystem's energy budget depends on primary productivity:

The primary producers use light energy to manufacture food which is utilized by all other trophic levels for all life activities such as growth, maintenance, and reproduction, and in many cases, locomotion. The ecosystem's entire **energy budget** is determined by the photosynthetic activity of the primary producers.

Although the actual quantity of energy that is transferred from one trophic level to the next varies with the time of the season and from one ecosystem to another, biologists have generalized what is called the 10% rule. This generalization suggests that 90% of the energy taken in at any trophic level is lost during the life of the organisms to carry on its own life processes and is lost as heat. Only 10% of the energy is therefore able to be transferred from one trophic level to the next.

If the corn plants in a given area of a corn field fix 10,000 J of energy, only 1,000 J will be available to be passed on to the mouse, 100 J would be passed on to the snake, and only 10 J would be passed on to the hawk. No wonder there are so few hawks in the ecosystem compared to the number of corn plants that support them. The idea that each higher trophic level has less energy available to it is known as the **pyramid of energy**. The figure below represents the 10% rule for energy transfer.



The quantity of energy available to any ecosystem will have a direct impact on the amount of food that can be produced by photosynthesis. Biologists use the term **gross primary productivity** (GPP) to refer to the amount of food produced in a given area per given time. Since the plants use some of their own food to carry on life functions, not all of the food produced is available to be passed along the food web. The amount of food that is available to be passed along the food web is known as net primary productivity (NPP) and is always less than GPP.

Since temperature and availability of water also affect photosynthesis, the value of NPP will vary in different ecosystems. The following table indicates the NPP for selected ecosystems (after Whittaker, R. H., and Likens, G. E. 1975).

Net Primary Productivity (NPP) for Selected Ecosystems	
Average NPP (grams dry matter/m ² /year)	
Tropical rain forest	2200
Northern Boreal Forest	800
Arctic Tundra	140

Do you notice any relationship between the location of these biomes and NPP?

Pyramids of Biomass and Number

Since the amount of water present within the tissues of different organisms varies, biologists use the dry mass of the organism for comparison since it is believed that dry mass more closely reflects the actual amount of "living matter" in the organism. The dry mass is known as **biomass**. The availability of energy (NPP) will also affect the number of organisms and the mass of the organisms at each trophic level. In general, the higher the NPP the higher is the biomass (dry mass) at each trophic level. The **pyramid of biomass** is a graphical representation of the total biomass of all the members of each trophic level. Generally the pyramid of biomass has the same shape as the pyramid of energy. There is a large base representing the total biomass of the producers with each higher trophic level having a progressively smaller size, representing the progressively smaller amount of biomass present. In a grassland environment, 10,000 kg of grass and other producers (dry mass) should support about 1,000 kg (dry mass) of grasshopper and other plant eating insects.

What biomass of frogs and other insect eating creatures would you predict to find in the same grassland environment?

The **pyramid of number** is the third type of graphical representation used by biologists to study ecosystems. The pyramid of number is often similar in shape to the pyramid of energy or biomass, but there are exceptions. Consider a single spruce tree in a boreal forest (biomass = 100 kg) which is infested by 100,000 spruce bud worms

(total biomass = 10 kg), which are in turn eaten by 5 insect eating birds (total biomass = 1 kg). The pyramid of biomass would appear normal (base representing 100 kg, middle piece representing 10 kg, and a top piece representing 1 kg). The pyramid of number for this example will not look normal. The pyramid of number would have a very small base representing the producer (1 tree), a very large herbivore level (100,000 spruce bud worms), followed on top by a small predator level (5 birds).

In this example, what causes the pyramid of number to differ so much from the pyramid of energy or the pyramid of biomass?

Conditions Necessary for a Stable, Self-sustaining or Sustainable Ecosystem:

Stability means that there is an ecological balance between the various organisms that make up the food web, and because of this balance the ecosystem is self-sustaining over long periods of time. To be stable there must be a balance between food production, food consumption, and decomposition of dead organisms and/or their wastes.

This means that a stable ecosystem must have a source of energy (usually sunlight for photosynthesis), producers to capture the sunlight and make food, and a means to recycle the materials. The greater the biodiversity in the ecosystem the more stable it will be.

The many interrelated food chains of an ecosystem give a community stability because every food level helps to control the numbers of organisms in the level below it. For example, predators such as lions help to ensure the health of the zebras. Some biologists have even remarked that the predator is the prey's best friend. The decomposers recycle the nutrients back to the plants. In turn, the plants grow to supply the food for the herbivores.



Biologists have also recognized that some species in the ecosystem function as a keystone species. A **keystone** species is one considered so important to the stability of the ecosystem, that if there was a decline in that species, the community would not be able to maintain its stability and may even collapse.

One example of a keystone species is the sea otter that lives off the coast of California. In this province capelin are considered a keystone species, especially in ocean webs that involve cod.