Ecology: Limits of Energy Transfer

06 - 07__Lesson 7

Text Reference **1.11**, page 34 - 39

All living things need energy, to carry out their daily activities, organisms such as animals, fungi, and bacteria get their energy by consuming food.

All food webs are based on green plants:_______________ . The producer provides the necessary energy link with the abiotic environment. The producer collects solar energy and basic nutrients and converts them to chemical energy through the chemical process________________.
This chemical energy is stored in plant structures such as roots and seeds, where it is usually called food energy.

Photosynthesis Equations

Photosynthesis comes from three Greek words that mean"putting together with light".

Photosynthesis occurs in producers, i.e. plants, these are able to capture the energy from the Sun through pigments called chloroplyll formed in organelles called chloroplast, together with carbon dioxide from the atmosphere and form sugars and oxygen:

$$\text{carbon dioxide} + \text{water} + \text{light energy} \longrightarrow \text{sugar (glucose)} + \text{oxygen}$$

$$6CO_2 + 6\,H_2O + \text{light energy} \longrightarrow C_6H_{12}O_6 + O_2$$

Cellular Respiration Equation

Respiration occurs in cells, in an organelle called the mitochondrion.
Respiration and photosynthesis occur constantly. During respiration, aerobic organisms break down or decay plant and animal materials, releasing carbon dioxide into the atmosphere.
The equation for cellular respiration is:

$$\text{sugar (glucose)} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

$$C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + 6\,H_2O + \text{energy}$$

Together, they form a natural cycle called the carbon cycle. The carbon cycle is a nutrient cycle, illustrated as:

$$\text{Sugar} + \text{oxygen} \underset{\text{chloroplast}}{\overset{\text{mitochondrion}}{\rightleftharpoons}} \text{energy} + \text{carbon dioxide} + \text{water}$$

Flow of energy along the food chains:

There is a constant flow of energy along food chains but each consumer uses or wastes nearly all the energy it takes in.

Food energy is used first of all by the plants themselves for their own life functions – to stay alive and to manufacture the chemicals they needs to grow, thus less than 100% of the solar energy they collect is available as food energy for ________________.

Stored plant energy is transferred to animals when herbivores eat the plants. Energy stored in herbivores is transferred again when _______________eat the herbivores.

Herbivores likewise use much of the food energy for their own body functions - again less than 10% of the energy taken in is available for consumers at the next trophic level.

Some of the energy was lost as the plant respired, and some is lost as indigestible material which passes through the herbivore's gut. The same losses occur when carnivores eat herbivores, and to the end of the chain.

Hence, each trophic level receives _____ energy.

Most of the energy transferred to each successive level is converted to heat.

The transfer of energy from one trophic level to the next is quite inefficient with only a fraction of the energy converted by producers is made available to primary consumers and large amounts of generated heat being wasted.

Energy is "one -way" and is gradually lost along a food chain. Most energy is lost as _____ energy.

Factors that reduce the amount of energy available for transfer as you move up the trophic level:
1.

2.

3.

Thus, energy loss at each trophic level limits the length of the food chains because , by the 4th or 5th level there is no energy left to support another link, and it also gives rise to **biological pyramids**.

While food chains are useful to describe basic feeding relationships among organisms, scientists use a variety of pyramids (graphs), to illustrate different feeding relationships.

A food pyramid is a way of arranging food chains to show more clearly the transfer of energy through the ecosystem. There are three types of food pyramids that are used as models to study energy flow.

1. Pyramid of Energy

A pyramid of energy shows how much food energy is available at each trophic level in a particular ecosystem. Very difficult to use in the field because it involves calculations including numbers, masses and energy content of each type of organism.

The bottom part of the energy pyramid shows that the energy contents of organisms at the upper trophic level is always much less than at lower levels due to energy loss.

Energy Transfer

100 % energy in producers ⟶ 63.4 % is "lost" by metabolism, biochemical processes of living cells
⟶ 20.4 % to decomposers
⟶ 16.2 % actually makes it to primary consumers

Rule of Thumb: 10 % of energy in a lower trophic level is available to the next trophic level. (Energy efficiency is often expressed as a percentage).

[Recall: Due to loss of energy at each trophic level, thus limiting the number of trophic levels in a food chain to FIVE – having a very small number of organisms at each successive level.]

Assignment:

Create a pyramid of energy based on the following information:

1.Grass captures 65 000 kJ of energy from the sun. Rabbit eats the grass, and a fox eats the rabbit. The wolf eats the fox.

2. 88 00 kJ of energy from grasses —> snails, slugs, grasshoppers —> shrews, moles —> owls

2. Pyramid of Numbers

A pyramid based on number of organisms at each trophic level in an ecosystem is called a Pyramid of Numbers – it describes the **number of organisms that are required to feed the next trophic level**.

Pyramid of numbers is the easiest to construct and it assumes that each organism has the same amount of energy as the next.

Usually more organisms are found at lower trophic levels than at higher levels, because the producers and the primary consumers have the greatest numbers in a pyramid.

A large number of producers are required to support the food transfer through the food chain.

Assignment:
Create a pyramid of numbers, given the following information: 85 000 blades of grass, 8 500 beetles, 850 sparrows, 85 snakes, 8 hawks.

There are many **exceptions** due to various reasons, for example, due to the physical size of the members of a food chain, example: For every one tree there are many more insects feeding on it; or as in early spring, when many more consumers arrive before an appreciable number of producers do — these situations would lead to an inverted pyramid.

A pyramid of numbers does not show energy flow because of the great disparity in the size of the organisms.

3. Pyramid of Biomass

Another useful way to represent an ecosystem is through a pyramid of biomass. Ecologists must **directly** measure mass. Mass **must** be dry.

However, a pyramid of biomass is most difficult to use in the field, it also assumes that 1 g of a species has the same energy as 1 g of another species; it does not consider the energy contribution of each organism: e.g. 1 kg of grain is not equivalent in energy to 1 kg of chicken.

Definition: Biomass: weight of matter after the water content has been removed after drying.

Biomass is based on the total dry mass, (after water has been removed), of the organisms at each trophic level, and it shows the energy available in each trophic level of an ecosystem.

Under natural conditions, the amount of biomass decreases progressively with each higher step of the pyramid.

Assignment: Create a pyramid of biomass, given the following information:

1. 50 000 kg of roots, 5000 kg of mice, 500 kg of snake, 5 kg of hawk.

2. 900 g moss, algae —> 45 g duck —> 9 g falcon

A pyramid of biomass is slightly more useful than a pyramid of numbers because it takes into account of the size of the organisms, a pyramid of energy is the most useful.

Laws of Thermodynamics

Two basic laws govern the flow of energy through an ecosystem.

The first law describes the way in which energy flows through an ecosystem:

– as transfers through food chains – from the sun to producers,
– to consumers to top carnivore.

To complete the nutrient cycle, this energy needs to be replaced.

The second law describes the continual replacement of nutrients through exchanges between producers and consumers. These laws shape the way organisms in ecosystems interact with one another.

The first law of thermodynamics:
the total amount of energy in a system remains constant but it can be transformed from one form into another; it can not be created or destroyed.

The second law of thermodynamics:
during any energy transformation, some energy is lost, usually in the form of heat.

Summary

A pyramid of energy shows the total chemical energy being passed along each organisms to use at subsequently higher trophic levels.

A pyramid of numbers shows that organisms in lower trophic levels are usually more abundant than organisms in higher trophic levels.

A pyramid of biomass shows biomass decreasing among organisms in subsequently higher trophic levels.

Homework

1. Read pages 34 - 38
2. Answer: Understanding Concepts, page 39, # 1 – 13
3. Worksheet: Energy and Types of Pyramids