

Ecosystems Processes: Energy Flow

6

STRUCTURE

- 6.1 Introduction
- 6.2 Objectives
- 6.3 Understanding Energy Flow
- 6.4 Energy in Ecological Systems
- 6.5 Food Chains
- 6.6 Understanding Food Chains
- 6.7 Conclusion
- 6.8 Recapitulation
- 6.9 Unit-end exercise
- 6.10 The Teacher Section



6.1

The major pre-requisites for life to exist on earth include continuous supply of nutrients (in a usable form) to the living world, and appropriate quantum and quality of energy to keep the biochemical process going. In the last unit we looked at the first process, in this unit, we will try to understand the latter one. What is the ultimate source of energy for the life to thrive on our planet? The sun. Yes, but how does the sun's energy get utilized into the ecosystems and their processes? How do various elements of the ecosystems get their energy? Is there too much or too little energy available? How do the natural systems maintain an energy balance? These are some of the questions, which will be discussed in this unit.

6.2

On completion of this unit, you should be able to

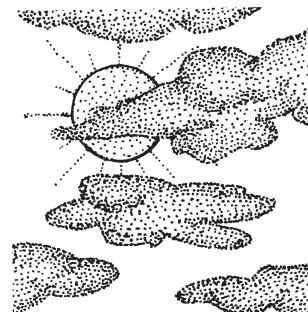
- Explain the flow of energy in ecosystems
- Define food chains and state their major types
- Appreciate links between nutrient cycles and energy flow and ecological significance of these processes.

6.3 UNDERSTANDING ENERGY FLOW

It is a fact that any kind of 'work process' will either require or release energy. Thus if we want to study the functioning or the working of an ecosystem, we must understand the basic principles and laws of thermodynamics, in an ecological context:

- (i) The first law of thermodynamics states that energy may be transformed from one type into another but is neither created nor destroyed.
- (ii) The second law states that no energy transformations are hundred per cent efficient, i.e. energy is always being transformed from a more useful to a less useful form.
- (iii) Under natural conditions, energy tends to flow from higher level to the lower one. This is a derivation from the second law of thermodynamics.

The ecological implication of these laws is that energy cannot be produced in ecosystems from nowhere. Thus when we say 'productivity of ecosystems', we refer to the transformation of one form of energy (say, solar) into another (say, organic form in plant bodies). Secondly, transfer of energy from one organism to the other, is never hundred per cent efficient, i.e. all energy transformations always involve energy loss in the form of heat energy that is not available to the organism. The amount of loss may vary from one transformation process to the other, but it invariably occurs. Let us, in the next section, try to analyze the energy flow in an ecosystem.



6.3.1

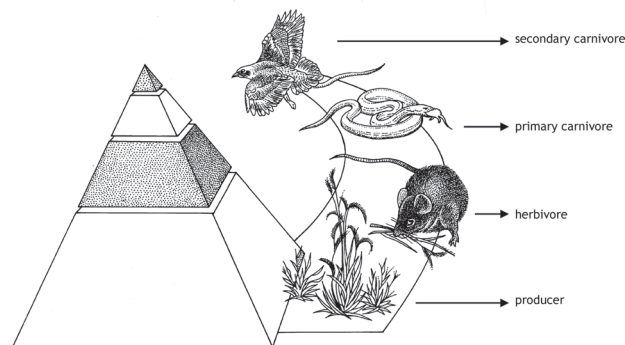
1. State the two laws of thermodynamics.
2. Explain the following: “No energy process is 100 per cent efficient”

6.4 ENERGY IN ECOLOGICAL SYSTEMS

The ultimate source of energy for all ecological systems is the sun. The energy that enters the earth's atmosphere as heat and light is balanced by the energy that is absorbed by the biosphere, plus the amount that leaves the earth's surface as invisible heat radiation (first law of thermodynamics). When solar energy strikes the earth, it tends to be degraded into heat energy. Only a very small part (about 10 per cent) of this energy gets absorbed by the green plants, and is subsequently transformed into food energy. The food energy then flows through a series of organisms in ecosystems. All organisms, dead or alive, are potential sources of food for other organisms. A grasshopper eats the grass, a frog eats the grasshopper, and a snake eats the frog and is in turn eaten by a peacock. When these creatures die they are all consumed by decomposers (bacteria, fungi, etc.).

6.5 FOOD CHAINS

In an ecosystem, the sequential chain of eating and being eaten is called a **food chain**. It is this process which determines how energy moves from one organism to another within the system. In a food chain, energy (organic form) is transferred from one organism to another. Ideally, this transfer or flow of energy from the sun to green plants to herbivores to carnivores should be 100 per cent efficient. But in reality this does not happen, because at each link in a food chain, 80 to 90 per cent of the energy transferred is lost as heat (second law of thermodynamics). It is because of this loss that fewer individuals are found at each successive level of the food chain (e.g. fewer carnivores than herbivores). This also limits the number of levels in a food chain. All



organisms are part of a food chain, and may be part of more than one. Food chains usually consist of producers, primary consumers, secondary consumers, tertiary consumers and decomposers.

Every organism in an ecosystem can be assigned a feeding level, referred to as the **trophic level**. A trophic level consists of those organisms in food chains that are the same number of steps away from the original source of energy. Green plants would be grouped in the first trophic level (producers), herbivores in the second trophic level (primary consumers), and carnivores in the third (secondary consumers) and so on.

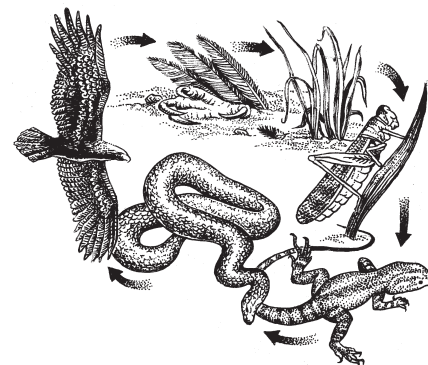
Can you think of a food chain that you have seen operating in nature?

Types of Food Chains

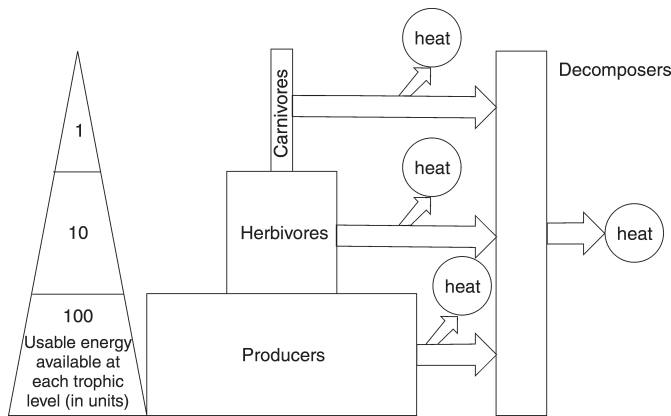
Though all food chains comprise of a series of living organisms which are interdependent on each other for food and hence energy, they may not always be similar. In nature there are two major types of food chains: the first starts from a base of green plants and goes on to herbivores and finally to carnivores. This is called the grazing food chain. The other starts from a base of dead organic matter, proceeding to a variety of other organisms, including scavengers, insects and microorganisms, and is called the detritus food chain. Grazing food chains and detritus food chains are linked, as dead organisms from the grazing food chain form the base for the detritus food chain. This in turn provides nutrients vital to green plants. One could not exist without the other. A number of food chains interwoven with one another give rise to a structure similar to the delicate web of a spider. These interlocking patterns formed by several food chains that are linked together are called **food webs**. Exploring connections between various components of an ecosystem can be an exciting activity.

6.5.1

1. What role do decomposers play in nutrient cycling and energy flow?
2. What are food chains? Give an example of food chain from your surroundings.
3. What are the two major type of food chains? Are they linked?



6.6 UNDERSTANDING FOOD CHAINS



Trophic levels in a food chain can be shown graphically through **ecological pyramids**, with producers at the base and successive levels of consumers forming the higher layers. Ecological pyramids are of three basic types: **pyramid of numbers**, in which the numbers of individual organisms are depicted; **pyramid of biomass**, based on the total dry weight or other measures of the total amount of living matter; and **pyramid of energy**, in which the energy assimilated and/or productivity at successive trophic levels are shown. Ecological pyramids are used for comparing biomass and energy flow between trophic levels. Such comparisons can be used for identifying which ecosystems or communities are more efficient in terms of energy transfer.

BIOLOGICAL MAGNIFICATION

In food chains, it is not only nutrients that get transferred. Toxic substances may be transferred from one trophic level to another too. In some cases, the concentration of the toxic substance increases with every increase in the trophic level. This increase in concentration of a toxic substance, with every link in the food chain, is called **biological magnification** or **biomagnification**.

The oft quoted example of biomagnification is the buildup of DDT across various trophic levels in a food chain. To control mosquitoes, DDT was sprayed in Long Island, U.S. DDT levels used were carefully regulated so that they were not directly lethal to fish and other wildlife, but only to the mosquitoes. As mosquitoes got killed, the DDT did not get washed out to sea as was predicted. Rather, the poisonous residues got absorbed on detritus and eventually became concentrated in the tissues of detritus feeders and small fishes, and step-by-step got concentrated in the top predators such as fish-eating birds. As a result, the shells of eggs laid by these birds were not fully formed and hence could not give protection to the embryo. Thus no chicks hatched. This ultimately wiped out whole populations of predatory birds, leaving the island ecosystem unbalanced.

Can you recall the story, 'Cats were parachuted'. Do you think biomagnification was a problem there?

6.7 CONCLUSION

Understanding the flow of energy in and through ecosystems can help in developing a greater understanding of how nature works. Before the evolution of green plants, the movement of solar energy on our planet would have been quite different than what it is today. Detailed studies of energy flow and energy balance in ecosystems (through the past and in the present) can help in understanding the energy balance of the earth and the role of living beings and processes in the same. This in turn would help in establishing the impacts of human on the earth's energy balance.

6.8 RECAPITULATION

- Energy flow in ecosystems is governed by the two laws of thermodynamics
- Energy movement is always unidirectional (from a higher end to a lower end) and hence this movement is called 'energy flow'.
- The ultimate source of energy for ecosystem processes is the Sun. The ecosystems on earth can harness/process a very small fraction of solar energy reaching the earth.
- The sequential chain of eating and being eaten by other organisms in nature is called 'food chain'. Food chains are the link through which the nutrients as well as energy move in an ecosystem.
- Study of food chains operating in an ecosystem can help in understanding the energy flow in, and productivity of, an ecosystem.

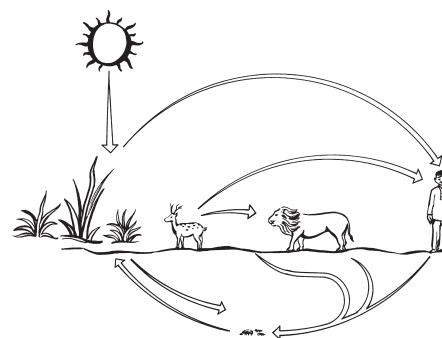
6.9

1. Define food chains. Give their types.
2. Describe biological magnification.
3. Food chains are the link between nutrient cycling and energy flow. Explain.

6.10

Energy Relay

As we know, the ultimate source of energy for all processes on our planet is the sun. In most ecosystems, this solar energy is trapped by green plants and converted into organic energy (carbohydrates) through the process of photosynthesis. A part of this organic energy is utilized by the green plants for their own growth, repair, reproduction, etc., and the remaining is available to plant-eating animals. Plant-eaters are eaten by meat-eaters, and thus a part of this is in turn available to meat-eating animals. This natural chain of eating and being eaten is called as 'food chain'. Thus a food chain is that



sequence of organisms through which energy is transferred in an ecosystem. All organisms are part of a food chain and may be part of more than one. Depending on the number of steps away from the original source of energy in a food chain, each group of organisms comprises a trophic (feeding) level. Thus green plants (producers) make the first trophic level; herbivores (primary consumers) the second; and carnivores (secondary consumers) the third. If each organism is food for another and so on, then food chains in nature would be neverending. But in reality it is not so. Why? Because with each step added onto the food chain, more and more energy gets lost, at the end leaving such little and low quality energy that no living being can use it. How does energy get lost? This can be a very abstract concept for your students to understand. The game explained, 'energy relay' here can help you in explaining this concept.

Group size: Up to 60 players

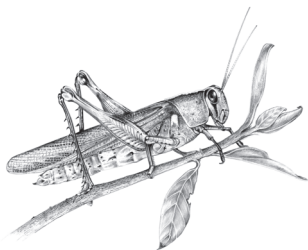
Duration: 30 minutes

Requirements: Two transparent tumblers or cups of the same size, spoons (one for each player), measuring cylinder

Objective: To demonstrate that energy is lost as it passes along the food chain.

Procedure:

1. Make the players stand in a line. The line should have about fifteen players. If there are more than fifteen players, make them stand in two or three lines of fifteen players each.
2. Take a cup of water. Call two or three players and ask them to measure the amount of water in the cup using the measuring cylinder. All players should be asked to make a note of the amount of water that is put in the cup.
3. Give the cup of water and a spoon to the first player in the line. Give an empty cup and a spoon to the last player in the line. Give one spoon each to all the players in the line.
4. Ask the first player to take a spoonful of water from the cup and transfer it to the second player's spoon. The second player then transfers the water he/she received to the third player in the line. After this transfer, the second player gets another spoonful of water from the first player. Meanwhile, the third player passes the spoonful of water to the fourth player and so on. The last player receives water in his/her spoon and empties it into the cup that he/she holds.
5. After all the water has been emptied into the last player's cup, call a couple of players and ask them to measure, using the measuring cylinder, the amount of water.
6. Ask them to show the measuring cylinder to all the players so they can make a note of the amount of water in the last cup.



THE MINAMATA DISASTER

In the fishing village of Minamata on the southern island of Kyushu in Japan, in the early 1950s, cats started dying in large numbers. They had eaten poisoned fish. Soon, the signs of poisoning appeared in human beings too. Many of the victims died, others became ill and suffered convulsions, loss of muscular control, slurred speech, impaired sight and other symptoms. Babies were born blind, deformed and mentally deficient. Scientific investigations revealed the poison to be an organic form of mercury—methyl mercury. It was found that the methyl mercury compound was present in the waters of Minamata Bay. But where did the mercury come from? When investigated, it was found that a factory there, the Chiso Chemical Plant discharged mercury into the Bay, along with its other waste. The inorganic form of mercury underwent chemical reactions with the organic compounds present in the Bay and this resulted in methyl mercury being formed. The methyl mercury was absorbed by fish, which in turn were eaten by the fishermen and others at Minamata. This was the cause of the problems.

By the 1970s, around 150 people in and around Minamata had died of methyl mercury poisoning and more than 1000 others had been declared victims. Chiso Chemical Plant, which lost the long legal battle to the villagers of Minamata, paid nearly US\$100 million as compensation amount. For the people of Minamata however, the tragedy continues. Few of those affected by the poison have recovered; most will have to live with the damage for the rest of their lives.

Discussion

What happened to the missing spoons of water?

Explain that each spoon of water represents a quantity of energy and that some amount of energy loss takes place with every transfer. This is the Second Law of thermodynamics.

With this game as an example, clarify the concept of energy loss and discuss the loss of energy that would take place in food chains in nature.

6.10.1 ENERGY RELAY: THE FEEDBACK

(credit points: 5)

Can this game, with small variations, be used for explaining any other concept to children? Share one such idea with us.

