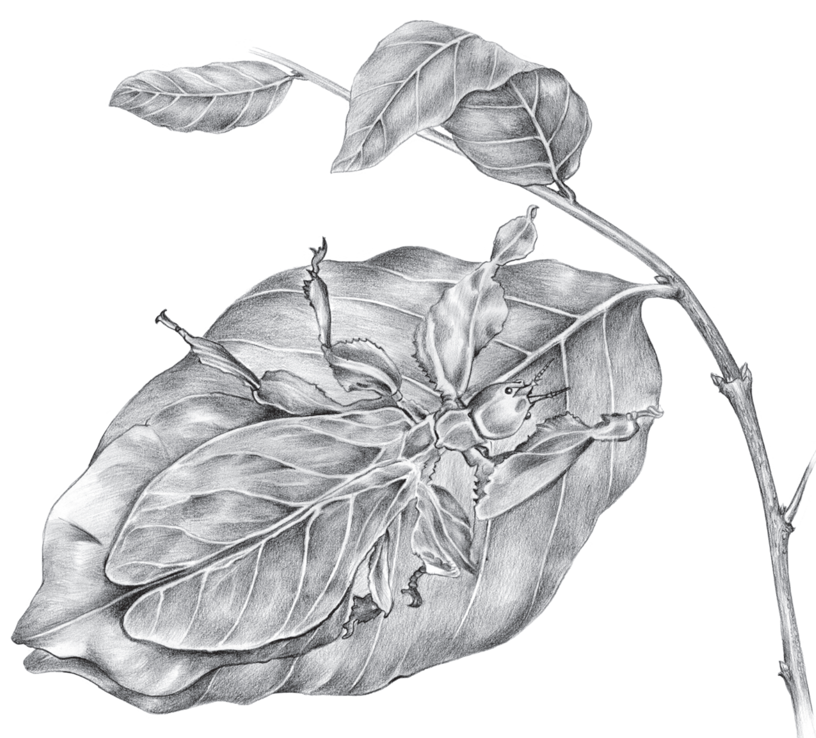
Ecosystems Processes: Nutrient Cycles

5

STRUCTURE



5.1

We have seen how ecotones are links between ecosystems. Links also exist within an ecosystem. Various components of an ecosystem are interdependent. Such dependencies may be for food, shelter or even reproductive activity. Frequent interactions among the components of an ecosystem are common. In the last Unit, we looked at the various components of an ecosystem (i.e. the structure of an ecosystem). In this unit, we will understand the kinds of processes take place in an ecosystem (i.e. the functions of an ecosystem). We will particularly study the process of nutrient cycling in detail.

5.2

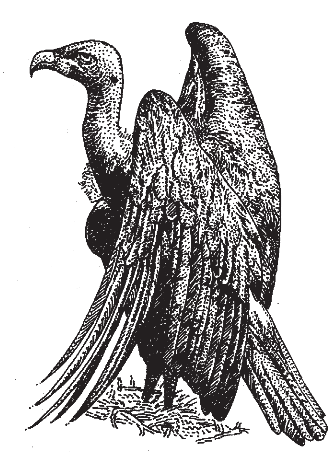
On completion of this unit, you should be able to:

- Understand that several bio-chemical processes take place in an ecosystem
- Define nutrient cycling and describe the carbon cycle
- Appreciate and state the significance of the role of nutrient cycling in ecosystem functioning

5.3 NUTRIENT CYCLING: LINKING THE BIOTIC AND ABIOTIC

The two major processes that form the basis of ecosystem functioning are **energy flow** and **nutrient cycling**. In this Unit, we will look at nutrient cycling in detail.

Simply put, nutrient cycling is the cycling of nutrients required by living organisms, through different parts of the biosphere.



Living organisms need food to grow and to reproduce. Any food or element required by an organism to live, grow, or reproduce, is called a **nutrient**. Depending on the amount it is needed in, a nutrient can be classified as a macronutrient (needed in large quantities, e.g., carbon, oxygen, hydrogen, nitrogen, phosphorous, etc.), or a micronutrient (needed in small quantities e.g., iron, zinc, copper, iodine, etc.). In nature, the nutrient elements and their compounds continuously move from the nonliving environment to the living organisms, and back to the nonliving environment. This cyclic movement of minerals from their reservoirs (air, water and soil), to the living components, and back to the reservoirs is called **nutrient cycling** or **biogeochemical cycles**.

5.3.1

Fill in the blanks

1. The two major bio-chemical processes in an ecosystem are __________ __________ and __________ ______________
2. Any food or element required by an organism to live, grow, or reproduce, is called a ________________
3. Depending on the quantity in which a nutrient is required by a living organism, nutrients can be broadly categorized as ____________ and __________

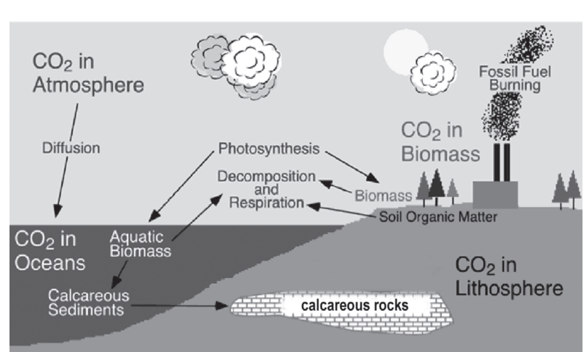
5.4 CARBON CYCLE

Each nutrient e.g. carbon, oxygen, phosphorous, magnesium and so on, follows a unique cycle. Some elements like oxygen and nitrogen, cycle quickly and so are readily available for use by organisms. Others, such as phosphorous, magnesium, etc., take time for cycling, as they are released slowly. It is usually such slow cycling nutrients that become the limiting factors for plant growth (for more details, refer the box on 'Law of Minimum' in Unit 2). It is for this reason that such nutrients are supplied to crop species through synthetic fertilizers.

In this section, we will look at examples of two significant nutrient cycles— Carbon and Nitrogen.

As you know, Carbon is the basic building block of carbohydrates, fats, proteins and other organic elements necessary for life. The Carbon cycle is based on carbondioxide gas which makes up (see Unit 1) about 0.03 per cent of atmosphere and is also dissolved in water (the hydrosphere).

Producers (mainly, the green plants on land) absorb carbon-di-oxide from the atmosphere, and through the process of photosynthesis, convert it into complex carbohydrates. Then the process of respiration, breaks down the carbohydrates giving energy, and converting carbon back to carbon-di-oxide, releasing it back to atmosphere or in the water for re-use by producers. This linkage between photosynthesis and respiration (on land and in water) circulates carbon in the biosphere and is a major part of the Carbon cycle.



Carbon Cycle

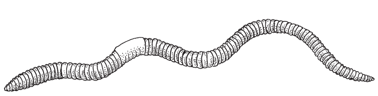
As the carbon cycle figure shows, some carbon lies deep in the earth in fossil fuels. This is released into the atmosphere as CARBON-DI-OXIDE only when these fuels are extracted and burnt. Another way in which sedimentary carbon enters the atmosphere is volcanic eruptions.

The oceans also play a major role in regulating the level of carbon-di-oxide in the atmosphere. Carbon-di-oxide is readily soluble in water. Some of the carbon-di-oxide is therefore dissolved in the oceans and seas. Part of this is again removed by the marine producers (small green plants called algae). Also, in these ecosystems, some organisms use carbon-di-oxide or other forms of carbon to build shells and skeletons. When these organisms die and as their bodies settle down at the bottom of the oceans, the Carbon contained in them gets stored in the ocean floor. In fact most of the earth's carbon is stored in the ocean floor sediments and on the continents. This carbon enters the cycle at a very slow pace as the sediments dissolve. This carbon then becomes dissolved in the water and then enters the atmosphere.

At this point it is important to understand that Carbon plays a key role in the temperature regulation mechanism of our earth (refer 'Green House Effect' Unit 1)—If too much carbon is removed, the earth will cool; if too much Carbon is generated, the earth will get hotter.

5.5 SIGNIFICANCE OF NUTRIENT CYCLING

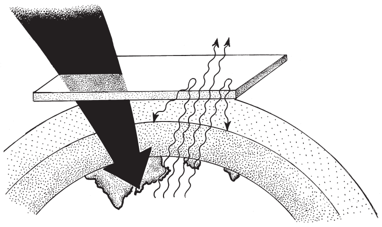
Existence of life depends on continuous cycling of nutrients from the nutrient pool (in the abiotic component of environment) to the living beings and then back to the nutrient pool. These complex series of invisible, delicately balanced, and interrelated biochemical reactions fuel life on earth. These reactions use the power of the sun to take gases from the air and nutrients from the soil, and the resulting energy and chemical compounds move through all plants and animals on the earth. These nutrient cycles, driven directly or indirectly by incoming solar energy and gravity, include the carbon, oxygen, nitrogen, phosphorous, sulphur and hydrologic (water) cycles.



Also, biogeochemical (nutrient) cycles connect past, present and future forms of life. Thus some of the carbon atoms in the skin of your nose may once have been a part of a petal, a dinosaur's skin, or even a diamond!

5.6 RECAPITULATION

- Nutrient cycles are the link between abiotic and biotic components of ecosystems. By the process of nutrient cycling, the nutrients from their pool (mainly in the soil, in some cases the atmosphere), fuelled by the energy from the sun, get converted into organic substances, then enter into a chain of biotic elements through food chains (more on food chains in the next unit). Again, as the biotic components finish their life-cycles and die, the nutrients come back to their pool.
- Human activities have impacted these cycles leading to disbalance in nature. For example, humans have intervened in earth's phosphorous cycle in three ways. 1. By mining large quantities of phosphate rock



GLOBAL WARMING

As you know, Troposphere, the lower-most layer in the atmosphere, traps heat by a natural process called the 'greenhouse effect'. The amount of heat trapped depends on the concentrations of heat-trapping gases or 'greenhouse' gases. Carbon-di-oxide is one of them. Recent studies have shown a sharp increase in carbon dioxide concentrations in the atmosphere. This increase is due to disturbance in the carbon cycle, mainly attributed to fossil fuel burning and fast-shrinking forest cover due to rapid and rampant felling of trees and clearing of forest lands for other uses and priorities. This has enhanced the greenhouse ability of the troposphere, resulting in increased heat trapping and rise in global mean temperature of the earth. This phenomenon is referred to as 'Global Warming'. Some possible effects of global warming are: impacts on agriculture and food production; severe impacts on natural ecosystems like damage to their ability to regulate themselves; sea level rise due to melting of polar ice caps—this may threaten about one third of world's population and a third of the world's economic infrastructure concentrated in coastal regions. Food and freshwater supplies to certain human communities may also be affected, and disease patterns are also likely to be altered.

mainly for use in inorganic fertilizers and detergents; 2) A lot of available phosphate is removed by humans in the process of cutting large numbers of trees in the rainforests (where once the trees are cut, the soil nutrient gets washed away very rapidly in the rains, making the forest land unproductive); 3) adding excess phosphate to aquatic ecosystems in runoff of animal wastes (from livestock), runoff of fertilizers from cropland, and also discharge of sewage (detergents have very high level of phosphates). We have already looked at the impacts of too much nutrients in (refer box 'Too Much Nutrients' in this unit) water bodies. Scientists estimate that human activities have increased the natural rate of phosphorous release into the environment by over 3 folds. This is just one example of human interference into the natural cycling of nutrients. Such changes in turn have influenced both abiotic as well as the biotic components of nature.

TOO MUCH NUTRIENTS!

Eutrophication is a natural process by which waterbodies gradually age and become more productive. Three main stages explain the process of eutrophication. These are oligotrophy, mesotrophy and eutrophy. Stagnant water bodies go through these stages as part of their life cycles. In nature eutrophication is a slow process and may take thousands of years to progress.

When one or more of these stages is sped up or even skipped over completely, the natural balance is disrupted and may destroy the ecosystem. Human activities have accelerated this process tremendously. The nitrates and phosphates from synthetic detergents, domestic sewage, agricultural run-off and some industrial wastes, give unnatural nourishment to algae (microscopic plants), causing them to flourish in huge amounts on waterbodies. As the algal growth explodes, it forms a cover on the water surface. This could starve the submerged life in the waterbody of oxygen and sunlight which are vital for life and photosynthetic activity. If uncontrolled, they choke the oxygen supply normally shared with other organisms like fish, etc., living in water. When these algae die, their decomposition uses up even more oxygen. As a result, the water becomes deficient in oxygen, fish die of suffocation and bacterial activity decreases. These conditions encourage organisms that can survive in the absence of oxygen (anaerobic organisms) to increase in number and attack the organic wastes. When anaerobic organisms break down organic substances, they release foul-smelling gases such as methane and hydrogen sulphide, which are harmful to the oxygen-requiring (aerobic) forms of life. Such disturbances slowly lead to the death of all forms of life in the waterbodies. This phenomenon is known as eutrophication.

5.7 CONCLUSION

Nutrients are available on the earth in fixed quantities. Through nutrient cycling, the various nutrients necessary for life on earth, move from the respective nutrient pool (in the abiotic components) to the biotic components and back. In nature, the nutrient cycles operate in a balanced manner.

5.8

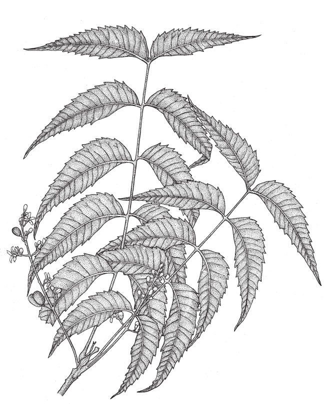
1. Describe the process of nutrient cycling and exemplify it.
2. Comment on the statement 'human disturbances to nutrient cycling date back to the invention of agriculture'
3. Nutrient cycles are the link between abiotic and biotic components of ecosystems. Elaborate.

5.9

C-O Exchange Cycle

Each nutrient e.g. carbon, oxygen, phosphorous, magnesium and so on, follows a unique cycle. Some elements like oxygen and nitrogen, cycle quickly and so are readily available for use by organisms. Others, such as phosphorous, magnesium, etc., take time for cycling, as they are released slowly from their pool (rocks in the earth, including the oceanic floors). It is usually such slow cycling nutrients that become the limiting factors for plant growth. It is for this reason that such nutrients are supplied to crop species through synthetic fertilizers.

One simple way of explaining these cycles to learners is through the example of the water cycle—the process of evaporation and transpiration of water from water bodies and plants, formation of water vapours, and their condensation. Another cyclical process, which can be explained in a simplified manner, is the carbonoxygen exchange cycle. Carbon is the basic building block of carbohydrates, fats, proteins, nucleic acids (DNA/RNA) and other organic compounds necessary for life. This cycle is specifically important to understand because carbon-di-oxide is the key component of nature's temperature regulation mechanisms. If too much of carbon-di-oxide is removed from atmosphere, the Earth will cool; and vice versa. Even slight changes in the Carbon cycle can affect climate and thus life on earth. The following activity called 'untangling the cycle' can help you in explaining the C-O exchange on our planet and some consequences of increasing carbon-di-oxide is proportion in the atmosphere.



Group size: 8 or more

Duration: 30 45 minutes

Requirements: Paper, pens/pencils, pins to put on tags

Objective: To describe the C-O exchange in atmosphere

Procedure:

a) Prepare sets of tags/badges, with each set having 4 tags—'carbon-di-oxide', 'oxygen', 'Plants' and 'Animals'. Prepare enough sets so that each student will get one tag.

b) Ask students to make groups of 8 or 12 or 16 (multiples of four, remaining can be designated as observers) and ask each group to stand in a circle. Distribute the tags to the group members at random and ask them to pin them on their dress.

c) Tell students to follow your instructions as you call them out:

Call out 'ANIMALS' and tell all those with 'Animal' card to extend their RIGHT hands to the centre of the circle; Next call out 'O_2' and ask these to extend their LEFT hands. Now ask the 'ANIMALS' to reach for the LEFT hands of O_2. This symbolizes that ANIMALS breathe O_2.

d) Now ask 'PLANTS' to extend their RIGHT hands. Next call out 'carbon-di-oxide' and ask them to extend their LEFT hands. Since PLANTS need carbon-di-oxide for making food, ask them to take hold of carbon-di-oxide by holding the LEFT hands of carbon-di-oxide with their extended right hands.

e) Ask 'PLANTS' to hold the RIGHT hands of O_2 with their LEFT hands, since they release O_2.

f) Ask 'ANIMALS' to hold the RIGHT hands of carbon-di-oxide with their LEFT hands, since they exhale carbon-di-oxide. (LEFT hands are used for giving and the RIGHT for taking).

g) Now the players are all tangled up. Tell them that the left hand link signifies giving out of a gas, while the right hand link signifies 'taking in' of a gas. Let each student confirm that it is so in her/his case. Their task is now to untangle this jumbled network to form a circle. They must not release hands to do this. Once untangled, a circle will be formed which represents the cycling of O_2 and carbon-di-oxide between plants and animals.

Discussion

Depict the simplified cycle on the board and initiate an indepth discussion on the carbonoxygen exchange cycle. You may wish to discuss the possible impacts that humans have had on this cycle through deforestation, fossil fuel burning, etc. Asking a few 'plants' to drop their hands, or raising the number of 'carbon-di-oxide' in the circle can actually demonstrate this. What effects will such incidents have on the cycle?

5.9.1 C-O EXCHANGE CYCLE: THE FEEDBACK

(credit points:5)

Share with us one teaching idea (besides this one) that has helped you explain an abstract concept better in your classroom OR develop an interactive teaching idea to explain water cycle to students.