UNIT 2

ECOSYSTEMS

Structure

2.1 INTRODUCTION

Earth is the only planet, revolving around the sun, which is known to support life. Despite the vastness of earth, life exists only in a very thin layer enveloping the earth called biosphere. Sun is the only source of energy which enables continuous interaction among various life forms.

In the previous unit you have already learnt about the word ‘environment’ and its definition. You have also been familiarised with the external and internal environment of organisms that also include us. Both the external and the internal environment of an organism have an impact on its existence and survival. The components of the external environment of an organism include physical as well as living components. The action and interaction of the physical and living components of an organism make a system of relationship called ecosystem. This unit deals with the structure and properties of ecosystem, basic concepts of ecosystem functioning, and the factors controlling it. It also deals with the development of ecosystem. The unit will familiarise you with interactions like competition, parasitism and mutualism that exist between living beings. This unit will also focus on how we as living beings interact with other living and nonliving components of the ecosystem. You will also become aware that ecosystems are able to maintain homeostasis by active effort, resisting the tendencies toward disorder.

For centuries humans have considered the earth and the environment as a virtually unlimited resource but subtle and gradual changes have altered our environment in many different ways. We wish that this unit enables you to use your intelligence and skills to the best of your advantage for managing our environment and keeping it healthy for future generations.

Expected Learning Outcomes

After completing the study of this unit you should be able to:

- ❖ define and explain the basic concept of ecosystem, its structure, function, and properties;
- ❖ explain the terms biosphere, biome, aquatic zone, landscape and population;
- ❖ describe the development, control and stability of the ecosystem in order to act positively towards the environment;
- ❖ discuss that the flow of energy and cycling of material are central to ecosystem functioning and indiscriminate intervention would lead to damage and disruption of the environment; and
- ❖ explain your duties and obligations towards the environment.

2.2 WHAT IS AN ECOSYSTEM?

You and I, as you know, live in a defined area of the earth where plants and animals, including ourselves, develop relationships with each other for life, food, water, shelter and mates. This discrete unit has both living and non-living environmental components, which are interdependent and interrelated in terms of their structure, components and functioning. Such a discrete unit is called an ecosystem.

2.2.1 Definition of Ecosystem

The word ecosystem, was coined by Prof. Arthur Tamsley in 1935. The prefix 'eco' means environment.

An ecosystem is defined as, "any unit (a biosystem) that includes all the organisms that function together (the biotic community) in a given area, interacting with the physical environment (abiotic component) so that the flow of energy clearly leads to defined biotic structures and cycling of materials between living and nonliving parts".

The ecosystem is thus, a dynamic system which involves the interactions between living and non-living components of an ecosystem and includes the input, transfer, storage and output of energy as well as cycling of essential materials through the ecosystem. All the processes that occur in the ecosystem are energy dependent. Fig. 2.1 illustrates this beautifully. Ecosystems differ greatly in composition, in the number and kinds of species, in the kinds and relative proportions of non-biological constituents and in the degree of variation in time and space.The study of an ecosystem is based on its structure and function.

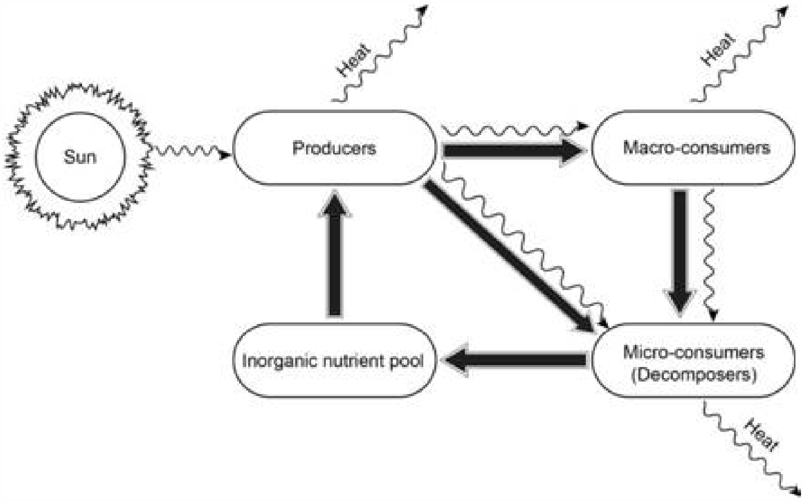


Fig. 2.1: Schematic representation of an ecosystem. The dotted lines represent the boundary of the system. The three major components are the producers, the consumers, and the abiotic elements. The arrows indicate interactions within the system and with the enviroment. Energy does not cycle because all the energy of the ecosystem is derived from the sun and it dissipates as heat.

2.2.2 Ecosystem Features

Ecosystems have both structural and functional features some of which you have studied in Unit 1, and others which you will study in this unit. You will learn about some other aspects in the forthcoming units. The ecosystem features are as follows:

I. Structural Features

The Structural aspect of the ecosystem refers to all the elements that make up an ecosystem – the individuals and communities of plants and animals and the non-living factors present in the ecosystem. The structural components include:

A. Abiotic components (Non-living Components):

- i) Inorganic compounds – carbon, nitrogen, carbon dioxide, water.
- ii) Organic compounds – proteins, carbohydrates, lipids, which link the abiotic to biotic components.
- iii) Climatic regimes – temperature, moisture, light and topography

B. Biotic Components (Living Components):

- i) Producers – plants
- ii) Consumers – primary, secondary, tertiary.
- iii) Decomposers – saprotrophs

II. Functional Features

Functional aspects refer to all the processes and interactions performed by the organisms in an ecosystem and include:

- i) Energy cycles
- ii) Food chains
- iii) Diversity – interlinks between organisms
- iv) Nutrient cycles – biogeochemical cycles
- v) Succession

2.2.3 Size of an Ecosystem

Ecosystems may vary in size from the smallest puddle of water or a terrestrial habitat, to a landscape or large forest, a biome, or even the entire global biosphere or ecosphere (Fig 2.2).

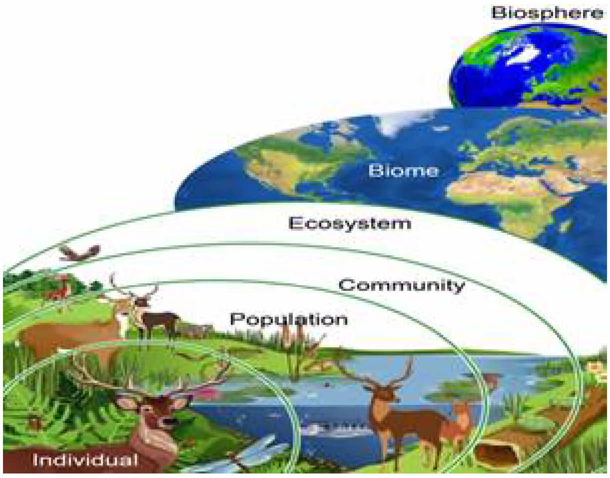


Fig. 2.2 : Size of ecosystem in decreasing order: Biosphere, biome, landscape, ecosystem, community, population, individual.

2.2.4 Largest Ecosystem: Biosphere

Before we explain the functioning of the components of the ecosystem, let us first discuss the largest ecosystem, namely, "the biosphere".

Biosphere is that part of the earth where life can exist. It is a narrow layer around the surface of the earth. If you visualise the earth to be the size of an apple the biosphere would be as thick as its skin.

Biosphere, also called ecosphere, is that part, of the earth, water and atmosphere in which many smaller ecosystems exist and operate. The three main subdivisions of the biosphere are: (1) **lithosphere** (land); (2) **hydrosphere** (water); (3) **atmosphere** (air) or the gaseous envelope of the earth which extends up to a height of 22.5 km. Fig. 2.3 shows the idealised scheme of biosphere in relation to hydrosphere, atmosphere and lithosphere. The area of contact and interaction between these three components is really important for life, as it is here that the entire life is confined and the basic processes of life, like photosynthesis and respiration occur.

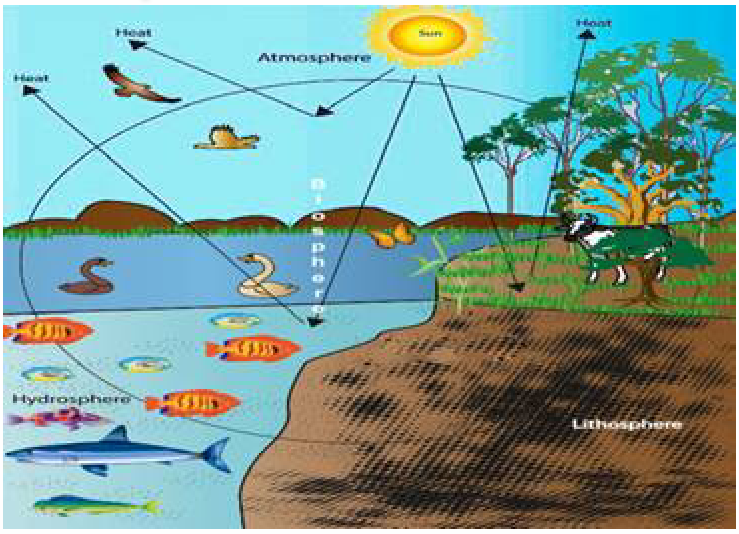


Fig 2.3: Idealised scheme of a biosphere in relation to hydrosphere, atmosphere and lithosphere.

The biosphere extends from the floor of the ocean some 11,000 metres below the surface of the earth to the top of the highest mountains, or about 9,000 metres above the mean sea level. Its most densely populated region is just above and below the sea level. Life in the biosphere is abundant between 200 metres (660 feet) below the surface of the ocean and about 6,000 metres (20,000 feet) above sea level.

Biosphere is absent at extremes of the North and South poles, the highest mountains and the deepest oceans, since existing conditions there do not support life. Occasionally spores of fungi and bacteria do occur at great height beyond 9,000 metres, but they are not metabolically active, and hence represent only dormant life.

Living organisms are not uniformly distributed throughout the biosphere. Only a few organisms live in the polar regions, while the tropical rain forests possess an exceedingly rich diversity of plants and animals. The nutrients necessary for living organisms come from air, water and soil and not from outside. The same nutrients that are present in the biosphere are recycled over and over again for life to continue. The energy required for the life within the biosphere comes from the sun without which the biosphere will collapse.

The terrestrial part of the biosphere is divisible into enormous regions called biomes, which form vast ecosystems and are characterized, by climate, vegetation, animal life and general soil type. The dozen or more biomes of the earth are spread over millions of square kilometres and span entire continents. No two biomes are alike. The climate determines the boundaries of a biome and abundance of plants and animals found in each one of them. The most important climatic factors that determine the boundaries of the biomes are temperature and precipitation (rain or snow).

Aquatic systems are also divided into distinct aquatic life zones, which however are not called biomes but are very similar. The aquatic life zone are regions of relatively distinct plant and animal life. The major difference between the various aquatic zones is due to salinity, levels of dissolved nutrients, water temperature and depth of sunlight penetration. You will learn about the different types of terrestrial ecosystems namely biomes and aquatic life zones on our earth in Unit 3.

SAQ 1

1. a) In the following statements, put a tick (√) mark on the correct ones and a cross (x) on the wrong ones in the given boxes.

   i) An ecosystem is a natural unit of study, consisting of a community of organisms (biotic components) and the non-living environmental factors (abiotic components). ( )

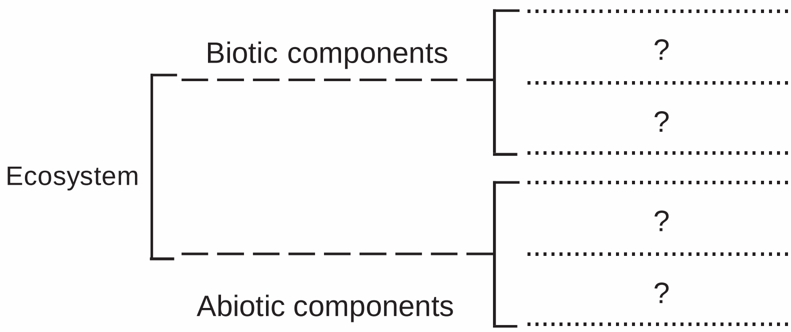
   ii) All ecosystem have well-defined boundaries. ( )

   iii) Ecosystems represent enormous contrast in size and complexity. ( )

   iv) An ecosystem having autotrophs and heterotrophs but no decomposers could be self-contained. ( )

   v) Ecosystems are self-sustaining because they are well insulated from outside influences. ( )

b) Arrange the following sub-components of an ecosystem:
energy, consumers, environment, inorganic elements, decomposers, primary producers and soil.



2.3 COMPONENTS OF THE ECOSYSTEM

Each biome or aquatic zone can be subdivided into smaller units called "ecosystem". An ecosystem is thus, a subdivision of biome and can also be called an ecological system. Recall the definition of an ecosystem from subsection 2.2.1. Any complete definition of an ecosystem includes the biotic as well as the abiotic components and the interaction between the two. For example the desert biome of Rajasthan contains the Thar Desert ecosystem which is characterised by arid conditions, sandy terrain, and succulent plants. Animals found there are lizards and snakes. Similarly, a pond is also an ecosystem of the freshwater aquatic zone and would be characterized by a lentic (standing) fresh water body containing aquatic organisms and plants.

The various kinds of organisms that inhabit an ecosystem form its populations. In ecology, 'a population is a group of potentially interbreeding individuals that occur together in space and time'. The individual comprising a population are members of the same species.

If you look around yourself, you will notice that populations of plants and animals seldom occur by themselves. The reason for this is quite obvious. In order to survive individuals of any one species depend on individuals of different species with which they actively interact in several ways. A population of squirrels would require fruits and nuts for food and trees for shelter. Even plants cannot exist by themselves; for example, they require animals for seed dispersal and pollination, and soil microorganism to facilitate nutrient supply to them through decomposition.

In nature 'an aggregation of populations of different species (plant and/or animals) in an area, living together with mutual tolerance and beneficial interactions amongst themselves and with their environment, form a biotic community.

Communities in most instances are named after the dominant plant form species. A grassland, for example, is dominated by grasses, though it may contain herbs, shrubs, and trees, along with associated animals of different species. Communities may be large or small.

2.3.1 Abiotic Components

You will recall, having read earlier that the physical or abiotic components are the inorganic and non-living parts of the ecosystem. Each of these abiotic factors may be studied individually, however, each of these factor is influenced by and in turn influences all the other factors.

2.3.2 Biotic Components

The biological or biotic components of an ecosystem interact in an abiotic background (Fig. 2.4) and include:

Food refers to complex organic compounds such as carbohydrates, proteins and fats. Green plants first produce simple carbohydrates like glucose and later various complex carbohydrates.

1. **Producers/Autotrophs**

   Chlorophyll bearing green plants, green and purple bacteria and blue green algae are the main biological or biotic members in nature which manufacture their own food from simple inorganic substances by the process of photosynthesis. In this process the chlorophyll bearing organisms in the presence of sunlight take up atmospheric carbon dioxide through their leaves and combine with water to produce organic substances or food.

   Chemosynthetic bacteria also synthesise their own food but instead of the sun energy they use simple chemicals released from the interior of the earth to prepare food by the process of chemosynthesis. Organisms that are able to manufacture their own food are called **autotrophs** or **producers**.

2. **Consumers/ Heterotrophs**

   All other organisms that are unable to make their own food but depend on other organisms for food to meet their energy needs for survival are called **heterotrophs or phagotrophs or consumers**.

   Among consumers, animals such as goat, cow, deer, rabbit and insects like grasshoppers which eat green plants are called **primary consumers** or herbivores. Organisms which eat a herbivore, like a bird that eats grasshoppers are carnivores as they eat other animals. These carnivores are also called **secondary consumers**. Carnivorous organisms like cats which eat secondary consumers like birds are called **tertiary consumers**. Thus, while the primary consumers are herbivores, the secondary and tertiary consumers are carnivores. Animals like tigers, lions, and vultures which are not killed or eaten by other animals are **top carnivores**.

3. **Decomposers or Saprotrophs or Reducers**

   Both the consumers and producers complete their life cycles and die and new generation of their population develop. You must be wondering what happens to the dead organisms. In the ecosystem there is a continuous breaking up or decomposition of the organic matter of the dead organisms and there is a continuous cycling of materials. Certain bacteria which are micro organisms and some fungi are responsible for the decomposition and recycling of material. The organisms are called **decomposers or saprotrophs or reducers**. Most of the saprotrophs are microscopic and all are heterotrophic in nature. The role of decomposers is very essential and important.

Fragments of decomposing organic matter are called detritus

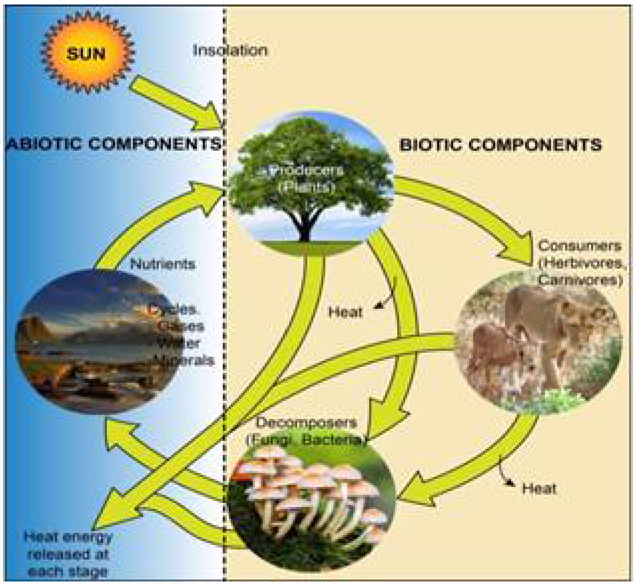


Fig. 2.4: Biotic factors are dependent on abiotic factors. Light and heat energy from the sun are the main key components that biota depend on. Biomass of producers is used by consumers who obtain energy by ingesting food. The assimilated energy is used for various functions of the body like respiration and movements. When the organism dies the energy stored in tissues is used by the decomposers.

2.4 TROPHIC LEVELS

You are now aware that an ecosystem is considered as a discrete unit, where complex natural community obtains food directly or indirectly from plants through one, two, three or four steps and accordingly these steps are known as the first, second, third and fourth trophic (trophe = nourishment) levels or food levels (Fig. 2.5).

A trophic level refers to a position or a level in a food chain or ecological pyramid. It is occupied by a group of organisms that have a similar feeding mode. Trophic levels are numbered according to the number of steps or levels an organism is away from the source of food or energy that is the producer. A food chain would start at trophic level 1. Similarly the base of an ecological pyramid is also at trophic level I. The trophic level 1 is occupied by the primary producers that are referred to as autotrophs. The next trophic level in a food chain or ecological pyramid is trophic level II which consists of organisms that feed on the primary producers and are referred to as primary consumers, or heterotrophs or herbivores .Trophic levels III,IV and V would be occupied be occupied by carnivores. Given below are the probable numbers of trophic levels that can exist in an ecosystem and the types of organism groups that occupy the various trophic levels:

Humans, being omnivores, may belong to more than one trophic level.

Green plants (producers); trophic level I – Autotrophs

- Herbivores (primary consumers); trophic level II – Heterotrophs
- Carnivores (secondary consumers); trophic level III – Heterotrophs
- Carnivores (tertiary consumers); trophic level IV – Heterotrophs
- Top carnivores (quarternary consumers); trophic level V – Heterotrophs

Energy derived from food thus, also flows through the trophic levels: from producers to subsequent trophic levels (Fig. 2.5). This energy always flows from lower (producer) to higher (herbivore, carnivore etc.) trophic levels. It never flows in the reverse direction. Furthermore there is a loss of some energy in the form of unusable heat at each trophic level so that the energy level decreases from the first trophic level upwards. As a result there are usually four or five trophic levels and seldom more than six as beyond that very little energy is left to support any organism.

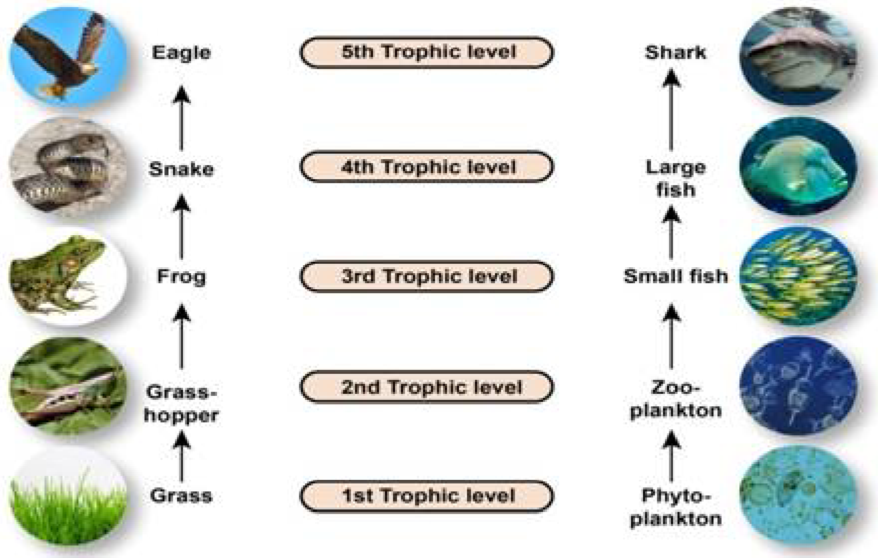


Fig. 2.5: Trophic levels in a food chain in: i) a terrestrial and an ii) aquatic environment.

SAQ 2

a) Give two examples each of organisms that occupy the first, second and third trophic levels.

b) Pick an animal of your choice and show how it can occupy several different trophic levels?

2.4.1 Food Chain

You now know from the previous section that organisms in the ecosystem are related through feeding or trophic levels, that is one organism becomes food for the other. The transfer of food energy from one trophic level to another trophic level in an ecosystem by the repeated process of eating and being eaten is known as food chain. **The food chain can thus be defined as a linear sequence of links of organisms in which an organism becomes food for the next organism** (Fig. 2.6, 2.7and 2.8). The arrows in these three figures denote the direction and movement of nutrients and energy from producer to consumer. Similar to the trophic levels and for the same reasons the links or steps in a food chain are usually upto four or five.

Each link in the food chain can also be called a trophic level.

2.4.2 Types of Food Chains

In nature, three main types of food chains have been distinguished:

i) **Grazing Food Chain:** In this type of food chain the primary consumers, are herbivores and use the plant or plant part as their food. This food chain begins from green plants. An example of such a food chain is given below (Fig. 2.6):

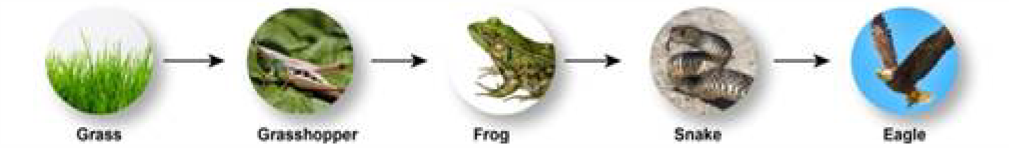


Fig. 2.6: A grazing food chain designated as follows: Grass→ grasshopper → frog → snake→ eagle.

In a community of organisms in a shallow area of the sea, about 30% of the total energy flows via detritus chains. In a forest with a large biomass of plants and a relatively small biomass of animals, even a larger portion of energy flow may be via detritus pathways.

ii) **Detritus Food Chain:** This type of food chain starts from dead organic matter of decaying and metabolic wastes of animals and plant bodies called detritus to the micro-organisms which are primary detritus feeding organism called detrivores or decomposer then to secondary detritus feeders and finally to herbivore and then to predators. The energy contained in detritus, serves as a source of energy in this food chain. An example of such a food chain is given below (Fig. 2.7):

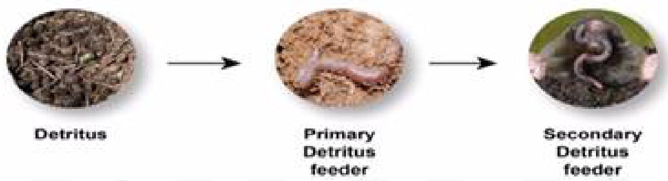


Fig. 2.7: A detritus food chain designated as follows-dead decaying organisms (plants and animals) → earthworm → mole.

iii) **Parasitic Food Chain:** This type of food chain starts with green plants, then goes to the plant or the herbivores on which the parasitic organisms feed. This parasitic food chain ends with parasitic organisms which unlike predators do not kill the host. An example of such a food chain is given below. (Fig. 2.8):

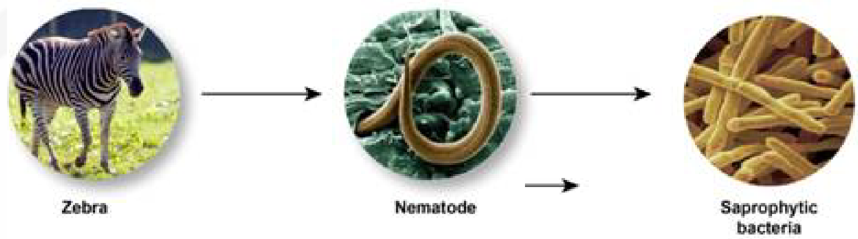


Fig. 2.8: A parasitic food chain designated as follows-zebra→nematode→bacteria.

In nature the food chains are interconnected at various points and together take the form of a food web.

All food webs begin with autotrophs and end will decomposers.

2.5 ECOSYSTEM FUNCTIONING

The processes of matter cycling and transfer and movement of energy are essential for ecosystem function and structure. The processes of cycling of matter and the use of energy in an ecosystem define the fundamental functions of an ecosystem. Energy does not cycle in an ecosystem as the flow of solar energy is unidirectional. As a result the ecosystem needs a continuous inflow of high-quality energy in order to maintain their function and structure. This energy is provided by the solar energy of the sun. For this reason, ecosystems are “open systems” needing a net inflow of energy from the sun to continue over time. Without the sun, the biosphere of our Earth would shortly run out of energy and collapse. This is because producers which as you are aware are autotrophs use the solar energy of the sun along with nutrients and convert them into food materials which are stored within their bodies. All the food materials or nutrients that we or other animals consume are obtained directly or indirectly from such producers. As a result there is a continuous flow of energy from the sun through various organisms and then to outer space:

Sun is the ultimate source of all energy, which caters to the need of our ecosystems. It has been observed that 30% of the total solar radiation entering our atmosphere is reflected by the earth - atmosphere system. The remaining 70% of the radiation is absorbed by the earth’s atmosphere. Of this 19% is absorbed directly by the atmosphere and the rest by the earth.

The trapping and flow of energy also involves the circulation of nutrients which include basic inorganic elements such as, carbon, hydrogen, oxygen and nitrogen, as well as sodium, calcium, and potassium, which occur in small amounts. In addition, compounds such as; water, carbonates, phosphates and a few others also form part of living organisms. For an ecosystem to function, it is essential that there is a continuous flow of energy and cycling of nutrients.

SAQ 3

1) Explain the statement? ‘‘The ultimate source of energy for our planet is the sun.’’

2.6 NUTRIENT CYCLES

By now, you must be well aware that the living world depends upon the flow of energy and the circulation of nutrients through ecosystem. Both influence the abundance of organisms, the metabolic rate at which they live, and the complexity of the ecosystem. You have already studied that energy is ultimately lost as heat forever in terms of the usefulness of the system. On the other way hand, nutrients of food matter are never lost or used up, instead they can be recycled again and again indefinitely.

A nutrient cycle may also be referred to as **a perfect** or **imperfect cycle**. A perfect nutrient cycle is one in which nutrients are replaced as fast as they are utilised. Most gaseous cycles are generally considered as perfect cycles. In contrast sedimentary cycles are considered relatively imperfect, as some nutrients are lost from the cycle and get locked into sediments and so become unavailable for immediate cycling.

Nutrients that are needed by organisms in large amounts are called macronutrients, while those which are needed in minute amount or traces, are called micronutrients Among more than 100 chemicals that occur in nature about 40 are present in living organisms.

Carbon, hydrogen, oxygen, nitrogen and phosphorus in the form of elements and compounds make up 97% of the mass of our bodies and are more than 95% of the mass of all living organisms. In addition to these, 15 to 25 other elements are needed in some form for the survival and good health of plants and animals. These elements or mineral nutrients are always in circulation moving from non-living to living and then back to the non-living components of the ecosystem in more or less a circular fashion. This is known as **biogeochemical** cycling. There are two basic types of cycles, depending on the nature of the reservoir:

i) **Gaseous Cycle** – where the reservoir is the atmosphere or the hydrosphere and

ii) **Sedimentary Cycle** – where the reservoir is the earth’s crust.

2.6.1 Gaseous Cycles

Let us first study some of the most important gaseous cycles; namely – water, carbon and nitrogen

Water Cycle (Hydrologic) – water is one of the most important substances for life. On an average, water constitutes 70% of the body weight of an organism. It is one of the important ecological factors that determines the structure and function of the ecosystem. Cycling of all other elements is also dependent upon water as it provides a means for their transportation during the various steps, and it also serves as a solvent medium for their uptake by organisms.

Water covers about 75% of the earth's surface, occurring in lakes, rivers and oceans. The oceans alone contain 97% of all the water on earth. Much of the remainder is frozen in the polar ice and glaciers. **Less than 1% water is present in the form of fresh water in rivers, lakes, and aquifers. Yet this relatively negligible portion of the planet's water is crucially important to all forms of terrestrial and aquatic life**. There is also underground supply of water. Soils near the surface also serve as reservoir for enormous quantities of water (see Fig. 2.9).

Water moves in the Earth's hydrologic cycle by connecting ocean, land, and atmosphere. The water from the oceans move to the atmosphere by the process of evaporation. From the atmosphere the water moves to oceans and land by precipitation in the form of rain or snow. From land, the rain and melted snow water are transported either by run off from streams and rivers and subsurface ground water into the oceans, and/or by evaporation from land and transpiration (evaporation of water from plant leaves.) by plants to the atmosphere again. This cycle is driven by solar energy in which about one third of all solar energy is dissipated on cycling is about 10×10^{20} g of water, that is nearly 0.004% of the total. This amount of water is all the time moving in the cycle. The rest of the earth's water as you know is already bound in cold storage (in the form of glaciers and ice).

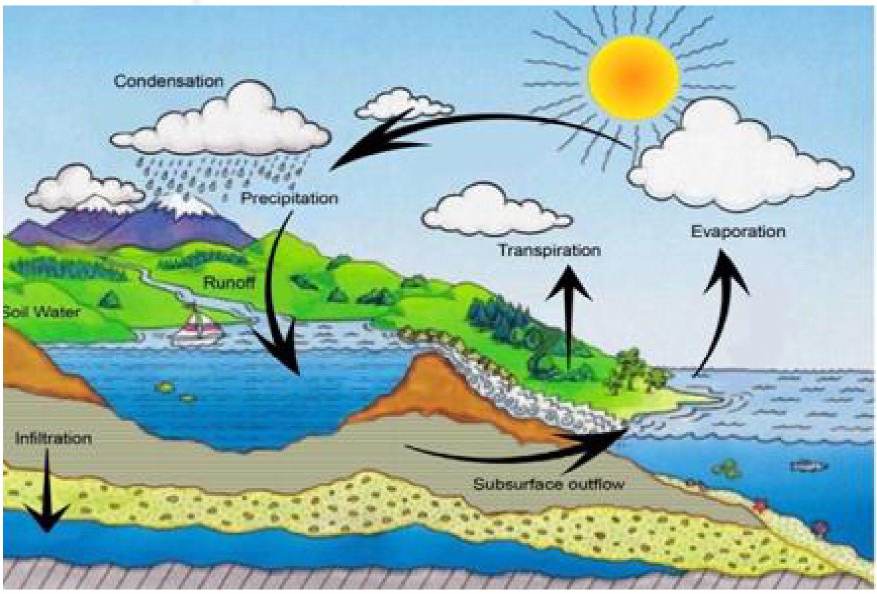


Fig. 2.9: The water or hydrological cycle depicting the major pathway of water movement through the ecosystem.

Life as you know depends on this continuous water cycle but human activities are damaging the environment by polluting the atmosphere to such an extent that the rainfall patterns are getting altered, leading to prolonged drought periods extending over years in countries such as those of Africa, while causing devastating floods in countries such as the US and India.

The Carbon Cycle

Carbon is a minor constituent of the atmosphere as compared to oxygen and nitrogen. However, as you are well aware carbon is the element that anchors all organic substances from coal and oil to DNA (deoxyribonucleic acid: the compound that carries genetic information). Without carbon life could not exist as it is vital for the production of carbohydrates (organic matter) through photosynthesis by plants that use the inorganic carbon dioxide and water in the presence of solar energy and in this process release oxygen in the atmosphere. Carbon is a building block of all living organisms. It is a component of proteins that are the building block of life and lipids that form the plasma membrane of all plants and animals. Carbon is also a part of the ocean, air, and even rocks. Because the Earth is a dynamic place, carbon does not stay still and is on the move.

The carbon in the carbon cycle (Fig. 2.10) may be either ‘organic’ or ‘inorganic’. The majority of the inorganic carbon exists as carbon dioxide, carbonate and hydrogen carbonate. The carbon found in organic compounds is included in both the abiotic and biotic parts of the ecosystem and is found in living or dead organisms, fossil fuels, small deposits in

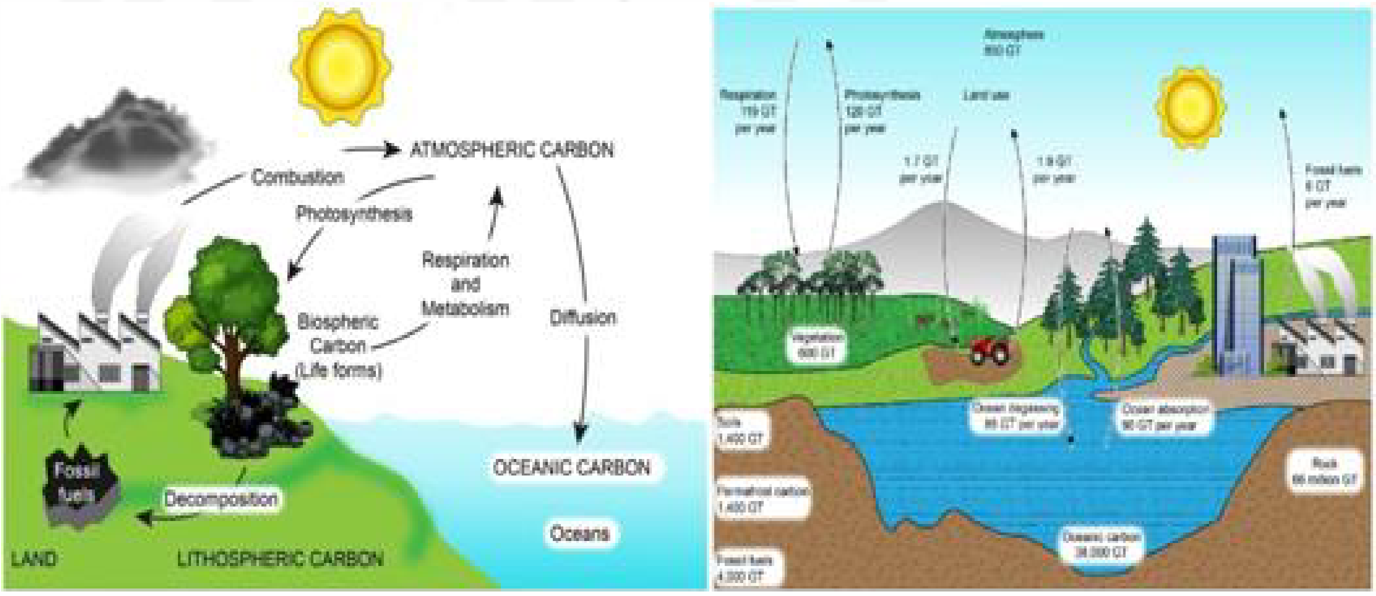


Fig. 2.10: a) Atmospheric carbon is fixed by plants in their biomass and gets transferred plants to the animals feeding on them, and so further moves up the food chain. Respiration, digestion, and metabolism of plants and animals result in some transfer of carbon back to the atmosphere. Some carbon also moves to the lithosphere when these living organism die or when wood and leaves decay or when animals excrete. Some of the living beings buried millons of years ago have been converted into fossil fuel. Mining and burning of fossil fuels cause this carbon to move from the lithosphere to the atmosphere. Some of this atmospheric carbon gets dissolved in the ocean and thus, completes the cyele; b) A generalized global carbon cycle in which estimated volumes are given in Gigatonnes of CO2 (a gigaton is equal to one billion metric tons).

rocks, dissolved in water or dispersed in the atmosphere. There is a continuous two-way flow of carbon between the organic and inorganic forms whereby there is a continuous exchange of carbon dioxide between the atmosphere and organisms on one hand, and between the atmosphere and the sea, on the other. The carbon cycle is based on carbon dioxide gas (CO_2). In terrestrial ecosystems, CO_2 is removed from the atmosphere, and in aquatic ecosystems CO_2 it is removed from water.

The oceans contain about 50 times more CO_2 than the atmosphere and act as a major carbon-storage sink and so play a crucial role in the global carbon cycle. Marine species remove some carbon dioxide during photosynthesis.

Carbon from the atmospheric pool moves to green plants, and then to animals and finally, from them directly to the atmosphere by process of respiration at various trophic levels in the food chain, or to bacteria, fungi and other micro-organisms that return it to atmosphere through decomposition of excretory wastes and bodies of organisms when they die. Carbon cycle regulates atmospheric CO_2 level to 0.032% despite photosynthetic uptake. In the normal course carbon is returned to the environment about as fast as it is removed. The carbon cycle ensures that the CO_2in the atmosphere is present at acceptable levels. This in turn moderates the temperature for life to exist. If the carbon cycle removes too much carbon, the atmosphere will become cool and if too much carbon is added to the atmosphere, the atmosphere will get warmer.

Global Carbon Cycle

Some carbon however enters a long term cycle referred to as **''Global Carbon cycle''** in which carbon accumulates in the form of organic matter in the peaty layers of bogs and moorlands or as insoluble carbonates (for example the insoluble calcium carbonate (($CaCO_3$) of various sea shells) in bottom sediments of aquatic systems. This sedimentary carbon eventually turns into sedimentary rocks such as lime stone and dolomite. In deep oceans such carbon can remain buried for millions of years till geological movement may lift these rocks above sea level. These rocks may be exposed to erosion, releasing their carbon dioxide, carbonates and bicarbonates into streams and rivers. Hard water has usually flowed through lime stone at some point, picking up carbonates which they accumulate as 'fur' in kettles when the water is boiled. Fossil fuels such as coal, petroleum and natural gas are also part of the carbon cycle which may release their carbon compounds after several years. These fossil fuels are organic compounds that were buried before they could be decomposed and were subsequently transformed by time and geological processes into solid or liquid hydrocarbon fuels. When fossil fuels are burned the carbon stored in them is released back into the atmosphere as CO_2 (2.10 b). The current global cycle shows an increased concentration of CO_2 in the atmosphere. The resulting climate change phenomenon is at the forefront of the environmental problems faced by the world at present.

The Nitrogen Cycle

Nitrogen is an essential constituent of protein which is a building block of all living tissue. **It constitutes nearly 16% by weight of all the proteins**. There is an inexhaustible supply of nitrogen in the atmosphere but the elemental form cannot be used directly by most of the living organisms. Nitrogen needs to be **'fixed'**, that is, converted to ammonia, nitrites or nitrates, before it can be taken up by plants. Nitrogen fixation on earth is accomplished in three different ways: (i) by certain free-living bacteria and bluegreen algae (e.g. *Anabaena*, *Spirulina*), and symbiotic bacteria (e.g. *Rhizobium*); (ii) by human being using industrial processes (fertilizer factories) and (iii) to a limited extent by atmospheric phenomena such as thunder and lighting.

As you can see from Fig. 2.11, nitrogen at any time is tied up in different 'compartments' or 'pools' — the atmosphere, soil and water, and living organisms. The periodic thunderstorms convert the gaseous nitrogen in the atmosphere to ammonia and nitrates which eventually reach the earth's surface through precipitation and then into the soil to be utilized by plants. More important, however, are certain microorganisms capable of fixing atmospheric nitrogen into ammonium ions (NH_4^+). These include free living nitrifying bacteria (e.g. aerobic *Azotobacter* and anaerobic *Clostridium*) and symbiotic nitrifying bacteria living in association with root nodules present in leguminous plants (e.g. *Rhizobium*) as well as blue green algae (eg. *Anabaena, Spirulina*). Ammonium ions can be directly taken up as a source of nitrogen by some plants, or are oxidized to nitrites or nitrates by two groups of specialised bacteria: *Nitrosomonas* bacteria which promotes transformation of ammonia into nitrite. Nitrite is then further transformed into nitrate by the bacteria *Nitrobacter*.

Volcanoes are also important sources of nitrogen. They have been emitting small quantities of nitrogen for centuries and contribute significantly to the nitrogen reservoir of the atmosphere.

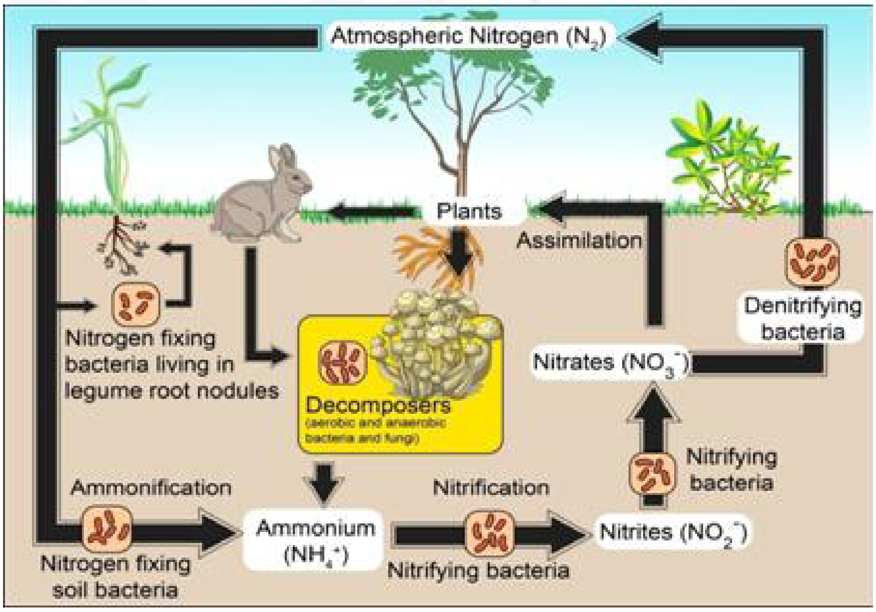


Fig. 2.11: A schematic nitrogen cycle showing the flow of nitrogen through the land environment. Presence of bacteria is a key elements in the cycle as it provides different forms of nitrogen compounds that can be assimilated by higher organisms.

The symbiotic bacteria capable of fixing atmospheric nitrogen live in the root nodules of leguminous plants like beans, peas, alfalfa etc. In agricultural ecosystem legumes of approximately 200 species are the pre-eminent nitrogen fixers. In non-agricultural systems some 12,000 species ranging from cyanobacteria to nodule-bearing plants, are responsible for nitrogen fixation.

The nitrates synthesised by bacteria in the soil are taken up by plants and converted into amino acids, which are the building blocks of proteins. These then go through higher trophic levels of the ecosystem. During excretion and upon the death of all organisms nitrogen is returned to the soil in the form of ammonia. In the soil as well as oceans there are special denitrifying bacteria (e.g. *Pseudomonas*), which convert the nitrates/nitrites to elemental nitrogen. This nitrogen escapes into the atmosphere, thus completing the cycle.

Nitrogen has become a pollutant (in the form of nitrogen dioxide and nitric oxide) because of human intrusion into the natural cycle and this can disrupt the balance of nitrogen in the air.

2.6.2 Sedimentary Cycles

Phosphorus, calcium and magnesium circulate by means of the sedimentary cycle. Sulphur is to some extent intermediate, since two of its compounds hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), add a gaseous component to its normally sedimentary cycle. The element involved in the sedimentary cycle normally does not cycle through the atmosphere but follows a basic pattern of flow through erosion, sedimentation, mountain building, volcanic activity and biological transport through the excreta of marine birds. The sulphur cycle is a good example for illustrating the linkage between air, water and the earth's crust, and hence, a brief account of this cycle is given.

Sulphur Cycle

The sulphur cycle is mostly sedimentary except for a short gaseous phase. (Fig.2.12.).The large sulphur reservoir, as mentioned before, is in the soil and sediments where it is locked in organic (coal, oil and peat) and inorganic (pyrite rock and sulphur rock) deposits in the form of sulphates, sulphides and organic sulphur. It is released by weathering of rocks, erosional runoff and decomposition by bacteria and fungi of organic matter and is carried to terrestrial and aquatic ecosystems in salt solution. Sulphur is found in gaseous forms like hydrogen sulphide and sulphur dioxide in small quantities in the atmosphere, which is thus a small reservoir. Sulphur enters the atmosphere from several sources like volcanic eruptions, combustion of fossil fuels, from surface of ocean and from gases released by decomposition. Atmospheric hydrogen sulphide also gets oxidised into sulphur dioxide (SO_2). Atmospheric SO_2 is carried back to the earth after being dissolved in rainwater as weak sulphuric acid (H_2SO_4). Uptake of sulphur by plants is in the form of sulphates (SO_4^{-2}) which are incorporated into sulphur bearing amino acids in the proteins of autotroph tissues through a series of metabolic processes. The sulphur then passes into the grazing food chain. Sulphur bound in living organism is carried back to the soil, to the bottom of ponds and lakes and seas through excretion and decomposition of dead organic material. Under aerobic(in presence of oxygen) conditions fungi like *Aspergillus* and *Neurospora* and under anaerobic conditions(without oxygen) bacteria like *Escherichia* and *Proteus* are largely responsible for the decomposition of proteins.

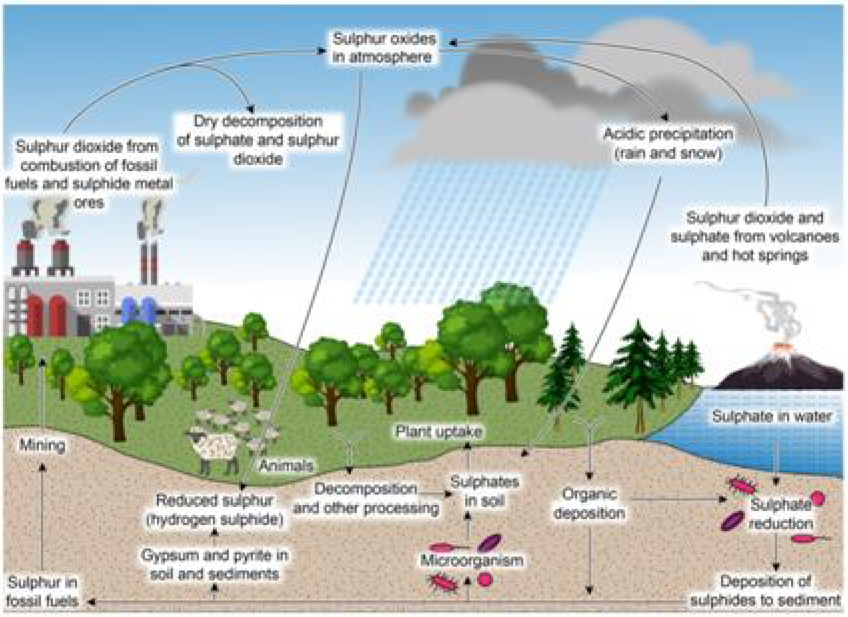


Fig. 2.12: The sulphur cycle, showing the two reservoirs namely, sedimentary and gaseous.

You should bear in mind that the nutrient cycles discussed here are only a few of the many cycles present in the ecosystem. You should also be aware that these cycles usually do not operate in independently but interact with each other at some point or the other.

SAQ 4

1) a) Choose the correct answer.

Which of the following contribute to the carbon cycling?

i) Respiration

ii) Photosynthesis

iii) Fossil fuel combustion

iv) All of the above

b) Tick mark the correct answer.

The main reservoir of nitrogen in the biosphere is the

i) atmosphere

ii) rocks

iii) oceans

iv) organisms

c) Which of the following statements are true and which are false? Write (T) for true and (F) for false:

i) The water cycle is driven by solar energy. [ ]

ii) The carbon in the carbon cycle may be either organic or inorganic. [ ]

iii) The oceans contain about 50 time less carbon dioxide than the atmosphere. [ ]

iv) Sulphur, phosphorus and calcium cycles are completely sedimentary. [ ]

v) Plants take up sulphur in the form of sulphur dioxide. [ ]

2.7 ECOLOGICAL SUCCESSION

A community is also called a biotic community. **"A biotic community is defined as a group of interacting populations living in a given area".** A biotic community represents the living part of an ecosystem and functions as a dynamic unit with trophic levels and energy flow and nutrient cycling system as described earlier.

Biotic communities exhibit progressive change as part of their normal development. The orderly process of change or replacement of some inhabitants or species of the community in an area, through time is known as community development or more traditionally as ecological succession. The time scale for ecological succession can be decades (for example, after a wildfire), or even millions of years after a mass extinction.

2.7.1 Types of Ecological Succession

Ecological changes are fairly predictable and orderly. Within an ecological community, the species composition will change over time as some species become more prominent while others may fade out of existence. As the community develops over time, vegetation grows taller, and the community becomes more established. This final stage of succession is quite stable and the community in this is called the climax community.

Ecological succession includes (1) primary and (2) secondary succession

2.7.2 Primary Succession

Primary succession is initiated when a new area that has never previously supported an ecological community is colonized by plants and animals. This could be on newly exposed rock surfaces from landslides or lava flows. Primary succession thus, occurs where no community exists before, such as rocky outcropping, newly formed deltas, sand dunes, emerging volcanic islands and lava flows. An example, which can be used as a model showing development of primary succession, is the invasion and colonisation of bare rock as on a recently created volcanic island.

Although succession ends with the establishment of a climax community, this does not mean that a climax community is static. It does change though slowly, even when the climate is constant. It will change rapidly however, if the community is disturbed in some way.

Primary succession first begins by the entry of lichens which can invade and colonise bare rocks, once they enter by various methods of dispersal. Lichens get a foot hold on the bare rocks by means of their tenacious, water-seeking fungal component and form the first community, very appropriately often called the pioneer community. (Fig. 2.13). Lichens are soil builders, producing weak acids that very gradually erode the rock surface. As organic products and sand particle accumulate in tiny fissures of the rocks, mosses, larger plants, such as grasses also get an opportunity to establish themselves and begin a new seral stage. In time lichens that made the penetration of plant roots possible are no longer able to compete for light, water and minerals and are succeeded by larger and more nutrient demanding plants such as shrubs and finally trees. (Fig. 2.13)

Seral stage (Sere) or seral community is the intermediate community stage in succession in an ecosystem which is progressing towards its climax community.

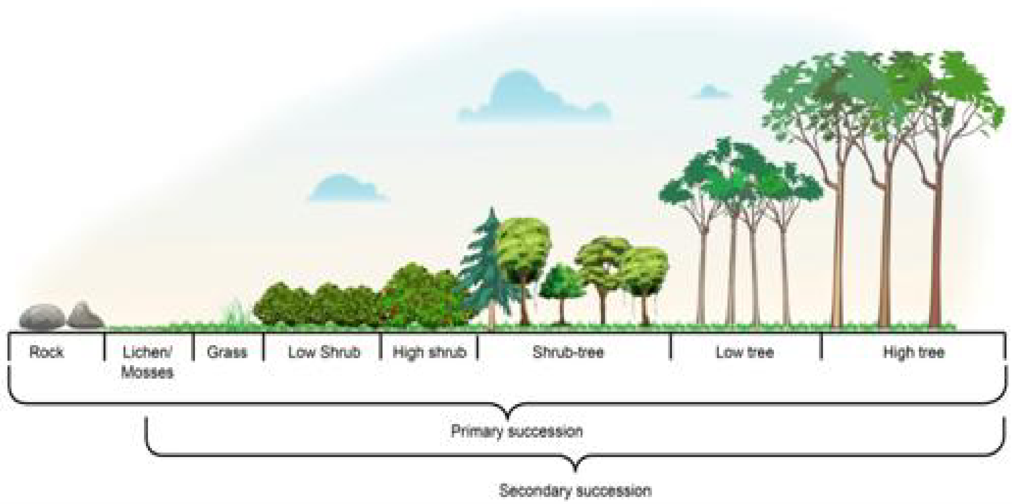


Fig. 2.13: Stages of primary succession in a terrestrial community. The orderly series of species replacement during succession can be seen in this sequence — from a bare exposed rock to a fir-birch-spruce community. Pioneer species of lichens and mosses begin the soil-building process, followed by the invasion of increasingly larger plants until a more stable long-lived, climax forest community forms.

2.7.3 Secondary Succession

Secondary succession occurs when a community in an area is drastically disturbed leading to its destruction which results in a new community moving into that area. Secondary succession is more common than primary succession and is often the result of natural disasters such as fires, floods, and winds, as well as human interference such as logging and tree-cutting.

Secondary succession in grassland communities is much faster, taking 20 to 40 years to develop while on the other hand, fragile disturbed tundra may require many hundreds of years to recover, if it ever does.

In secondary succession the basic features are similar to those of primary succession, but the seres occur at a more rapid pace. This is because the soil is already formed and available. Secondary succession is said to occur when the surface is completely or largely denuded of vegetation but has already been influenced by living organisms and has an organic component. In such areas seeds, spores and plant propagates, such as rhizomes may be present in the ground and thus influence the succession.

2.8 ECOSYSTEM AND HUMAN INTERVENTION

As you are aware, humans can and do change natural communities. We are often guilty of accidentally or deliberately altering the complex and myriad factors that maintain the delicate equilibrium of ecosystems. Today, approximately 40 per cent of the earth's photosynthetic productivity is used or influenced by human activities. Often in order to correct the wrongs of the past intervention we tend to undertake well-intended but uninformed measures. However, our efforts falter or fail because of lack of basic information. All this shows that we have still not learnt to live in harmony with the ecosystems of which we are a part. Our technology has far outpaced our basic knowledge and understanding of the environment. As we turn to the scientific community for answers and solutions, ecologists will play an increasingly important role in changing the ways in which we interact with the natural world. Each of us will also have to be aware about the consequences of disturbing the delicate balances of ecosystems and should make efforts not to be a contributor to damaging or degrading the ecosystems.

SAQ 4

In the following statements choose the appropriate word from the alternatives given in the parenthesis.

i) In an ecosystem succession that occurs after a fire is (primary/secondary) succession.

ii) The first plants to grow in a new ecosystem is termed as (new/pioneer) species.

iii) Lichens contribute to primary succession by (decomposing organic matter from animals and plants/breaking down the rock to form soil).

iv) Natural disasters such as hurricanes and volcanic emissions are linked to (primary/secondary) succession.

2.9 SUMMARY

- Environment is the sum total of living and non-living components that surround and influence an organism. Living components are called biotic components while non-living components are called abiotic components.
- The biosphere is that region of water, earth and atmosphere where life systems exist. Within the biosphere there are several major regions containing specific types of ecosystems. The major terrestrial regions are called biomes, which are characterised by their dominant vegetation. The other portion of the biosphere is the aquatic zone.
- An ecosystem is the simplest entity that can sustain life. At its most basic, an ecosystem is formed of a variety of individual organisms, micro organisms, plants and animals which interact with each other and with their physical environment. It sustains two processes, the cycling of chemical elements and flow of energy. It is a self-regulatory system based on feedback information given by its living and non-living components.
- Ecosystems are considered functional units of nature having no specific size or limits.

- The abiotic components of the ecosystem consist of physical factors such as light, temperature, rainfall, water and nutrients. The biotic component of the ecosystem consists of autotrophs or producers, and heterotrophs or consumers, and decomposers. These organisms belong to different trophic levels. Trophic levels tell us how far the organism is removed from the producers in its level of nourishment and which organisms share the same general source of nutrition.
- Three main types of food chain can be distinguished namely grazing, parasitic and detritus food chains. Several intersecting food chains form a food web, which depicts the pattern of food consumption in an ecosystem.
- The nutrients in an ecosystem are continuously cycled and recycled. Nutrients essential to organisms are distributed in various chemical forms in air (atmosphere), soil or rock (lithosphere), water (hydrosphere) and living beings. Over time, elements move from one sphere to another by means of biogeochemical cycles. Key cycles described in the unit are water, carbon, nitrogen and sulphur. Soil microorganisms and organisms present in the roots of leguminous plants play a key role in cycling of elements, particularly nitrogen and sulphur.
- Ecosystem succession occurs when a series of communities (each community is called a seres) replace one another. Each community changes the environment to make conditions favourable for a subsequent community and unfavourable for itself till the climax community is established.
- Ecological succession includes (1) primary and (2) secondary succession
- Primary succession is initiated when a new area that has never previously supported an ecological community is colonized by plants and animals called the pioneer community.
- Secondary succession occurs when a community in an area is drastically disturbed leading to its destruction which results in a new community moving into that area.
- The final stage of succession is quite stable and is called the climax community.

2.10 TERMINAL QUESTIONS

1. Give one to two words for the definitions given below:

   i) The basic, functional, self sustaining unit of biosphere, consisting of all living and non living components of a particular area that interact and exchange materials with each other.

   ii) The entire region of the surface of the earth comprising of atmosphere, lithosphere and hydrosphere where organisms can live.

   iii) Non-living components like air, water, soil, light, organic and inorganic compounds in the ecosystem.

iv) The sequential process of eating and being eaten in an ecosystem which also involves with this the transfer of energy from one trophic level to another.

v) The process of change in the species structure of an ecological community over time in which the time scale can be in decades.

2. In your food chain give three for each of the following:

i) Who are the producer? ....

ii) Who are the consumers? ....

iii) Who are the herbivore ?..

iv) Who are the carnivores? ....

v) Who are the decomposers? ....

vi) Who are the autotroph? ....

vii) Who are the heterotrophs? ....

viii) Who are the predators? ....

3. Tick the correct answer from the following:

a) A producer is :

I. at the start of a food chain

II. at the bottom of the ecological pyramid

III. an autotroph

IV. all of these

b) A detritus food chain begins:

I. always in the ocean

II. with a producer

III. with decaying organic matter

IV. with air pollution

c) Natural disasters such as hurricanes and floods are linked to:

i) old field succession

ii) primary succession

iii) secondary succession

iv) climax succession

d) Top consumers for obtaining energy eat

I. herbivores

II. carnivores

III. omnivores

IV. all of the above

4. What are the two types of biogeochemical cycles and what are their distinguishing features?

5. Describe three pathways whereby atmospheric nitrogen is converted into fixed forms that are usable by plants, and two pathways whereby fixed nitrogen is returned to the atmosphere.

2.11 ANSWERS

Self-Assessment Questions

1. a) (i)

   (ii) X

   (iii)

   (iv) X

   (v) X

   b) (i) biotic components-primary producers, consumers, decomposers.

   (ii) abiotic components-energy, environment, inorganic elements and soil.

2. a) wheat, corn (first trophic level)

   goat, rat (second trophic level)

   lion, cat (third trophic level)

   b) Hint: e.g., Grizzly bear,1

   Second trophic level (herbivore) like squirrel as it eats tubers and various other plant products; third trophic level (carnivore) like bear as it eats animals like squirrel which is a herbivore; fourth trophic level (top carnivore) like mountain lions as it eats animals like grizzly bear which are carnivores.

3. In an ecosystem the producers utilise solar energy and store it in the food they prepare which are mainly carbohydrates. The plant tissues that have the stored solar energy in them serve as a source of energy for the herbivores. And the herbivores pass on the energy to the carnivores and so on and so forth. Thus the ultimate source of energy for our planet on the whole can be considered to be the sun.

4. a) (iv)

   b) (i)

   c) (i) T; (ii) T; (iii) F; (iv) F; (v) F.

5. (i) secondary succession;

   (ii) pioneer;

   (iii) breaking down the rock to form soil;

(iv) secondary succession.

Terminal Questions

1. i) Ecosystem

   ii) Biosphere

   iii) Abiotic factors components

   iv) Food chain

   v) Ecological succession.

2. You can give your own answers.

3. a) (iv); b) (iii); c) (ii); d) (iv)

4. a) Gaseous cycles where the primary reservoir is the atmosphere as far as living organisms are concerned, examples carbon and nitrogen.

   b) Sedimentary cycles where the principle reservoir lies in the earth's crust and is released into the ecosystem by, weathering, mining and erosion. Examples are phosphorus and sulphur.

5. Atmospheric nitrogen is fixed (i) into ammonium by biological fixation through nitrogen fixing bacteria and blue green algae, (ii) by lightning as photochemical fixation into nitrates, (iii) by industrial fixation in the form of nitrate and ammonium fertilisers.

   Nitrogen is returned to the atmosphere through the process of denitrification of nitrates and as oxides of nitrogen in automobile exhaust and industrial combustion.

2.12 FURTHER READING

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