UNIT 3 DESCRIPTION OF ECOSYSTEM

Structure

3.1 INTRODUCTION

Unit 1 introduced you to a general concept of the human environment. You learnt about the abiotic and biotic components that constitute the environment. You and I live in a defined area of earth where plants and animals, including ourselves, develop kinship with one another for life, for food, water, shelter, mates. etc. These discrete units have living and non-living components, which in their natural life processes, are interdependent and interrelated in terms of their **structure, components,** and **functioning**. Such units are called ecosystems. Different types of ecosystems, with diverse subsystems within each, form the course material of this unit. A study of this unit will enable you to understand the concepts in Units 4 and 5.

Objectives

After studying this unit you would be able to:

- define and describe various ecosystems on earth,
- describe the components of an ecosystem and explain their functioning,
- list and describe the life-supporting and limiting factors,
- describe biomagnification of harmful substances relevant to man, and
- explain the role of species diversity in ecosystem stability.

3.2 WHAT IS AN ECOSYSTEM?

A species or an oganism can never live alone. They are always influencing each other and organising themselves into communities, besides they have functional relationship with their external environment. This structural and functional system of communities and their environment is called **ecosystem**. The word **ecosystem** was coined by Tansley in 1935. The prefix 'eco' means environment.

The central theme of ecosystem concept is that at any place where an organism lives, there is a continuous interaction b tween the living and the non-living components, i.e., between plants, animals and their environment. They continuously produce and exchange materials. This means, that there are mechanisms for continuous absorption of materials by organisms for the purpose of production of organic materials and their conversion back into the inorganic form, much of which is then released back into the environment.

The interaction between living and non-living components of an ecosystem involve **input, transfer, storage** and **output of energy and essential materials through the system**. Each of these processes is energy-dependent. As a result of these complex interactions, the ecosystem has to adjust to these changes and attains a state of equilibrium. An ecosystem, therefore, is a system that is *self-regulatory based on feed-back information about the population, and the limiting factors which control the living and non-living components*.

Before we explain the functioning of the components of the ecosystems let us first talk about a larger unit of natural landscape biosphere.

3.2.1 Biosphere

Biosphere is defined as that part of the earth and atmosphere in which many smaller ecosystems exist and operate. Three main subdivisions of the biosphere are lithosphere, (solid matter); hydrosphere (liquid matter), and atmosphere or the gaseous envelope of the earth which extends upto a height of 22.5 km. Figure 3.1, shows the idealised scheme of biosphere in relation to hydrosphere, atmosphere and lithosphere. The area of contact and interaction between these components is really important for life, for it is here that the entire life is confined and the basic processes of life like photosynthesis and respiration occur.

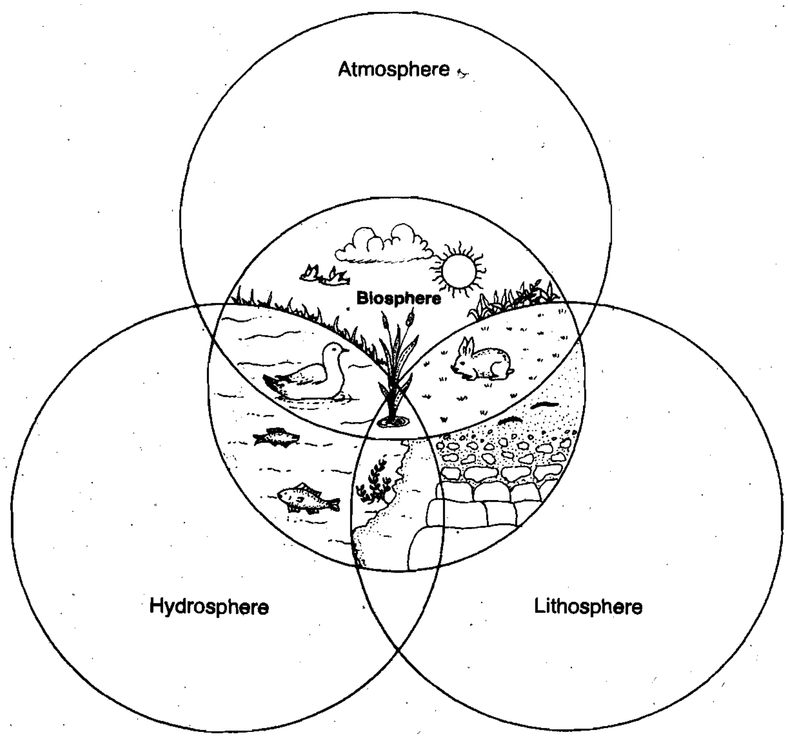

Fig. 3.1: Idealised scheme of the biosphere.

Living organisms are, mostly, confined to the parts of biosphere that receive solar radiation during the day. As stated above this includes atmosphere, the surface of land, the few metres of soil and the upper layers of water of oceans, lakes and rivers. The illuminated zone may be a few centimeters in turbid water of a river, and upto about 100 metres in clearest part of an ocean. In the ocean, the biosphere does not end where light ceases as gravity enables the energy flow to continue downward, since fecal pellets, cast skins and oganisms dead and alive are always falling from the illuminated regions into the depths.

In addition to the extension of the biosphere downwards, there is a limited extension upwards also. On very high mountains, like Himalayas, the limit above which chlorophyll bearing plants can not live appears to be about 6,200 meters.

In simple words, biosphere can be viewed as the part of the earth consisting of oceans and the surface of the continents, together with the adjacent atmosphere (i.e. the troposphere) However, polar ice caps and the higher mountains slopes above the snow line are known as **parabiosphere**.

Since living organisms require inorganic metabolites from each of the subdivision of the biosphere, water from the hydrosphere, mineral from lithosphere and chemical elements from atmosphere, a brief discussion on the nature and working of each subdivision will help us to know the mechanism which influences **metabolic** activities of living organisms.

a) **Atmosphere**

Atmosphere is of much significance to life as all the components of air (except inert ones) serve as metabolites, and each chemical element circulates through a cycle maintaining a perpetual supply of metabolites. Recall Foundation Course in Science and Technology Block-4, Unit16, where you got the basic idea of nutrient cycling in the biosphere. It is at this stage that the role of organisms and significance of atmosphere to life emerge on the interface of the biospheric subdivisions. The metabolic role of a few important gases in the following pages will highlight the importance of atmosphere.

The green plants incorporate a variety of inorganic elements and compounds. For example, during the process of converting solar energy into chemical energy, atmospheric carbon dioxide enters the living world as the basic constituent of all organic compounds. Carbon dioxide along with water is used by all plants in their **photosynthetic** process to produce organic substances such as, glucose a vital molecule in living things, and oxygen.

The chemical reaction involved in the process is as follows :

$$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Carbon dioxide + water ——————> glucose (carbohydrate) + oxygen

Photosynthesis thus provides food for us to eat and oxygen for us to breath. Here, the carbon and oxygen supplied by carbon dioxide remain in living matter until death. And only after decomposition of the living matter, the CO_2 returns to the atmosphere to complete the cycle. At this point we should remember that photosynthesis occurs only in chlorophyll bearing organisms, namely, green and purple bacteria, blue green algae and the vast population of higher plants.

Oxygen, an important constituent of the atmosphere, enters the living world through respiration which is a familiar process in both plants and animals including man. Through it, glucose molecules are converted into energy needed for various activities. Respiration and photosynthesis together form a cycle called **photosynthesis—respiration** cycle, which can be depicted as following :

Light

$$\boxed{6\,CO_2 + 6H_2O \xrightarrow{\text{Photosynthesis}} C_6H_{12}O_6 + 6O_2}$$

$$\boxed{6\,CO_2 + 6H_2O \xleftarrow{\text{Respiration}} C_6H_{12}O_6 + 6O_2}$$

Heat Energy

Carbon dioxide of the atmosphere is replenished not only through the process of respiration or biological oxidation but also through combustion of fuels and volcanic erruptions. The other important constituent in this cycle is water.

Nitrogen is also an essential component of living systems. It is required by organisms for the synthesis of proteins, nucleic acids, and other nitrogenous compounds. In nature, atmospheric nitrogen is fixed by specialized organisms. There are industrial processes to convert atmospheric nitrogen into fertilizers.

Movement of materials through living organisms involves many more substances than those contained in water and carbon dioxide. In addition to carbon, oxygen, hydrogen and nitrogen, all organisms need phosphorus, sulphur, sodium, potassium, calcium, magnesium, iron, manganese, cobalt, copper, zinc and probably chlorine and some certainly use for special functions, aluminium, boron, bromine, iodine, selenium, molybdenum, vanadium, silicon, strontium, barium and possibly nickel.

b) **Hydrosphere**
You know that water is the most important component of protoplasm; hence it is essential for life in all living organisms. In metabolism, it is the only source of hydrogen and one of the several sources of oxygen.

The earth is sometimes called the watery planet as this is the only planet in the solar system which has an abundant supply of water. Oceans form 71 per cent of the total surface area of the earth. Water evaporates with the help of solar energy and moves into the atmosphere. Water vapour after gaining higher altitudes cools, condenses to form clouds, which precipitate as rain or snow and thereby, return to the parent water system, the hydrosphere. You will read some more about it in Unit 4.

Water is used as a raw material for various metabolic processes. The living organisms draw it mainly from the hydrosphere. During the process of metabolism, water consumed by oganisms is partly excreted back into the environment and a portion used for building the oganisms is returned to the environment after their death and decay.

c) **Lithosphere**
The other sub-division of the biosphere is the lithosphere which helps in the metabolic process in two ways. One, it is the only source of most of the minerals for organisms belonging to either terrestrial or aquatic conditions, and two, it forms the soil, required mainly by terrestrial plants.

Keeping in view, the two basic processes of life i.e., photosynthesis and respiration we have in the above paragraphs examined the three main sub-divisions of biosphere.

Thus biosphere in reality is the largest definable unit of natural landscape in which many smaller ecosystems operate.

SAQ 1
Fill in the blanks with appropriate words.

The biosphere is constituted by ....,

.... and .... The entire life exists

in the narrow belt of their contact in the .... Solar

energy enters living systems, only through .... by

chlorophyll bearing organisms, the ...., ...

.... blue green algae, phytoplankton and the vast population of higher plants.

3.2.2 Biome and Community

Biomes are the major subdivisions of the terrestrial portion of the biosphere each recognizable by the characteristic structure of its dominant vegetation. The earth's dozen or more biomes are spread over millions of square miles and span entire continents. No two have climates, exactly alike; the average weather conditions in a given region determine the boundaries of a biome and the abundance of plants and animals found in each one. The most important climatic factors are precipitation and temperature.

Although a biome can be considered a very large ecosystem, it differs from ecosystem such as a pond or a patch of woodland in its complexity and internal variations. Thus, the coniferous taiga biome contains lakes, bog, and other ecosystems within itself, in addition to the overall evergreen forest ecosystem. The evergreen forest itself varies considerably from one locality to the next within the biome.

A group of plants that dominate a terrestrial biome is called its *climax* vegetation

In each biome, the kind of **climax vegetation** is uniform like grasses, conifers, deciduous trees—but the particular species of a plant may vary in different parts of the biome. The kind of climax vegetation depends upon the physical environment and the two together determine the kinds of animals present. There is usually no sharp line of demarcation between adjacent biomes, infact each blends with the next through a fairly broad transition region.

The distribution of the biomes appears to be governed by the interaction of four main variables, which also interact to influence one another namely, growing season, which in turn depends on annual temperature especially the minimum and the maximum, mineral availability and rainfall both averages and minimum.

The other section of the biosphere, the **aquatic** life zone is divided into more or less identifiable life or vegetative and animal zones. These zones, however, are **not** named biomes. On the basis of penetration of light in aquatic systems these zones are: (i) **Euphotic zone** which consists of producers, such as phytoplankton, and consumers. This zone is known as the producing region as it is this zone where sunlight is available. This extends down to the 600 feet below the surface of the ocean water. (ii) **Aphotic zone** which receives no light. This zone has mostly consumers.

We can now conclude that possibly there is no area where life does not exist. Any area which exhibits evidence of life and where organisms are present, both plants and animals, is known as the **habitat** of that specific oganism(s). Whereas, the **population** of plants, and animals living together in a given space is defined as a **community** in biological terminology. By population here we mean the interacting individuals of the same species.

3.3 COMPONENTS OF ECOSYSTEM

Recall the definition of an ecosystem from Section 3.2. Any complete definition of an ecosystem includes the physical environment as well as the biological components and the interaction between the two. The biological or biotic components of an ecosystem include:

i) Organisms, basically green plants, certain bacteria and algae, that can synthesise their own food in the presence of sunlight. These are the **autotrophs** or **producers**.

ii) All other organisms that do not make their own food but depend on other organisms to obtain their energy for survival. These are called **heterotrophs** or **consumers**.

Among consumers some animals such as goat, cow, deer, rabbit and insects which eat green plants are called **primary consumers** or herbivores. Organisms which eat a herbivore, like a frog that eats grasshoppers are called **secondary consumers**. Organisms which eat these secondary consumers are called **tertiary consumers**. While the primary consumers are herbivores, the secondary and tertiary consumers are carnivores. Animals like lions and vultures which are not killed or eaten by other animals are **top carnivores**.

Amongst the producers also there is division. Only the green plants and some special types of bacteria which can trap solar energy and produce food are called **primary producers**, the heterotrophs which are food for other animals become **secondary producers**.

Consequently an ecosystem is considered as a basic unit, where complex natural community obtain their food from plants through one, two, three or four steps and accordingly these steps are known as the first, second, third and fourth **trophic levels** or food levels such as :

- green plants (producers) ; trophic level I
- herbivores (primary consumers) ; trophic level II
- carnivores (secondary consumers) ; trophic level III
- top carnivores (tertiary consumers) ; trophic level IV

These are shown in Figure 3.2.

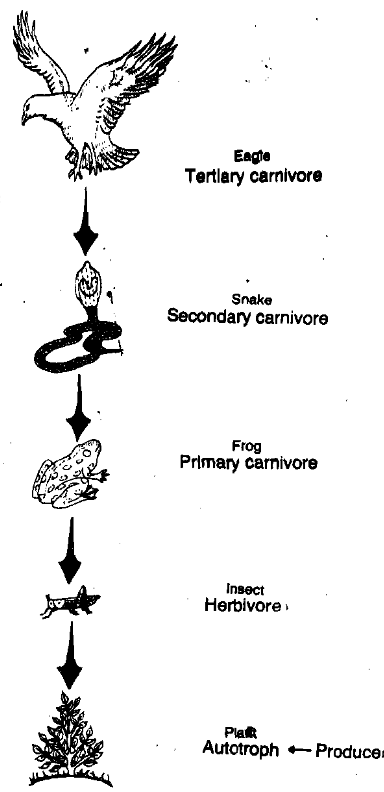

Fig. 3.2: Trophic levels in an ecosystem

Both the consumers and producers complete their life cycles and new generations of population develop while the old ones die. You must be wondering what happens to the dead. There is a continuous breaking up or decomposition of the dead organic matter everywhere in the ecosystem. There is a continuous cycling of materials. Certain fungi and bacteria which are responsible for the decomposition are called **decomposers or reducers.** The role of decomposers is very special and important. Certain decomposers are also called **scavengers**. Water, carbon dioxide, phosphates and a number of organic compounds are largely the by-products of organism activity or death of organisms.

The other important components of the ecosystem are abiotic or nonliving components. These are basically inorganic elements and compounds, such as carbon dioxide and water, nitrogen, phosphates, sulphates etc., and a number of organic compounds largely the by-products of organism activity or death. Other important abiotic components of the ecosystem are the physical factors including temperature, moisture, solar radiation, etc. It is in this abiotic background that biotic organisms i.e. plants, animals and microbes interact.

SAQ 2

Tick (√) against the correct statement and (×) against the wrong statement.

i) Goats, cows, deer, lions are consumers of first order. [ ]

ii) Green plants can remain both in I trophic and II trophic levels. [ ]

iii) All fungi and bacteria are called scavengers. [ ]

iv) The abiotic factors include light and temperature. [ ]

3.4 FUNCTIONAL COMPONENTS OF AN ECOSYSTEM

Coming to the functional aspect of an ecosystem, we may study it in terms of the following:

- energy flow,
- food chain,
- diversity pattern in time and space,
- nutrient or biogeochemical cycles,
- development and evolution.
- control or cybernetics.

With the help of the following flow chart, we can interpret the functional aspect of an ecosystem or the interactions between various components which involve the flow of energy and cycling of materials (Fig. 3.3).

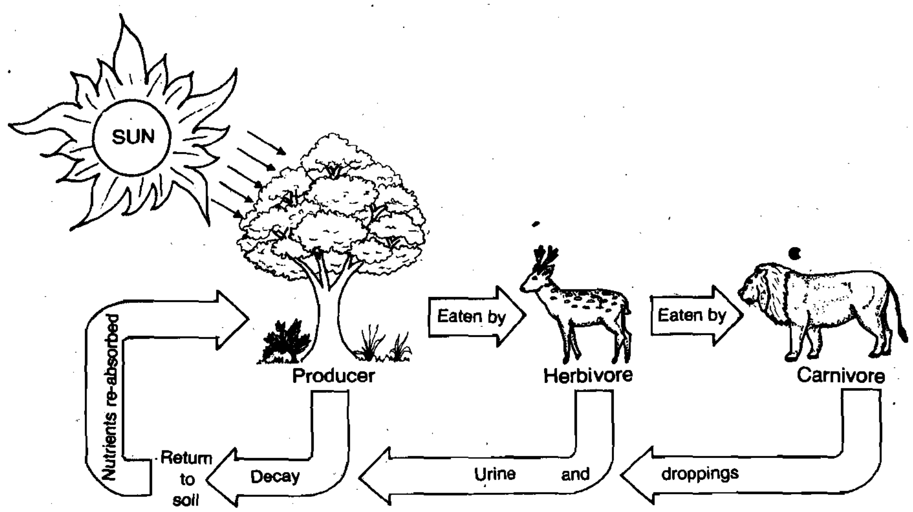

Fig. 3.3: Natural balanced ecosystem.

Implicit in the system, such as autotroph ———> heterotroph, producer ———> consumer, or producer ———> herbivore ———> carnivore relationship, is the direction of energy movement through the ecosystem. In the process, solar energy is converted into chemical energy through photosynthesis by plants, which also incorporate into their protoplasm a number of inorganic elements and compounds. These green plants are grazed subsequently by heterotrophs. This means that not only is the chemical energy in the form of carbohydrates, fats, and proteins are transferred into herbivores but a host of other nutrients as well. This process continues upto the decomposer level through the carnivores. Another features of the process is that the energy trapped by green plants when transferred from one food level or trophic level to another also depicts energy losses at each transfer along the chain. The following diagram depicts the energy transfers and energy losses in an ecosystem (Fig. 3.4).

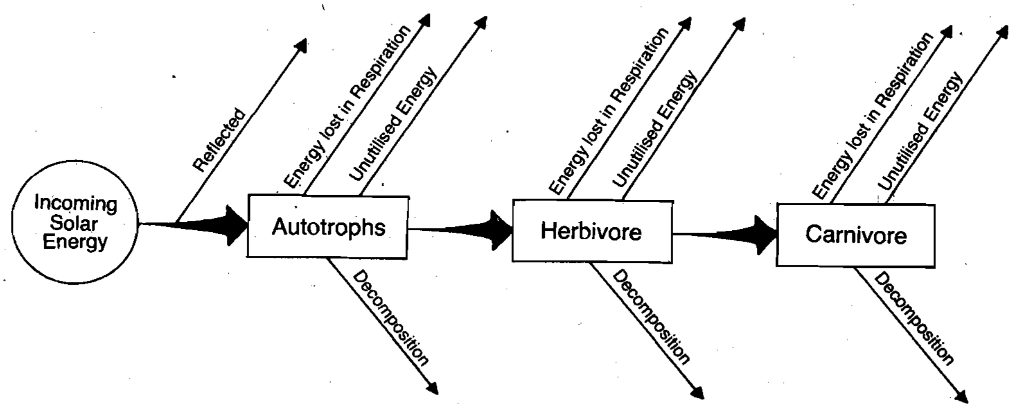

Fig. 3.4: Flow of energy in an ecosystem.

From the above diagram, we can conclude the following:

- energy movement is unidirectional unlike the nutrients/materials in an ecosystem, that is, the initial energy trapped by an autotroph does not revert back to solar input,
- energy that passes from herbivore to carnivore does not pass back to herbivore from carnivore. As a consequence of this unidirectional and continuous energy flow, the ecosystem maintains its entity and prevents collapse of the system.

However, transfer of nutrients along with chemical energy does not indicate loss of nutrients like that of energy. This is because the fecal matter, excretory products and dead bodies of all plants and animals are broken down into inorganic materials by decomposers and eventually returned to the ecosystem for reuse by the autotrophs.

An ecosystem is, therefore, a system, of regularly interacting and interdependent components forming a unified whole. The interaction of its components involves the flow of energy and cycling of materials (Fig. 3.5).

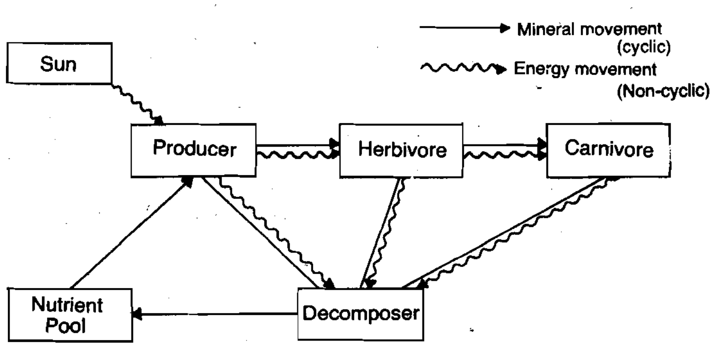

Fig. 3.5: Diagramatic representation of energy and mineral movement in ecosystems.

In the functioning of ecosystem the transfer of energy from one trophic level to another, i.e., sun to autotrophs, and from autotrophs to heterotrophs means accumulation of new organic materials into the system. These accumulated new organic materials are broken down by the microorganisms or decomposers. This may be subscribed as a process in the **recycling sequence.** During this process, the biomass is broken into its components, which become the raw material for the autotrophs.

The three living components, i.e. **producers, consumers,** and **microconsumers** (decomposers) form the three functional kingdoms of nature since they are based on the type of nutrition and the energy sources they use.

Thus, for a balanced condition, an ecosystem must have self sufficient and self-regulating **structural systems.** So far as, the abiotic and biotic components are concerned, they invariably indicate a natural tendency to maintain the functional balance within a certain range of environmental fluctuation. In all ecosystems, there is a self-regulatory mechanism or **control** to check and balance the system.

SAQ 3

State whether the following statements are true or false. Write T or F in the boxes provided:

i) Energy is at the base of an ecosystem. ☐

ii) Ecosystem is a self sustaining unit of nature. ☐

iii) Decay of organic matter does not affect the normal functioning of an ecosystem. ☐

iv) Primary producer is known as autotroph. ☐

v) Primary producer is known as primary consumer. ☐

vi) Decomposer is decayed material of an ecosystem. ☐

vii) Trophic level is based on species classification. ☐

3.5 FOOD CHAIN AND FOOD WEB

You have learnt that energy flow in an ecosystem is a one way process. We can identify the sequence of oganisms through which the energy flows and this sequence is known as **food chain.** For example, plants are eaten by insects, who are eaten by frogs, these frogs are eaten by fish, who are eaten by human beings. In this food chain, there are five trophic or feeding levels. Several factors are important in determining an animal's place in a food chain. Each species occupies a specific place and has special adaptations that make it fit for that place.

Flow of energy in ecosystems, from sunlight through photosynthesis in autotrophic producers, to the tissues of herbivores, the primary consumers, to the tissue of carnivores, the secondary consumers, determines the number and **biomass** of organisms at each level in the ecosystem. Flow of energy is greatly reduced at each successive level of nutrition because of the energy utilization by the oganisms and heat losses at each step in transformation of energy. This largely accounts for the decrease in biomass at each successive level. In addition no predator is completely efficient at capturing its prey; some energy is lost in the hunt.

Some animals eat only one kind of food and therefore, are members of a single food chain. Other animals eat many different kinds of food, so they are not only members of different food chains but also may occupy different positions in different food chains thus ensuring the survival of their species. An animal may be a primary consumer in one chain, eating plants but a secondary or tertiary consumer in other chains, eating herbivorous animals or other carnivores.

Humans are at the end of a number of food chains. For example, a man might eat a big fish, which in turn ate little fishes, which ate small invertebrates, which ate algae. The ultimate size of the population of any animal, is limited by the number of links in the food chain, the efficiency of energy transfer at each step in the chain, and ultimately by the amount of light energy falling on the earth in that region.

Since man can do nothing about increasing the amount of light energy and very little about the efficiency of energy transfer, he can only shorten the food chain, to get energy i.e., by eating the primary producers—plants, rather than animals.

In highly populated countries, people tend to be vegetarians because then the food chain is shortest and a given area of land can in this way support larger number of people. Suppose that a farmer has a crop of wheat and vegetables. He can eat it directly or feed it to his cattle and then eat the cattle. Figure 3.6 shows that the sun's energy is used most effectively if people are vegetarians.

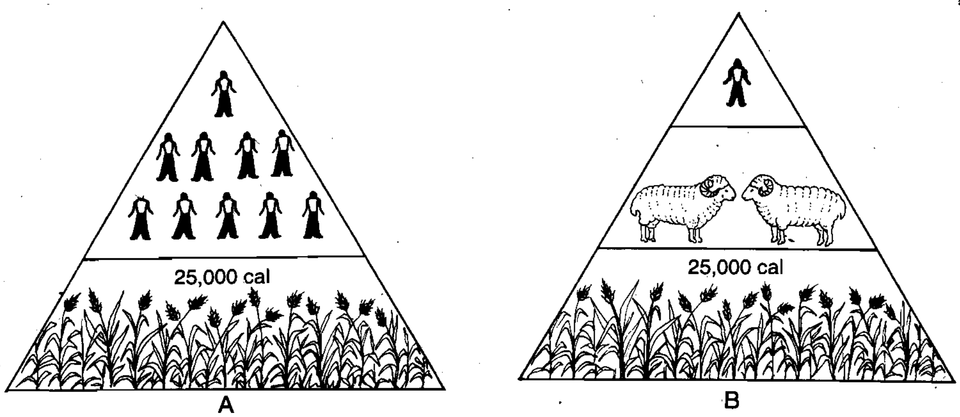

Fig. 3.6: The relative efficiency of vegetarian and non-vegetarian diets
(A) In a vegetarian diet 25,000 calories support 10 people.
(B) In the same time 25,000 calories of plant matter support only one person who eats meat.

In nature, three types of food chains have been distinguished.

- **Grazing Food Chain:** The consumers which start the food chain, utilising the plant or plant part as their food, constitute the grazing food chain. This food chain begins from green plants at the base and the primary consumer is herbivore, for example: grass ⟶ grasshopper ⟶ birds ⟶ hawks or falcon.
- **Parasitic Food Chain:** It also begins from green plant base, then goes to herbivores which for example may be the host of a huge number of lice which live as ecotoparasites.
- **Detritus Food Chain:** The food chain starts from dead organic matter of decaying animals and plant bodies to the micro-organisms and then to detritus feeding organism detrivores, and to other pedators.

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

Food chains are not always as simple as the one just described. Often, several different species may use the same item for food and one species may feed on different species of food organisms.

3.5.1 Food Web

A food chain represents only one part of the energy flow through an ecosystem and our ecosystem may consist of several interrelated food chains. However, the term food chain implies a simple, isolated relationship, which seldom occurs in ecosystems. More typically, the same food resource is part of more than one chain, especially when that resource is at one of the lower trophic levels. Thus there are interconnected networks of feeding relationships that take the form of **food webs** (Fig. 3.7).

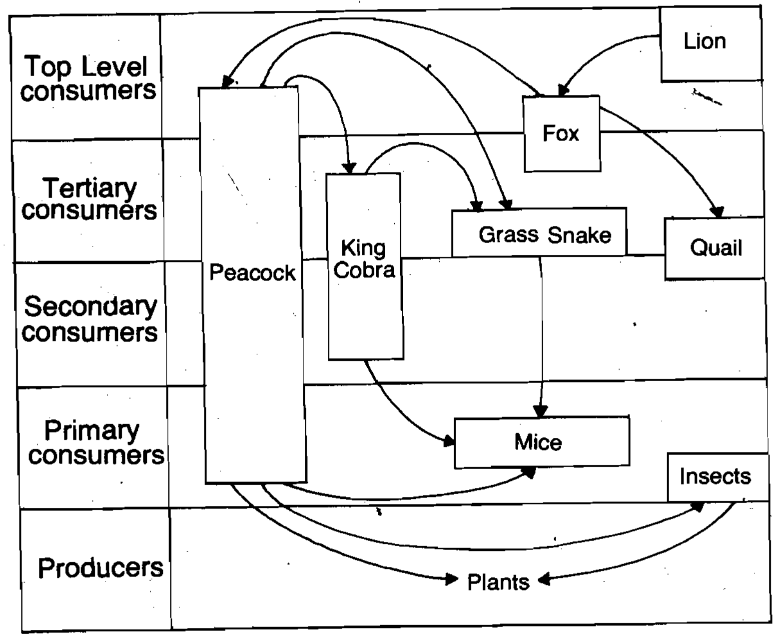

Fig. 3.7: A simplified scheme of a food web.

3.5.2 Pyramids

You have studied trophic levels in Section 3.3. These few steps of trophic levels can be expressed in a diagrammatic way ; and are referred to as ecological pyramids. The food producer forms the base of the pyramid and the top carnivore forms the tip. The ecological pyramids are of three categories (Fig. 3.8).

- Pyramid of numbers,
- Pyramid of biomass, and
- Pyramid of energy or productivity.

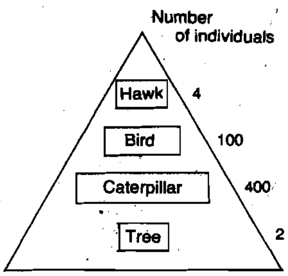

Fig. 3.8(a): Pyramid of numbers.

Pyramid of Numbers

This deals with the relationship between the numbers of primary producers and consumers of different orders. For example, we might have the following pyramid for a grass fields (Fig. 3.8 (a)) where the base of the pyramid represents the food production base for higher trophic levels.

But it is very difficult to count all the organisms, so, a pyramid of numbers does not completely define the trophic structure for an ecosystem. A pyramid of numbers does not take into account the fact that the size of organisms being counted in each trophic level can vary. A count in a forest would have a small number of large producers, the big trees, which supp rt a large number of herbivores and which in turn support a number of carnivores. Thu depending upon the size and biomass, the pyramid of numbers may not always be upri ht, it may even be completely inverted (Fig. 3.8(a)).

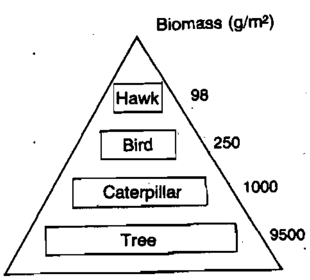

Fig. 3.8(b): Pyramid of biomass.

Pyr mid of Biomass

Anot er approach is to weigh individuals in each trophic level instead of counting them. This would give us a pyramid of biomass, i.e., the total weight of all organisms at a given level. Fo most ecosystems on land, the pyramid of biomass has a large base of primary producers ith a smaller trophic level perched on top (Fig. 3.8(b)). In contrast, in many aquatic ecos stems, e roducers are tiny phytoplankton that grow and reproduce rapidly. Here, the pyrami of mass can have a small base, with the consumer biomass at any instant actually exce g the producer biomass. The phytoplankton are consumed about as fast as they reprodu is just that the survivors (they may be few) are reproducing at a phenomenal rate.

Pyramid of Energy

When we wish to know about the functional roles of the trophic levels in an ecosystem, an energy pyramid is probably the most informative, for the pyramid shape is not distorted by over emphasis on variations in the size and metabolic rates of the individuals. An energy pyramid more accurately, reflects the laws of thermodynamics, hence the pyramid is always right side up, with a large energy base at the bottom. A pyramid of energy must be based on a determination of the actual amount of energy that individuals take in, how much they burn up during metabolism, how much remains in their waste products, and how much they store in body tissue. The energy inputs and outputs are calculated so that energy flow can be expressed per unit of land or water per unit time. Let us explain this with an example.

Laws of thermodynamics: 1st law — Energy is neither created nor destroyed but converted from one form to another.
2nd law — When energy changes from one form to another some of the energy is lost.

An ecosystem receives 1000 calories of light energy in a given day. Most of the energy is not absorbed; some is reflected back to space ; of the energy absorbed only a small portion is utilised by green plants, out of which the plant uses up some for respiration and of the 1000 calories, therefore only 100 calories are stored as energy rich materials.

Now suppose an animal, say a deer, eats the plant containing 100 cal of food energy. The deer uses some of it for its own metabolism and stores only 10 cal as food energy. A lion that eats the deer gets an even smaller amount of energy. Thus usable energy decreases from sunlight to producer to herbivore to carnivore. Therefore, the energy pyramid will always be upright. See Figure 3.8(c).

SAQ 4

Fill in the blanks

i) A pyramid based on a count of the producers and consumers in an ecosystem is known as ....

ii) A pyramid constructed after calculating the accumulated energy at each trophic level is known as ....

iii) The passing of the sun's energy from one trophic level to another is ....

iv) Interconnected feeding relationship in an ecosystem form ....

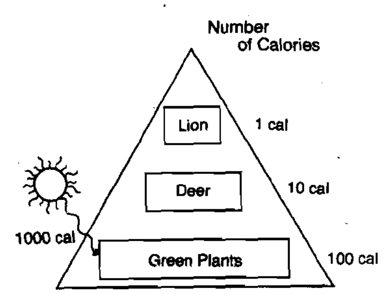

Fig. 3.8(c): Pyramid of energy.

3.5.3 Biomagnification

Biomagnification is a man-induced process in the ecosystem which brings input of nondegradable pollutants into the food chain. These nondegradable pollutants not only accumulate but are often biologically magnified in the food chain system. By nondegradable pollutants we means those materials which can not be metabolised by the living organisms. Some examples are substances like pesticides, anti-knocking agents used in internal combustion engines, anti-fouling paints etc.

Since, an ecosystem in its natural functioning may not handle these novel materials they get accumulated in the body of living organisms. Furthermore, in the course of the natural process, weaker organisms are eaten by stronger ones, and the concentration of nondegradable substances goes on increasing as we move from the lower to the higher levels of a food chain.

Let us take an example, DDT (dichloro-diphenyl trichloroethane) a broad-spectrum pesticide which kills harmful insects as well as beneficial insects is not readily decomposed. It lasts for a relatively long time (nearly 20 years) following one application; at the same time it is, of low toxicity to humans, which has encouraged its worldwide application. The other reason for its extensive use is its cost-effectiveness.

Figure 3.9 depicts various steps in a food chain where DDT enters biosphere at the initial stages of the food chain. You can see that the concentration of DDT which is initially, 0.02 ppm (parts per million) in the water after spray to control insects gets magnified in the food chain system. Microscopic plants take up contaminated water and small fish eat these plants and when these fish are eaten by water birds the pesticide in their bodies multiplies manifold even though the original dose sprayed was low and considered harmless. The DDT concentration at the third step is 2000 ppm after magnification through the food chain.

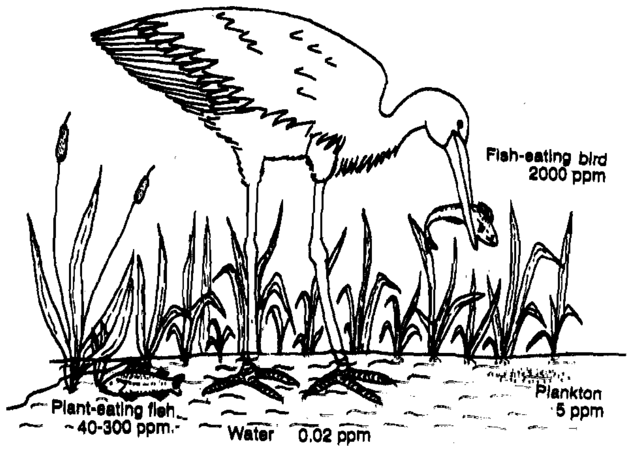

Fig. 3.9: Biomagnification of non-degradable pollutant in the food chain.

This example shows that a non-metabolite when it moves from one step of a food chain to another higher one, is concentrated or magnified and may become lethal when compared to the amounts initially introduced into the biosphere.

3.6 LIMITING FACTORS

By now we have come to understand that the existing natural ecosystem is often confronted with negative impacts of modern technology. These often cause stress, especially by altering the fundamental stability of an ecosystem.

Apart from this we know that various environmental factors like light, temperature, humidity, wind speed, availability of food, nutrients etc., keep changing. These changes affect the well being and survival of the organisms in an ecosystem as they can thrive only if all the factors essential for life are available. For example, a plant may have adequate nutrition, light, water and space but just one essential nutrient, say phosphorus, is lacking. The plant will not be able to survive. **This essential nutrient then becomes a limiting factor for the plant's survival.** We need to consider two laws to explain the organisms response to these environmental changes.

- **The law of minimum** which states that the growth and well being of an organism is ultimately limited by that essential resource that is in its lowest supply relative to what is required. The most deficient resource is, therefore, called the **limiting factor.**

- **The law of tolerance** states that for each physical factor in the environment a minimum and maximum limit exists, called the **tolerance limit** beyond which the organism does not thrive or survive. For example, an insufficient amount of vitamin A leads to drying of skin, night blindness and abnormal bone formation, whereas, an excess of vitamin A will produce gastrointestinal upsets, loss of hair, dermatitis and pain in bones. **Either too little or too much of any required factor like food, energy, heat, vitamins, minerals, water or oxygen threatens the survival of organisms and even entire species.**

SAQ 5
In high mountainous areas we would find trees only upto a certain height after which suddenly the land becomes devoid of trees. Beyond this 'tree line' the mountains are covered with snow for the major part of the year. Could you think of some limiting factors that do not allow the trees to survive beyond the tree line?

....

....

3.7 DIFFERENT TYPES OF ECOSYSTEMS

After studying various aspects of an ecosystem, we will now learn about different types of ecosystems on our earth. Broadly speaking, there are two major types of ecosystems: the aquatic and the terrestrial.

Aquatic ecosystems can be subdivided into freshwater, estuarine and marine systems. These are differentiated on the basis of major chemical differences in water content. The **terrestrial ecosystems** consist of several major biomes such as forests, grasslands tundra, etc. These are determined largely by variations in climatic conditions between the poles and equator. These biomes can be differentiated on the basis of their predominant types of vegetation such as grasses, shrubs or trees.

3.7.1 Terrestrial Ecosystems

The distribution of biomes appears to be governed by annual variation of temperature, i.e., maximum and minimum temperature, mineral availability, rainfall both average and minimum and availability of sunlight. For instance forests are generally associated with heavy rainfall but the type is influenced by temperature and light; the same is true for deserts which occur in regions where rainfall is very low.

Let us now consider the characteristics of some major biomes.

Biome **Description**

Tundra Northern most region adjoining the icebound poles. Similar communities at high altitudes. Devoid of all trees except stunted shrubs in the southern parts. Ground flora includes lichens, mosses and sedges. The soil is frozen for most part but top layer melts during summer allowing a short growing season. The typical animals are reindeer, arctic fox, polar bear, snowy owl, lemming, arctic hare, patarmigan; reptiles and amphibians almost absent (Fig. 3.10).

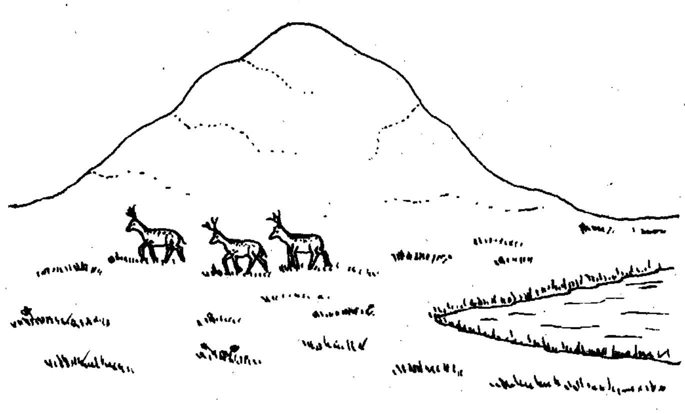

Fig. 3.10: Tundra.

Threats—Mechanical abrasions, road building and oil pipelines threaten the tundras. Plants grow very slowly in the disrupted tundras, especially as decomposition occurs slowly in the soil.

Taiga Also known as boreal forests extend in a giant circle around northern Europe, Asia and North America but in areas of more moderate temperatures than tundras. The dominating vegetation is coniferous evergreens mostly spruce with some pine and firs. Amongst the animals are small seed eating birds and their predators such as hawks, fur bearing carnivores, little mink, elka, puma, Siberian tiger, wolverine, wolves etc.

Fig. 3.11: Taiga forest.

Threats—Lumbering, unregulated hunting and trapping and agricultural development.

Temperate Deciduous Forest

On an average have moderate temperature and abundant rainfall through out the year. Most of the trees drop their leaves in winter. Extend over central and southern Europe, eastern North America, western China, Japan, New Zealand etc. The flora include trees like beach, oak, maple and cherry. Most animals are familiar vertebrates and invertebrates. These are generally the most productive agricultural areas of the earth, partly because of the controlled pace of decay and decomposition in the soil.

Threats—Agricultural activities and high human population densities have converted most of the forests into agricultural land. Thus very little of the original community is left.

Fig. 3.12: Temperate deciduous forest.

Tropical Rain Forest

Tropical areas of high rainfall in the equatorial regions which abound with life. Tropical rain forests cover only about 7% of the earth's surface but house about 40% of the world's plant and animal species. Habitat is dominated by multiple storeys of broad-leafed evergreen species. Most animals and epiphytic plants are concentrated in the canopy or tree-top zones; high temperatures result in very rapid decomposition of soil organic material which is taken up by the plants and the nutrient pool is tied up within the bodies of living organisms. Therefore, the soil quality is quite poor.

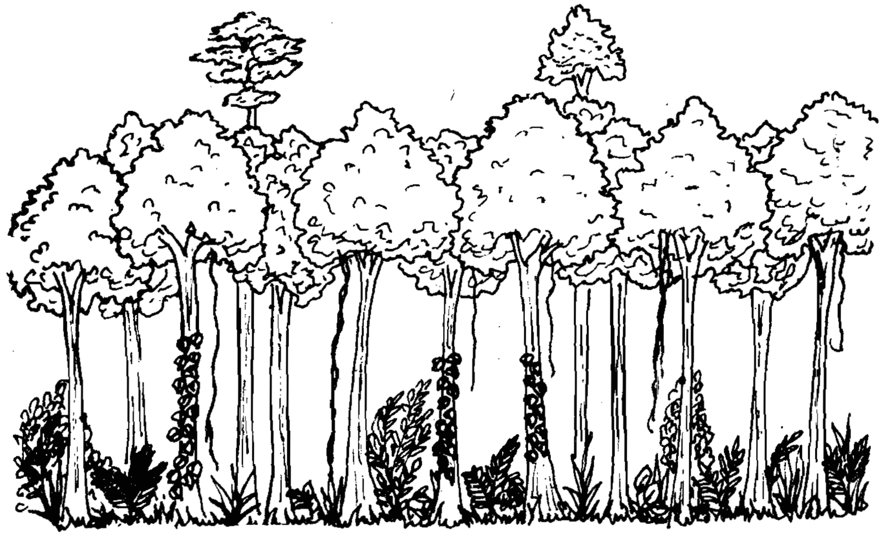

Fig. 3.13: Tropical rain forests.

Threats—Unfortunately most of us may never see the incredible beauty of the tropical rain forests as these are rapidly being cut down.

Savanna

Tropical region dominated by grasses with scattered trees and fire resisting thorny shrubs. The fauna include a great diversity of grazers and browsers such as antelopes, buffaloes, zebras, elephants and rhinoceros; the carnivores include lion, cheetah, hyaena, mongoose and many rodents. Savanna is most extensive in Africa.

Threats—Agriculture and pressures of human population have reduced the savanna to a great extent.

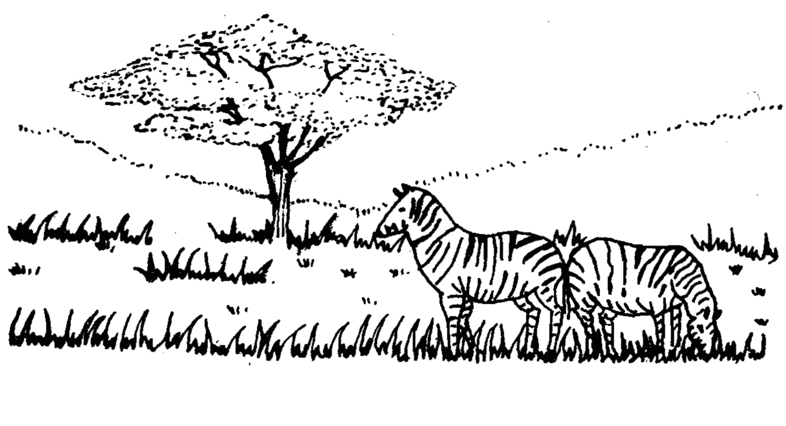

Fig. 3.14: Savanna.

Grasslands

Continental interiors especially in the temperate situation with rather low rainfall, e.g., North American Midwest and Ukraine dominated by grasses. The fauna include large herbivores like bison, antelope, cattle and rodents, prairie dogs, wolves, and a rich and diverse array of ground nesting birds. The soil is rich in mineral content and useful for farming and grazing.

Fig. 3.15: Grassland.

Threats—Original community destroyed by agricultural development for which the habitat is eminently suitable. In places massive erosion has occurred due to overgrazing and over exploitation.

Desert Continental interiors; with very low and sporadic rainfall with low humidity. The sun's rays easily penerate the atmosphere making ground temperatures very high but nights often cold by contrast. Drought resistant vegetation such as cacti, euphorbias, sagebrush, etc., present. Animals may be numerous but mostly nocturnal. Many species of reptiles and mammals and some birds present.

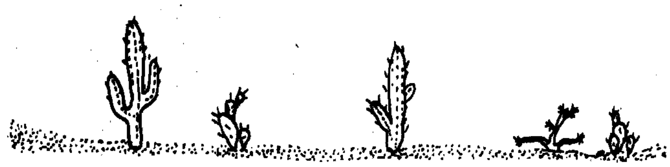

Fig. 3.16: Desert.

Threats—Threatened in some places by irrigation and residential-industrial development. Irrigation frequently accentuates the already high mineral content of soil leading to salinity.

SAQ 6

What is the relationship between rates of decomposition and fertility of soil in the tundra, temperature and tropical regions.

....

....

3.7.2 Aquatic Ecosystems

Aquatic ecosystems cover more than 70% of earth's surface and are as diverse in species as the biomes. Here, we will discuss characteristic features of fresh water, marine and estuarine ecosystems which are distinguished on the basis of their salt content.

Periphyton include flora and fauna attached to or closely associated with larger aquate plants. This includes clumped and filamentous green and blue algae and various small *invertebrates*.

Fresh Water Ecosystems

Fresh water ecosystems are characterised as **lotic** (having flowing water) or **lentic** (still water). Lotic water systems which include freshwater streams, springs, rivulets, creaks, brooks and rivers etc., tend to become over their course from being narrow, shallow and relatively rapid to increasingly broad, deep and slow moving. Waterfalls are not uncommon features of lotic ecosystems. As would be expected only organisms well adapted to maintaining their position in flowing water and capable of adhering to an exposed surface are found in the upper reaches of a stream. Adhering organisms associated with large aquatic plants are termed periphyton.

Various types of fishes such as darters, trout, and salmon are found in mountain streams. Further downstream we also find warm water fish, such as catfish and carp. The most important primary producers of lotic systems are algae but the major source of food is the organic matter brought in from the surrounding terrestrial ecosystems. Therefore, nutrient levels tend to the higher downstream because there is continual addition of nutrients.

Lentic bodies like pools, ponds, some swamps, bogs and lakes vary considerably in physical, chemical and biological characteristics. In general, they can be considered to have three zones—**littoral, limnetic** and **profundal** (Fig. 3.17). The **littoral** zone extends from the shoreline to the innermost rooted plants, and is dominated by floating and emergent vegetation rooted in the bottom such as reeds and cattail, water lilies and some submerged but rooted species. Frogs, snakes, snails, clams and considerable variety of adult insects and their larvae are also found here. The **limnetic zone** is the open water, down to the depth where light penetrates. This zone contains phytoplankton that consists of diatoms, green and blue green algae, a variety of zooplankton from protozoans to microarthropods. In this zone a variety of larger swimming organisms, the **nekton**, including fish, amphibians and larger insects are also found.

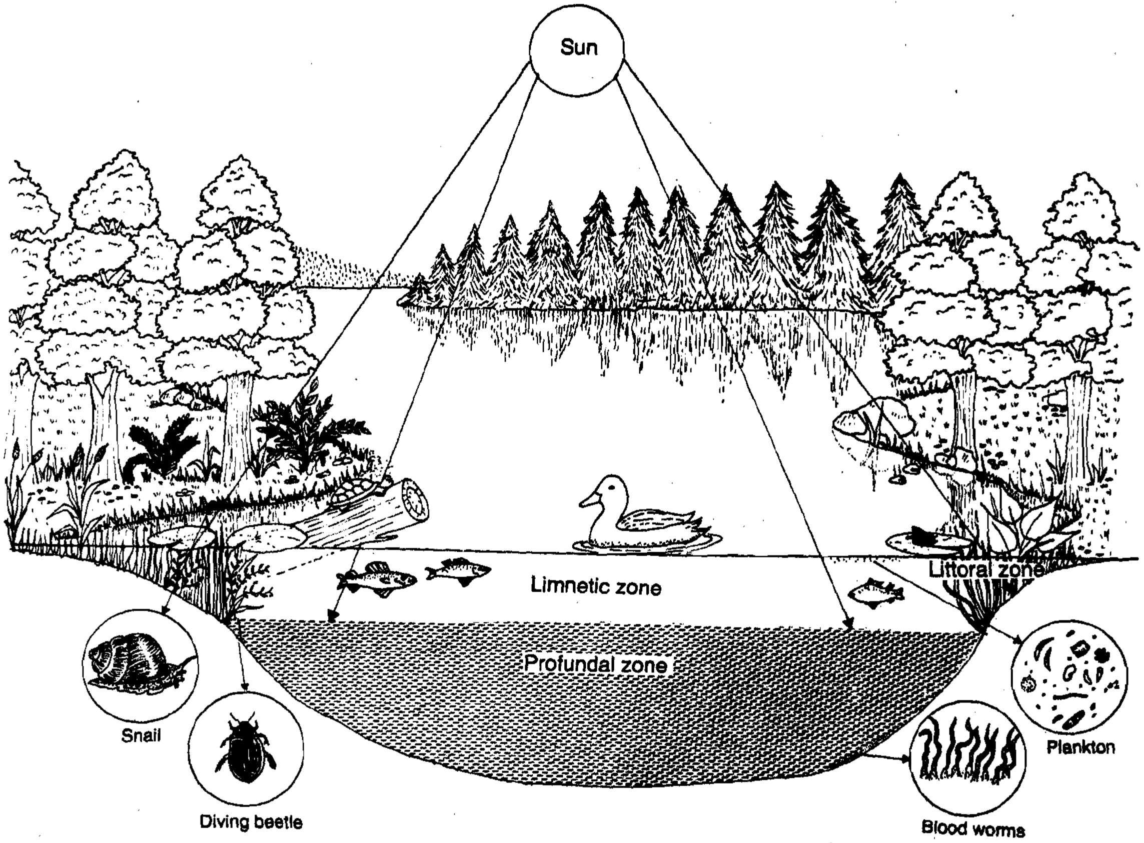

Fig. 3.17: Fresh water lake ecosystem.

The profundal zone is found below the limnetic zone and in deep lakes this zone may constitute the largest water volume of the lake. Profundal zone gets its food from the limnetic zone. This zone consists mostly of decomposers. The nekton in this zone varies with the temperature and nutrient conditions.

Marine Ecosystem

Nearly three-quarters of the earth's surface is covered by ocean with an average depth of 3,750 m and with salinity averaging 35 ppt (parts per thousand), about 90 per cent of which is sodium chloride. Marine ecosystems are of singular ecological significance. Concentration of the nutrients in the ocean is low. The major zones in marine ecosystem are **littoral, neritic, pelagics** and **benthic** (Fig. 3.18). **The littoral** zone is the shoreline between land and the open sea. Waves and tides have maximum effect in this zone because sometimes extremes, of temperature, moisture, and light intensity is felt by this zone which results in a diversity of species. If the shores are rocky you will find more sessile organisms like algae, barnacles, starfish, etc., if sandy, organisms that have adapted by burrowing in or adhering to sand are dominant.

Nitrates, phosphates and other nutrients are measured in parts per billion in contrast to salts, such as sodium chloride, which are measured in parts per thousand.

In bays where mud flats occur, algae are found on the surface. Often photosynthetic bacteria are found beneath the algae with abundance of clams, worms and crustaceans. Coral reefs and fringes of coral are formed by colonial coelentrates.

The neritic zone is a region shallow enough to support plants rooted to the seafloor. Below it is the continental shelf, extending to a water depth of about 200 m. This zone constitutes about 7.5 per cent of the total ocean area and is relatively rich in species and high in productivity owing to the depth of light penetration and the presence of nutrients washed from land. Extensive communities of giant kelps as well as of smaller uni-and multicellular forms, along with clams, snails, worms and echinoderms dominate the ocean bottom. Phytoplankton and zooplankton are relatively abundant and support some of the greatest fishing grounds in the world. However, the productivity of coastal oceans has its limits. Almost everywhere in the world and combined effects of extensive fishing and pollution have reduced the commercial fishing catch.

The **pelagic zone** is the open sea, constituting 90 per cent of total ocean surface. Photosynthesis on the surface of this zone is mainly carried out by various types of phytoplankton. In addition there are zooplankton along with shrimp, and jellyfish etc. This zone, although the largest in size, is low in nutrients, hence low in productivity.

Fin and blue whales are also found in this zone. The organisms in pelagic zone below the level of light penetration are completely dependent on the rain of detritus of upper regions for their nutrition. In deeper water many animals have poor vision, others including fishes are bioluminescent and some deep-water fish have light producing organs.

The greatest known depth being 10,750 m in the Marianas Trench in the Pacific Ocean.

The **benethic zone** forms the floor of the ocean. It extends from the edge of the continental shelf to the deepest ocean trenches. Organisms here are heterotrophic. Rooted animals are sea lilies, sea fan, sponges etc. Snails and clams remain embedded in the mud while starfish, sea cucumbers and sea urchins move on its surface (Fig. 3.18).

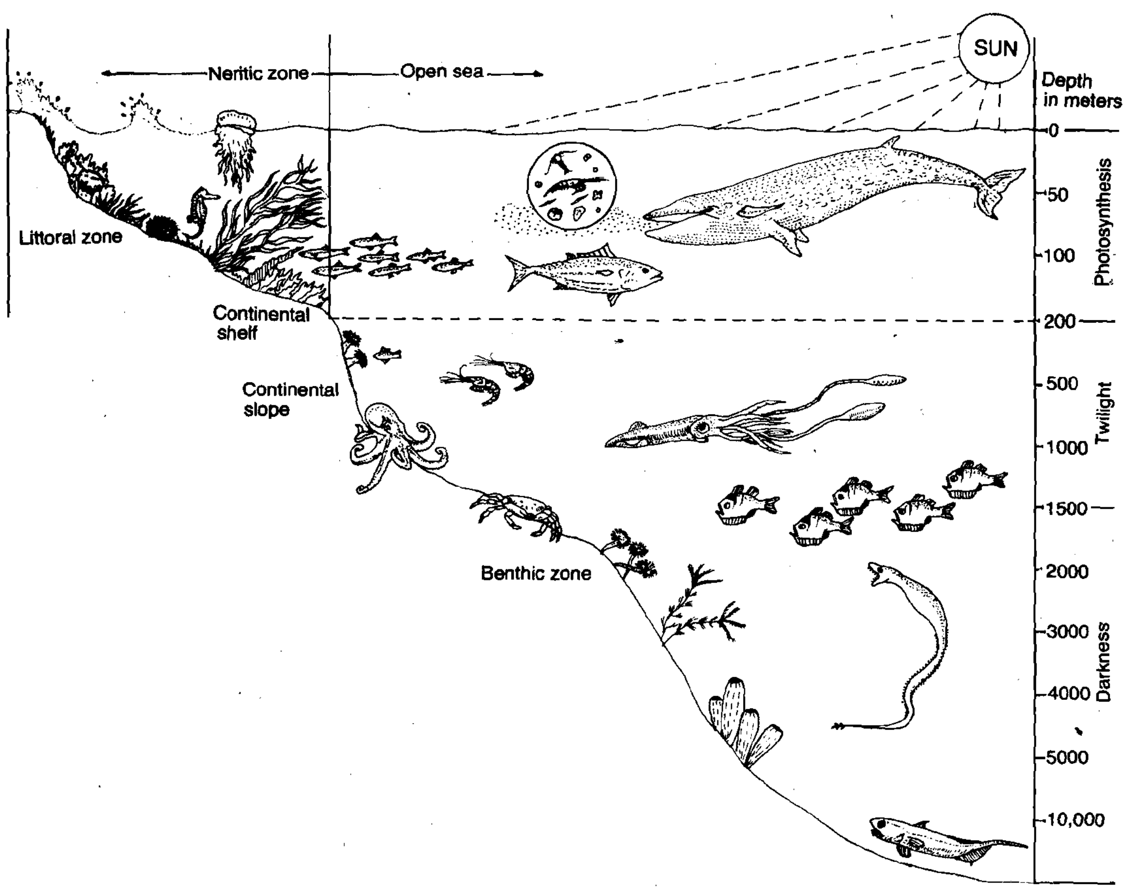

Fig. 3.18: Various zones of the marine ecosystem.

SAQ 7

Give four differences between fresh water and marine water ecosystems.

....

....

....

....

....

Estuaries

Coastal bays, river mouths and tidal marshes form the estuaries. In these ecosystems, fresh water from rivers meets ocean water, the two are mixed by action of tides. The degree of mixing of salt and freshwater depends in parts on the morphology of the estuary basin, the rate and volume of freshwater flow and the amount of tidal inflow. Estuaries are highly productive as compared to the adjacent river or sea because they have:

- easy access to deep sea,
- less salinity than the ocean,
- a high concentration of nutrients originating from the sea as well as land,
- rooted plants supported in shallow water.

Major components here are species which are able to tolerate wide fluctuations in salinity, such as oysters and crabs and some sea shrimps. Estuaries also contain producers like seaweeds and marsh grasses as well as benthic algae and phytoplankton, which are capable of photosynthesis nearly through out the year. Estuaries provide nursaries for many deep water fishes that do not produce viable young ones in the harsher environment of the open sea.

3.8 SPECIES DIVERSITY WITHIN AN ECOSYSTEM

One fascinating attribute of an ecosystem is the diversity of species that make up the system. A diversity of functional groups is naturally to be expected because the food webs in an ecosystem involve autotrophs, herbivores, carnivores, detritivores, and so on. But surprisingly, a diversity of species exists within each functional component. For instance, if you collect, some phytoplankton using a plankton net from a nearby pond, chances are that you will find more than 20 species of algae. Diversity of living organisms appears to be a feature of our entire biosphere, something that attracted the attention of naturalists for centuries. When one realizes that there are more than 3 lakh different species of beetles on this planet, nearly 20,000 species of fishes and probably many more waiting to be discovered, one naturally becomes curious about the evolutionary and ecological factors that had been responsible for such great diversification.

As a parameter, species diversity by itself, is not so informative because the term is relative. If you were told that a particular community has 14 species of birds, you would not know if that value represents a low diversity or high diversity unless you compare it with bird species diversity in another community. However, it is the geographical patterns in species diversity seen in our biosphere that tell us a lot about the factors contributing to diversity. One of the most noticeable patterns is that species diversity on earth is maximum in the tropics and decreases progressively towards the polar areas. Take birds for example—Colombia, situated near the equator in the tropics has nearly 1400 species of birds, while New York State in the temperate latitudes has 105 species, and Greenland, situated close to the north pole (70^o latitude) has only 56 species of birds. Our country, much of which lies in the tropics, also has a high diversity of bird species, more than 1000. Plants also show similar trends—there are nearly 2,000 species of vascular plants in the temperate state of Ohio (USA), but 20,000 of them in the small country Ecuador, situated on the equator. Species diversity is more on continents than on islands at the same latitudes. Besides, the latitudinal trends it is seen that species diversity is less in high altitude ecosystems.

The rich variety of flora and fauna we have around us is part of our natural heritage, and we have to ensure that human activities do not despoliate this great diversity and leave a poorer biosphere for the next generation. One way is to monitor the species diversity of ecosystems that are subjected to the ravages of human influence such as pollution and deforestation. Like energy transfer and productivity, species diversity of a community is also a measure of its health and well being.

3.8.1 Measures of Species Diversity

The mere number of species in a community alone is not an adequate measure of species diversity. The relative abundance of species, that is, how many individuals are there representing each species is also an important component of the measure. Let us take an example to demonstrate this point. Consider two different forests—I and II, each with 5 different tree species (A,B,C,D,E) and each forest having a total of 100 trees.

	A	B	C	D	E	Total
Forest I	92	2	2	2	2	100
Forest II	20	20	20	20	20	100

If you landed at a random spot in Forest I, and then in the same way later in Forest II, which forest would give you the impression of greater tree species diversity? Obviously the second forest, although the number of species and the total number of individuals is exactly the same in both the forests. Thus you realize that our concept of species diversity is invariably linked with their actual numbers and also, with the 'commonness' and 'rarity' of species, as the ecologists call it.

Ecologists, realizing that species number alone, called the 'species richness' is an inadequate measure, developed quantitative indices that incorporate both the components—species richness and their relative abundance. Two species diversity indices commonly employed by ecologists are the Simpson Index and the Shanon—Wiener Index. When an ecosystem is adversely affected by natural or man-made causes, some sensitive species in the system might get eliminated i.e., species richness decreases, but the altered conditions might favour the proliferation of one or two resistant species so their relative abundance changes. In many polluted ponds, you might have noticed that the pollution-tolerant and hardy water hyacinth grows in unusual abundance, often at the expense of other sensitive species in the pond, which disappear to accommodate the hyacinth.

3.8.2 Diversity-Stability Relationships

Are species diversity and community stability related to each other? Does stability promote diversity or does diversity lead to stability of a community? These questions have been engaging the attention of ecologists and conservationists for a long time. Considering the persistent threat to the survival of many ecosystems on earth as a consequence of human activities, one would indeed like to find out about the factors that contribute to the stability of a biological community. Let us first answer the basic question—what exactly is meant by a 'stable' community? Stability has been interpreted in different ways; three concepts of stability are in vogue:

i) the population densities of species remain fairly constant through time-constancy of numbers,

ii) the community as a whole remains unchanged in the face of any major disturbance i.e., resistance to perturbation, and

iii) the community has the ability to return to normal state or equilibrium sooner or later if disrupted by a major disturbance.

Looking at the richness of species diversity in the tropics which are generally believed to be stable, ecologists until recently held the view that diversity promotes stability in a community.

More recent work, however, particularly using theoretical models, challenges this view. For one thing, their high species diversity, notwithstanding, tropical communities do not appear to be any more stable than their temperate counterparts. The stable and predictable environments of the tropics do certainly permit the evolution of a complex ecosystems, each with many component species, but it would be a delicately balanced, fragile system; on the other hand, the unstable and unpredictable temperate systems demand a structurally simple but robust community. To give a rough analogy, you can afford to build a very complex residential unit with feeble foundation and delicate construction materials if the site is known to be geologically quite stable, but at a site that is prone to frequent landslides and earthquakes, you would build only a simple but robust and sturdy unit.

These findings bring out a warning for those concerned with tropical ecosystems like ours: any complacency that tropical ecosystems can take plenty of abuse by man because they are stable is totally unjustified; human activities indifferent to environmental quality could have disastrous consequence in these complex but delicately balanced ecosystems.

SAQ 8

Explain briefly how tropical ecosystems are different from temperate ecosystems in terms of diversity and stability.

....

....

....

....

....

3.9 SUMMARY

In this unit you have studied that:

- An ecosystem is a system formed by the interaction of a variety of individual organisms both plants and animals, with each other and with their physical environment. It is nearly self-regulatory based on feedback information about its living and nonliving components.
- The biosphere is that region of the 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 section of the biosphere is the aquatic zone.
- The abiotic components of the ecosystem consist of physical factors such as light, temperature, rainfall, mineral, nutrients, water, etc.
- The biotic components of the ecosystem consist of the autotrophs or producers and heterotrophs or consumers and decomposers. These organisms belong to different trophic levels which describe how far the organism is removed from the plant in its level of nourishment.
- The flow of energy through the ecosystem is a one way process and the sequence of organisms through which the energy flows is known as a food chain. Several intersecting food chains form a food web which depicts the pattern of food consumption in an ecosystem. Though energy flow is unidirectional, nutrients are continuously cycled and recycled with an ecosystem.
- Nondegradable pollutants often accumulate and magnify at each trophic level in the food chain and may become lethal when compared to the amount initially introduced into the biosphere.
- The growth and survival of organisms is ultimately limited by that essential resource that is in lowest supply relative to what is required. This resource becomes the limiting factor. Also, either too much or too little of any factor threatens the survival of the organisms.
- An important feature of the ecosystem is the diversity of organisms within it. Species diversity is maximum in the tropics decreasing progressively towards the poles. Under stress, natural or man-made, the species diversity decreases. Greater diversity indicates the well being of an ecosystem.

3.10 TERMINAL QUESTIONS

1) Imagine we have three closed glass jars A, B and C filled with water representing three ecosystems. A contains only algae, B only snails and C contains both algae and snails.

The source of energy for these is sunlight. After sometime it is noticed that the algae in A and the snails in jar B begin to deteriorate, while the snails and algae in jar C do not show any change.

Keeping the definition of an ecosystem in mind, explain the reasons, for these observations.

....

....

....

....

....

....

2) Which one of the following statements best explains the ecosystem? Tick the correct choice.

   i) An ecosystem is a defined unit of landscape with abiotic and biotic components.

   ii) An ecosystem is a defined unit of landscape with a definite life system.

   iii) An ecosystem is a defined unit of landscape with a stable life system.

   iv) An ecosystem is a defined unit of landscape with a static life system.

3) Write four or five lines on the following:

   a) Limiting factors

   b) Food web

   c) Trophic level

   d) Biomagnification

....

....

....

....

....

3.11 ANSWERS

Self Assessment Questions

1) Lithosphere, hydrosphere, atmosphere, biosphere, photosynthesis, green, purple bacteria

2) i) × ii) × iii) × iv) √

3) i) F ii) T iii) T iv) T v) F vi) F vii) F

4) i) Pyramid of numbers ii) Pyramid of energy iii) food chain iv) food web.

5) Beyond the 'tree line' there is hardly any vegetation in the mountains. The limiting factors here are high velocity winds and extreme cold conditions. Temperature plays an important part in the distribution of fauna and flora. High velocity winds do not allow tree to grow.

6) Tundras have a very slow rate of decomposition therefore the nutrients are not released as fast as they are used hence the soil is not fertile.

   Temperate regions have balanced rate of decomposition in the soil hence they make up one of the best agricultural areas. Tropics are very fertile areas because the rate of decomposition is very high, since nutrients are also used up rapidly, therefore, soil quality is often poor.

7)

Fresh water	Marine water
1) Low percentage of sodium chloride	1) High percentage of sodium chloride upto 27%
2) Nutrient levels tend to be higher towards the bottom because there is a continual addition of nutrients	2) Nutrient level is low
3) Major zones are littoral, limnetic and profundal	3) Major zones are littoral, neritic, pelagic & benthic
4) Waves and tides are absent in this ecosystem	4) Waves, and tides have effect on this ecosystem

8) Tropical ecosystems have a greater diversity of flora and fauna than temperarte ecosystems. But this greater species diversity makes the tropical ecosystems more complex but not necessarily more stable. In general, tropical ecosystems are complex but fragile but the temperate ecosystems are simple but robust.

Terminal Questions

1) Since jar A contains only algae, after sometime it would use up all the nutrition and the system would not function. Jar B contains only snails. They too would die since they would use up all the oxygen and nutrients in the water. But jar C contains both producers and consumers and the algae would produce oxygen as a by-product of photosynthesis. The ecosystem would be stable.

2) i)

3) Refer to Sections 3.3 and 3.5 in the unit.