U4BY/CY-06

Indira Gandhi National Open University
School of Sciences

LSE-02
ECOLOGY

Environment and it's Components

1

Uttar Pradesh
Rajarshi Tandon Open University

UGBY/ZY – 06

Ecology

Block

1

ENVIRONMENT AND ITS COMPONENTS

ECOLOGY

Ecology is an elective course for undergraduate studies for science and non-science students. Ecology deals with the reciprocal relationships between the living organisms and their physical environment. This subject is becoming increasingly important for furthering human welfare and for improving the quality of life. In view of the growing population and finite resources, ecological considerations help to develop a harmonious relationship between man and nature. In addition, we can apply this knowledge in understanding environmental problems that confront mankind. Therefore, the reference to ecology in newspapers, socio-economic writings, in national and international environment planning meetings is becoming more frequent these days.

Ecology is intimately connected with various disciplines of science, humanities and in fact with all aspects of human endeavour. Ecology is primarily a field study. It is a science of great practical significance having applications in the management of natural resources, agriculture, control of pests and pathogens and in the conservation of soil, water, biotic diversity and the life support systems of our biosphere. In the following Units we have discussed the basic ecological concepts and the philosophy of ecological concerns in a holistic perspective. We hope you would enjoy going through this course. To get your opinion and suggestions for this course, a feedback form is attached at the end of each block. After finishing the block, kindly fill the form and mail it to us.

Course Objectives

This course will enable you to:

- understand the concept of environment, ecology and ecosystem,
- discuss various biotic and abiotic environmental components like soil, water, light, in relation to plant and animal communities,
- describe the structure and organisation of ecosystem,
- identify the types of ecosystems,
- outline energy flow and nutrient cycling in ecosystem,
- define and explain community, population and the role of ecology in human welfare.

Study Guide

To get maximum benefit out of this study material please take note of the following points:

i) Make a notebook with one side ruled and the other side plain, keep a pen and some coloured pens/pencils with you.

ii) Read the material slowly and attentively. Spend enough time on figures and flow charts. Try to draw the figures/flow charts and label them properly. This will help you in better understanding of the text.

iii) While studying the text, underline the important points with a distinct colour (red, green, blue etc.) in the block itself. Write down salient points in the space provided on each page, or in your notebook if necessary.

iv) After finishing a section or subsection; ask yourself — what have I learnt? Try to list the important points in your notebook and compare them with the text and see if you hav missed any.

v) Attempt all the self-assessment questions (SAQs), wherever they appear. **Don't** skip any of them as they are designed to assess your understanding of the subject. If you cannot answer, read the text again.

vi) The answer to the SAQs and Terminal Questions are given at the end of each unit. **Don't** get tempted to see the answers, before you try them.

vii) If you don't understand any word in the text, consult a dictionary. For scientific and technical words consult the glossary given at the end of each block or a scientific dictionary if necessary.

iii) In case you get stuck with some fundamental concept, consult NCERT school books. You will find them very useful and easy to understand. For exploring the topics further we have given a list of suggested readings at the end of each block. These books and NCERT books are available at your Study Centre.

BLOCK 1 ENVIRONMENT AND ITS COMPONENTS

Roots of ecology extend to origin of humanity itself. Man has subconsciously been applying the principles of ecology in managing his natural resources. Recently, because of increased problems faced due to degradation of our natural environment, this subject has been systematised. Therefore, a working knowledge of the principles of modern ecology has become essential.

In the first unit of this block we have explained briefly some of the basic terms and concepts of ecology, such as environment, population, community, ecosystem and biosphere. An attempt has been made to give you a comprehensive view of ecology, its branches and its interrelationship with other biological disciplines. Some historical perspectives of this important field have also been included to give you an idea of the growth of ecology as a discipline.

In unit 2, we have discussed environmental factors — light, temperature and atmosphere that influence every organism. You will learn effects of these factors on climate, which in turn affects distribution, behaviour and survival of plants and animals. You will also learn that different species develop special features in order to adapt to extremes of light, temperature and atmospheric conditions.

The third unit deals with water as an ecological factor wherein its properties — surface tension, viscosity, buoyancy and transparency have been discussed in context of living organisms. Comparative description of fresh water, saline water and brackish water and their impact on the distribution of living communities have been dealt with. You will also learn about hydrological cycle and the ecological implications of drought and water logging in relation to adoption in plants and animals.

The last unit is devoted to the study of soil. First, we have explained the basic concepts and terms related to this precious environmental resource. Then we have described the process of soil formation, the various types of soils based on their mode of transportation and the basic properties of soil, i.e., structure, texture and profile. Finally, we shall discuss the various physical and chemical properties of soil and see how soil biota influence the fertility of soil.

After studying this block, you should be able to:

- define and explain environment, ecology and ecosystem,
- describe various environmental components like light, heat, atmosphere, water, soil and their significance to ecosystems,
- describe the adaptations in plants and animals to light, temperature and water.

Dedicated to
Late Professor S. C. Goel

UNIT 1 ECOLOGY AND ECOSYSTEM

Structure

1.1 INTRODUCTION

You have already been introduced to the concepts of environment, ecology, ecosystem, energy flow and nutrient cycling in the foundation course on Science and Technology. As you are aware ecology is the scientific study of the reciprocal relationship between organisms, including microbes, plants, animals as well as man, with their environment. It deals with the ways in which organisms are moulded by their environment, how they make use of environmental resources including energy flow and mineral cycling. Everything that surrounds or affects an organism during its life time is collectively known as its environment which comprises both living (biotic) and nonliving (abiotic) components. The extinction of many plant and animal species, pollution of the environment and population explosion are some of the major ecological problems affecting the balance of nature on a global scale. In order to manage the earth and its life support systems, it is thus imperative to understand its ecological processes.

In this unit, which is the first unit of the ecology course, we will begin by briefly explaining some of the basic terms and concepts of ecology. We shall then discuss the comprehensive definition, history, scope and the various branches of ecology. Besides, we will also describe the basic features of ecosystem structure and function.

Before starting this unit please go through Units 14 and 15 of the Block 4 (Environment and Resources) of the foundation course to refresh your memory about ecology. These units will help you understand the contents discussed in this unit.

Objectives

After you have studied this unit you would be able to:

- define and use in the proper context terms such as ecology, environment, population, community, ecosystem and biosphere,
- outline the development of the discipline of ecology,
- describe the three main subdivisions of ecology, namely autecology, synecology and habitat ecology,
- show with the help of a diagram the interrelationship between ecology and other biological disciplines,

- distinguish between natural and man-made (artificial) environments,
- enumerate the basic numerical and structural attributes of population,
- describe the characteristic features of community and distinguish between major and minor community,
- describe the components of an ecosystem.

1.2 ECOLOGY

1.2.1 Definition

Very often a word has a precise well-defined meaning in scientific literature but is loosely used in everyday language. It is, therefore, necessary for you to be clear about a few concepts and definitions before we begin the study of ecology.

Ecology is a familiar term today. Although ecological studies have been going on for many years, however, it is only recently that people have become aware of ecology as a part of their daily life. These days newspapers and magazines provide ample space to highlight the nature and the consequences of man's impact on nature — deforestation, soil erosion, the Bhopal gas tragedy, the Chernobyl disaster, ozone hole, global warming and many other problems. Public outcry about such problems clearly emphasises the relevance of ecology for our society. Ecology is now a well-developed branch of science having increasing importance to human welfare and survival.

The term ecology was coined only as late as 1868. It has been derived from two Greek words namely, **'Oikos'** meaning home or estate and **'logos'** meaning study. Literally it means the study of the home or household of nature. Ecology is defined 'as the scientific study of the relationship of the living organisms with each other and with their environment.'

Ecological studies are aimed to understand the relationships of organisms with their environment. This could be best achieved by extensive field observations and experimental studies to verify the field observations.

1.2.2 History of Ecology

The roots of ecology lie in Natural History, which is as old as human civilisation itself. As a matter of fact man indulged in ecology in a practical sort of way, though unknowingly, since early history. In primitive societies every individual was required to have intimate knowledge of his environment for survival, i.e., of the forces of nature and of plants and animals around him. Primitive tribes, which were dependent on hunting, fishing and food gathering needed detailed knowledge of their environment to obtain their sustenance. Later, the adoption of settled agricultural life further stressed the need to learn practical ecology for the successful domestication of plants and animals.

Our ancient Indian texts are full of references to ecological principles. The classical texts of the Vedic period (1500 BC-600 BC) such as the **Vedas**, the **Samhitas**, the **Brahmanas** and the **Aranyakas-Upanishads** contain many references to ecological concepts.

'Caraka' is to be pronounced as Charaka i.e. चरक and **'Susruta'** as Sushruta i.e. सुश्रुत

The Indian treatise on medicine, the **Caraka-Samhita** (1st Century AD-4th Century AD) and the surgical text **Susruta-Samhita** (1st Century AD-4th Century AD), show that people during this period had a good understanding of plant and animal ecology. These texts contain classification of animals on the basis of habit and habitat, land in terms of nature of soil, climate and vegetation; and description of plants typical to various localities. **Caraka-Samhita** contains information that air, land, water and seasons were indispensable for life and that polluted air and water were injurious for health.

Similar awareness of ecological issues was prevalent in Europe in the 4th Century BC. The early Greek philosophers were well aware of the importance of environmental studies. Hippocrates in his work **'On Airs, Waters and Places'** stressed the need for ecological background for medical students, as he emphasised the effect of water, air and locality on health and diseases in man. Aristotle classified animals on the basis of habit and habitat.

Theophrastus (370-250 BC) was the first person to introduce ecological approach long before the term ecology was coined. He studied plant types and forms in relation to altitude, moisture and light exposure.

After a gap of several centuries European naturalists made significant contribution to ecological thinking. The French Naturalist Georges Buffon (1707-1788) in his book **Natural History** (1756) made a serious attempt to systematise the knowledge concerning the relation of animals to environment.

In the early eighteenth century Anton-van Leeuwenhoek (1632-1723), the microscopist, pioneered the study of food chain and population regulation which have grown into the major areas of modern ecology.

It was Hanns Reiter who in 1868 appears to have coined the term 'ecology' by combining the two Greek words Oikos (home) and Logos (study). However it was the German biologist Ernst Haeckel (1866-1870) who for the first time elaborated the definition of ecology as follows:

> "By ecology we mean the body of knowledge concerning the economy of nature — the investigations of the total relations of animal both to its inorganic and to its organic environment; including above all, its friendly and inimical relation with those animals and plants with which it comes directly or indirectly into contact — in a word, ecology is the study of all the complex interrelations referred to by Darwin as the conditions of the struggle for existence."

A few years earlier to Haeckel, the French zoologist Isodore Geoffroy St. Hilaire and the English naturalist St. George Jackson Mivart had proposed the terms "ethology" and "hexicology" respectively, which are almost similar to 'ecology'. A British zoologist Charles Eton (1927) in his pioneering book **"Animal Ecology**' defined ecology as scientific natural history.

The concept of community in ecology was applied by Karl Mobius (1877) to animals. Whereas Forbes (1887), Warming (1909), Cowles (1899), Clements (1916) and many others made notable contributions to the study of plant and animal communities.

The concept of 'population' and its several related aspects developed in the early part of the twentieth century. Mathematical techniques were used for understanding community ecology. These mathematical and statistical methods have since been applied for an understanding of population dynamics.

In 1935 a distinguished British botanist, Sir Arthur Tansley introduced the concept of the ecosystem or ecological system. This was a major development in the history of ecology.

The concept of ecosystem alongwith the ideas on the trophic-dynamic aspect of community developed by Lindeman (1942), and biogeocoenoses by Sukachev (1944) stimulated investigations on the organism — environment complex from a holocoenotic standpoint and led to a major breakthrough in the progress of ecology. Recently, an American ecologist Eugene P Odum (1971) has defined 'ecology as the study of the structure and function of nature'.

In India, ecological studies began as elsewhere with the descriptive phase at the end of the nineteenth century. Descriptive accounts of the forests were prepared by the forest officers (1875-1929). However, the first comprehensive ecological contribution was made in 1921 by Prof P. Dudgeon of Allahabad University who described the role of environment in the succession of communities.

By the 1940s there was sufficient ecological information of the descriptive and observational kind. There was now a need for precise determination of the behaviour and distribution of plants (individually or in groups) in relation to specific environmental factors. This led to the experimental approach (1940-1965). Extensive synecological studies were carried out on forest and grassland communities and autecological studies on trees, herbs and grasses under the guidance of Prof. R. Misra, who established a flourishing school of ecology at the Banaras Hindu University, by the 1960s.

In the early sixties the need for developing a better understanding of the structure and function of different ecosystems was considered necessary for the effective management of natural resources, especially in view of the growing human population.

With this view, the International Biological Programme (IBP) was launched (1964-1974) with a focus on the biological basis of productivity and human welfare. Under the aegis of this programme, productivity of different terrestrial and aquatic ecosystems was evaluated apart from studies on human adaptability, conservation of ecosystem and the use of biological resources.

The IBP is a world-wide plan of study of biological productivity and human welfare, initiated by International council of Scientific Unions (ICSU) a non-governmental organisation in Paris. IBP was launched with the aim of filling in the lacunae in the knowledge of certain ecological areas, by means of a co-ordinated comprehensive approach including standardisation of methods to ensure comparable results. The study was divided into 7 sections depicted below.

Areas Studied in the IBP Programme

- Productivity of terrestrial communities
- Production process
- Conservation of terrestrial communities
- Productivity of fresh water communities
- Productivity of marine communities
- Human adaptability
- Use and management of biological resources

Much of the recent interest in ecology stems from the problems caused by rapid population growth and widespread deterioration of environment due to pollution of air, soil and water. Ecological studies are now increasingly geared to promote conservation and rational utilisation of natural resources through international efforts such as Man and Biosphere Programme of UNESCO (MAB), United Nations Conference on Human Environment held at Stockholm in 1972, United Nations Environment Programme (UNEP), International Union for Conservation of Nature and Natural Resources, (IUCN) and World Wide Fund for Nature (WWF). The science of ecology has much to contribute in solving the problems of environment.

SAQ 1

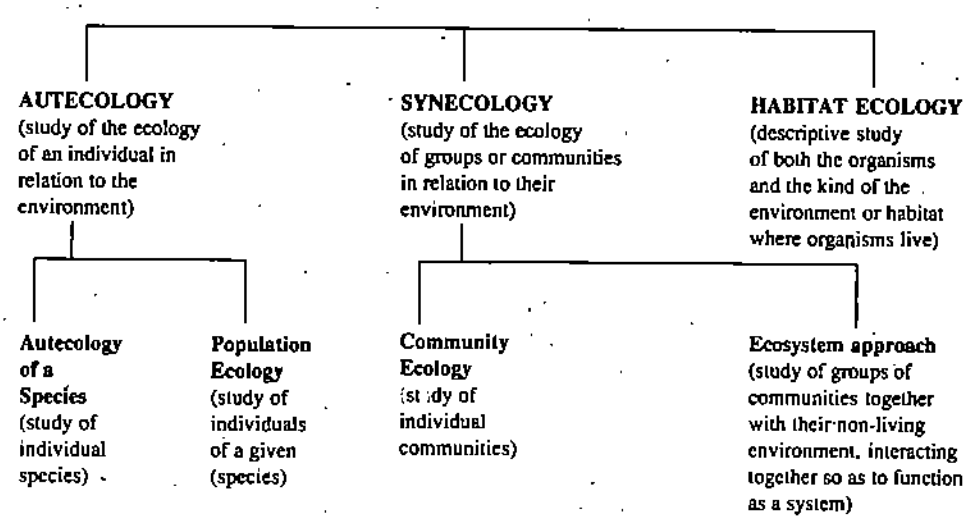
Describe in 10 lines the ecological awareness contained in the Caraka-Samhitas and Susruta-Samhita.

1.2.3 Subdivisions of Ecology

Ecology was earlier divided into plant and animal ecology. However, modern ecology does not make any such distinction since plants and animals are intimately interconnected and interdependent amongst themselves and on their environment.

The three main subdivisions of ecology today are given below:
i) Autecology, ii) Synecology, iii) Habitat ecology.

Main Subdivisions of Ecology



i) **Autecology:** It is the study of individual species or individuals in relation to the environment. There are two approaches to autecological studies (a) **autecology of species** where individual species are studied (b) **population ecology** where individuals of the same species are studied.

ii) **Synecology:** It is the study of the community of living organisms as a unit. The difference between autecology and synecology could be explained by the following example. If a neem tree (or several neem trees) or a crow (or several crows) are studied in relation to the environment then this would be an autecological study. However, if the study deals with a forest community as a whole in which many different birds, trees and animals share the same area, then it would be called a synecological approach.

Synecological studies can be of two types. a) **community ecology** is concerned with the study of biotic (living) community comprising of interdependent plants and animals in a particular area, b) **ecosystem ecology** which is a recent development in ecology. It deals with the community of living organisms and their environment as an integrated unit of nature.

iii) **Habitat ecology** : It is the study of the habitat or environment of organisms and its effect on the organisms. In this approach different types of habitats such as terrestrial, fresh water, marine, and estuarine are the focus of study.

1.2.4 Relationship of Ecology with Other Disciplines of Biology

In order to understand the scope and relevance of ecology let us consider its position in relation to other biological disciplines, with the help of a diagram in the shape of a cake see Fig 1.1.

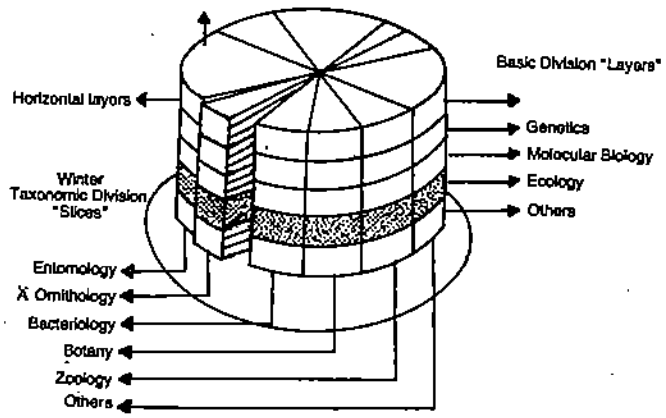


Fig 1.1 : The layered biological cake showing the relationship of ecology with other biological disciplines.

This hypothetical biological cake has several horizontal layers representing the 'basic' divisions of biology, common to all organisms — morphology, physiology, genetics, ecology, evolution, molecular biology, developmental biology etc. These horizontal layers are divided vertically into unequal 'taxonomic slices' of biology as well. Each such slice is labelled by the specific kinds of organism. The thicker slices represent large divisions of biology and are labelled Zoology, Botany, Bacteriology etc. The thinner slices are labelled a Phycology, Ornithology, Protozoology as they deal with specific type of organisms.

Let us consider slice 'A', i.e. ornithology — the study of birds. This slice with its horizontal layers of molecular biology, developmental biology, genetics, ecology etc. indicates that there are different approaches to the study of birds. The approach may be molecular or ecological, or of any other type, or a combination of two or more approaches. The 'biological cake' analogy helps us appreciate that ecology is a basic division of biology.

It is often important to restrict work to certain taxonomic species or groups because different kinds of organisms require different methods of study. For example, one cannot study pigeons and bacteria using the same methods. However, the modern ecological principles have provided many unifying concepts such as energy flow, nutrient cycling and population dynamics for comparing diverse ecosystems.

SAQ 2

Fill in the blanks choosing appropriate words from the list given below:

a) The study of a single population of a tree species in a forest is .... in approach.
b) The study of the aquatic community of a pond is .... in approach.
c) The study of a biotic community in relation to its environment is referred as .... approach.

synecological, autecological, ecosystem

1.3 ENVIRONMENT

All organisms are intimately dependent on the environment from which they derive their sustenance. Organisms from virus to man are obligatorily dependent on the environment for food, energy, water, oxygen, shelter and for other needs. The environment is defined as 'the sum total of living, non-living components; influences and events, surrounding an organism'. The relationship and interaction between organism and environment are highly complex.

For the convenience of study, environment is broadly classified into two components: abiotic (or non-living) and biotic (or living), as shown in Table 1.1.

Table 1.1 : Components of environment

Abiotic Components	Biotic Components
Energy	Green plants
Radiation	Non-green plants
Temperature & heat flow	Decomposers
Water	Parasites
Atmospheric gases and wind	Symbionts
Fire	Animals
Gravity	Man
Topography	
Geologic substratum	
Soil	

You should realise that the environment is not static. The biotic and abiotic factors are in a flux and keep changing continuously. The organisms can tolerate changes in environment within a certain range called 'range of tolerance'.

1.3.1 External and Internal Environment

Let us try to understand the concept of environment with some examples. Consider Fig 1.2 Can you identify the environment of a single carp fish in the pond?

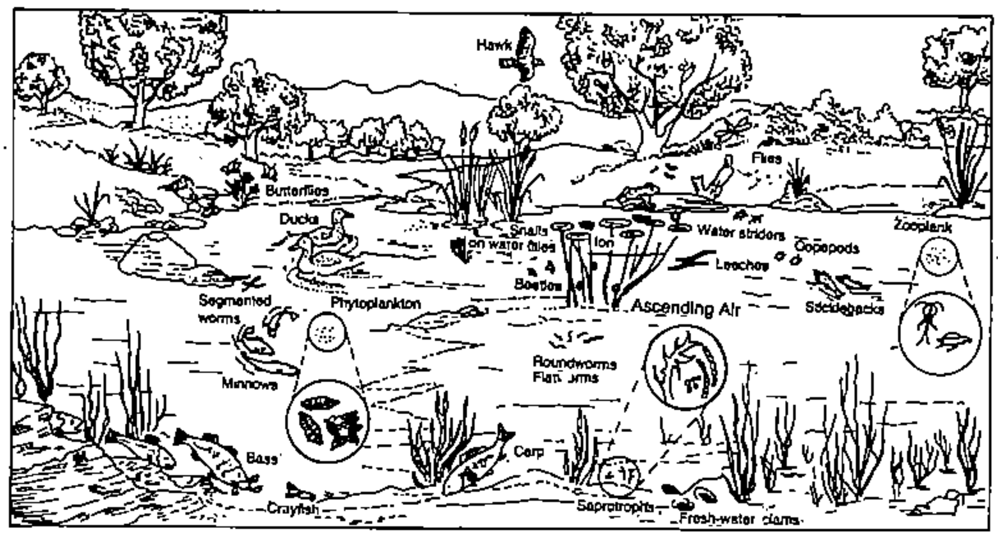


Fig 1.2 : A pond

Its environment consists of abiotic components such as light, temperature, water in which nutrients, oxygen, other gases and organic matter are dissolved. The biotic environment consists of microscopic plankton as well as higher plants and animals and decomposers. The plants are of different kinds such as phytoplankton, partly submerged plants and plants and trees growing around the edge of the pond. The animals consist of zooplankton, insects, worms, molluscs, tadpoles, frogs, birds and various kind of fishes. The decomposers are the saprotropns.

The environment of the fish described above is its external environment. Living organisms also possess an internal environment, enclosed by the outer body surface. The body surface acts as an exchange barrier between the external and the internal environment (Fig 1.3a & b). In the case of unicellular organisms however, the boundary of the cell is also the boundary of the organism. The exchange of materials in single celled organisms is carried out directly with the external environment to which they are exposed (Fig 1.3a).

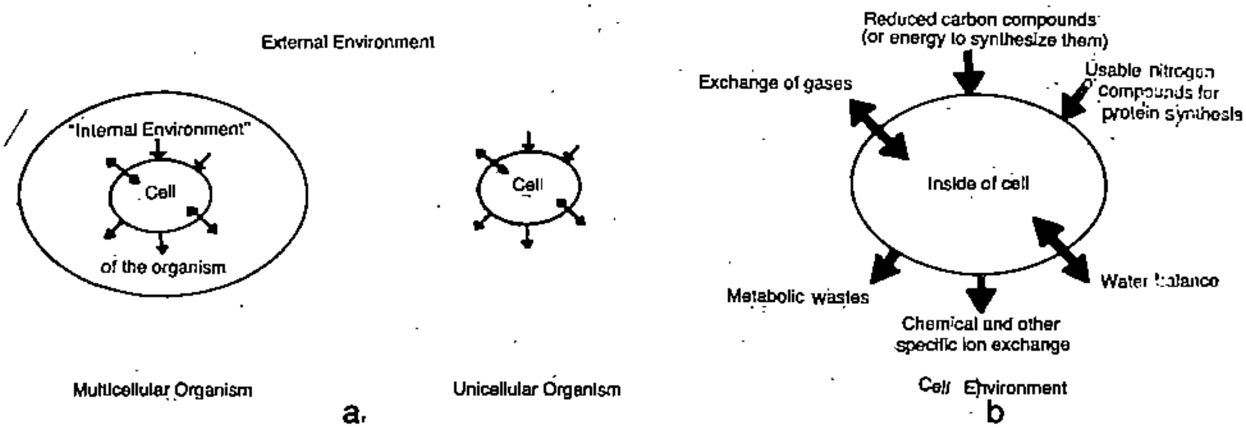


Fig 1.3a : In multicellular organisms except for the cells forming the outer body surface, most cells are exposed to the internal environment of the organism from which they exchange energy and materials, whereas in unicellular organisms the cell surface is also the boundary between organism and environment. All exchanges are made directly between the cell and the external environment.

Fig 1.3b: Exchanges that are necessary between a living cell and its immediate environment.

The internal environment is relatively stable as compared to the external environment. However, it is not absolutely constant. Injury, illness or excessive stress upsets the internal environment. For example, if a marine fish is transferred to a fresh water environment, it will not be able to survive.

1.3.2 Natural versus Artificial (Man-made) Environment

The environments discussed so far are, natural environments. In several instances man has greatly altered the natural conditions and created new situations known as artificial or man-made environments. Examples of artificial environment are cultivated fields or cities. Let us see the difference between the natural and artificial environment by considering the city environment.

The city environment is a product of man's own design. The atmosphere of the city is generally polluted due to the emission of various gases from factories, motor vehicles and electric power plants. Water is obtained not from streams directly but after it has been filtered and disinfected in a water treatment plant. The metabolic wastes and garbage are not disposed of locally but have to be carried through sewer lines for treatment or for dumping in a remote place far away from the city. No food is grown in the city but is imported from rural areas for the city dwellers.

In a city people live in buildings made of bricks, stones and cement. Houses and offices of well-off people are air-conditioned creating an atmosphere which remains free from the influence of outside environment. Furthermore, to make life comfortable modern amenities like fans, fridge, radio, television etc. are installed, requiring electricity which is generated by man artificially.

The man-made city environment consumes excessive amounts of energy and materials and needs constant care, supervision and management to keep it habitable (Fig 1.4).

SAQ 3

Define environment and explain the difference between internal and external environment in four lines.

....

....

....

....

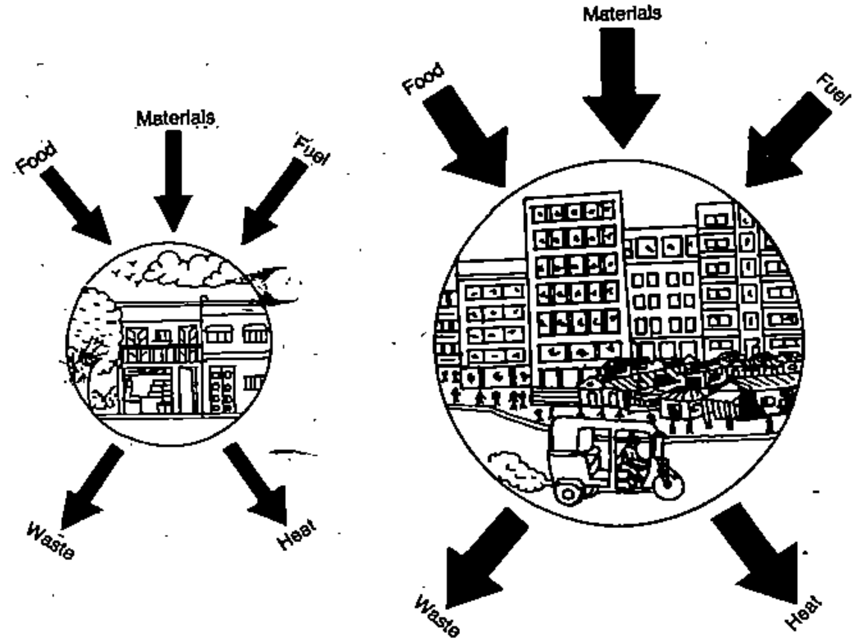


Fig 1.4: As cities grow in size, more food materials and energy are drawn from the environment and increased amounts of heat and waste are returned to the environment. a) a small town, b) a large city.

1.4 POPULATION

You must be familiar with the term 'population'. It is one of the most talked about issues of this century. It is feared that the rapid growth of the world population if allowed to continue, might outstrip the food supply in the near future. The present high rate of population growth is a major concern of the governments, scientists and administrators. Have you ever wondered as to what is meant by population?

Species is defined as a group of natural populations consisting of sexually or potentially interbreeding organisms of the same kind, reproductively isolated from other such groups.

In a technical sense 'population' is defined as a group of freely interbreeding individuals of the same species present in a specific area at a given time. For example, when we say that the population of a city is 50,000, we mean that there are 50,000 individuals of *Homo sapiens* in that town. Other living organisms, for example cats and dogs present in the city are not included as they are populations of two different species.

In nature, population of a species is subdivided into a number of local breeding populations called **deme.** Demes are geographically separated populations of the same species. For example, the garden lizards of Qutub Minar, Delhi, form a separate deme from the garden lizard of Lodi Gardens, Delhi or the garden lizards of Swaraj Bhawan, Allahabad.

Consequently, in a deme each individual has an equal opportunity of mating with another individual of the opposite sex, but not with individuals in another deme. Because of frequent mating and similar environmental conditions members of a deme resemble each other more closely.

A population has traits of its own which differ from those of individuals forming a population. An individual is born once and dies once but a population continues, perhaps changing in size depending on the birth and death rates of the population. An individual is female or male, young or old but a population has sex ratio and age structure

A population exhibits certain characteristics which can only be expressed at the population level and not shared by the individuals of the population. For example, individual organisms are born, grow and die but characteristics such as birth rate, death rate, density are only meaningful at the population level.

The attributes of a population are of two basic types : i) **Numerical attributes** such as density, natality (birth rate), mortality (death rate), dispersal and ii) **structural attributes** like age distribution, dispersion and growth form. Some of the basic attributes of population are briefly described below.

a) Numerical attributes:

Density : number of individuals per unit area.
Natality (Birth rate) : the rate at which new individuals are added to a population through reproduction.

Mortality (Death rate) : the rate at which individuals are lost from a population by death.
Dispersal : the rate at which individuals of a population emigrate or migrate from an area.

b) Structural attributes:

Population growth form : refers to the pattern of population growth. There are two basic patterns of population growth represented by "J" and "S" shaped growth curves, see Figure 1.5 for explanation.

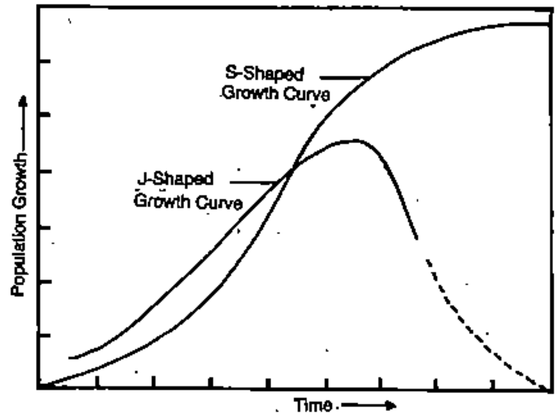
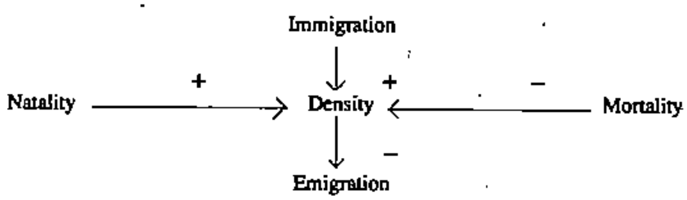


Fig 1.5 : Two types of population (S-shaped and J-shaped) growth curves.

Dispersion: the pattern of distribution of individuals in space,
Age distribution : the proportion of individuals of different age groups in a population.

Now you know some of the more important attributes of a population. It is reasonable to ask: How populations are studied? Do all attributes have equal importance, or are some more important than others? In analysing population, the main attributes studied is the density of the population which depends on four parameters: i) natality, ii) mortality, ii) immigration and, iv) emigration (see below)



Thus whenever the density of a population falls or rises, we try to find out which of the four parameters have changed.

The two contrasting curves of population growth may be modified or combined or in different ways depending on the peculiarities of different organisms and environment. Generally the 'J' shaped growth curve is typical of species which reproduce rapidly and which are greatly affected by seasonally fluctuating environmental factors such as light, temperature and rainfall. In this type of curve the population density increases rapidly in exponential (geometric) progression 8, 16, 32, 64, 128 etc. manner till a peak is reached. After this there is a sudden crash or decline due to environmental or other factor. The S shaped or sigmoid growth curve is characteristic of biological population in general. In this type of curve there is a slow increase initially in the population density, followed by exponential growth (similar to that of 'J' graph's exponential growth). After this the population density growth slows down gradually due to increase in environmental resistance (sum total of environmental limiting factor which prevent the biotic potential from being realised) until an equilibrium is reached and maintained.

Active migration is not possible in plants, though seeds may be dispersed over long distance by wind, water and animals.

1.5 COMMUNITY

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, 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, alongwith associated animals of different species.

The definition and description of the community so far must have made you aware that the size of a community is not fixed or rigid; communities may be large or small.

A mat of lichen on a rock surface or a cow dung pad covering only a few centimetres, a forest or a coral reef extending over a considerable area are all examples of communities as each would contain several interacting and interdependent populations of different species of organisms.

1.5.1 Types of Community

On the basis of size and degree of relative independence communities may be divided into two types:

i) **Major Community :** These are large-sized, well organized and relatively independent. They depend only on the sun's energy from outside and are independent of the inputs and outputs from adjacent communities. A tropical ever green forest in the North-East of India is a good example of a major community.

ii) **Minor Communities :** These are dependent on neighbouring communities and are often called societies. They are secondary aggregations within a major community and are not therefore completely independent units as far as energy and nutrient dynamics are concerned. A cow dung pad would be a good example of such a community.

1.5.2 Growth-form and Structure

In a community the number of species and size of their populations vary greatly. A community may have one or several species. The environmental factors determine the characteristic of the community as well as the pattern of organisation of the members in the community, the characteristic pattern of the community is termed structure which is reflected in the roles played by various populations, their range, the type of area they inhabit, the diversity of species in the community and the spectrum of interactions between them. As a result the structure of community is as follows:

i) **Dominance :** In each community, a few over topping species are present in greater bulk. By their greater number or biomass (living weight) the dominant species modify the habitat characteristic and influence the growth of other species in the community. In most communities only a single species, being particularly conspicuous, is dominant and in such case the community is named after the dominant species, as for example spruce forest community. In some communities, however, there may be more than one dominant species, as in oak-fir forest in the west Himalayas.

Relative abundance is a measure of relative proportion of different species occurring in a community

ii) **Species diversity :** An important attribute of a community is its species diversity. The diversity is calculated both by the number of species (richness) and the relative abundance of each species (evenness). The greater the number of species and more even their distribution the greater is the species diversity.

It is important to realise that species diversity and dominance are interrelated. Communities with one or a few dominant species are characterised by low species diversity whereas communities where no single species is truly dominant and individuals are equally distributed among all species, are characterised by high species diversity.

Diversity is also related to the stability of the community. A stable community is one which is able to return to its original condition after being disturbed in some way. Communities with high species diversity are comparatively more stable because many alternative pathways exist in such communities to enable the individuals to obtain the required energy and nutrients. To put it differently, the presence of a large number of species would mean that if one species disappears or declines, its function and place can be assumed at least in part by another. It is now however, increasingly realised that in some situations greater diversity does not necessarily result in greater stability. Stability is more dependent on the number of well adapted species than on the total number of species present.

Communities created by man such as lawns, or agricultural fields are very unstable and require great deal of constant manipulation and maintenance.

iii) **Mutual interrelationship among individuals of a community :** Mutual interrelationship includes all the direct and indirect effects that organisms have upon each other. The three relationship which we shall discuss are (a) competition, (b) stratification, and (c) dependence.

a) **Competition :** Demand for a common resource by different organisms results in competition. Competition between individuals of different species is called interspecific; when it occurs between individuals of the same species it is called intraspecific.

b) **Stratification :** Different organisms in a community develop a characteristic pattern of stratification to minimise competition and conflict among the members of the community. Plants and animals of each layer differ in size, behaviour and adaptation from those of other layers. Tropical forests represent good example of vertical stratification as shown in the Fig 1.6.

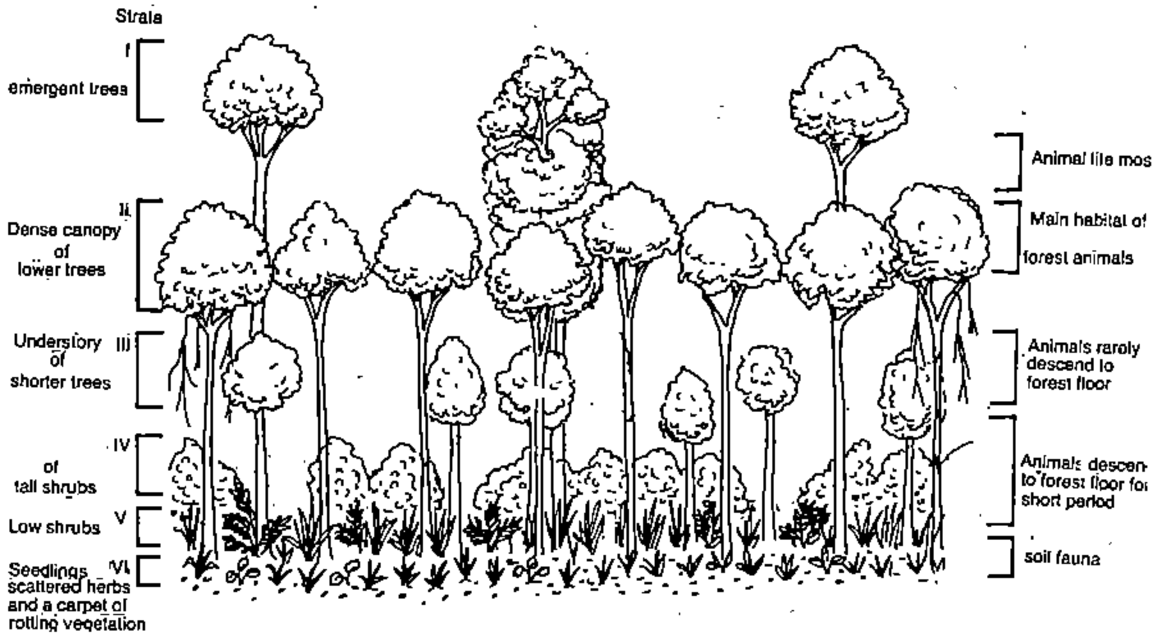


Fig 1.6 : In order to avoid competition organisms in a community exhibit vertical stratification, as shown in a segment of a tropical forest, which may have as many as five or six strata or vegetation, providing a number of habitats for organism.

The tall growing trees form the overstory and modify the light and moisture conditions for the shorter trees growing under them. These in turn determine the conditions for the ground vegetation. In moist tropical rain forests upto five distinct strata can be formed.

Competition in the community is not limited within a species. Different species in the community compete with each other for nutrients, space, light and other resources. Plants and animals of each layer differ in size, behaviour form and adaptation from those of other layers. Stratification is a practical strategy to minimise interspecific competition i.e. competition between different species. For example, if several different species develop simultaneously and have similar demands, then they will all survive in approximately equal numbers and occupy the same position (dominant or not dominant) and layer in the community. Those species which do not have overlapping requirements will affect each other much less and hence will occupy different functional positions or sub layers in the community. For example, consider a tall growing tree which outgrows a potentially short one under the same conditions. The former occupies a higher level. The tall trees with widespread canopy dominate the area and influence light and moisture conditions. As a result the tall trees control the characteristic in a forest community. Only those species of organisms can survive which can withstand the environmental conditions created by the dominant species. The community characteristics changes if the dominant species is eliminated due to some reason. This is because the position of dominance would be assumed by other species. The non-dominant species present in the lesser strata probably offer little direct competition to the dominant species. Indirectly, however, they may offer serious competition to the dominant species in matters of regeneration. For a dominant species to be successful it should be able to compete with other species during its early phase of growth. Competition for survival is most obvious between seedlings of different species since all depend on the same restricted environment.

c) **Dependence :** In a community there are some species which are wholly dependent on the dominant member for survival. Bryophytes, thallophytes and a few vascular small plants are examples of such organisms. These dependent organisms require special conditions such as shade and moisture provided by the dominant species. The dependent species will die if the dominant species are eliminated.

Animals in a community are usually dependent on plants. Large mobile animals like deer are not necessarily limited to a single community. However, several less mobile species are definitely restricted to a single community. For example, certain species of insects and birds have specific association with a particular vegetation type.

In addition to the mutual interactions among organisms of a community, they also actively interact with their environment. In a community only those plants and animals survive which are adapted to a given environment. The climate determines the type of environment, and hence the type of organisms in a community. For example, it is the variation in the climate which determines whether a given area becomes a desert or a forest. The environment of an area in turn would determine the types of organisms which could survive there.

iv) Trophic structure : Organisms in a community are closely interrelated with each other through feeding relationships.

Another aspect which is quite obvious in a community is that in areas of extreme climatic conditions both species diversity or the number of species are greatly reduced. This is because only a few species are able to adapt to the difficult environment.

Communities which extend over a considerable area generally have also locally diverse conditions of soil or topography. Thus in a community local habitats may be supporting markedly different species which are very different from the general community composition.

Members of a community share the same habitat and its resources. A community represents only the living organisms occupying a given area. When both the living and non-living components are considered as an integrated unit we would be dealing with an ecosystem, a concept which will be considered in the next subsection.

SAQ 4

Identify the following statements as true or false. Write T for the correct statement and F for the wrong statement in the boxes provided.

a) The density of population would rise if emigration increases. [ ]
b) The density of population would rise if mortality decreases. [ ]
c) The growth rate of an organism can be measured only at the population level. [ ]
d) In biological populations the 'J' graph of population growth is more common. [ ]
e) In a community, high species diversity usually leads to greater stability. [ ]
f) A dominant species can be eliminated if environmental conditions change. [ ]
g) Teak trees and scrub vegetation in a forest would occupy the same strata. [ ]
h) Species diversity is calculated only on the basis of the number of species. [ ]

1.6 ECOSYSTEM

Plants, animals and human beings live in association with a wide variety of other plants and animals. These communities of organisms are not mere **ad hoc** collections of individuals or populations but they represent a highly ordered dynamic and complex organisation. Such complex natural organisation with their living and non-living environments that controls them and from which the living organisms derive their sustenance are technically called as "ecosystem" or an "ecological system".

The interaction between living organisms and their environment is very much a two way process: organisms affect and are in turn affected by their surroundings. Professor Arthur Tansley, a British botanist, in 1935 proposed the term ecosystem and defined it as the "system resulting from the integration of all living and non-living factors of the environment". He regarded ecosystem as not only the organism complex but also the whole complex of physical factors forming the environment.

The concept of this interacting system has proved extremely valuable and the ecosystem is regarded as a basic unit for ecological studies.

1.6.1 Components of Ecosystem

The components of the ecosystem can be categorised into abiotic or non-living and biotic or living components;

The biotic and abiotic components of environment and ecosystem are the same.

Abiotic components : The important abiotic components are

a) Energy : basically from the sun is essential for maintenance of life. In the case of plants, the sun directly supplies the necessary energy. Since animals cannot use solar energy directly they obtain it indirectly by eating plants or animals or both. Energy determines the distribution of organisms in the environment.

b) Materials: (a) organic compounds — proteins, carbohydrates, lipids, humic substances which are formed from inorganic substance and reconverted into them on decomposition. (b) inorganic compounds — oxygen, nitrogen, carbon, carbon dioxide, water, sulphur, nitrates, phosphates, and ions of various metals are essential for organisms to survive.

c) Climatic factors: light, heat, temperature, wind, humidity, rainfall, snowfall etc.

d) Edaphic factors (structure and composition of soil along with its physical and chemical characteristics) : also exert significant influence on the organisms.

Biotic components : Biotic components include living organisms comprising plants, animals and decomposers and are classified according to their functional attributes into producers and consumers.

a) Producers — Autotrophs (self-nourishing) are green plants as they synthesise carbohydrates from simple inorganic raw materials like carbon dioxide and water in the presence of sunlight by the process of photosynthesis for themselves, and indirectly for other non-producers. In terrestrial ecosystem, producers are basically herbaceous and woody plants while in marine and fresh water ecosystems producers are various species of microscopic algae. Chemosynthetic bacteria are also producers. However, unlike plants which constitute the major producers, these bacteria, which are found in deep ocean trenches where sun energy is absent, derive energy by the process of chemosynthesis from the hydrogen sulphide seeping through cracks in the sea floor.

b) Consumers — Heterotrophs (other nourishing) are incapable of photosynthesis and depend on organic food derived from animals, plants or both. Consumers can be divided into two broad groups namely macro and micro consumers. (i) Macro consumers or phagotrophs feed on plants or animals or both and are categorised on the basis of their food sources. Herbivores are **primary consumers** which feed mainly on plants e.g. cow, rabbit. Carnivores feed only on animals. **Secondary consumers** feed on primary consumers e.g. wolves. Carnivores which feed on secondary consumers are called **tertiary consumers** e.g. lions which can eat wolves. Organisms which consume both plants and animals are called **omnivores** e.g. men. (ii) Micro consumers — Saprotrophs (decomposers or osmotrophs) are chiefly bacteria and fungi which obtain energy and nutrients by decomposing dead organic substances (detritus) of plant and animal origin. Some of the products of decomposition such as inorganic nutrients released in the ecosystem are reused by producers and thus recycled. Earthworm and certain soil organisms such as nematodes, and arthropods are also detritus feeders and help in the decomposition of organic matter.

1.6.2 Size of Ecosystem

As you know an ecosystem may be as small and as simple as a cow dung pad or as complex and large as an ocean or the biosphere itself, comprising a wide variety of species. An interesting point to observe is that ecosystems occur within ecosystem. To take an example, cow dung ecosystem may be contained in a forest ecosystem which is contained in the biosphere.

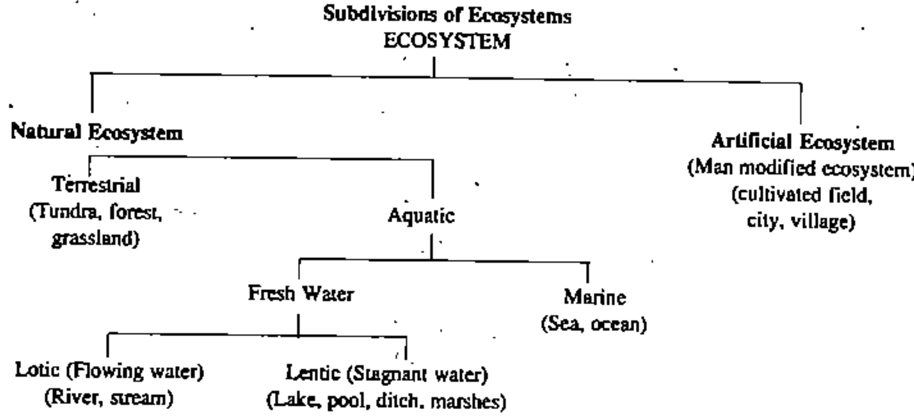
In some cases, like a pond ecosystem, the boundaries are well defined. In the case of forests, grasslands and deserts there are no sharp boundaries. These ecosystems often are separated from adjacent ecosystems by a transition zone or a diffused boundary zone called ecotone. Organisms of adjacent ecosystems intermingle in the ecotone zone; consequently they may have greater diversity of species than the neighbouring ecosystems.

1.6.3 Types of Ecosystem

Basically ecosystems are of two types : terrestrial and aquatic. If you travel from plains to the mountains in the Himalayas, you notice significant changes in the landscape. Deserts, grasslands, crop fields, forests and glaciers represent different terrestrial ecosystems. Oceans, estuaries, mangroves, coastal marshes, rivers, lakes, ponds and swamps are examples of aquatic ecosystem.

Ecosystems can also be grouped into two categories, namely natural and artificial or man-made as shown below:

Subdivisions of Ecosystems



1.6.4 Natural and Artificial Ecosystem

i) Natural ecosystems are those which are mostly free from human disturbances, such as tropical forests, grasslands, oceans, lakes and deserts.

ii) Artificial or man-modified ecosystems are formed as a result of human modification of the natural ecosystems. For example, man has transformed natural forests and grasslands into crop fields. An extreme example of an artificial ecosystem is a city. Increasing human interference has destroyed many natural ecosystems and replaced them with artificial ecosystems, such as crop fields, urban centres and industrial estates.

All ecosystems are fully integrated with the neighbouring ecosystems and communicate with each other in varying degrees through the import and export of both energy and nutrients.

Material/nutrient cycling is exchange and recycling of minerals and chemicals between living and non-living components of the ecosystem.

An ecosystem is a dynamic system characterised by energy flow and nutrients cycling. Substances constantly flow through it, and there are sufficient supplies of energy within the ecosystem to allow for this flow to take place. See Fig 1.7. Ecosystems also possess considerable self-regulating ability, called homeostasis, due to which they tend to recover from minor perturbations.

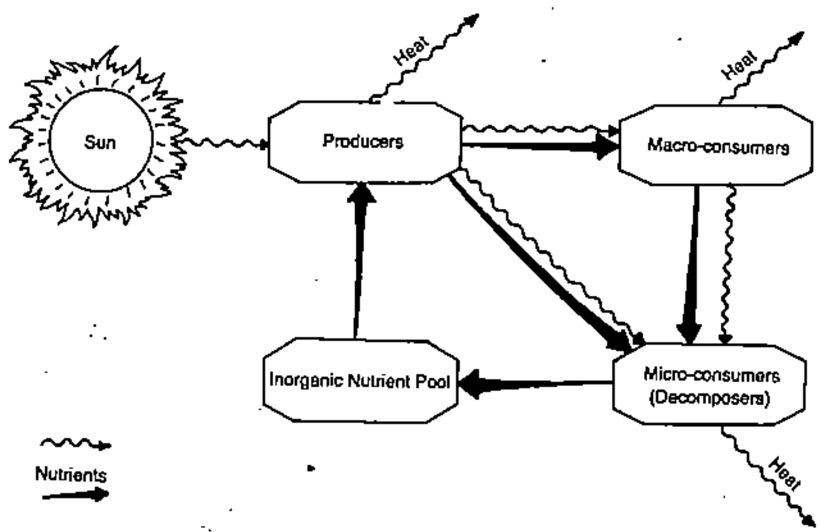


Fig 1.7 : A diagram illustrating the manner in which nutrients cycle through an ecosystem. Energy does not cycle because all that is derived from the sun eventually dissipates as heat.

SAQ 5

Fill in the blanks choosing appropriate words from the list given below:

a) .... recycle material for initial use by the producers.

b) Carnivores feed only on ....

c) Energy is captured and converted into food only by the .... of the biotic community.

d) Chemicals .... through the ecosystem while energy .... through it.

e) Biotic community interacting with its physical environment constitute an ....

f) Adjacent ecosystems are often separated from each other by a transition zone called ....

animals, ecosystem, saprotrophs, flow, producers, ecotone, cycle

1.7 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.

As you can see in Fig 1.8 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 sea level. Its most densely populated region is just above and below the sea level.

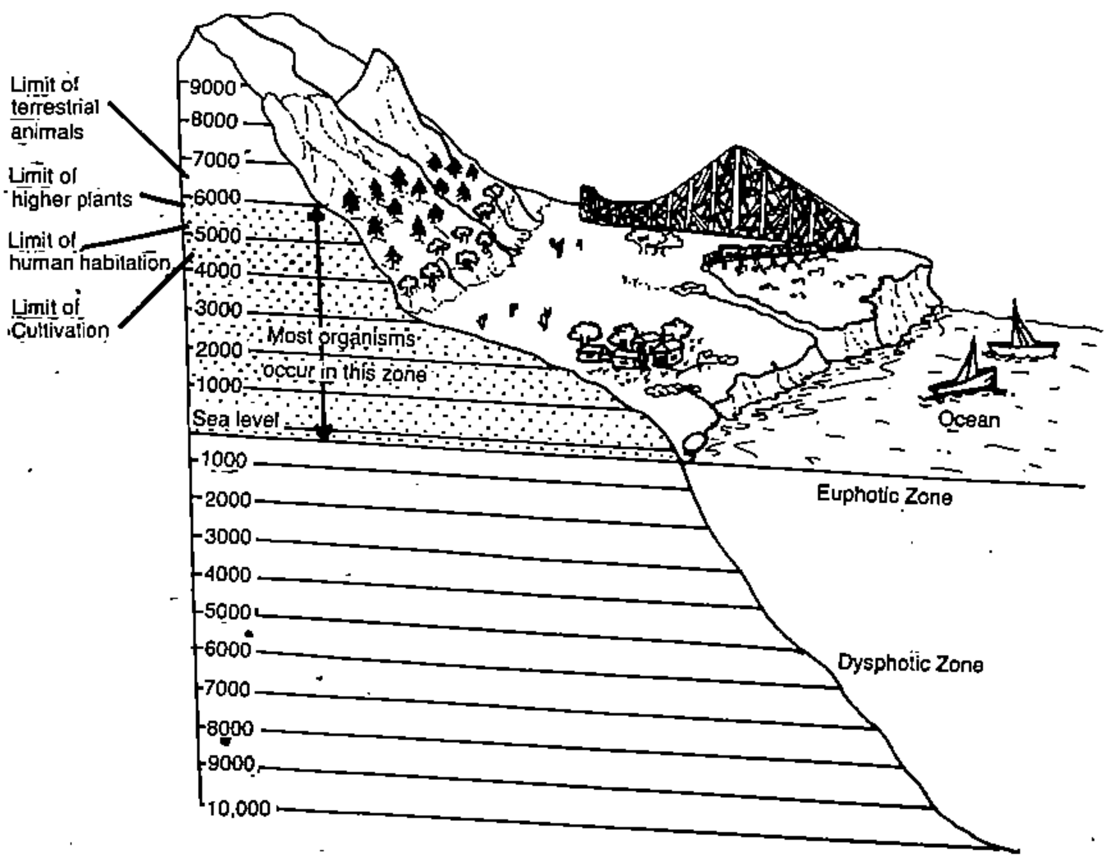


Fig 1.8 : Vertical dimensions of the biosphere. Life exists from the highest mountain peaks to the depths of the ocean. Life at the extreme is however, rare. Most organisms are limited to a narrow region depicted here between 6000 metres above sea level and 200 metres below sea level.

Biosphere represents a highly integrated and interacting zone comprising of atmosphere (air), hydrosphere (water) and lithosphere (land) as you can see in Fig 1.9.

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 as shown in Fig 1.8.

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.

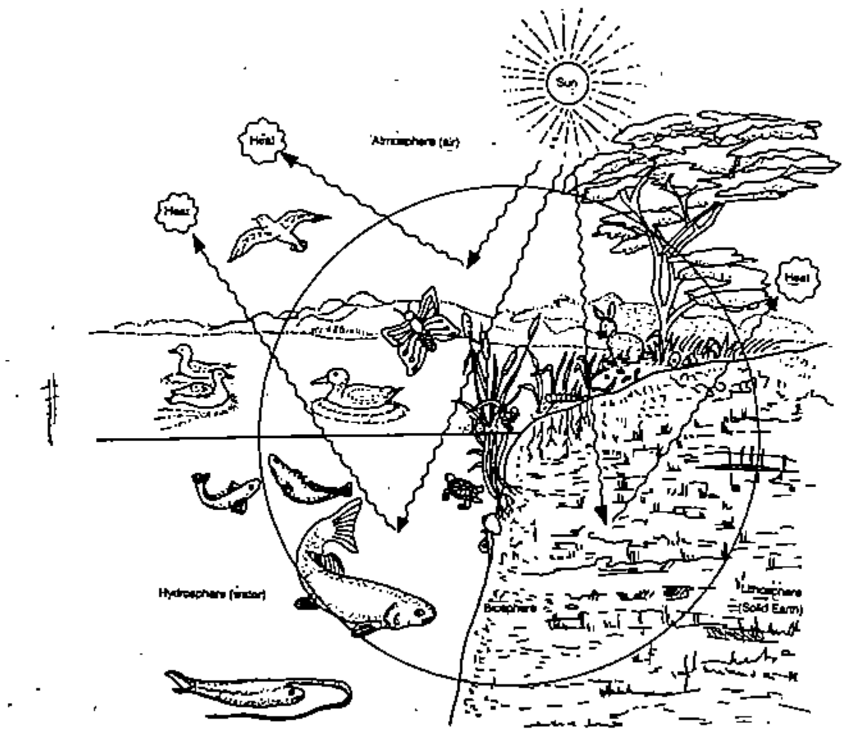


Fig 1.9 : The biosphere exists at the intersection of lithosphere, atmosphere and hydrosphere. As shown here the biosphere is energized by sunlight.

The energy required for the life within the biosphere comes from the sun. The nutrients necessary for living organisms come from air, water and soil and not from outside. The same chemicals are recycled over and over again for life to continue. Living organisms are not uniformly distributed throughout the biosphere. Only a few organisms live in the polar regions, while the tropical rain forests have an exceedingly rich diversity of plants and animals.

1.8 SUMMARY

In this unit you have studied the following:

- Ecology : the study of relationship of living organisms to one another and to their environment.
- History of ecology from primitive man to the present time with special reference to the development of ecology in India.
- The subdivision of ecology into (i) autecology — study of individuals or populations of a single species with respect to their environment, (ii) synecology — study of interacting population of different species, (iii) habitat ecology — which deals with the study of habitat and the organisms within it.
- The relation of ecology with other biological fields such as botany, zoology, protozoology etc.
- The environment, which consists of biotic, abiotic factors, influences and events surrounding the organisms and may be artificial or natural, external or internal.
- Population : a group of sexually or potentially interbreeding organisms of the same species which has attributes of two basic types (i) numerical attributes — density, natality (birth rate), mortality (death rate), dispersal and (ii) structural attributes like age distribution, dispersion and population growth form.
- Community is a localised group of several populations of different species and may be classified into major and minor communities.
- Community attributes consist of growth form and structure: dominance, species diversity, mutual interrelationship among members of a community and trophic structure.

- Ecosystem, which is a localised group of community and their physical environment maintained on energy flow and nutrient cycling.
- Components of ecosystem such as i) abiotic or non-living environmental factors: energy, materials, climate, and edaphic factors ii) biotic or living environmental factors: plants, animals and decomposers.
- Natural ecosystem which is unaltered or only slightly altered by man, and artificial ecosystem which is a result of major alterations of natural ecosystem by man.
- Biosphere, which contains all the living organisms on earth, together with their interaction with global physical and chemical environment, and maintains a system of energy use and material cycling. This system runs on energy from the sun which after use is given up in space as low grade heat.

1.9 TERMINAL QUESTIONS

1) Fill in the blanks choosing the appropriate words:

   a) Biosphere consists of .... , ... and ....

   b) The density of population .... with increase in mortality and emigration.

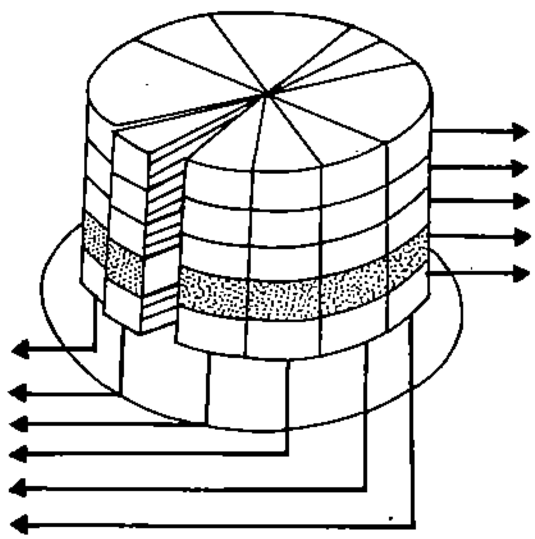
   c) The living organisms in a forest form a .... community.

   d) The density of population .... with increase in natality and immigration.

   e) The community of organisms on a log form a .... community.

   minor, lithosphere, major, atmosphere, increases, decreases, hydrosphere

2) Label the hypothetical cake diagram showing the relationship of ecology with other biological disciplines.



3) State the difference between natural and artificial ecosystems in five lines and give examples.

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....

4) State the difference between macroconsumers and microconsumers in five lines.

....

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....

5) Given below are important ecological terms and their definitions. What you have to do in this exercise is to match the appropriate definition in column II with the ecological terms in column I. Write the number of the appropriate match in the given box.

Column I		Column II
1) Ecology	[ ]	It is an assemblage of population of different species inhabiting a particular area, living together with mutual tolerance and beneficial interactions amongst themselves and with their environment.
2) Community	[ ]	It is defined as the scientific study of the relationship of living organisms with each other and with their environment.
3) Ecosystem	[ ]	It is defined as a group of organisms of the same species occupying a particular area, at a particular time, capable of mating freely.
4) Population	[ ]	It is a unit consisting of a community in a given area, interacting with the physical environment so that a flow of energy leads to closely defined trophic structure, biotic diversity and material cycling within the system.

6) Describe in brief the contributions of ancient Greek philosophers in the development of ecology.

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7) State the various definitions of ecology given by the following ecologists.

a) Ernst Haeckel

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b) Charles Elton

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c) Eugene P. Odum

....

....

8) Outline the divisions of ecology.

9) Answer very briefly the following questions:
   a) What do you understand by dominant species?

   ....

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   ....

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   b) What is species diversity?

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   c) What do you understand by relative abundance?

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10) What are the vertical limits of the biosphere?

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1.10 ANSWERS

Self-assessment Questions

1) The Caraka-Samhita and Susruta-Samhita have sufficient material to indicate that people during this period had a good understanding of animal and plant ecology. Both the Caraka-Samhita and Susruta-Samhita classify animals on the basis of habit and habitat, land on the basis of nature of soil, climate and vegetation. Plants typical to various localities are also described. In addition the Caraka-Samhitas contain information that air, land, water and seasons were indispensable for life and that polluted air and water were injurious to health.

2) a) autecological, b) synecological, c) ecosystem.

3) Environment is defined as the sum total of living, non-living components, influences and events surrounding an organism. The environment external to an organism is its external environment and the environment enclosed within the body of an organism or in a living cell is referred as internal environment.

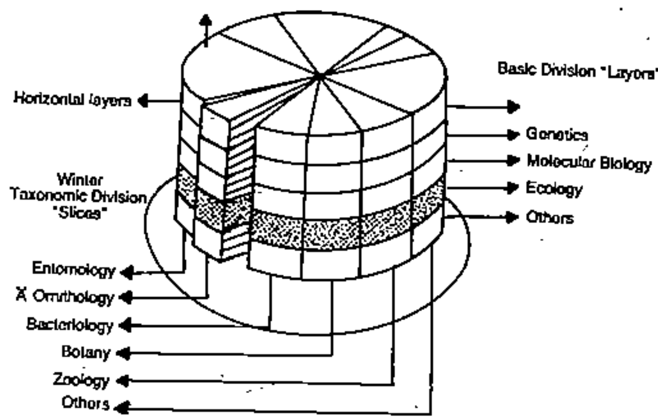
4) a) False, b) True, c) False, d) False, e) True, f) True, g) False, h) False.

5) a) saprotrophs, b) animals, c) producers, d) cycle, flows, e) ecosystem, d) ecotone.

Terminal Questions

1) a) Atmosphere, lithosphere, hydrosphere; b) decreases; c) major; d) increases; e) minor

2)



Biological cake diagram showing the relationship of ecology with other biological disciplines.

3) Natural ecosystems are those which are undisturbed or relatively undisturbed by humans, such as a natural forest, an estuary, whereas artificial ecosystem are those ecosystems which have been significantly altered by humans or created with specific objectives such as wheat field, tea garden, lawn.

4) Both are heterotrophs, but while macroconsumers feed on living plants or animals or both for obtaining nourishment, microconsumers decompose dead bodies of plants and animals and obtain energy from the decomposition of the dead bodies.

5) 1) ———— 2
2) ———— 1
3) ———— 4
4) ———— 3

6) The early Greek philosophers were well aware of the importance of environmental studies. Hippocrates in his work on airs, waters and places, stressed the need for ecological background for medical students as he explained the effect of water, air and locality on health and diseases on man. Aristotle classified animals on the basis of habit and habitat. Theophrastus studied plant types and forms in relation to altitude, moisture and light exposure and is regarded as the first person to introduce the ecological approach long before the term ecology was coined.

7) a) Ernst Haeckel defined ecology as the body of knowledge concerning the economy of nature — the investigations of the total relations of animal both to its inorganic and to its organic environment, including above all, its friendly and inimical relation with those animals and plants with which it comes directly or indirectly into contact — in a word, ecology is the study of all the complex interrelations referred to by Darwin as the conditions of the struggle of existence.

b) Charles Elton has defined ecology as scientific natural history.

c) Eugene Odum has defined ecology as the study of the structure and function of nature.

8) The divisions of ecology.

Main Subdivisions of Ecology

- **AUTECOLOGY** (Study of the ecology of an individual in relation to the environment)
  - **Autecology of a species** (Study of individual given species)
  - **Population Ecology** (Study of individuals of a given species)
- **SYNECOLOGY** (Study of the ecology of groups or communities in relation to their environment)
  - **Community Ecology** (Study of individual communities)
  - **Ecosystem approach** (Study of groups of communities together with their non-living environment, interacting together so as to function as a system)
- **HABITAT ECOLOGY** (Descriptive study of both the organisms and the kind of the environment or habitat where organisms live)

9) a) In a community dominant species are a few overtopping species which by their greater bulk modify the habitat characteristics they occupy and influence the growth of other species of the community.

b) Species diversity is a measure of the number of species (richness) and the relative abundance of each species (evenness).

c) In a community different species vary in their abundance. Relative abundance is a measure of relative proportion of different species in a community.

10) The vertical limits of the biosphere extend from 9000 metres above sea level to the floor of the ocean which is 11000 metres below the sea level.

UNIT 2 ENVIRONMENTAL COMPONENTS: 1. LIGHT, TEMPERATURE AND ATMOSPHERE

Structure

2.1 INTRODUCTION

In unit 1 we have given you a general introduction to the discipline of Ecology. You have learnt about the environment and its biotic and abiotic components that affect the organisms. This and the following two units deal with some of the abiotic components of the environment and their mutual interaction.

Among the abiotic components a knowledge of physical environmental factors like light, temperature, winds, water, soil etc. is important if we wish to understand the survival, distribution, abundance and adaptability of organisms in different ecosystems of the earth. In this unit, we will describe the solar radiation reaching the earth, its qualitative and quantitative features, temperature and the atmosphere. We will also learn about the instruments used for the measurement of light. Variations in light and heat significantly affect the distribution and behaviour of biotic communities. Green plants trap sun's energy and convert it to chemical energy through the process of photosynthesis. In animals, light reception is the most important sensory modality in the exploration of environment. Most animals are equipped with light receptors, which to a great extent influence their behaviour.

Organisms are adapted to a certain range of temperature only in which they can survive and reproduce. Plants and animals tolerate extremes of temperature by developing special structural and physiological adaptations or develop special strategies to avoid unfavourable temperature regimes. Wind is yet another important factor which affects the distribution and behaviour of organisms. The importance of wind is especially prominent in case of plants which have special needs to withstand high wind velocity. Some of these adaptations will be briefly discussed in the unit.

We have discussed the abiotic factors separately for the sake of convenience but they seldom operate independently. The discussion that follows in this unit and other units will help you to appreciate their integrated influence on the living organisms and ecosystem processes.

Objectives

After reading this unit you should be able to:

- differentiate between quality, quantity and duration of light and its importance to various ecosystems and describe instruments used for light measurement,
- outline global radiation balance and explain variation in light climate in terrestrial and aquatic ecosystem,
- describe the latitudinal and altitudinal variations in temperature and its influence on the formation of biomes,
- describe the composition and stratification of the earth's atmosphere,
- outline the features of global wind circulation, inversion, monsoon,
- explain the importance of adaptations in plants and animals to different light conditions and extremes of temperature and wind,
- use in proper context the terms solar constant, albedo, lux, photoperiodism, adiabatic change, thermoperiodism, cardinal temperatures, homeotherm, poikilotherm, stenotherm and eurytherm, exotherm and endotherm.

2.2 LIGHT

All of us know that the sun is the ultimate source of energy for all activities in our biosphere. The electromagnetic radiations from the sun supply energy which warms up the earth and the atmosphere to provide a favourable global temperature for the living organisms. In addition, light plays a variety of roles in the living world. It is essential for photosynthesis, the process by which light is converted into usable chemical energy. It is involved in the transmission of information, for instance, it helps plants and animals to programme their life cycles, coordinates the opening of buds and flowers, dropping of leaves and a variety of other physiological processes. Variation in the amount of light generally affects the local distribution of plants. In animals light regulates reproduction, hibernation and migration and of course makes vision possible. All these biological phenomena are readily influenced by variation in the intensity, and by seasonal or diurnal variations of light.

In the following sections we will discuss briefly the properties of solar radiations, and their global distribution.

2.2.1 Electromagnetic Spectrum

In FST-1 (Unit 10, Section 10.2.1) you have learnt about the electromagnetic spectrum which extends from gamma rays, x-rays, ultra-violet, visible, infrared to radiowaves. The spectral distribution and the intensity of solar radiation incident on the earth surface is known. As shown in Fig 2.1 the radiations that strike the earth extend from near ultraviolet to beyond the red to infrared. You know that visible light is only one small part of electromagnetic spectrum.

Electromagnetic radiation has a dual nature of wave and particle. Among the photobiological phenomena caused due to light, many are best explained in terms of wave nature of light, and many others by the particle nature. (If you wish to revise this concept, please see section 1.1 Dual nature of matter and radiation, chemistry, class XI-XII, NCERT). Electromagnetic radiation is a form of energy. It propagates in the form of discrete packets of energy called photons. The photons of each wavelength have different quanta of energy. The amount of energy of a particular wave depends upon its wavelength or frequency and can be expressed as:

$E \propto \upsilon$ E = energy of wave (joule/sec)

$E = h\upsilon$ υ = frequency of wave (Hertz cycles/sec)

h = Planck's proportionality constant. It has a value of $\sim 1.6 \times 10^{-34}$ cal/sec.
$= 6.6 \times 10^{-34}$ joule/sec.

υ = pronounced as nue

Frequency is inversely proportional to wavelength and can be expressed as

$$\upsilon = \frac{C}{\lambda}$$

C = velocity of light (3.0×10^{10} cm/sec or 3.0×10^{8} m/sec)

λ = wavelength (in cm or m)

1 cm = 10^{-2} meter (m)
1 µm (micrometer) = 10^{-6} m
1 nm (nanometer) = 10^{-9} m
1 Å (Angstrom) = 10^{-10} m

The human eye responds to waves in the range of 400 nm to 700 nm. These waves produce vision and are called visible light. Our eye is most sensitive to 555 nm.

Photosynthesis needs energy of wavelengths roughly comparable to that of visible light.

Red light is low energy wave with deep penetrability. That is why red signals are used for road lights.

Look at the visible region of electromagnetic spectrum in Fig 2.1. The varying wavelengths of visible light are perceived as different colours. Blue light has shorter wavelength, relatively higher frequency and high energy than red light which has higher wavelength relatively lower frequency and lower energy. As indicated earlier, visible light has a spectrum of colours and each colour has a specific range of wavelengths. Scientists use special colour filters to obtain light of a particular wavelength and study its effect on the various biological processes and behaviour of the organisms.

The radiations which affect the photobiological phenomena lie between 300 nm and 900 nm. In Fig 2.1 you will see the region of ultra violet, visible and infrared regions and the photobiological phenomena caused by them. You may spend sometime studying this figure. Before reading the next section we would like you to complete the following SAQ. You may find it useful to consult the glossary to remind yourself of some of these photobiological phenomena.

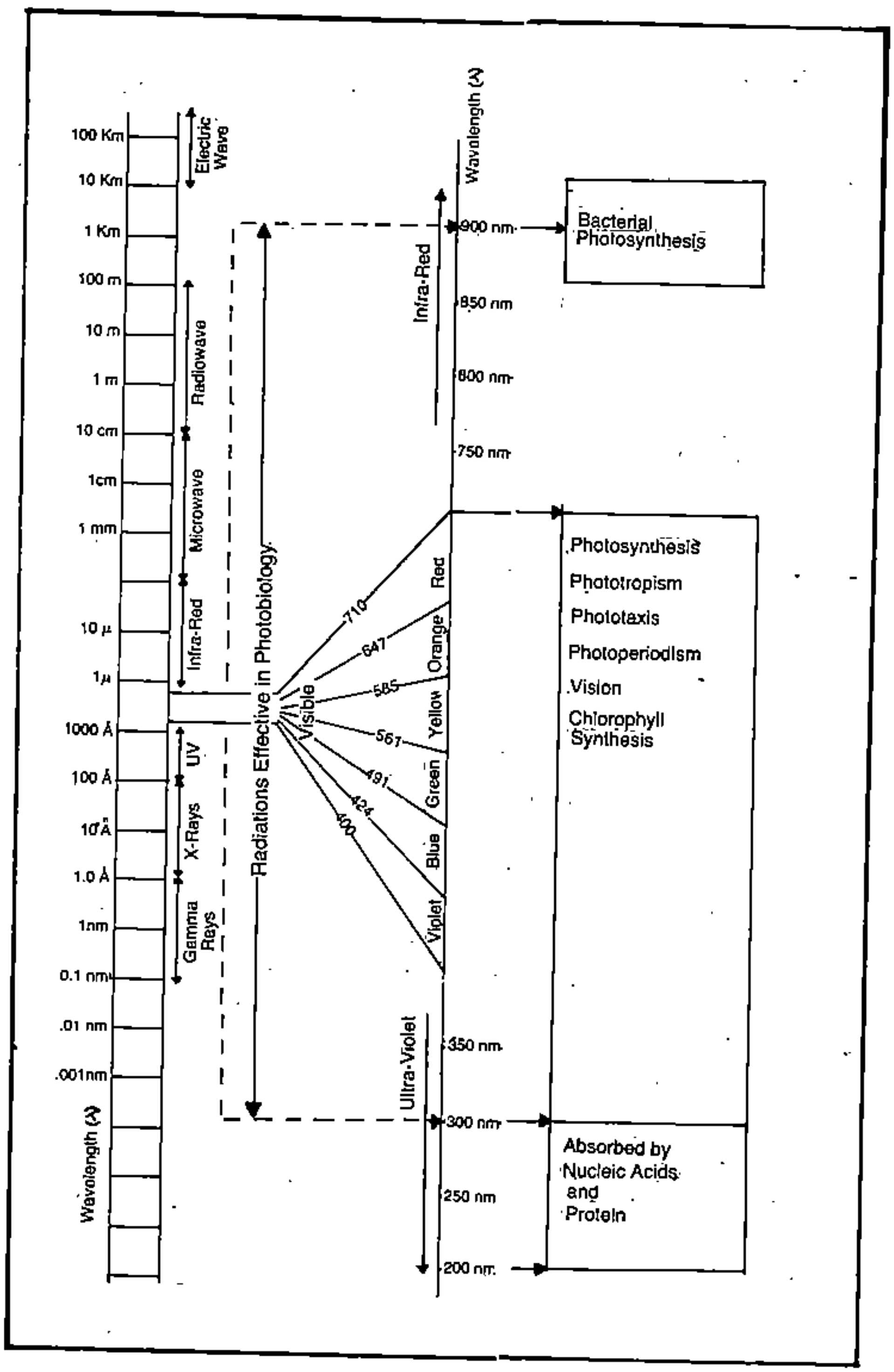


Fig 2.1 : Electromagnetic spectrum of solar radiations and the regions effective for photobiological phenomena

The present unit used for measuring energy is joule/metre/sec. 4.18 Joule (J) = 1 calorie (c) = 4.187×10^7 erg Watt = Joule/sec.

SAQ 1

a) Calculate the energy per quantum for radiation of wavelength 2×10^{-5} cm. (speed of light = 3×10^{10} cm/second). Express your answer in joule and calorie.

....

....

....

....

b) Match the given ranges of wavelength in column 1 with the corresponding statements in column 2.

....

....

....

....

Range of wavelengths Column 1	Statements Column 2
i) 900 nm	a) Absorption by proteins and nucleic acids
ii) 200 nm — 300 nm	b) Radiations effective in photobiological phenomena
iii) 300 nm — 900 nm	c) Bacterial photosynthesis
iv) 390 nm — 760 nm	d) Visible light

2.2.2 Solar Energy Input

We have mentioned earlier that the spectral distribution and the intensity of solar radiation incident on the earth's surface are known. Of the enormous amount of energy that is radiated by the sun (5.6×10^{27} cal/min), only about one-half of 1 billionth of that amount is intercepted by the earth. Not all the solar radiation can penetrate the earth's atmosphere; however, the amount of solar energy received at the top of atmosphere is constant. This energy is referred to as **solar constant**. It is defined as the rate at which solar radiation falls on a unit area is a plane surface, which is oriented perpendicular to the solar beam, when the earth is at its mean distance from the sun. On an average the value of solar constant is 2 cal/cm^2/min.

As the solar radiation travels through the atmosphere it interacts with it and gets diminished in three different ways: by reflection, scattering and absorption. Fig 2.2 shows the result of interaction of 100 units of solar radiation with earth and atmosphere. About 30% of the total incoming solar radiation is reflected by clouds and a portion of it is back-scattered and lost in space. About 19% of it is directly absorbed by oxygen, ozone, water, ice crystals and suspended particles. This absorbed radiation is converted into heat energy and the air is warmed to some extent. The remaining 51% is absorbed or reflected by earth's surface that is converted to heat. Thus a total of 70% (19% by atmosphere and 51% by earth) of the radiation absorbed by earth and atmosphere is involved in the functioning of our biosphere.

The blue colour of the sky is due to the scattering of the blue portion of visible sunlight by nitrogen and oxygen molecules present in the earth's atmosphere.

The earth has a variety of surfaces — rough, smooth, ice-covered, or water-covered and areas with different types of vegetation. The amount of radiation absorbed or reflected depends upon the nature of surface features i.e. topography of the area. The percentage of reflectivity of the incident radiation in meteorology is called albedo, which is

$$\text{Albedo} = \frac{\text{Reflected radiation}}{\text{Incident radiation}} \times 100$$

Albedo of snow covered landscapes is higher than vegetated landscape or water column. Freshly fallen snow typically has an albedo between 75 to 95%. Ocean waters have low albedo and therefore they appear darker than the adjacent continental land masses. Rough surfaces have low albedo than smooth surfaces. Also the light coloured surfaces reflect more than dark surfaces. Reflectivity also depends upon the angle of incident radiation. The surfaces that are less perpendicular to the sun's rays are more reflective than surfaces that make almost a right angle with the incoming solar radiation.

We have learnt that earth and atmosphere receive solar radiation, absorb a part of it and get warmed up. We also know that during night earth cools down. So where does the energy of

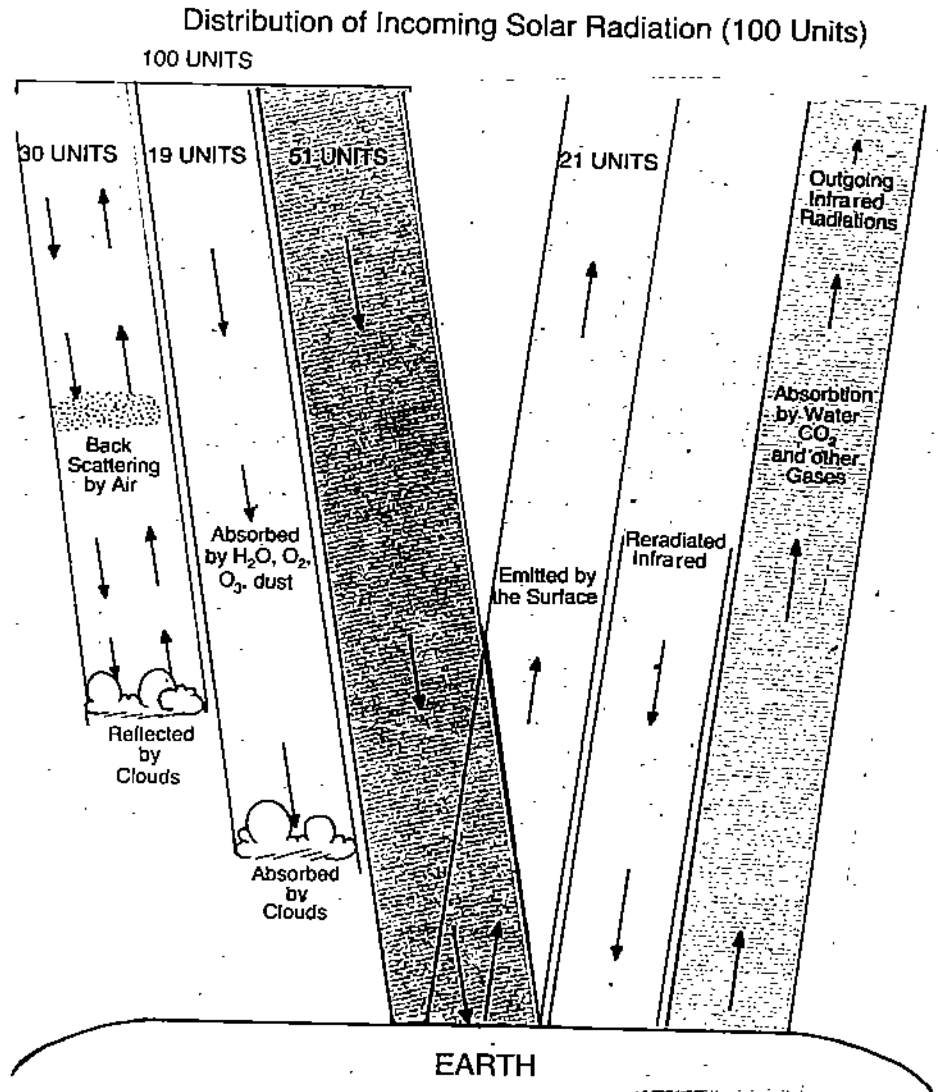


Fig 2.2 : The global disposition of solar radiation and terrestrial infrared radiation, based on 100 units of incident solar radiation.

Calorie is written with small c (calorie) and kilocalorie is written with capital C or as kcal (Calorie).

Broad spectral distribution of solar radiation reaching the earth
Visible light = 39%
Infrared = 60%
Ultraviolet = 1%

radiation absorbed by the earth go? Actually, the absorbed radiation in turn is continually re-radiated from the earth as heat in the form of infrared radiation and is sent off to outer space continually. If it had not re-radiated the air temperature would rise steadily day by day. Look at Fig 2.2. Larger percentage of the infrared radiation is absorbed by the atmosphere, water vapours, carbon dioxide and some other gases and so they impede its loss to space. Part of it re-radiates back to earth surface and helps in maintaining global temperature. The value of solar radiation at sea level is approximately 1.5 gc/sq cm/min (~10,000 fc).

The spectral distribution of solar radiation is greatly altered as it passes through cloud cover, water and vegetation. Short ultraviolet radiation is abruptly reduced by ozone layer in the outer atmosphere. Visible light is broadly reduced by absorptions in the atmosphere. Fig 2.3 shows spectral distribution of solar radiation above the atmosphere, after it passes through the atmosphere and reaches earth during clear weather, and under plant cover. Study this figure carefully before you move on to the next section.

2.2.3 Radiation Instruments

In this section we will learn about the instruments used for measuring solar energy, light intensity and duration of light.

Measurement of solar energy input

A variety of instruments have been designed to measure the energy of solar radiations of all wavelengths as well as of a particular range of wavelengths. **Pyrenometer** (Fig 2.4)

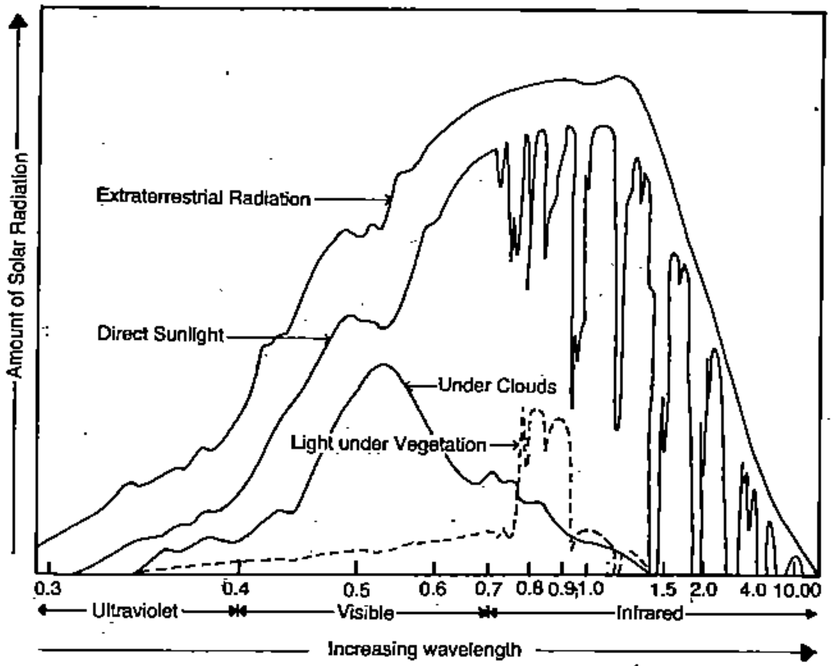


Fig 2.3: Spectral distribution of solar radiation on earth during clear weather, under cloud co. under vegetation (Redrawn from Gates, 1965).

measures the energy of sunlight of short wavelengths, indirect sunlight and scattered skylight radiation. The receiver of radiation A has alternate black and white strips. These act as hot and cold thermocouple junctions respectively. This arrangement is enclosed in a spherical glass bulb which shields the receiving surface from disturbances by wind. But the glass container limits the wavelength response to the range of 280 nm to 3,000 nm.

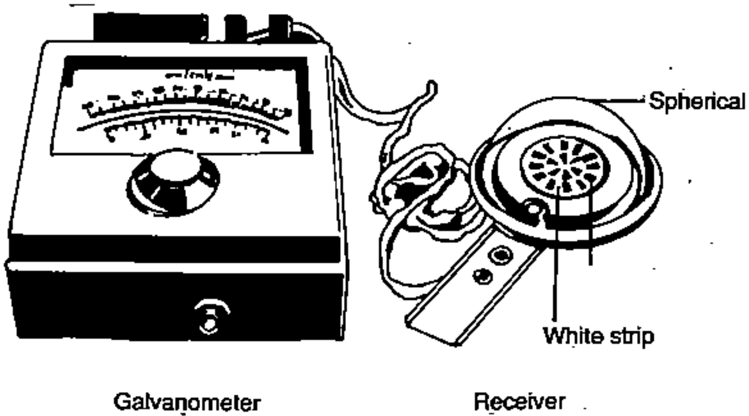


Fig 2.4 : A Pyrenometer

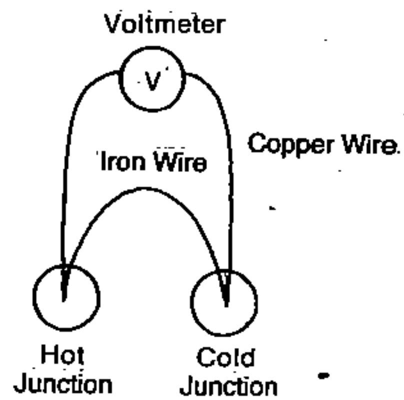


Fig 2.5 : A thermocouple

When two wires/strips of different materials/alloys are joined together and their two junctions are kept at different temperatures, an emf develops between them. This is known as themo-emf.

When the receiver is placed in the sunlight the temperature of black strips, increases because it absorbs all radiations falling upon it. But the white strips remain cool as they reflect all incoming radiation. Thus if we connect a thermocouple between these strips, a thermo-emf develops as shown in the margin (Fig 2.5). Galvanometer B (Fig 2.4) shows a deflection indicating this emf. In this way the radiations absorbed by the receiver can be measured. Normally, the galvanometer is calibrated to give a nearly linear voltage response to incident radiation/fluxes absorbed by the receiver.

Radiometer measures the flux of energy of all wavelengths received on a single surface of the receiver. There are also instruments that can measure the difference between the downward incident solar radiation and upward streams of reflected re-radiation and gives us the net value of radiation. This is called **net radiometer** (Fig 2.6 a). It has two exposed surfaces one upward facing (x) and another downward facing (y). The principle of this instrument is similar to that of the pyrenometer. The receiver A is a long thin blackened metal strip which is painted white on either side. The white and blackened parts of this strip are connected to a thermocouple.

Since the black receiver is not enclosed within a glass cover, it responds to all wavelengths. However, exposed receiver may not give us very accurate value because its surface may transfer heat to air by convection and conduction. Moreover, the moisture can also influence

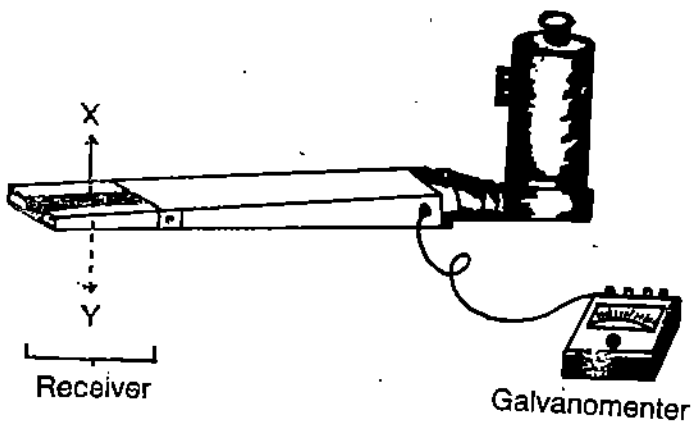


Fig 2.6a: A net radiometer

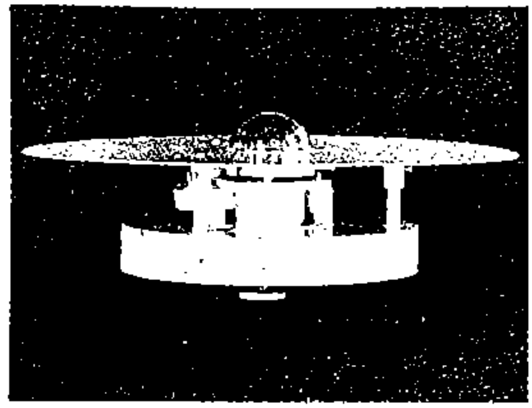


Fig 2.6b: Thermoelectric pyrenometer
(Courtesy, India Meteorological Department, Pune)

it. To avoid such disturbances the receiver is either ventilated at a constant rate or it is covered by suitable material which is transparent to visible as well as infrared radiations.

At meteorological department of India, Pune, solar radiation is measured by a thermoelectric pyrenometer shown in Fig 2.6b. The sensor is made up of blackened copper constant thermopile. When exposed it gives rise to a thermoelectric current proportional to the incident radiation. The current is fed to a continuously recording millivoltmeter.

Measurement of Light Intensity

How do we measure the intensity of a source of light falling on a surface? You know that light spreads out uniformly in all directions from a source. The amount of light shining on a unit area decreases with increasing distance. This decrease is equal to the square of the distance away from the source. Fig 2.7 shows how the intensity of light decreases with distance from the source.

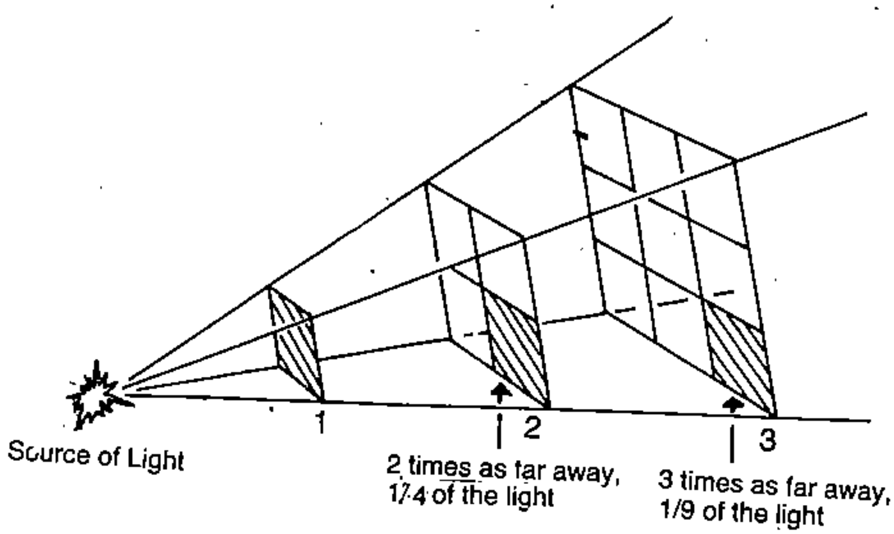


Fig 2.7: Decrease in apparent brightness with distance

Lux — pronounced as looks
We can see objects with about 0.25 ft-c of light and we require about 20 ft-c for reading. Temperate plants use about 2,000 ft-c for photosynthesis and tropical species use 8,000 ft-c or a little more. Sunlight at noon on a bright day is about 10,000 ft-c.

1 foot candle = 10.76 lux metre (lm)

Light intensity is measured in lux (mètre candle). A lux is the amount of illumination shed on a square metre of curved surface, one metre from a standard candle. Previously, the unit foot candle (ft-c) was used. A foot candle is the amount of illumination shed on a square foot of curved surface, one foot from a standard candle. To get an idea of the magnitude of foot-candle, please read the accompanying margin remark.

Photometer (Fig 2.8) measures the intensity of light. The metallic plate A is a photocell which emits electrons from its surface when light of sufficient frequency impinges upon it. The emission of electrons emerging from the irradiated surface constitute the current. This current is measured by a sensitive ammeter which is calibrated to give the amount of current generated as the value of light intensity in metre candle.

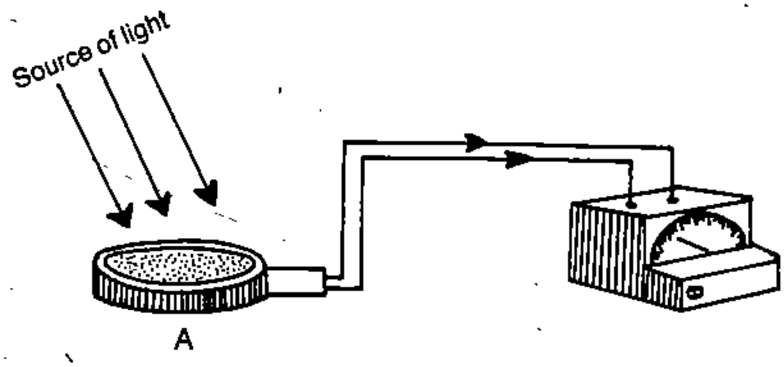


Fig 2.8: A photometer

Duration of Light

Sunshine recorder (Fig 2.9) measures the duration of sunshine. The recorder consists essentially of a glass sphere of about 10 cm in diameter mounted concentrically in a spherical metallic bowl (B) which itself is mounted on a marble base. The inner surface of the bowl is flanged to take 3 sets of special cards for use at different periods of the year. A semi-circular brass bar supports the bowl and sphere and has degrees of latitudes engraved on it. It can be moved and set to any latitude in its range. The rays of the sun when focused sharply on the card burn a trace on the card gradually. The length of the burn indicates the duration of sunshine, which is read off the hour marks printed on the cards.

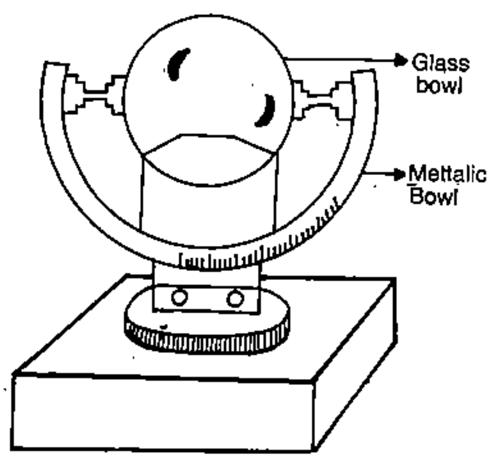


Fig 2.9a: Sunshine recorder

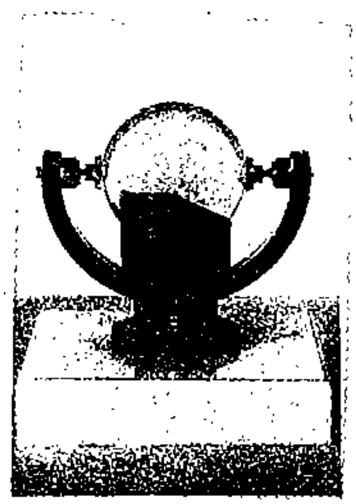


Fig 2.9b: A photograph of sunshine recorder.

2.2.4 Periodic Variations in Light — Diurnal and Seasonal

We know that rotation of the earth on its axis accounts for day-to-night variations in the amount of radiations falling at a given place and seasonal variations occur due to the orbiting of the earth around the sun. Since the earth's equatorial plane is inclined to its orbit at an angle of 23°.27′, the rays of the sun do not fall vertically on all parts of the earth. From March 22nd to Sept. 22nd (Autumnal equinox), the northpole is inclined towards the sun. So the most intense solar beam is focused on the northern hemisphere. We in the northern hemisphere, have summer season and on the northpole the sun shines for 24 hours of the day. While on South pole it is dark for six months and the southern hemisphere has winter season. The opposite situation exists on the poles from September 24 to March 20 (spring equinox) when the northern hemisphere has winter season and southern hemisphere has summer season (Fig 2.10).

There is also horizontal variation in the distribution of radiation on the earth. Because the earth is nearly spherical in shape, parallel beam of incoming sunlight does not fall vertically on all parts of the earth. It strikes lower latitudes more directly than higher latitudes. Therefore, at higher latitudes the incident radiation falls obliquely on the surface, travels more through the atmosphere, and spreads over a greater area and thus is less intense (Fig 2.11) than the vertical beam falling on or near the equator.

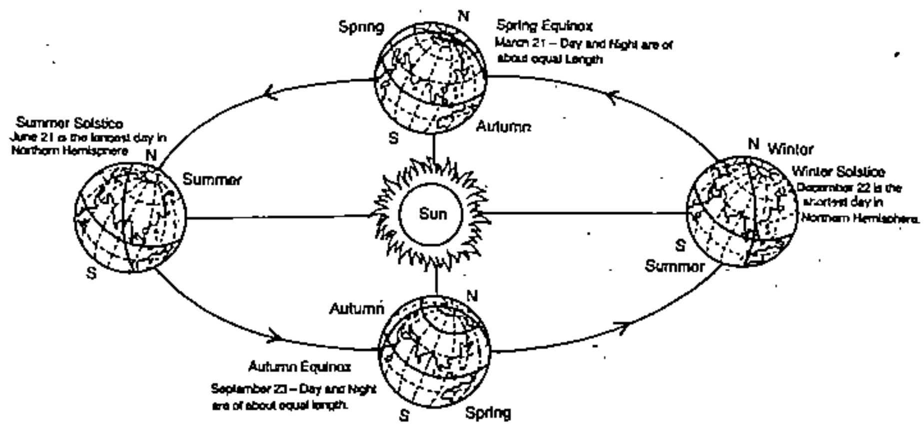


Fig 2.10: Annual variation in the amount of incoming solar radiation, causes seasons.

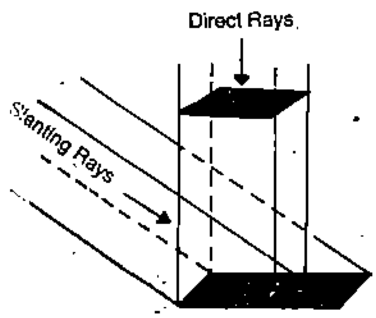


Fig 2.11: Variation in the angle of incidence of solar radiation. Direct rays transfer more intense insolation per unit area of earth surface than oblique rays.

Of the total radiation energy incident upon a leaf, 50% is transformed and used in vaporisation, 19% is lost by radiation, 30% reflected or transmitted from the leaf surface. It is found that in Helianthus leave, 0.42 to 1.66% is available for photosynthesis.

2.2.5 Light and Distribution

We have mentioned in the beginning that the variation in the amount of light generally affects the global and local distribution of plants and animals. Light plays a great role in species composition and development of vegetation. We have already discussed the global variation of light intensity. Let us study the causes of variation in light climate in terrestrial and aquatic ecosystem. In order to provide a comprehensive idea of light climate of any locality, information on the following three aspects needs to be provided: i) Intensity or amount of light per unit area per unit time, ii) The quality or wavelength composition, and iii) Photoperiod or duration.

Significant local variation in the light in the terrestrial ecosystems results due to the interception of light by vegetation. In a forest, tall trees with fully expanded canopy receive maximum sunshine and absorb a major portion of the incident light especially in the red and blue regions. The undershrub and herb layers receive only light filtered through the tree canopy from above. In a thick forest the light interception by the multistoreyed vegetation (Fig 2.12) is very efficient and on the forest floor light intensity may be only 1% of the incident solar radiation received at the top of the canopy.

Due to selective absorption, spectral light quality changes as it passes through the tree canopies. Yet, we find that some plant species are adapted to functioning in such low light intensities. On the basis of relative preference for natural growth in bright or diffused light the plants have been classified into two categories — **sciophytes** (shade loving) and **heliophytes** (bright-light loving). Some plants are more rigid in their preference for shade or bright light. These are termed as obligate sciophytes and obligate heliophytes respectively. There are some heliophytes that can also grow in shade but not so well. These are called **facultative sciophytes**. Similarly, the sciophytes that can also grow in bright light are called **facultative heliophytes.**

Plants can survive only when the total energy harnessed in photosynthesis exceeds that used in respiration. The intensity of light at which energy harnessed through photosynthesis is just sufficient to meet the energy requirement of respiration is called **light compensation point**. In deep shade, under trees the amount of light is not enough to carry on photosynthesis to satisfy the immediate need of the plants. Therefore, they lose leaves and usually branches. The leaves in a tree canopy are arranged in a way so as to function above light compensation point.

So far we have discussed the influence of light on the distribution of species in terrestrial ecosystem. Let us see the distribution of light in aquatic ecosystems.

Red algae have supplementary pigment phycoerythrin enabling them to utilise energy of green wavelength and live at greater depth

Vertical stratification of light intensity with increasing depth and accompanying changes in its spectral quality occur due to its limited penetration in water. Generally, less than 1% of sunlight can penetrate upto a depth of about 30 metre in a water body. The light penetration can be further reduced by suspended material in water like silt, clay, solute content, plankton which significantly decrease the intensity of light and change the light quality. Often, plants such as duckweed (lemna) which float freely on the surface of water can intercept the incoming light. Besides, pure water also absorbs light at a rapid rate and causes profound changes in its spectral distribution. Red and blue wavelengths are mostly filtered out and the remaining predominantly greenish light penetrates to a greater depth.

Fig 2.12 : Stratification of light in multistoreyed vegetation.

We know that the amount of photosynthesis is directly related to the intensity of light and thus the light compensation point in water reaches at a certain depth which is called **compensation depth.** The zones above and below this depth are called photic zone and aphotic zones respectively.

A lake has three zones as shown in Fig 2.13. The **littoral zone** includes all those areas where light penetrates to the lake bottom and where aquatic plants, aquatic animals and decomposers grow. The **profundal zone** includes areas too deep to be penetrated by light useful for photosynthesis. This area is below the compensation depth. **The limnetic zone** is open, sunlit water above the profundal zone. It extends outward from the littoral zone. Tiny free floating plankton especially phytoplankton dominate in this area.

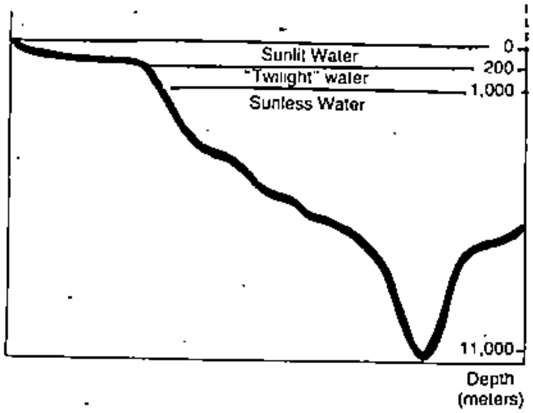


Fig 2.13 : Zonation of a lake according to light penetration.

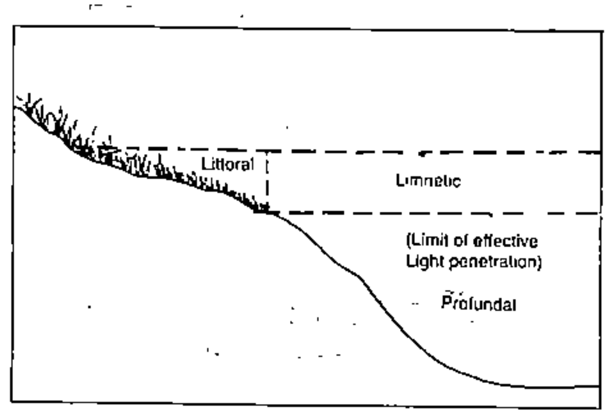


Fig 2.14 : Penetration of light at various depths in the ocean.

The knowledge of photoperiodism is of great practical utility in selection of species and seasons of their cultivation.

Light is an important factor in regulating the distribution pattern of marine organisms. The accompanying Fig 2.14 shows various depths to which light penetrates in the ocean.

2.2.6 Photoperiodism

Activity like breeding and migration in animals; flowering, seed germination in plants are regulated by the length of daily period of light and darkness. This behavioural phenomenon is known as photoperiodism. For example, plants such as radish, potatoes and spinach bloom when the light duration is more than 12 hours/day. Such plants are called **long day plants.**

Cereal, tobacco, dahelia and many other plants bloom when light duration is less than 12 hrs/day. These are called **short day plants.** Such responses show that plants have built-in mechanisms for measuring the duration of illumination and darkness and hence flower in a specific seasons.

Similar photoperiodic responses are observed in animals. These may be diurnal, lunar or annual. Reproduction and migration in birds are such annual photoperiodic responses. From such responses it seems that distribution of some plants and animals may be restricted because the necessary photoperiodic stimulus is available only at certain latitudes.

SAQ 2

a) Strike out the wrong words in the following statements.

i) The brightness of an object depends upon the amount of light it (absorbs/reflects).

ii) Higher the angle of incident radiation on a surface, the (more/less) will be reflected by it.

iii) The amount of energy (intercepted by the earth/reaching the top of atmosphere) is called solar constant.

iv) The incident solar beam has (more/less) intensity when it falls on a surface (vertically/obliquely).

v) Short day plants require light duration of (less/more) than twelve hours.

vi) Infrared/ultraviolet radiation is terminated by ozone layer.

vii) Infrared/visible radiation can pass through cloud cover.

viii) Visible/infrared light is broadly reduced by absorption in the atmosphere.

b) Match the statements in column 1 with that of column 2.

Column 1	Column 2
i) Sciophytes that can grow in bright sunlight	a) Facultative heliophytes
ii) Bright light loving plants	b) Heliophytes
iii) Shade loving plants	c) Sciophytes
iv) Plant that can grow in bright sunlight	d) Obligate sciophytes

c) Match the instruments in column 1 with their function listed in column 2.

Column 1	Column 2
i) Photometer	a) Energy of short wavelength and skylight radiation
ii) Net radiometer	b) Intensity of illumination
iii) Solarimeter	c) Difference between the energy of downward incident solar radiation and upward stream of reflected re-radiation.
iv) Sunshine recorder	d) Variation in the intensity of light during a day.

Now that you have finished this section, you may take a break and drink a cup of tea.

2.3 TEMPERATURE

Temperature is an approximate measure of the kinetic energy, or energy of motion of molecules. The faster the molecules move, the higher the temperature. Heat is the total molecular energy of a given amount of a substance measured in calories. Temperature is a convenient way to describe relative heating.

Temperature is a major physical environmental factor which profoundly influences the vital activities of living organisms like, metabolism, growth and reproduction. The primary effect of temperature is on the stability and activities of enzymes which carry out and regulate the biochemical reactions in the cells. Temperature also affects the properties of biomembranes.

We know that there are large temperature differences over the earth to which organisms must adapt. Temperature and availability of water in an area largely determine the types of plants and animals that can grow, survive and reproduce there. Every organism has a certain range of tolerance for temperature delineated by an upper and lower lethal temperature, which vary from species to species. Thus, temperature is one of the factors that limit the geographical distributions of plants and animals. Temperature also indirectly influences the availability of water which itself is an important ecological factor. Before we describe the adaptations in organisms due to temperature stress let us discuss the temperature variation at different latitudes and altitudes and examine the global picture of temperature.

Temperature is measured with the aid of a thermometer. In determining the temperature of air, direct or reflected sun-light must be excluded from the thermometer as fully as possible. While making the reading, it is necessary to expose the bulb to the full effect of the wind and keep it away from the hand and body.

2.3.1 Latitudinal Variations

The latitudinal variation of temperature over the earth is the result of two main variables

i) incoming solar radiation and

ii) the distribution of land and water masses

What do you think could be the other factors influencing temperature?

The movement of wind and water, and the direction of slopes of hills and mountains also modify the temperature.

We know that the length of the day varies at higher latitudes. That means the incoming solar radiation varies. However, if we compute the average, every point on the earth gets the same total hours of daylight each year, an average of 12 hours per day, but not the same amount of heat. The latter depends upon the amount of radiant energy delivered/unit area/hr and this depends upon the angle of landing sunlight. You have learnt in the previous section that vertical beams are more intense than the oblique beams that land on the higher latitudes. Hence we find a gradual decrease in the amount of incident radiant energy/unit area along the increasing latitudes, horizontally. Let us now take into account the outgoing infrared radiation. Look at the plot in Fig 2.15 which compares the absorbed solar radiation with the

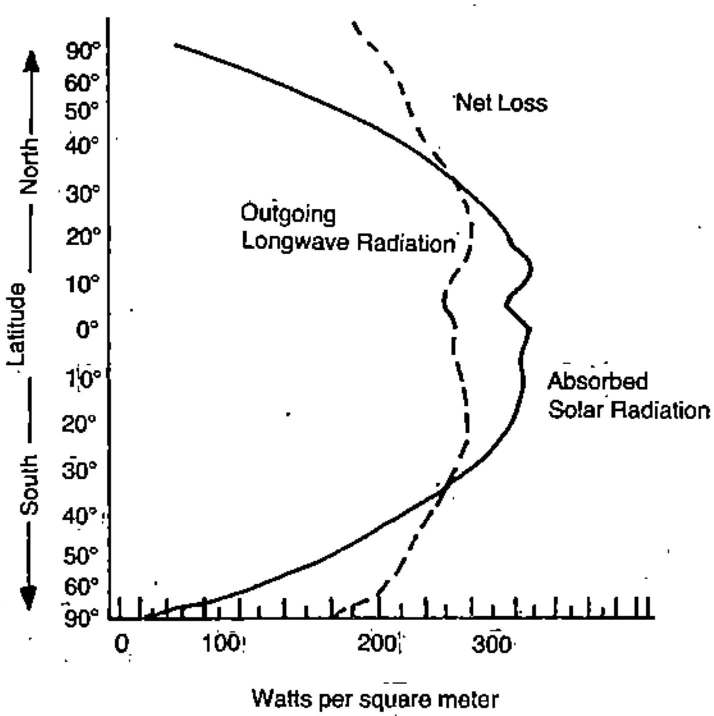


Fig 2.15 : Absorbed solar radiation and outgoing infrared/radiation at various latitudes.

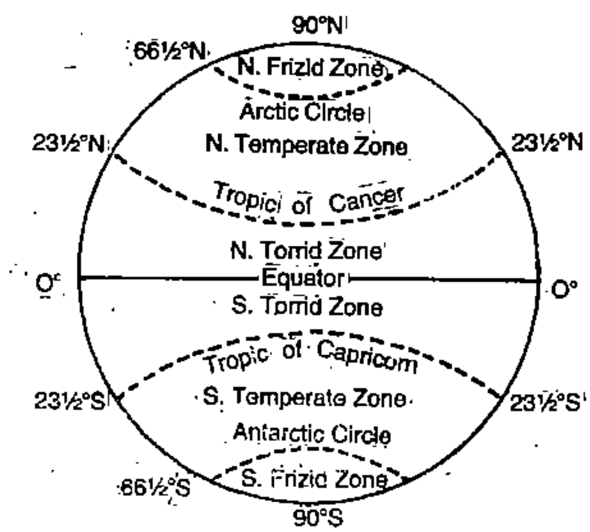


Fig 2.16 : Heat zones

outgoing infrared radiations at various latitudes. Notice that at lower latitudes the rate of warming by absorption of solar radiations is greater than the rate of cooling by outgoing infrared radiations. You can see that the reverse is true for higher latitudes where the rate of cooling far exceeds the rate of absorption. At about 28° N and 33° S the cooling and warming rates are equal. The poles get only about 40% of the radiant energy of that delivered to the equator. The heat changes in various latitudes are also brought about by the movement of warm and cold water masses and by the exchange of cold and warm ocean currents.

Table 2.1 : Comparison of Maximum and Minimum temperature of Calcutta (near the coast) and Nagpur (land locked) located at the ~ 22° N latitude.

Temperature —°celcius
Maximum = Max
Minimum = Min

Month	Calcutta		Nagpur	
	Max	Min	Max	Min
Jan	26	12	29	13
Feb	29	15	33	15
March	34	20	36	19
April	36	24	40	24
May	36	26	43	28
June	34	26	38	27
July	32	20	31	24
Aug	32	26	30	24
Sept	32	26	31	23
Oct	31	24	32	20
Nov	29	18	30	14
Dec	27	13	29	12

Besides the difference in temperature at different latitudes, we find a great difference in the temperature of places located at the same latitude. For example, Calcutta and Nagpur are at same latitude but the temperature at Calcutta is moderated by its proximity to the sea (Table 1).

Can you tell the reason for this difference? This is because land and water absorb heat differently and this produces more contrast even within the same latitude. The temperature of land locations/areas/stations have greater daily diurnal and seasonal temperature fluctuations.

On the basis of temperature variation three distinct heat zones can be distinguished in each hemisphere (Fig 2.16). The hot torrid zones are near the equator, moderate or temperate zones are in the middle, the cold zones are at the poles. Each zone is characterised by typical plants and animal populations found in the area.

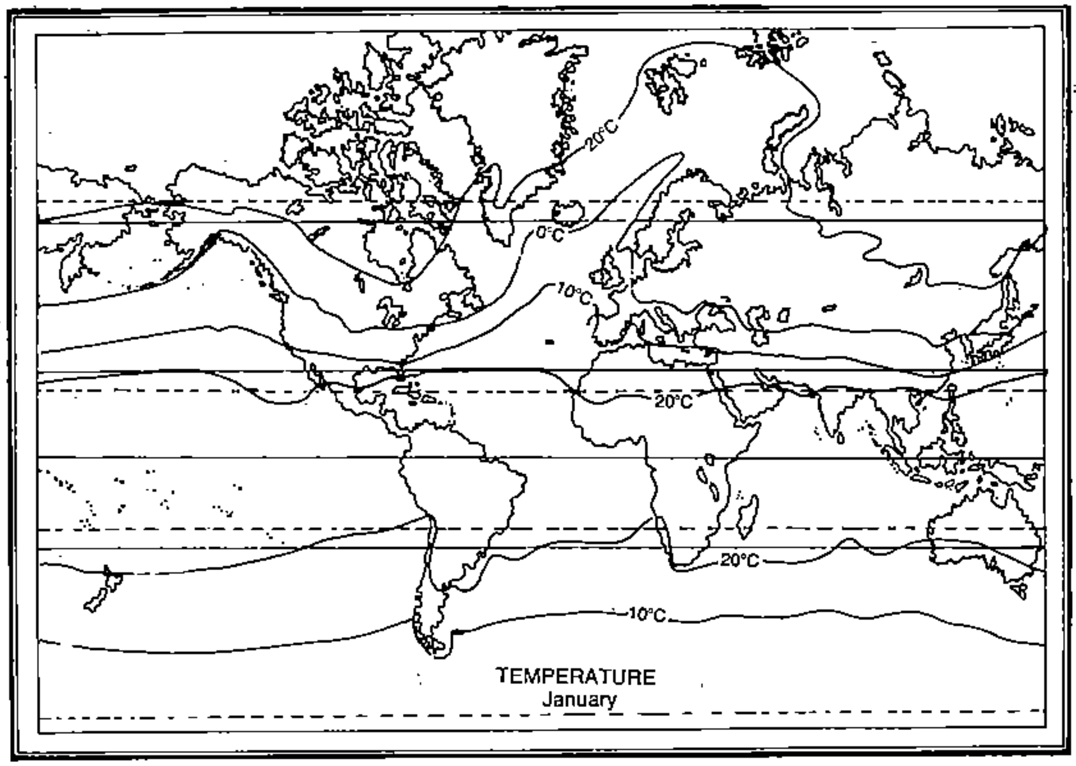
2.3.2 Altitudinal Variations

We know that temperature decreases with increasing altitude. This is mainly due to convection currents in the troposphere — the lowermost (and most dense) region of the earth's atmosphere. (You are told about different regions of atmosphere in section 2.4.2). As you know that the surface of the earth gets heated up on account of solar radiation and it also heats the air which is in immediate contact with the surface. This gives rise to convection currents which continuously transport air from lower region to higher ones and vice versa. When the air from sea level rises to the upper atmosphere of lower pressure it expands i.e. the volume increases. While expanding, the molecules push aside the neighbouring molecules. In doing so the molecules lose their kinetic energy and it is this energy loss which is reflected in a decrease in temperature. The same amount of energy is gained by the gas molecules when they are compressed while descending and thus the temperature increases. Such a change in temperature where no addition or substraction of heat takes place between the system and the surrounding is called **adiabatic change.**

2.3.3 Global Temperature

Let us now look at the global temperature in Fig 2.17

The isothermal map of the world shows the pattern of annual mean temperature on the earth. We find that the continental land masses have relatively broad temperature ranges. The southern hemisphere has less temperature variation than northern hemisphere because of more water mass in the former. Fig 2.18 shows the annual mean temperature in cities in India.



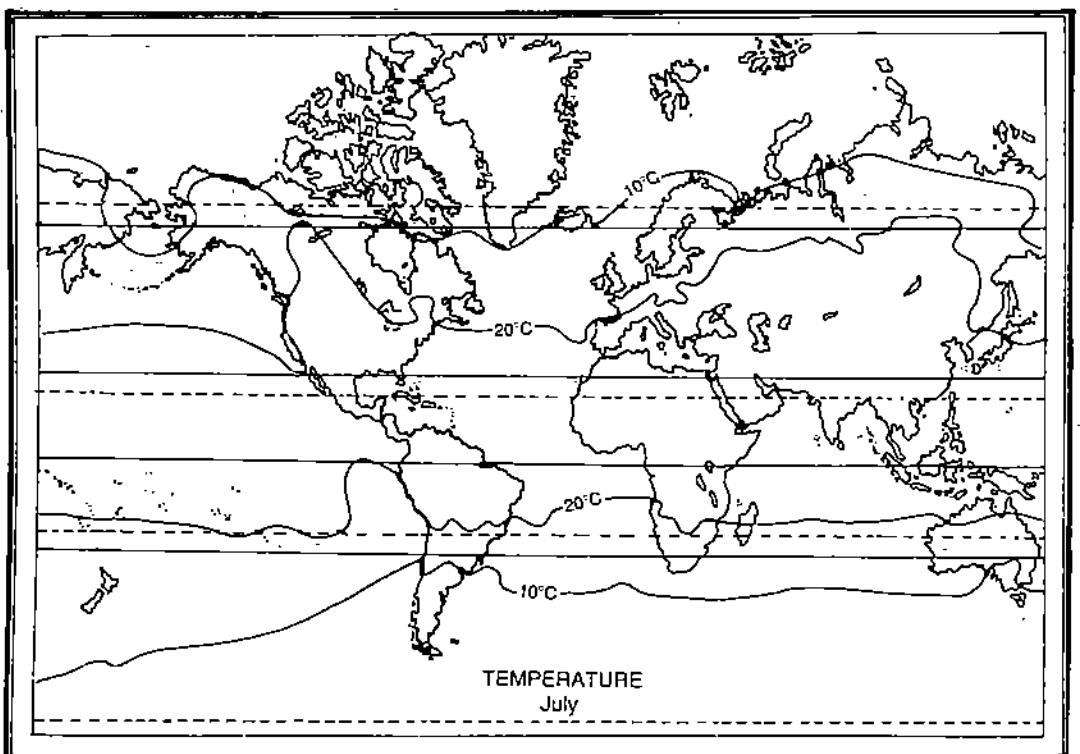
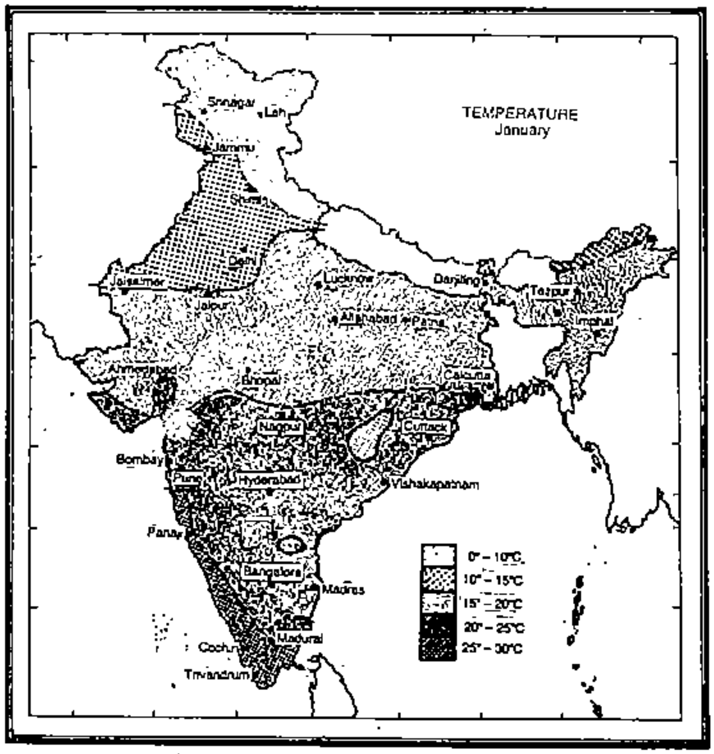


Fig 2.17 : Isothermal map of the world.

2.3.4 Temperature Stress

We have mentioned earlier that temperature alongwith water is an important influence on the geographical distribution and range of organisms. Every organism is restricted to a definite range of temperature, which may be quite dissimilar for different species. In other words, there is an upper and lower lethal temperature above and below which a given organism cannot perform the normal life activities and may suffer irreversible damage or may die.

The lower minimum and upper maximum lethal temperatures and optimum temperature are termed as cardinal temperatures and these vary from species to species. Some organisms have narrow limits of tolerance to high or low temperature (stenothermal) while some tolerate a wide range of temperature (eurythermal) (Fig 2.19). Besides tolerance temperature



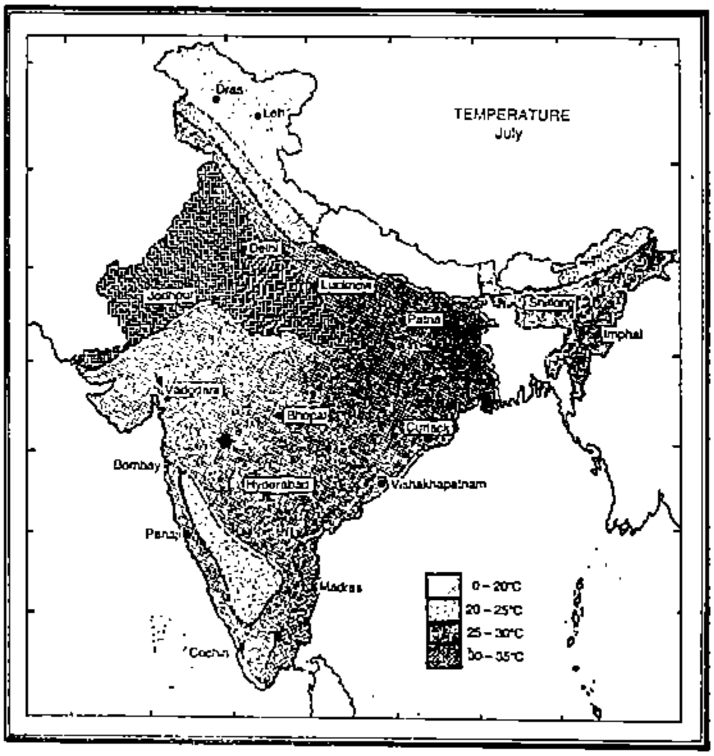


Fig 2.18 : Annual mean temperature in India. (These maps do not show the political boundaries.)

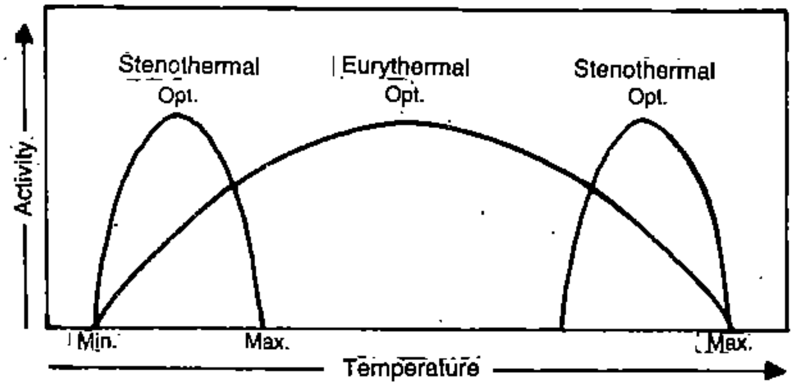


Fig 2.19 : Limit of tolerance of stenothermal and eurythermal organisms. Maximum, minimum and optimum lie in a very narrow range in stenothermal species. Eurythermal, show wide range of temperature tolerance.

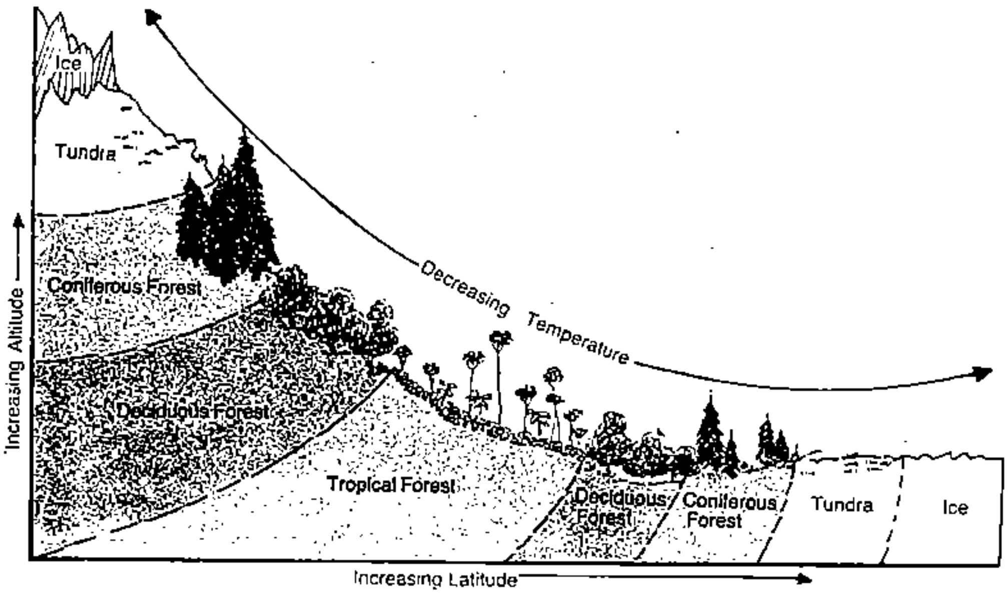


Fig 2.20 : Zones of vegetation change with altitude just as they do with latitude because vegetation is partially determined by temperature. The other factor is rainfall.

range, organisms have different optimum temperature for growth, development and reproduction i.e. at the specific temperature, they perform specific function with maximum efficiency. The characteristics of terrestrial biotic communities are determined by the temperature and rainfall. Thus we find that different biomes distributed throughout the globe in accordance with the temperature which in turn is influenced by other factors. Since the temperature varies with altitudes as well as with latitude the variation in the vegetation from equator to higher latitudes is somewhat similar to that from planes to higher altitude as shown in the Fig 2.20.

The biomes in different regions have been named according to the kind of vegetation they support such as coniferous forest, deciduous forest, grassland, savanna etc. The deserts and the tundras experience extremes of temperature. The organisms of such biomes survive at the limits of the temperature tolerance. We will now describe the temperature stress on the organisms living in these biomes.

Extremes of Heat and Cold

Deserts are regions of aridity with rainfall of less than 20 cm per year and the soil, though fertile, is too porous to retain any water. In summer there is great diurnal variation in temperature from 40°C during the day to below 15°C the same night. The light intensity reaches higher peak due to lack of cloud cover. The true deserts are Sahara in Africa and Great desert in Australia where the annual rainfall is less than 2 cm. Plants and animals which survive under such conditions have special features that allow them to withstand high temperature and lack of water.

The world's largest deserts are located near 30° latitude both north and south of the Equator.

The other extreme of temperature is seen in the arctic and alpine tundras. The word **tundra** means bare mountain tops in Finnish. Tundras are frozen most of the year round and are very similar to deserts as the rainfall here is also about 20 cm per year. But during the short summers, water is plentiful as the topmost layer of ice melts. The ground gets covered with short grass and patches of moss and lichens. Beneath the thawed layer of 3-5 cm, the soil called **permafrost** remains permanently frozen. Since the roots cannot penetrate deep in the soil trees do not grow here.

Arctic tundras are restricted to a band across the northern latitudes of the world. It is an arctic grassland that runs along the coasts and island of arctic oceans in Asia, Europe and North America. Alpine tundras occur at high altitudes at various latitudes around the world.

Now let us see how plants and animals adapt to these temperature extremes.

2.3.4 Adaptations

Every organism can live and reproduce within a certain range of climatic conditions. Organisms that live in hot or cold environments have behavioural and physiological features that enable them to survive extremes of temperature. As a survival strategy organisms either tolerate these extreme conditions or evolve ways of avoiding them altogether. For example, plants cope up with high temperatures in the desert by developing a thick layer of cuticle.

succulence i.e., water storage tissue in the leaves and stems. In many cacti the stem is green and carry out the functions of leaf and makes food by photosynthesis. These plants also have physiological adaptations. The stomata remain closed during the day to prevent the loss of water due to transpiration. CO_2 diffusion cannot occur in stomatal closure in the day. To carry on photosynthesis these plants have evolved special physiological adaptation. During night when their stomata open they trap CO_2 and store it in the form of four carbon acid. The CO_2 trapped in the leaf at night is subsequently released during the day and used in photosynthesis. This type of metabolism is called crusstulacean acid metabolism (CAM). The details will be covered in physiology course. Comparative study of plant responses to constant favourable temperature region verses alternating temperature shows that seed germination, vegetative growth or fruit production is best under the latter conditions. This shows that plants are adjusted to natural rythmic diurnal cycle temperature changes. The regulation of plant responses to periodic thermal changes is called **thermoperiodism.**

Let us now see what sort of strategy animals adopt to cope with temperature stress. Animals have advantage over plants as they can move from one place to another. They cope with temperature stress by regulating their internal and external environment by physiological and behavioural means. Probably you know that birds and mammals are capable of maintaining constant body temperature. They do so by using the energy of metabolism released during cellular respiration. They are called **homeotherms** or **endotherms** because they control constant body temperature by internal means. The body fat, feather, fur or hair etc. help to retain this heat. Some animals use a number of behavioural mechanisms to regulate their body temperature. This type of regulation is termed as behavioural thermoregulation. For instance, they can move to shady areas or take a dip in water during the hot period of the day. The desert animals such as snakes, lizards, scorpions, and rats are mostly nocturnal i.e. they remain hiding during the day to avoid the scorching sun and roam in search of food at night or early in the morning when temperature is generally low. Reptiles like lizard and snake are considered cold blooded because they cannot control their body temperature. However, experiments on these animals have revealed that they can also control their body temperature effectively by behavioural means. Reptiles move in and out of burrow in such a way that their body temperature remains fairly constant. It has been found that in spite of great temperature fluctuation of environment, desert lizard can maintain its body temperature between 31°C to 39°C. These animals are called **poikilotherms or exotherms** because they control body temperature to a considerable range by behavioural means. Animals also regulate their body temperature by losing excess heat by sweating and evaporation.

In colder climates animals have adaptations to gather heat. Birds warm up their body by increasing the muscular activity in their wings by shivering. The chameleons change their colour to black, thus increasing their heat absorbing capacity, the ectotherms bask in the sun. The animals also manipulate by exposing a certain portion of their body so as to acquire desirable heat.

Another way to avoid adverse climatic conditions is through migration. Probably you know that birds of northern or colder regions migrate to warmer southern regions during the winter season. Fishes also swim long distances until they reach water masses which have suitable temperature for their survival.

Some animals such as bats, hedgehogs, ground-squirrels, lizards reduce their metabolic activity and thus enter into hibernation to minimise their energy needs during winter. To overcome high temperature during summer insects, lungfish, amphibians etc. also suspend their activities and lead dormant life. This state is called aestivation.

SAQ 3

a) Tick mark (√) the correct statement.

i) The variations in temperature with increasing latitudes is due to the fact that

- a) Light shines for less number of hours [ ]
- b) There is decrease in intensity of solar beam [ ]
- c) Rate of infrared cooling exceeds the rate of absorption of solar radiation [ ]

ii) The effect of increasing altitude on vegetation is similar to the effect of increasing latitude because

- a) Mountains change the angle of sunlight [ ]
- b) Altitude and latitudes are higher up in biosphere [ ]
- c) Temperature decreases with both latitude and altitude [ ]

iii) Diurnal fluctuation in temperature is higher in
  a) Desert regions [ ]
  b) Coastal regions [ ]
iv) An animal whose body temperature tends to vary with the surroundings is called
  a) Poikilotherm [ ]
  b) Homeotherm [ ]
v) Stenothermal animals tolerate
  a) Wide range of temperature [ ]
  b) Limited range of temperature [ ]

b) Explain the reason for decrease in air temperature when air masses rise up.

....

....

....

....

c) Strike off the wrong words.
  i) On the average every point on earth gets the same total hours of (daylight/heat) each year.
  ii) The rate of warming by absorption of solar radiation is (greater/smaller) than the rate of cooling at (higher/lower) latitude.

2.4 ATMOSPHERE

You have already studied (Unit 15 of the FST Course) that the earth is surrounded by a gaseous envelope called atmosphere. The atmosphere is an essential part of our biosphere. It is important to study the composition of the atmosphere because this composition is responsible for the weather and climate on our planet and life supporting system.

2.4.1 Composition

The present day composition of atmosphere is the product of a lengthy evolutionary process that began more than four billion years ago. It is composed of a mixture of many different gases and suspended particles (Table 2.2). As you can see from the table there are about 12 gases in the atmosphere. However, most of them are present in trace amounts. Nitrogen and oxygen are the major constituents while CO_2 is only 0.03%. Because of continual mixing of atmospheric gases, this composition is almost constant for approximately 15 km height. We may travel anywhere on the earth and be confident that we are breathing essentially the same type of air.

Table 2.1.

The relative proportions of gases in the lower atmosphere (below 80 kilometres), excluding water vapour

Gas	Per cent by Volume	Parts per Million
Nitrogen	78.08	780,840.0
Oxygen	20.95	209,460.0
Argon	0.93	9,340.0
Carbon Dioxide	0.03	340.0
Helium	0.00052	5.2
Neon	0.0018	18.0
Krypton	0.00010	1.0
Methane	0.00015	1.5
Hydrogen	0.00005	0.5
Nitrous Oxide	0.00005	0.5
Xenon	0.000009	0.09
Ozone	0.000007	0.07

Atmosphere also contains minute liquid or solid particles in a suspended form which are known as **aerosols**. Most of these are found in the lower atmosphere (up to 80 km) near the earth's surface. They originate as a result of forest fires, wind erosion of soil, as sea salt crystals from ocean sprays as well as, from industrial and agricultural activities.

2.4.2 Stratification

On the basis of the variation in air temperature, the atmosphere has been divided vertically into four layers: (see Fig 2.21) the troposphere, stratosphere, mesosphere and thermosphere.

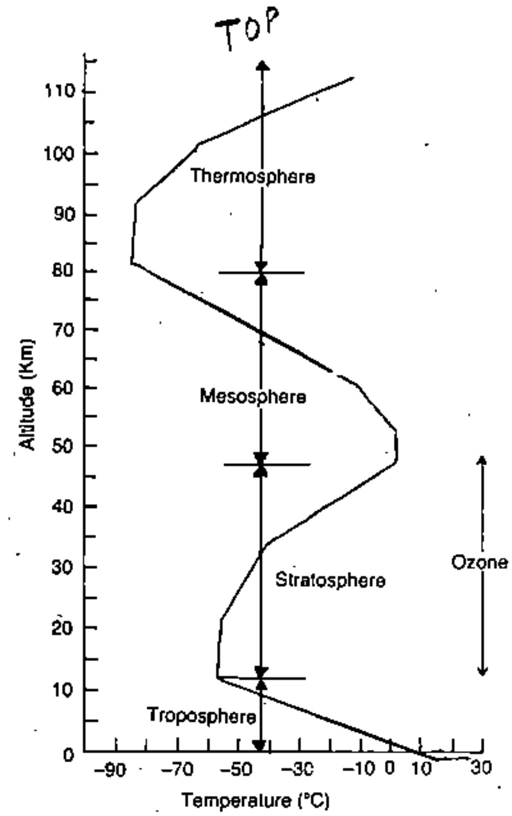


Fig 2.21 : The atmosphere is subdivided vertically into zones that are based on the profile of air temperature.

Troposphere or the lowermost layer extends up to an altitude of 15 km at the equator to 8 km at the poles. The temperature in this zone decreases with increasing altitude or height.

The next layer, the **stratosphere**, extends up to an altitude of approximately 50 km. Here a gradual increase in temperature occurs with altitude. Pilots of jet aircraft prefer to fly in the stratosphere as it is relatively stable and free from weather fluctuations apart from providing excellent visibility. Scientists are worried about the growing pollution in the stratosphere. As pollutants enter into this zone, they are likely to remain here for a long time. We shall be elaborating this in a later unit.

In **mesosphere**, the next layer, temperature is constant in the lower portion but then rapidly decreases with altitude. At 80 km the temperature is the lowest in the atmosphere (average –90° C). Above this is the **thermosphere** in which the temperature again increases at higher altitudes. Human activity at present seems to have little direct impact on the outermost atmospheric layer.

SAQ 4

a) Tick mark (√) the true statements in the boxes given against each.

i) The composition of the atmosphere is constant till approximately 80 km of height. [ ]

ii) Aerosols are distributed uniformly throughout the atmosphere [ ]

iii) Aerosols originate as a result of forest fires only [ ]

b) Choose the correct term from each pair provided in parenthesis.

i) As we go higher up in the troposphere, the air temperature (decreases/increases).

ii) Jet plane pilots prefer to fly in the (mesosphere/stratosphere).

iii) In thermosphere the air temperature (increases/decreases) with altitude.

iv) Temperature is (lowest/highest) at 80 km altitude in the atmosphere.

2.4.3 Pressure Gradient

You know that air pressure is the weight of the atmosphere over a unit area of the earth's surface. The average air pressure at sea level is approximately 1 kilogram per square centimetre. At any point at sea level the air pressure is the same. We know that gravity which holds everything on earth's surface, also holds the atmospheric gases in an envelope around the earth. Gravity compresses the atmosphere on the earth's surface so that air pressure decreases with increasing altitude.

Weather forecasters on the TV and Radio usually report air pressure in mm i.e., in unit of length. This in fact refers to the height to which a column of mercury can rise in the barometer at a specific station at a given time. However, it is more appropriate to express pressure in **millibars** (mb). The average pressure at sea level is 1013.25 mb.

mm is a measure of one dimension height while pressure is weight/area and so a separate unit millibar was used. One millibar is equal to 100 Newton/square metre (N/m^2). Now-a-days the unit Pascal (Pa) is used to denote pressure one Pa = 1 N/m^2 Newton is unit of force. The force required to give a mass of 1 kg an acceleration of one metre per second.

Let us see what happens to the air pressure and density as we go higher up in the atmosphere. Air density which is the mass per unit volume also diminishes with altitude. Ninety-nine per cent of the atmosphere's mass lies between the earth's surface and an altitude of approximately 32 km. Approximately half of the atmosphere's mass lies between the surface of the earth and an altitude of 5.5 km. At this altitude the air pressure too remains only one-half of the pressure at sea level.

In most cases the reduction of pressure is not a limiting factor for the distribution of plants and animals at high altitudes. There are other adverse conditions like low temperature, lack of food, unsuitable soil etc. Many species of beetles have been found in the highest meadows of Himalayas. While, earthworms have been found up to the snowline in the Andes mountains. However, for warm blooded vertebrates reduced air pressure and density at high altitudes causes impairment in respiration.

The expansion and thinning of air accompanying the lower air pressure at high altitudes triggers physiological changes in human beings. For example, a person at high altitude may experience dizziness, headaches and shortness of breath, but gradually adjusts or acclimatises to the low oxygen levels. However, people cannot adjust to pressure at altitudes higher than approximately 5.5 km.

Relatively a slight change in the air pressure can trigger important changes in the weather. A large volume of air which is relatively uniform in terms of its temperature and water vapour content is called an air mass. As air masses move from one place to another, surface air pressure falls or rises causing changes in weather. As a general rule low pressure causes stormy weather and when air pressure rises the weather improves.

2.4.4 Global Air Circulation

The major wind systems of the earth result because large masses of air around the earth's equator are forced to rise from the bottom due to surface heating (recall section 2.3.1 equator gets maximum sunlight). Cold air from high altitudes rushes in to replace the void thus created. The warm air from the equator travels towards the poles where it descends and returns towards the equator along the surface of the earth. This system is shown in Figure 2.22 and it is influenced by two factors:

1) The heat retention of **airmasses** is not the same as for oceans. You already know that land cools as well as heats up more rapidly, and land masses are not distributed uniformly.

2) A force associated with the earth's rotation deflects the air flow in the northern hemisphere to the right and in the southern hemisphere to the left.

Let us now explain air movements at tropical latitudes. The surface air that rushes to fill the equatorial void from the north is deflected to the right and becomes the **north-east trade wind.** It meets similar wind the **south-east trade wind** coming from the south that was deflected to the left. But less land is present in the southern hemisphere to obstruct the path of the south-east trade wind so the trade winds do not meet at the equatorial plane but somewhat to the north. This is called the **inter-tropical convergence** zone, a zone of heavy rainfal..

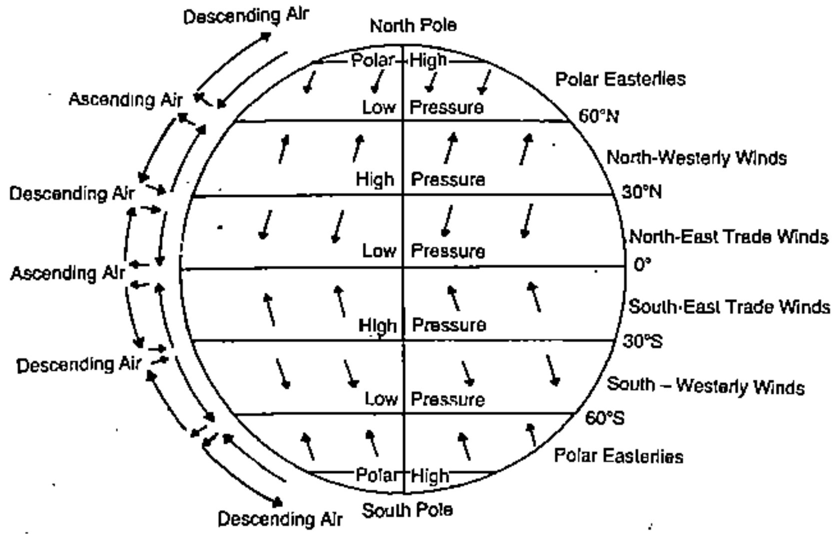


Fig 2.22 : Global wind patterns. Wind is the movement of air caused by temperature differences and rotation of earth.

The prevailing air currents also affect the distribution of different ecosystems. At the equator for example, the hot air gives up moisture, rises and undergoes adiabatic changes and the resulting rainfall supports luxuriant forests. The drier air descends at about 30° latitude, therefore, major desert regions of the earth like Sahara, and American south-west and the Thar desert in India are formed in this belt. The air again becomes warm, picks up moisture and ascends at 60° latitudes and then travels polewards. Almost no rainfall accompanies its descent in the planar regions.

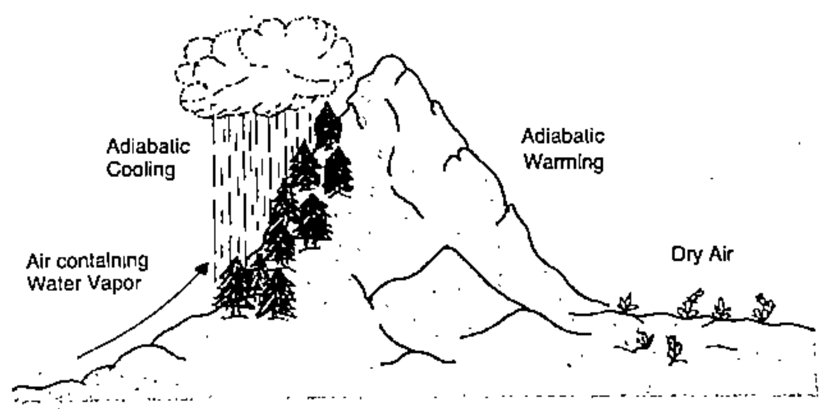


Fig 2.23 : Changes in air temperature. As air rises it expands which causes it to cool. Cool air holds less moisture so clouds form. Thus it rains heavily on the windward side of the mountain. As the air descends on the other side of the mountain it becomes compact and tends to pick up moisture from its surroundings. Therefore some of the wettest places on earth are on the windward side of mountains and some of the driest places exist on the other side of those mountains.

Monsoon

You have read in section 2.4 that coastal areas do not experience much difference in their climate but striking seasonal changes are seen on the large land masses like Asia. Here strong high pressure regions over Siberia in winter cause winds to blow out of the continent towards the coast. But we in India are protected from these cold winds by the Himalayan range of mountains. For this reason we do not experience a severe winter. In summer, however, strong low pressure regions over Siberia draw great quantities of moist air over the land from the oceans producing the great summer monsoon characteristic of south-eastern region countries. Again because of the Himalayan mountain range we get the heavy monsoon rains as the m isture-laden winds strike against them.

Inversion

We know that atmosphere is heated from below and warm air rises, but air can be prevented from rising by a condition known as inversion. An inversion refers to a situation characterised by warm air floating over cool air. One of the causes of inversion is the flow of winds across vast expanse of cold oceans. Here the moving air is cooled from the bottom instead of being heated. These winds are comparatively dry even though they cross oceans. Because of the low temperature of the surface winds the land under such an inversion can become desert. The Galapago's Islands which Darwin visited are desert because they lie under an inversion zone, even though they are at the equator, as they happen to be in the path of stable inverted air moving towards the intertropical convergence. Local inversions assume importance since pollution levels increase during such conditions. Because of low wind velocities, the air above the inversion is not able to mix with the low level air, making it stagnant. This is common during low temperature conditions; dew, frost or fog often forms. The ground thus remains cool and the trapped pollutants are unable to escape.

SAQ 5

a) Why do mountaineers take oxygen supply along if they have to climb higher than 5.5 kilometres?

....

....

b) Identify statements as true or false and explain why?

i) A force associated with the earth's rotation causes air masses to flow towards the right in the northern hemisphere and left in the southern hemisphere. [ ]

ii) North east trade winds and south east trade winds meet exactly at the equator to form the intertropical convergence zone. [ ]

iii) Most of the world's deserts are situated at 60° latitudes. [ ]

2.4.5 Wind

Strong current of air is known as wind, it is an important ecological factor as it affects plant life mainly on flat plains, along sea coasts and at high altitudes in mountains. It directly affects transpiration, causes mechanical damage and is an important agent of dispersal of pollens, seeds and fruits.

Plants in particular have a number of physical as well as anatomical and physiological adaptation to windy conditions. For example, high velocity winds may cause the breaking of branches of trees or even uproot the whole tree. In forests where there are trees of different heights the wind velocity is reduced by about 80 per cent, and damage is much less. Such trees in forests serve as natural **windbreaks** or shelter belts. A windbreak is a densely planted strip of tall trees usually between 15 m and 60 m wide, oriented at right angles to the direction of the wind so as to reduce the wind velocity near the ground. Windbreaks reduce the rate of transpiration, evaporation, abrasion, breakage, and soil erosion by wind. Often special trees and shrubs are planted around fields and orchards to provide protection against the damaging effects of strong winds.

In windy areas such as high mountains and coastal regions the canopy of trees becomes abnormal and becomes flag type or one sided (see Fig 2.24). Branches fail to develop on a windward side but develop towards the leeward side due to the protection provided by the stem.

Adaptations to high wind velocity

The mechanical force of the wind and the grinding action of sand, dust, snow and other materials driven by it cause the plants to adapt themselves if they have to survive.

Wind alone can influence the growth of plants in exposed regions. Trunks of trees often bend along the direction of the wind to prevent damage by high velocity winds on exposed mountain sides (Fig 2.24).

In the deserts where the strong winds carry fine grit and sand, only plants like the cacti which have a thick cuticle can protect themselves from the abrasive action of the sand.

If you have seen a coconut palm or any other palm tree, you would have noticed that the leaves are serrated and torn. This is again an adaptation to withstand the high wind velocity so that the leaves do not get broken and damaged.

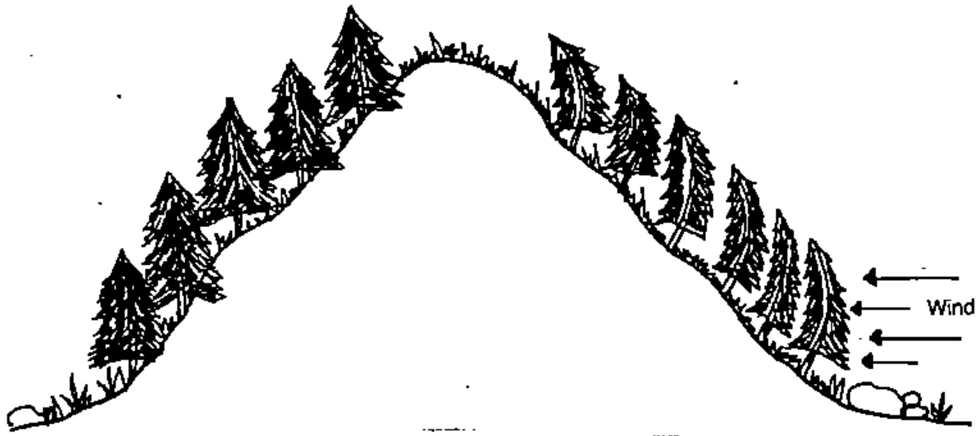


Fig 2.24 Pine trees bend almost at an angle on the mountains of Gulmarg to adapt to the high velocity winds.

In the high mountain ranges of the northern latitudes, the plants species often form cushions and mats that can withstand buffeting from strong winds that sweep the mountains. For instance, *Rhododendron* a kind of plant is found in the plains as well as high up in the Himalayas. In the plains it grows into a shrub while at high altitudes it is stunted and almost creeps along the ground.

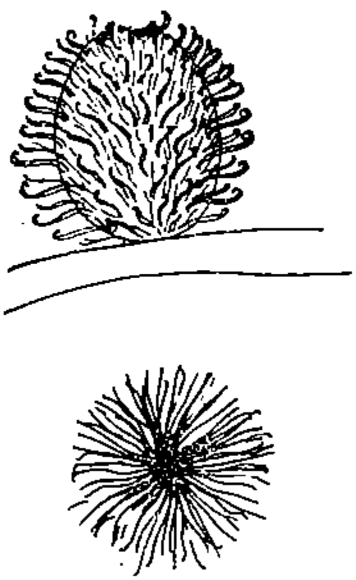


Fig 2.25 : Fruits (a) and seeds (b) of plants adapt for distance transportation by wind.

Wind as a medium for Dispersal

Many microorganisms, fungal spores and bacteria are freely transported over long distances even by moderate winds. In wind pollinated plants, the amount of pollen grains is relatively large because a large fraction of it may be wasted. Pollen grains in some genera like *Pinus* are specially adapted to float in air due to the presence of air bladders. Many plants produce extremely small seeds, others develop winglike structures or fine silky hairs that help them to float in air (Fig 2.25).

Wind is a universal agent for the dispersal of fruits and seeds which helps in better establishment of seedlings resulting in greater success of survival and healthy growth by avoiding competition.

Dispersal of pollutants

Wind determines the extent of initial dilution of pollutants, emission, direction and rate of dispersal. The more widely and rapidly they are dispersed, lesser will be their impact on the environment. If the wind speed is high, pollutant concentrations are likely to be relatively low, while low wind or absence of wind builds up high concentration of pollutants.

SAQ 6

a) Why do only plants adapt to windy conditions and not animals?

....

b) Trees of different heights are planted to shelter orchards or plantations. They are known as ....

c) Wind helps in wide dispersal of seeds and fruits leading to .... and .... growth.

2.5 SUMMARY

In this unit we have discussed the physical environmental factors — light, temperature and wind that affect survival and distribution of terrestrial plants and animals. You have learnt that:

- Electromagnetic spectrum has many kinds of radiation which differ in wavelength, frequency and energy. The radiations affecting various photobiological phenomena have wavelength in the range of 300 nm to about 900 nm.

- The global distribution of solar radiation and its spectra distribution reaching on the earth surface is affected by atmospheric conditions and vegetation. Quantity, quality, and duration of solar radiation can be measured by instruments.
- Latitudinal, altitudinal and periodic changes in light along with wind circulation affect the global temperature. The atmosphere is divided into horizontal layers on the basis of variation in temperature.
- Air pressure and density fall rapidly with altitude, and thinning of air with height triggers physiological changes in organisms.
- The atmospheric wind circulation causes redistribution of heat from the equator towards the poles.
- Organisms function at the limit of climatic tolerance. In tundras and desert regions or at places where there are larger fluctuation in temperature, plants and animals have behavioural, physiological and structural adaptations that enable them to survive extremes of temperature. Plants in regions of high wind velocity develop various structural adaptations to enable them to survive under such conditions.

2.6 TERMINAL QUESTIONS

1) a) Write the following electromagnetic radiations in increasing order of their energy and wavelength, visible, ultraviolet, X-rays, gamma rays and radiowaves.

....

....

b) Convert the following into centimetres, metres: 200 mm, 640 μm, 4,000 A^0

....

....

....

c) Calculate the energy per quantum of radiation of wavelength 1,000 nm in calories, joules and ergs.

....

2) Why do astronauts see earthshine from the space?

....

....

3) If you plan to spend your summer vacations in Argentina, what types of clothes would you carry?

....

....

4) Why gradients of vegetation are similar with increasing altitude and increasing latitude?

....

....

....

5) Explain the reason for decrease in temperature when the air rises up.

....

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....

6) What is windbreak or shelter belt?

....

....

....

....

2.7 ANSWERS

Self-assessment Questions

1) a) $\upsilon = \frac{C}{\lambda} = \frac{3 \times 10^{10}}{2 \times 10^5}$

$E = h\upsilon, 6.6 \times 10^{-34} \times \frac{3 \times 10^{10}}{2 \times 10^5} = 9.93 \times 10^{-19}$ joules.

Divide this by 4.18 you will get 2.37×10^{-19} calories.

[Velocity of light and wavelength should be taken in same units.]

b) i) c, ii) a, iii) b, iv) d

2) a) Right words :

i) reflects, ii) more, iii) reaching the top of atmosphere, iv) either less, obliquely or more vertically, v) less, vi) ultraviolet, vii) visible

b) i) a, ii) b, iii) c, iv) d

c) i) b, ii) c, iii) a, vi) d

3) a) i) c, ii) c, iii) a, iv) a, v) b

b) As the air rises up it expands and pushes the neighbouring molecules. In this process the molecules lose their kinetic energy and hence cool down.

c) i) daylight, ii) either greater, lower or smaller, higher

4) a) iii)

b) i) decreases, ii) stratosphere, iii) increases, iv) lowest

5) a) Above 5.5 km due to reduced air pressure and density the oxygen level is low.

b) i) True

ii) The zone is somewhat to the north because less land is present in the southern hemisphere to obstruct the path of the south-east trade wind.

iii) F, after leaving the moisture near the equator the dry air descend at about 30° altitude not at 60° altitude.

6) a) Because plants cannot move

b) Wind break or shelter belts

c) Better success of survival, healthy

Terminal Questions

1) a) Energy — Radiowaves < visible < ultraviolet < X-rays < gamma rays
For Wavelengths — reverse the above order

b) $200 \times 10^{-9} = 2 \times 10^{-7}$ m $= 2 \times 10^{-5}$ cm

$640 \times 10^{-6} = 6.4 \times 10^{-4}$ m $= 6.4 \times 10^{-2}$ cm

$4000 \times 10^{-10} = 4 \times 10^{-7}$ m $= 4 \times 10^{-5}$ cm

c) 1.99×10^{-19} J $= 4.75 \times 10^{-20}$ cal $= 1.99 \times 10^{-12}$ ergs.

2) Earth and its atmosphere reflect or scatter 30% of the total incoming radiation and hence astronauts find earthshine.

3) Argentina is in the southern hemisphere, therefore, you will need winter clothes.

4) There is decrease in temperature with increasing altitude and increasing latitude. Thus the influence of temperature on distribution of species is same.

5) As the air rises up it expands and pushes the neighbouring molecules. In this process the molecules loose kinetic energy and hence cool down.

6) In order to reduce the velocity of wind near the ground, tall trees are closely planted at right angle to the direction of the wind.

UNIT 3 ENVIRONMENTAL COMPONENTS: 2. WATER

Structure

3.1 INTRODUCTION

In unit 2, you have studied about light, heat and atmosphere. In this unit, we propose to discuss water which is another abiotic component of environment. In unit 4, we will deal with another important abiotic component, the soil. These three units are designed to show mutual interactions between various abiotic components. Their study will help you to understand the interaction between the abiotic and biotic components. Water covers about three-quarters of the earth surface and constitutes about 70% of the total body weight of the living organisms. Consequently, water has been termed as elixir of life.

This unit will first deal with the chemical structure and properties of water molecule which make it so unique and their relevance to the living systems. The next section deals with composition of waters in streams, lakes, estuaries and oceans. Distribution of water on the earth surface and the hydrological cycle i.e. movement of water from ocean to the land and back are discussed in a separate section. In the end, we shall look at the adaptations in plants and animals which enable them to survive under conditions of scarcity or over-abundance of water.

A study of this unit requires that you should be familiar with the basic concepts of atom, ion, light and heat.

Objectives

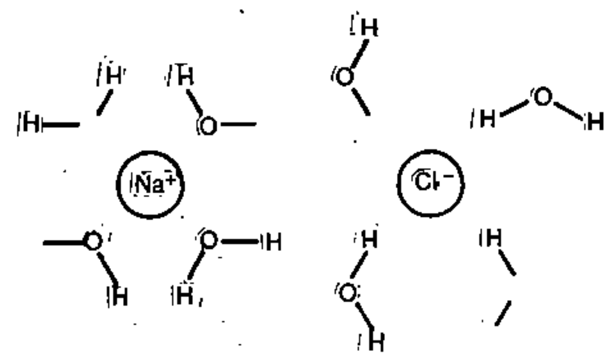
After going through this unit, you should be able to:

- define and use in the proper context the following terms: surface tension, precipitation, fresh water, saline water, brackish water, hydrological cycle, evaporation, evapotranspiration
- distinguish between fresh, saline and brackish water and indicate how living organisms are adapted to these conditions
- outline the hydrological cycle and distribution of water on the earth
- indicate the ecological adaptations in plants and animals to scarcity and over-abundance of water.

3.2 STRUCTURE OF WATER

It may interest you to know that water is a universal solvent and is a major constituent of all living organisms. Earth is the only planet where water exists in all its three phases. Availability and absence of water influence the distribution and abundance of plants, animals as well as human societies. The uniqueness of water is due to its structure and properties which are discussed in the following lines.

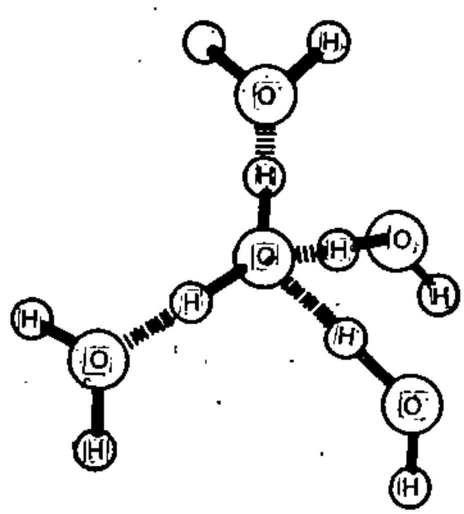
A water molecule (H_2O) consists of two atoms of hydrogen and one oxygen. The hydrogen atoms share their electrons with the oxygen atom. The shared electrons become asymmetrically distributed. The negatively charged electrons are attracted more towards the oxygen nucleus which is more positively charged (8+) than a hydrogen nucleus (1+). Consequently, the hydrogen nuclei develop a small (delta) positive charge and the oxygen nucleus a small (delta) negative charge. Such a molecule is known as a polar molecule (Fig 3.1). Remember that overall a water molecule is neutral since the number of electrons is equal to the number of protons.



Because of the polar nature of water molecules, they will cluster around ions and other polar molecules.

Fig 3.1: A water molecule.

The polar nature of H_2O molecule leads to the formation of a weak hydrogen bond between two adjacent molecules. Many water molecules join to form a lattice structure (Fig 3.2) which is responsible for the cohesive nature of water and many of its unusual properties like high surface tension, specific heat and heat of vaporisation.



Molecules of water join together transiently in a hydrogen – bonded lattice. Even at 37°C, 15% of the water molecules are joined to 4 others in a short – lived assembly known as a "flickering cluster"

Fig 3.2: Water structure.

3.3 PROPERTIES OF WATER

In this section we will discuss the characteristics of water that are favourable to biological systems. Most of the physical properties of water relevant to the living systems are due to its hydrogen bonding and lattice structure.

3.3.1 Cohesiveness and Surface Tension

Water flows freely, yet water molecules do not break apart. They cling together particularly to polar surfaces. Therefore, water can fill a tubular vessel and still flow so that dissolved and suspended molecules are evenly dispersed throughout the water body. For these reasons, water is an excellent transport medium both outside and within living organisms.

The surface tension of water is very high as compared to other liquids except mercury. The role of surface tension is obvious. Certain objects such as pollen and dust float at the surface of water even though they are denser, due to its high surface tension. For similar reasons significant amount of water is retained by the soil through capillary attraction for plant growth.

3.3.2 Transparency

Water is a transparent medium which enables penetration of sunlight to a considerable depth. Different wavelengths of light are absorbed by water at different depths. The long wave heat radiations are almost completely absorbed near the surface. Short wave radiations penetrate to a relatively greater depth. The zone upto which light rays penetrate in a water body is called photic zone and below this lies a zone of complete darkness called **aphotic zone.**

3.3.3 Thermal Properties

The range of temperature variation in the aquatic environment is smaller in comparison to air. This means the rate of change of temperature is slower in the aquatic environment than in air. This is because of unique thermal properties that minimise temperature changes. The temperature of liquid water rises and falls relatively slowly as compared to most other liquids. One calorie of heat energy is required to raise the temperature of one gram of water by one degree Celsius. This is about twice the amount of energy required by other covalently bonded liquids to bring about a similar temperature change. The many hydrogen bonds that link water molecules together absorb heat to a considerable extent without any corresponding change in temperature. Temperature of water drops slowly on losing heat.

3.3.4 Specific Heat

The heating and cooling of the water is relatively slow as compared to most of the other known liquids. This is mainly because the water molecules are linked with each other by hydrogen bonds. If the water is to evaporate, the hydrogen bonds will have to be broken and this requires energy. The specific heat of water is 4.18 joule (1 calorie per gram per degree centigrade). This means that it takes 4.18 joule of energy to heat one gram of water from 4°C to 5°C.

3.3.5 Solubility of Gases

Most gases which are important for biological processes dissolve readily and specially in water. The solubility of any gas in water generally varies between zero and a theoretical maximum saturation level. The latter represents the amount of gas that dissolves in water when the atmosphere and water are in equilibrium with one another.

The oxygen readily dissolves in waters. The amount of dissolved oxygen varies with depth in a water body. Dissolved oxygen is needed by living organisms for respiration and also for the decomposition of dead organic matter in a water body.

Aquatic vegetation and phytoplankton require carbon dioxide for photosynthesis. The carbon dioxide in aquatic environment is contributed by respiration of aquatic organism and decomposition. Carbon dioxide can directly diffuse from the atmosphere into the water and it readily dissolves to form carbonic acid (H_2Co_3) which effects the pH of the water. It is also present in fresh water as carbonates and bicarbonates of calcium, magnesium and other minerals. Nitrogen, hydrogen, sulphur dioxide and ammonia are some of the other gases which dissolve in water readily.

3.3.6 Phases of Water

The state of water can be changed from gaseous to liquid and liquid to solid and vice versa by the addition or removal of heat energy. To convert one gram of liquid to ice requires the removal of 80 calories of heat energy. To convert one gram of water into steam requires an input of 540 calories of heat energy (Fig 3.3). Change of liquid water into steam involves the breaking of hydrogen bonds which normally join the adjacent water molecule.

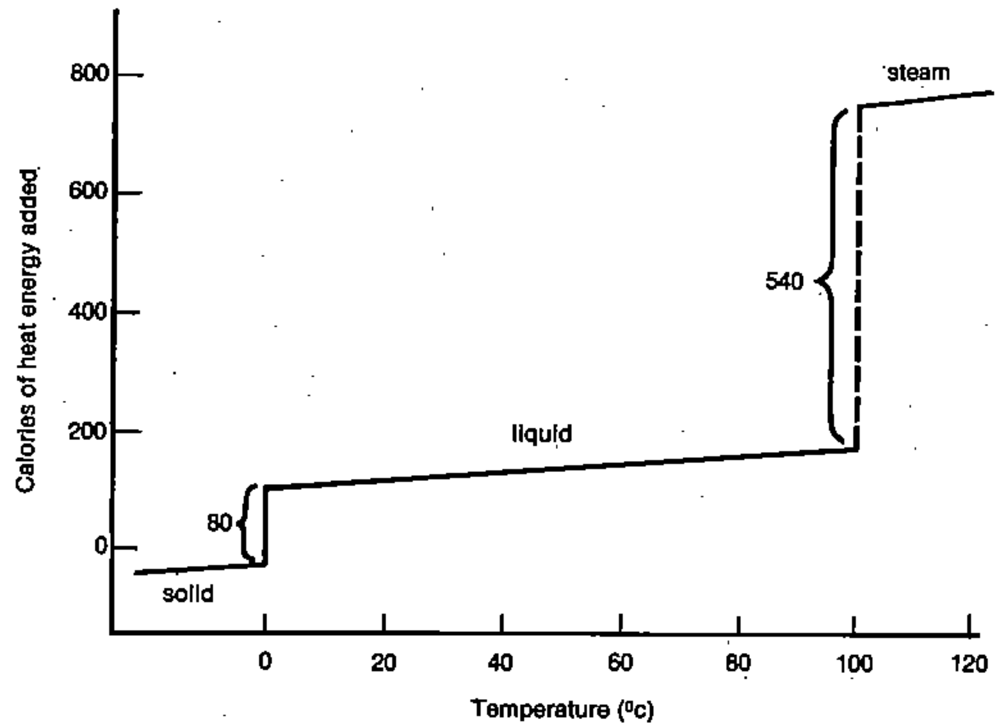


Fig 3.3: A gram of water is solid, liquid or vapour, depending on the number of calories of heat energy added.

Accordingly, a very large amount of heat energy is needed for the evaporation of water. This property of water is extremely helpful in moderating the earth's temperature and making it suitable for origin and continuance of life.

3.3.7 Density of Water in Relation to Temperature

On cooling, water molecules come closer which makes water dense. It is most dense at 4°C (Fig 3.4) but it is still a liquid and water molecules move freely. However, when temperature drops below 4°C the movement of water molecules ceases and the bonds between molecules

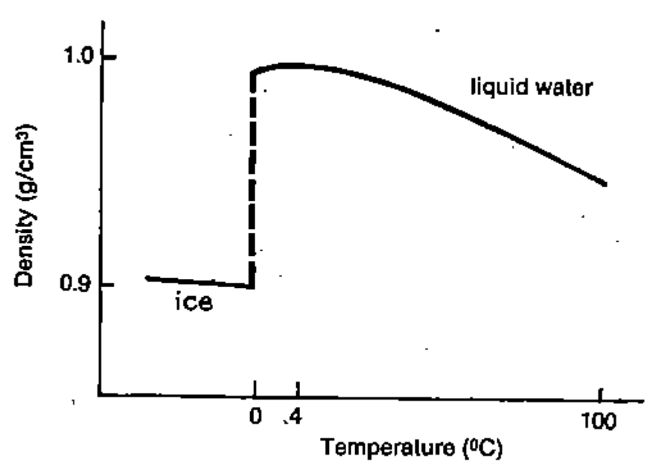


Fig 3.4: Water freezes at 0°C, boils at 100°C and is a liquid between these two extremes. Water is most dense at 4°C, therefore ice floats on liquid water.

become relatively less rigid and more open, this traps the air molecules in pockets formed between water moieties which make the ice lighter than water. It is for this reason that ice floats above the liquid water. Water always freezes in a top down manner. Formation of an ice sheet on the surface of a water body acts as an insulator and prevents freezing of the water below. This is important for the survival of aquatic organisms in areas where surface water freezes during the winter period.

SAQ 1

a) Complete the following statements.

b) Compare your answers with those given at the end of the unit.

i) Water requires one calorie of heat energy to raise the temperature of one gram of water by ....

ii) If water is to evaporate, the hydrogen bonds will have to be broken and thus requires ....

iii) Water helps animals maintain their normal internal ....

iv) The property of changing water to steam helps moderate the earth's temperature so that it is suitable for the origin and ....

v) After surface water freezes, the ice acts as an insulator to prevent .... water from freezing.

3.4 GLOBAL DISTRIBUTION OF WATER

After studying the different properties of water, you would like to know about the distribution of water on our planet (Fig 3.5).

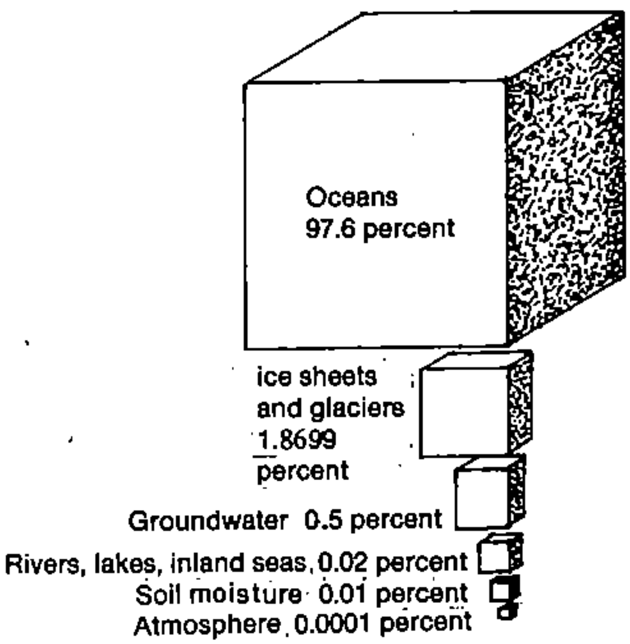


Fig 3.5: Free water storage on the earth. The majority of the world's supply of water is in the oceans. The readily available fresh water is found as ground water in porous rock beds. Although ice sheets and glaciers hold a great deal of fresh water, their turnover is too slow to be usable.

The water that precipitates in the form of rain is the primary source of fresh water on our planet. Glaciers, rivers, lakes, springs and wells are secondary sources and all of them are fed by rain or snow. These are only different forms of rain water and in the absence of rain they cannot last long.

Most of the rainfall in India takes place under the influence of South-West monsoon between June to September except in Tamil Nadu where it is under the influence of North-East monsoon during October and November. The rainfall in India shows great variation, unequal seasonal distribution, still more unequal geographical distribution and the frequent departures from the normal. A careful study of the rainfall map of India will show the marked disparity in the amount of rainfall received in different parts of the country. (Fig 3.6).

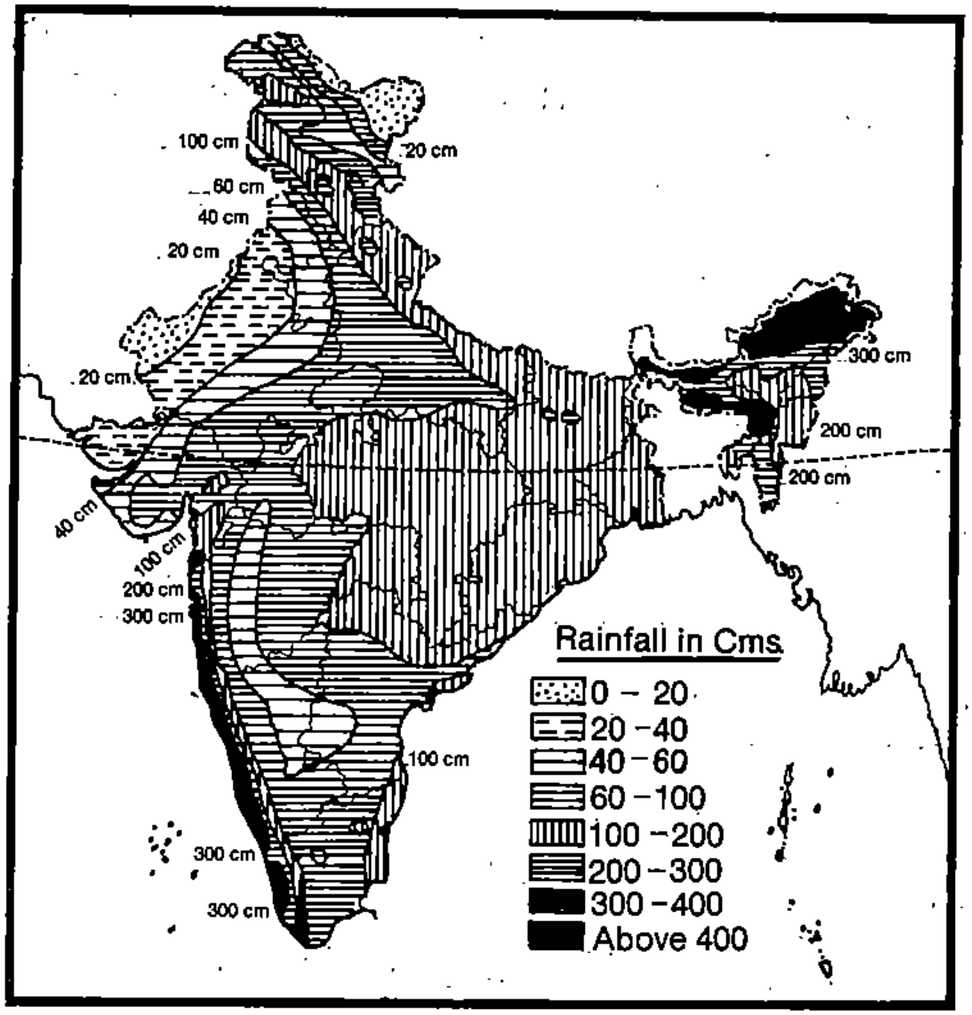


Fig 3.6: Rainfall map of India.

In our country Cherapunji — a place in Meghalaya State, gets a bumper annual rainfall of 11 metres while Jaisalmer gets a measly 0.2 metre per year. This is their usual share and they have learnt to live with it.

The deserts have 0.25 metre or less rain per year, grasslands and open woodlands get 0.25-0.75 metre per year, dry forests get about 0.75-1.25 metres per year and wet forests get over 1.25 metres per year. Some regions of our country suffer from floods almost every year due to heavy rainfall. Failure or delay in the monsoon causes drought. Sometimes both flood and drought are experienced simultaneously in different parts of the country. Occasionally flood and drought are experienced in the same region one after the other. We have no control over rainfall pattern which is the basic cause of flood and drought. We do not know how to prevent deluge or rainlessness.

The total quantity of water on our planet is fixed and its distribution is highly uneven. Almost 95% of the total water present on this earth is chemically bound into rocks and does not cycle. Of the remainder, about 97.3% is in the ocean, about 2.1% exists as ice in the polar caps and permanent glaciers and the rest is fresh water present in the form of atmospheric water vapour, ground water, and inland surface water. Thus, less than one per cent of the total fresh water participates in the hydrological cycle.

3.4.1 Ground Water

Ground water represents a major subterranean reservoir of fresh water. In general, it is not tapped by plants as it is too deep and does not suffer from loss due to evaporation. It slowly flows through the underground porous substratum from one place to another under the influence of gravity. Its flow may vary from a few millimetres to as much as a metre or so per day. At some places ground water reappears at the surface in the form of a spring. The zone of sub-surface formation that provides water to wells is called an **aquifer**. Some aquifers exhibit an unusually high hydrostatic pressure to force water upto the soil surface when a well is dug. Such a well from which water is pushed automatically to the soil surface is called an **artesian well**. In areas devoid of lakes and rivers ground water is the most important source of water. The total exploitable potential of ground water amounts to 42.3×10^{10} cubic metres in India. A quarter of it is already being used in the country for irrigation, industries and domestic uses. In many places ground water withdrawals have already exceeded the recharge rates causing serious problems.

The total amount of fresh water is more than enough to meet the present and future needs of mankind. But due to its uneven distribution, wide seasonal as well as yearly fluctuations, water shortage is a chronic problem in many parts of the world.

A close examination of the global distribution of water resources reveals three important features. First, much of the water is stored on more or less permanent basis. The largest quantity of water is in the oceans. The Arctic and Antarctic ice masses, glaciers and lakes are also major water reservoirs not available to man. Second, some of the Earth's water is in constant flux represented by snow, rainfall, cloud drift and river flow towards the sea. Third, the water on land is very unevenly distributed.

3.4.2 Water Cycle (Hydrological Cycle)

The movement of water on the earth is continuous and forms many complex inter-related loops (Fig 3.7). Cycling of water involves atmosphere, sea, earth and the entire living biota. The circulation of water is highly dynamic and global in extent. However, for the sake of convenience it is divided into different categories:

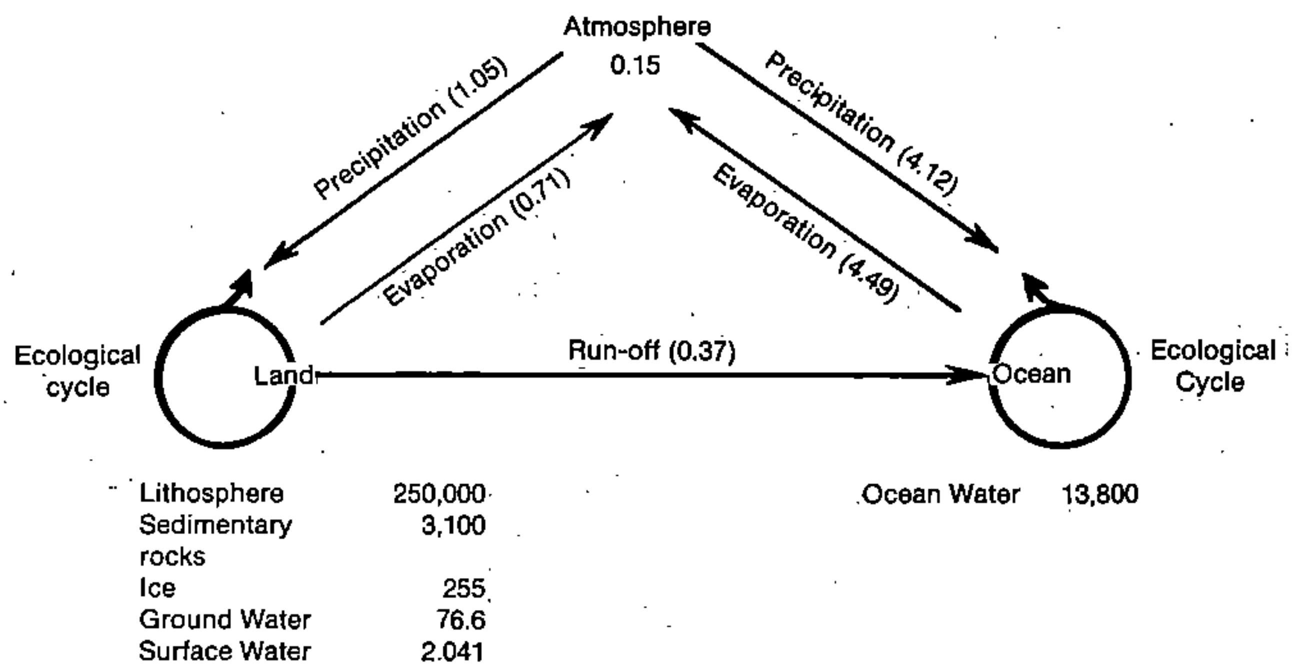


Fig 3.7: The general pattern of the hydrological cycle and the distribution of water in 10^{17} Kg, amounts in parentheses are annual rates.

i) **Precipitation** literally means falling from a height. In case of water, precipitation includes all forms in which atmospheric moisture descends to earth; rain, snow, hail, sleet and dew. The moisture that enters the atmosphere by the vaporisation of water condenses either into liquid (rain) or solid (snow, hail and sleet) before it can fall (Fig 3.8). Water returns to the land and the sea from the atmosphere by means of condensation, deposition and precipitation. **Condensation** is defined as the process by which water changes from vapour phase to a liquid state (in form of dew droplets). **Deposition** is the process by which water changes directly from a vapour into a solid (ice crystals) phase. In the atmosphere tiny droplets of water and ice crystals produced through condensation and deposition form clouds. You have to keep in mind that vaporisation absorbs energy (evaporation of sweat cools your body by using up excess body heat.) The energy used up in vaporisation is released when the water vapour condenses. The major amount of water on earth, is received as rainfall.

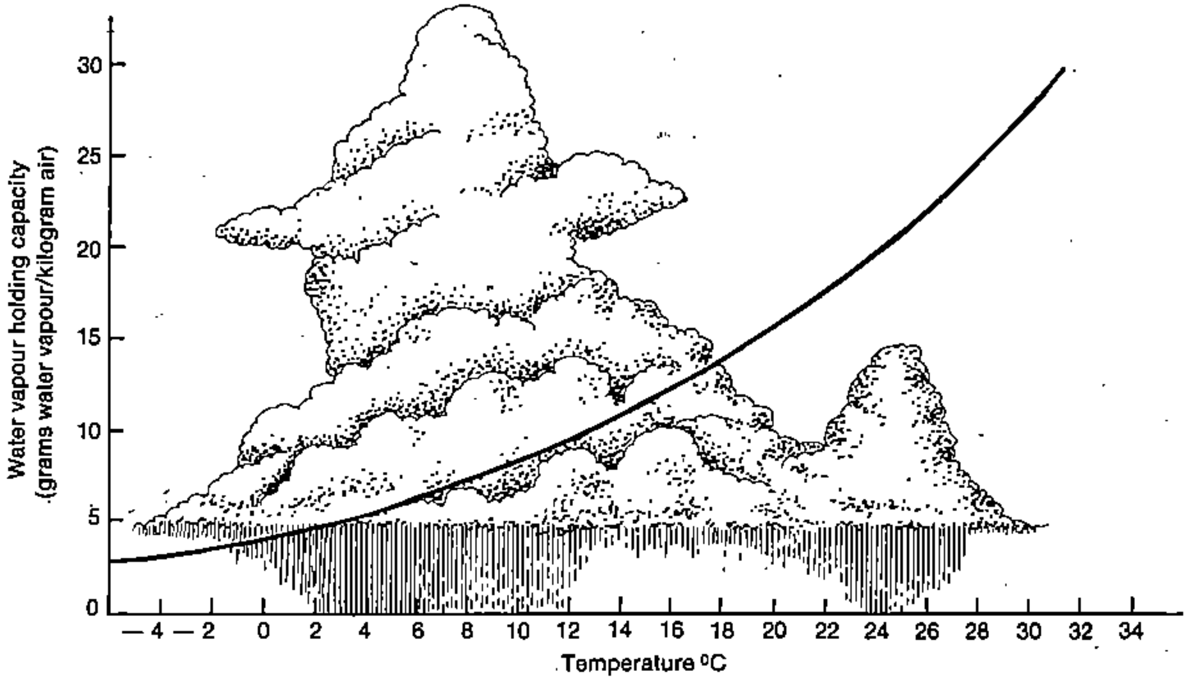


Fig 3.8: Relative humidity for a given parcel of moisture laden air varies with temperature. If the air is cooled, the relative humidity increases. When the relative humidity exceeds 100%, precipitation will occur.

The water cycle in nature is sustained by energy from the sun. Solar energy evaporates water from the sea and the land. Water vapours condense in the atmosphere to form clouds which are transported to long distance by wind currents. Rainfall and melted snow replenish water in rivers, which carry it back to the sea.

ii) **Run off:** Some of the rainfall is soaked into the soil and excess water flows over the land surface along the natural slope of the area. Run off is the main source of water for lakes and rivers which ultimately drain into the sea. Soil characteristics and the topography such as smoothness and steepness of the slope influence the rate and the magnitude of run off.

The flowing water acts as an agent of soil erosion and weathering of the underlying rock. Excessive run off during the rainy season causes flood in many parts of our country.

iii) **Sublimation** is the process by which solid water changes directly to vapour phase without passing through the intervening liquid phase. The gradual disappearance of flakes of ice during periods when the temperature remains well below freezing is an example of sublimation.

iv) **Evaporation** is the process by which liquid water changes into vapour at ambient temperature. Water evaporates from all aquatic bodies as well as from wet surfaces. Evaporation from the ocean surface is by far the largest source of atmospheric water vapour.

v) **Transpiration** refers to the loss of water in vapour form from plant leaves. On land, transpiration is considerable. For example, the loss of water through transpiration alone by one hectare (2.5 acres) of corn approximately amounts to 35,000 litres (8800 gallons) of water each day. Water loss from a vegetated area takes place both by evaporation and transpiration and it is referred to as 'evapotranspiration'.

After learning the cycling of water in nature you would like to know about the different types of water found on the earth.

3.4.3 Fresh Water

Water, a universal solvent, invariably contains many soluble salts. In fresh water the total salt content remains under 15 per cent. Different types of soluble salts released by weathering of rocks, soil erosion and decay of organic matter, readily dissolve in water. Dissolved salts are substances which have particular significance for floating aquatic vegetation and phytoplankton, since these organisms do not depend on the substratum for the supply of nutrients. Salts of nitrogen, phosphorus and silicon are most important substances found dissolved in fresh water. Nitrates, nitrites and ammonium salts are essential nutrients for plants. Dissolved silicates in the water are readily utilised by diatoms and sponges in the construction of their body structures e.g. shells in case of diatoms and spicules in case of sponges.

Many other elements like calcium, magnesium, manganese, iron, sodium, potassium, sulphur and zinc are found dissolved in water and influence the aquatic biota variously. Iron being an essential nutrient exists as ferrous oxide or ferrous sulphide in different fresh water bodies. Its availability is greatly modified by the pH of medium. Calcium is an essential element for plants as well as for animals. External coverings of arthopods and shells of molluscs and tubes of some worms need calcium carbonate.

3.4.4 Brackish Water

The content of dissolved salts in brackish water is higher than the fresh water and ranges between 0.5 to 35%. These waters of intermediate salinity range are distinct from fresh or marine waters. In estuary which represents the tail end of a river, mixing of fresh water with sea water results in brackish water. The salinity in an estuary increases from upper middle to lower reaches and at the mouth of the estuary the salinity is nearly equal to that of the sea.

3.4.5 Marine Water

The sea water is highly salty. The average salinity of sea water remains almost constant at 35 parts of salt per 1000 parts of water by weight and written as 35%. The average salt composition of the sea water is given in Table 3.1. Some salt lakes may also have salinity between 25% to 35%. The biotic activity in such habitats is greatly restricted.

The absence of many fresh water animals and plants from the marine environment is largely due to their inability to tolerate the high salinity of the sea water. Insects are mostly absent from marine environment except **Halobates** and shore collembolans like **Isotoma** and **Sminthurus**.

Table 3.1.
Composition of the sea water

Salt	Weight percent
NaCl	78.03
NaF	0.01
KCl	2.11
$MgCl_2$	9.21
$MgBr_2$	0.25
$MgSO_4$	6.53
$CaSO_4$	3.48
$SrSO_4$	0.05
$CaCO_3$	0.33
	100.00

SAQ 2

i) What do you mean by the salinity of fresh water?

....

....

....

ii) What is an estuary?

....

....

....

iii) What are the components which make the ocean water saline?

....

....

SAQ 3

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

i) The water on land is very evenly distributed. [ ]

ii) Living organisms, atmosphere and earth maintain between them a circulation of water and moisture, which is referred to as water cycle or hydrological cycle. [ ]

iii) Most water vapour is produced by evaporation of liquid water from the surface of the leaves. [ ]

iv) The process of vaporisation of ice without melting first is called sublimation. [ ]

v) The energy for driving the water cycle and for ensuring a constant supply of fresh water on land comes from the wind. [ ]

vi) All the vaporised water form clouds which move by winds, may pass over land where they are cooled enough to precipitate the water or snow. [ ]

vii) Movement of water in plants from roots to leaves is known as transpiration. [ ]

3.5 WATER STRESS AND ADAPTATIONS

Water is seldom available in uniform quantities in all places or even at any given site throughout the year. This is particularly so in our country due to wide geographical variation in rainfall pattern and monsoon climate.

Both excess and scarcity of water create severe problems for the society. Plants and animals develop various morphological, structural and functional adaptations to survive under conditions of over-abundance and scarcity of water.

3.5.1 Drought

Drought refers to a condition of water shortage and it can result from many reasons. Frequently less than the normal rainfall is a common cause of drought. Less than 75% of normal rainfall may be defined as drought. We may, however, bear in mind that not only the total rainfall but its distribution in time is vitally important for crops. Small deficit (or surplus) in rain is not necessarily directly related to agricultural productivity. A severe drought reduces stream flow and recharging of aquifer. This results in lowering of water table, loss of agricultural crops, wild life and aquatic life. Water level in lakes, streams and reservoirs drops due to failure of rains. As a result crop yield and fodder production suffer adversely resulting in food scarcity and human discomfort, and stress to livestock. The incidence of forest fire increases and overall conditions become difficult.

Due to the pressure of growing population over-exploitation of water resources has become a universal feature. Consumption of fresh water is due to rapidly growing urbanisation, industrialisation and mechanised agriculture which leads to over-exploitation of water resources. Over-exploitation of fresh water resources can create severe limitation to growth and development. Excessive withdrawal of ground water in coastal areas of Gujarat has resulted in salt water intrusion into the aquifers (Fig 3.9). Consequently, the ground water has become unfit for human consumption and agriculture on account of high salinity. Ponds, bogs and streams are sites where ground water appears at the land surface. Excessive withdrawal of ground water and overdrawing of ground water lower the water-table as well as the level of water in lakes and streams and may completely dry them up.

3.5.2 Water Logging

Over saturation of soil with water is called water logging. If for any reason, the water-table rises close to the ground surface it is bad for plants and soil fertility. Under water-logged conditions the air in the soil pores is replaced by water creating anaerobic conditions in the soil. Plant roots and aerobic soil biota will perish in oxygen deficient conditions and soil fertility will be lost.

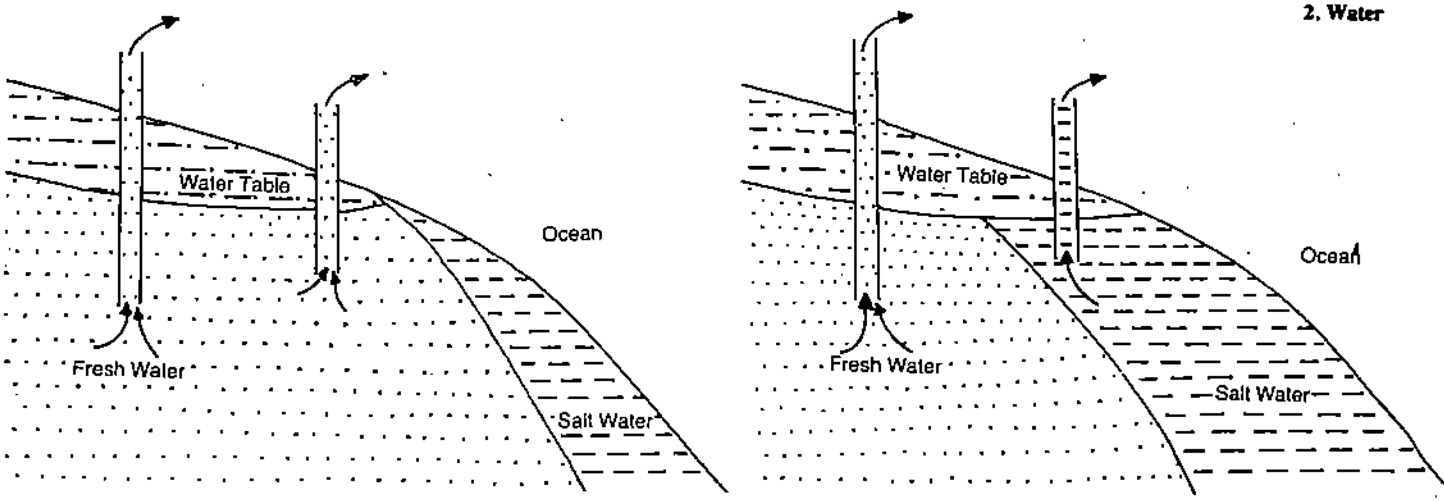


Fig 3.9: Salt water intrusion. The figure illustrates how salt water can intrude upon fresh ground water. When this occurs, the ground water becomes unusable for human consumption and for many industrial processes.

Rising of water-table upto the root zone affects plant growth adversely. When the water-table is near or just below the root zone, water rises upto the soil surface through capillary action. Water evaporates from the soil leaving behind the dissolved salts at the surface soil making it saline (Fig 3.10). Unless the salts are somehow washed away or washed down, the soil remains too saline to grow crops. It is important to prevent excessive irrigation and provide appropriate drainage facilities to prevent rising of water-table.

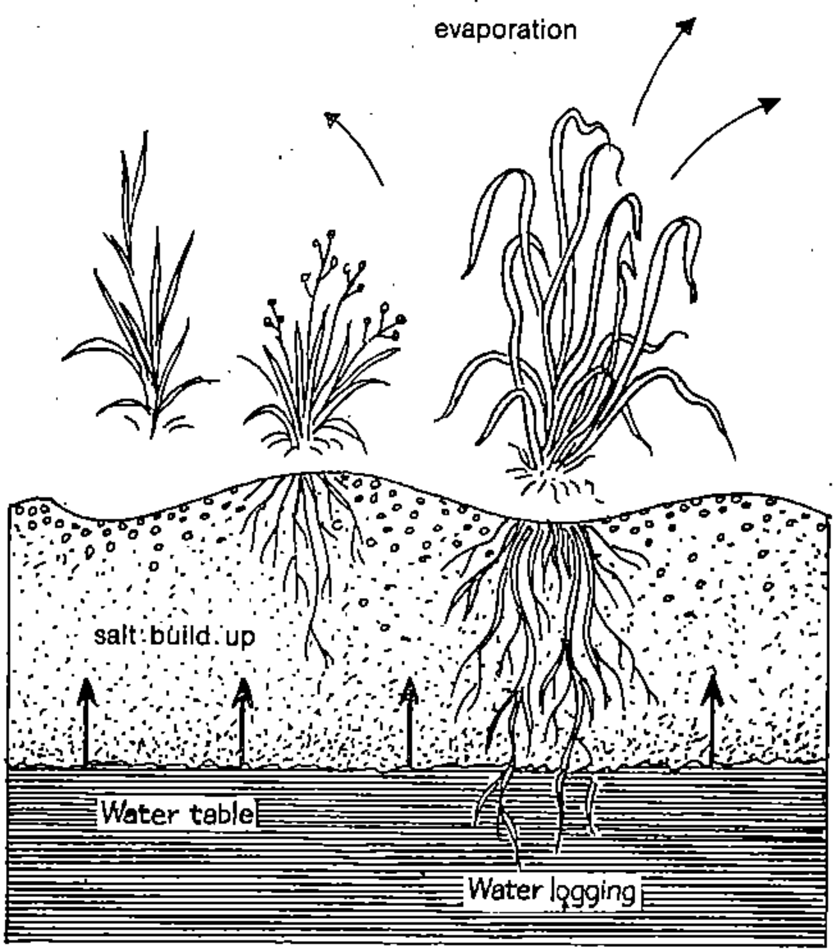


Fig 3.10: Salinisation and water logging. Salts and other minerals accumulate in the upper layers of poorly drained soil.

3.5.3 Water Adaptations

After becoming familiar with the two kinds of water stresses you would like to know about the adaptations in plants and animals which enable them to survive under conditions of water stress.

I Adaptations in Plants

Hydrophytes: Hydrophytes are those plants which grow in aquatic habitats like lakes, ponds, rivers, seas. According to their habitat they are further divided into the following categories.

Free floating plants: These plants remain in contact with water and air, but not with substratum. They float freely on the water surface. Leaves in some of these plants are very minute, while others are quite large. Some of the free floating hydrophytes are **Wolffia, Lemna, Spolrodella, Azolla, Salvinia, Pistia** and **Eichhornia** (Fig 3.11).

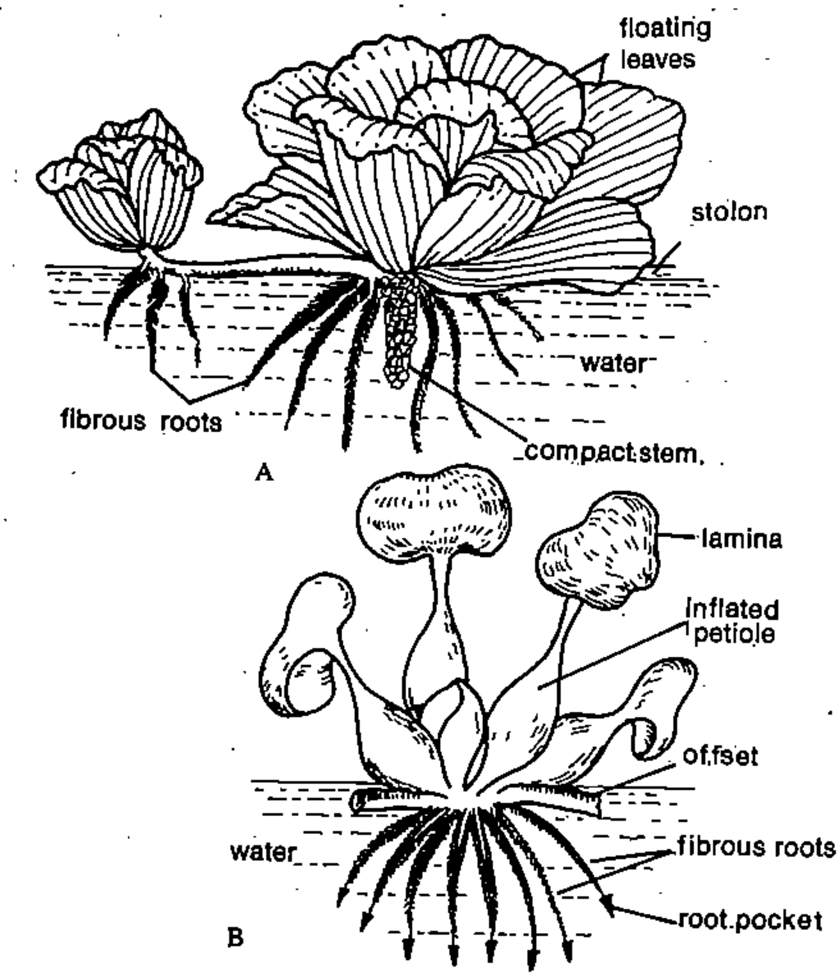


Fig 3.11: Free-floating hydrophytes. A) Pistia, B) Eichhornia.

Rooted plants with floating leaves: These plants grow on margins and in shallow water bodies. Roots of these hydrophytes are fixed in mud, but leaves have long petioles which keep them floating on the water surface. The remaining parts of the plant except leaves, remain in water. Some of the rooted hydrophytes are **Nymphaea, Nelumbo, Trapa,** and **Marsilea** (Fig 3.12).

Submerged floating plants: These plants remain in contact with only water, being completely submerged in water and are not rooted in the mud. Their stems are long and leaves generally small. Some of the examples are **Ceratophyllum** and **Utriculalria** (Fig 3.13).

Rooted submerged plants: These hydrophytes are found completely submerged in water but remain rooted in soil. **Hydrilla** is one of the examples which is a slender weed with fibrous roots (Fig 3.14).

Rooted emerged plants: These are plants of shallow waters. These hydrophytes require excess water but their shoots remain partly or completely exposed to air. The root system remains completely submerged in water, fixed in soil. In some, like **Ranunculus,** and **Sagittaria** shoots (Fig 3.15) are partly submerged and partly exposed out of water in air.

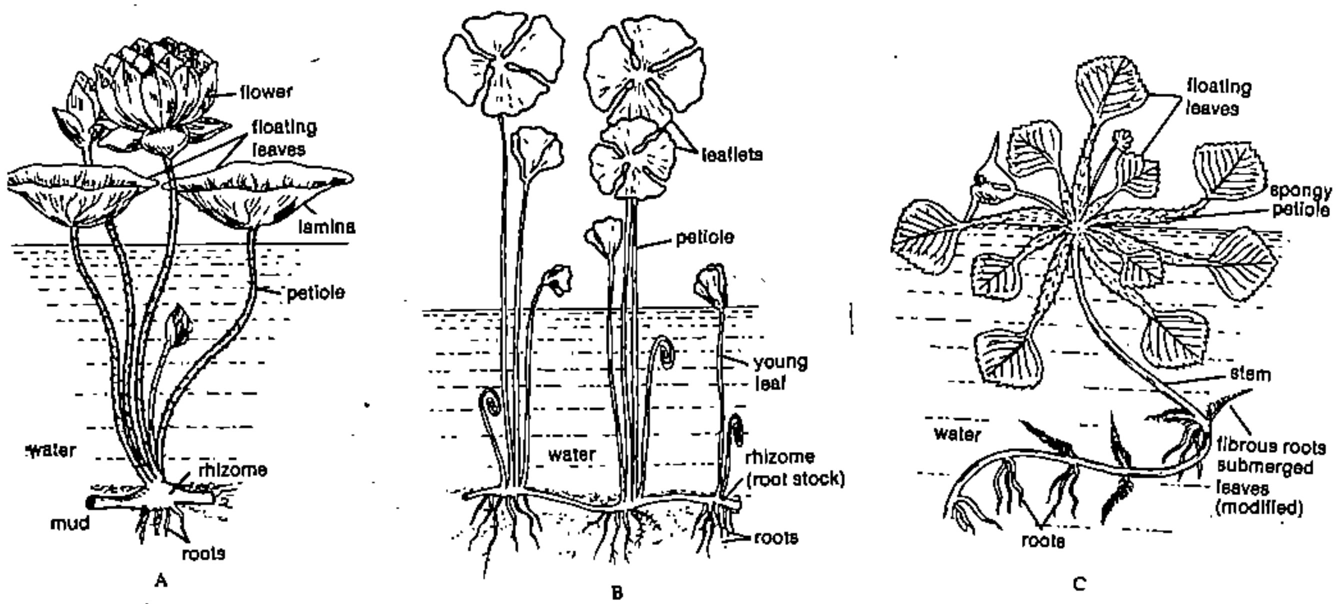
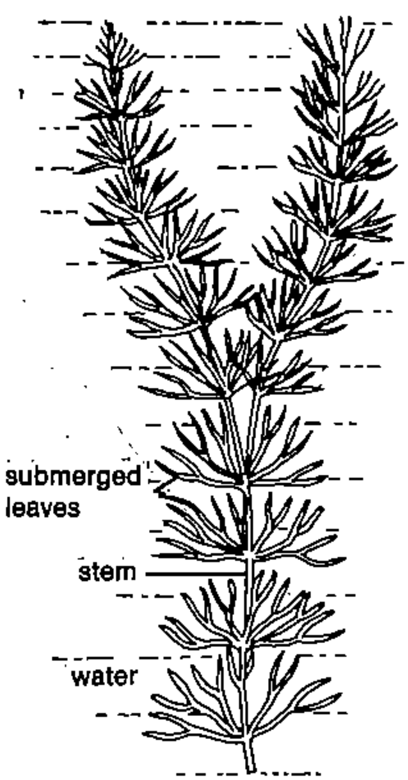


Fig 3.12: Rooted hydrophytes with floating leaves. A. Nelumbo, B. Marsilea, C. Trapa.



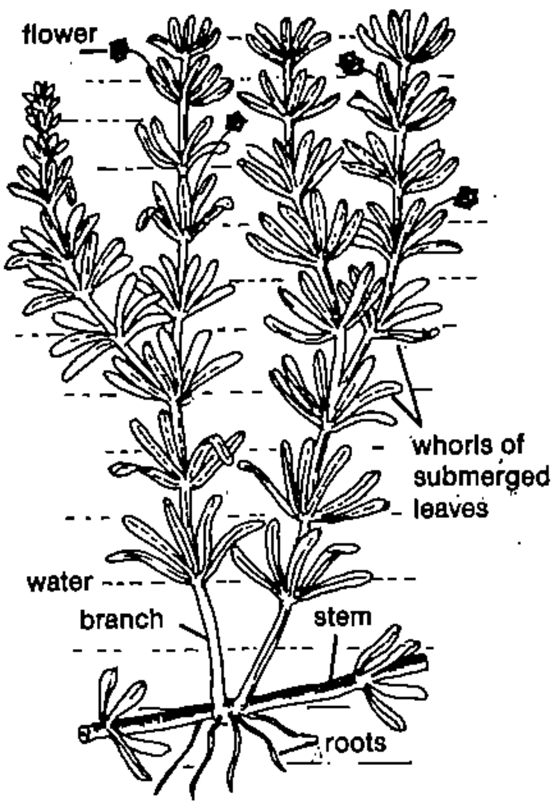


Fig 3.13: Submerged floating hydrophyte. *Ceratophyllum.*

Fig 3.14: Rooted submerged hydrophyte. Hydrilla

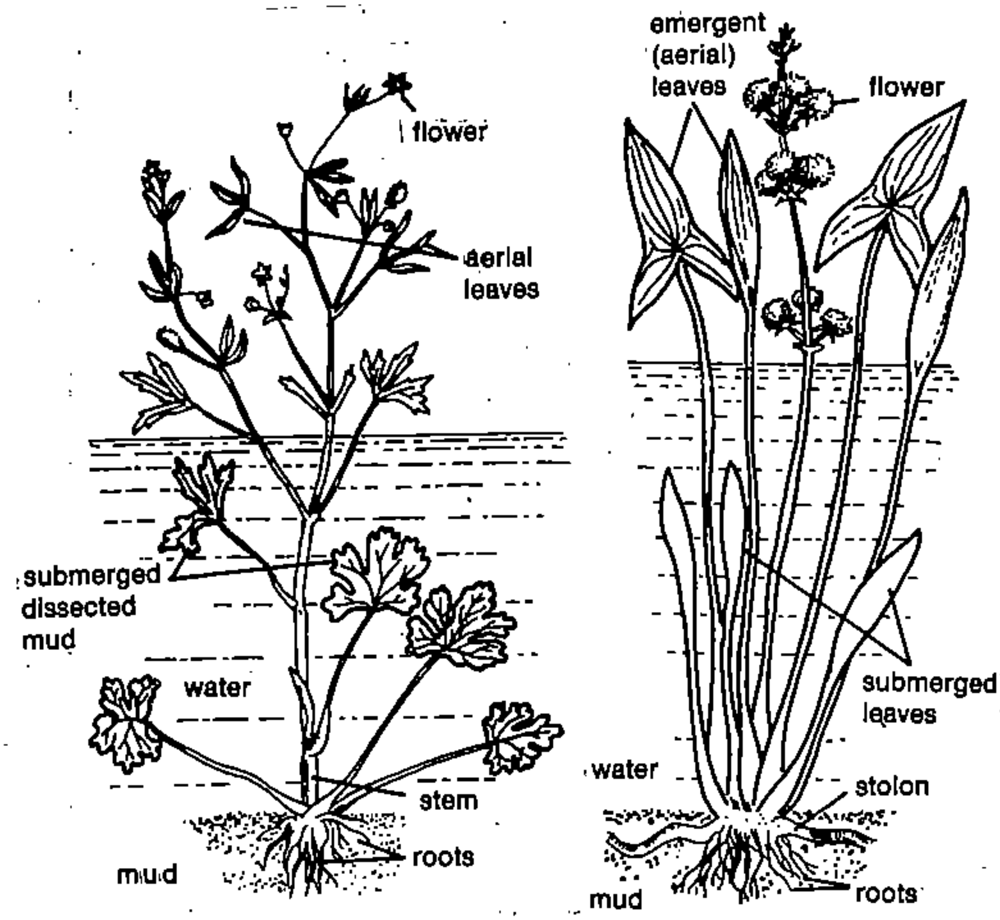


Fig 3.15: Rooted emergent hydrophytes. *A. Ranunculus, B. Sagittaria.*

Mesophytes: These plants grow in moist habitats and well-aerated soils. They prefer soil and air of moderate humidity but fail to survive in areas with water-logged soils or over-abundance of salts. In some respects they stand in between the hydrophytes and xerophytes. Broad leaved plants growing in wet depressions, along lakes and rivers are mesophytes. In general, mesophytes have well-developed root system. Stems are generally aerial, solid and freely branched. Mesophytes may show temporary wilting during noon hours.

Xerophytes: Xerophytes are sometimes loosely defined as 'plants of dry habitats'. But others have defined xerophytes as 'plants which grow on the substratum that usually becomes depleted of water to a depth of at least 2 decimetres during a normal season'. Thus, in arid zones, all plants not confined to the margins of streams or lakes have been considered as xerophytes. In heavy rainfall regions shallow-rooted plants of sandy soils, plants of dry ridgepots, and algae, mosses and lichens which grow on tree bark, rock or similar surfaces. On the basis of their morphology, physiology and pattern of life cycle xerophytes are classified into drought evaders or drought escapers. They complete their life cycle within a short period when moisture conditions are favourable but remain in form of seeds during dry unfavourable periods (e.g. *Argemone mexicana, Solanum xanthocarpum*) succulents (e.g. *Opuntia* sp., *Euphorbia splendens*) and non-succulents perennials (e.g. *Calotropis procera, Acacia nelotica*) as shown in Figs 3.16 and 3.17.

In the emergent species which grow on shore habitats the under-mud parts of stem and roots suffer from paucity of oxygen. Respiration is an essential function of all living cells and tissues and oxygen is needed for aerobic respiration. In marsh plants like **Oryza sativa** (rice) the roots have also developed the physiological adaptation of respiring anaerobically (without use of external oxygen). Many plants normally grow in mesophytic conditions. Mesophytes are plants that normally grow in habitats where water is neither scarce nor abundant but can withstand temporary submergence for a few weeks in the rainy season. In such a case a new set of roots having hydrophytic characters may develop. In **Saccharum benghalense** the old roots gradually die and new roots with abundant aerenchyma are formed when plants are inundated or when the substratum is oversaturated.

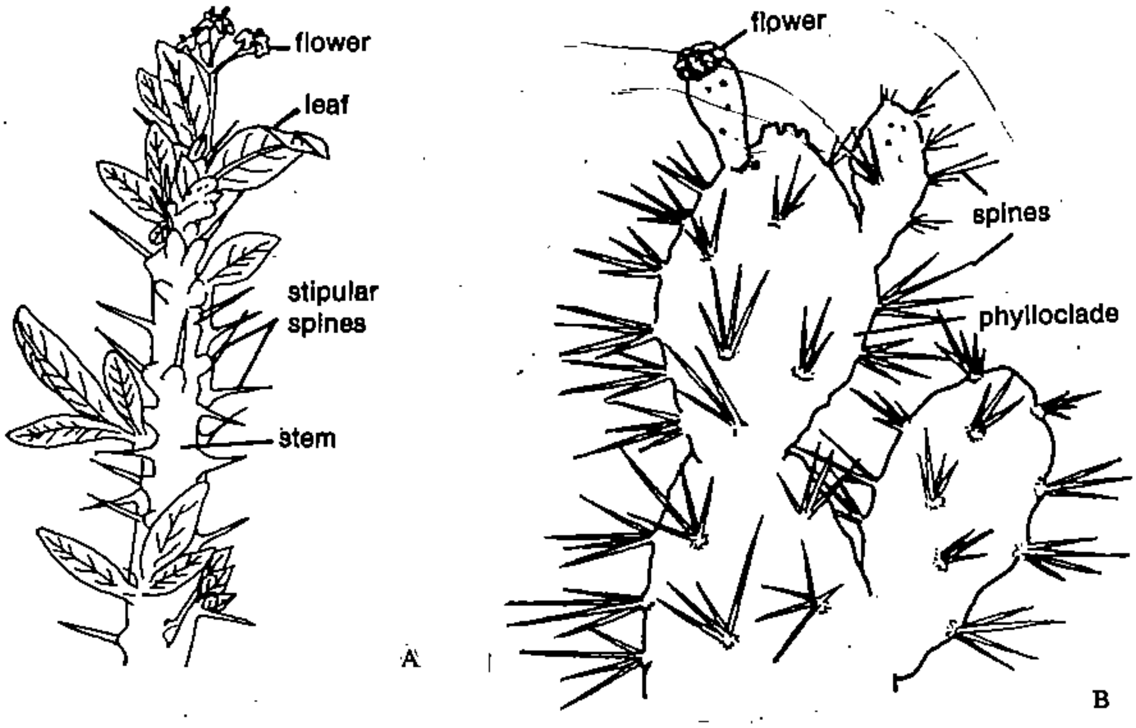


Fig 3.16: Succulent xerophytes. A. *Euphorbia splendens*, B. *Opuntia sp.*

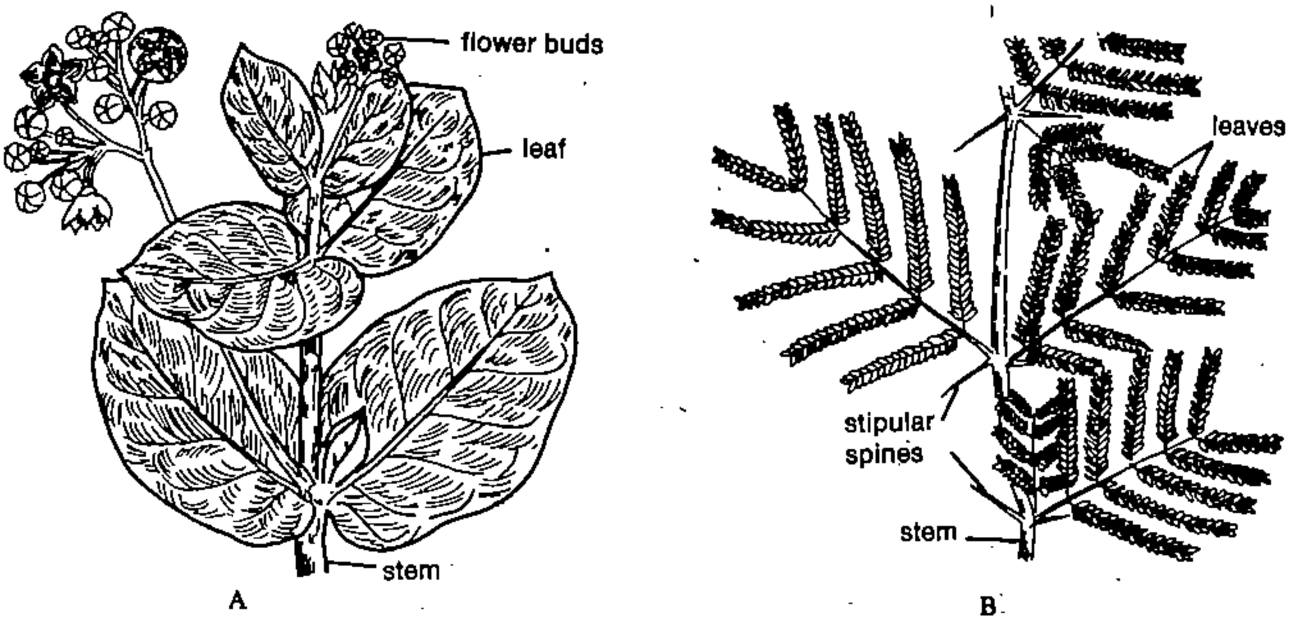


Fig 3.17: Non-succulent perennials A. *Calotropis procera*, B. *Acacia nelotica*.

The free floating species usually grow on the surface of water. The root system is greatly reduced since the entire plant remains in an intimate contact with water and absorption occurs through the surface of the plant body. The leaves have stomata only on surface not touching water. An erect stem is also unnecessary for the aquatic plants. In most free floating plants like *Wolffia*, *Lemna*, and *Azolla* root and stem are very poorly developed. Leaves are most prominent and well adapted to carry out absorption, photosynthesis, and rapid vegetative multiplication and provide buoyancy due to large air spaces in them.

In submerged water plants like *Hydrilla* the adaptations have developed in response to high density of the surrounding aqueous medium and low light intensity. The stem organs develop large air cavities or hollow spaces called lacunae. The airfilled lacunate tissues provide sufficient buoyancy to pull up the shoot for maintaining the plant in a well expanded shape in the water. Mechanical tissues such as sclerenchyma, woody xylem, secondary wood, bark normally present in the terrestrial plants to provide mechanical support are absent in hydrophytes. Therefore, the presence of lacunate tissue filled with air and the absence of mechanical tissues are two chief adaptations (Fig 3.18).

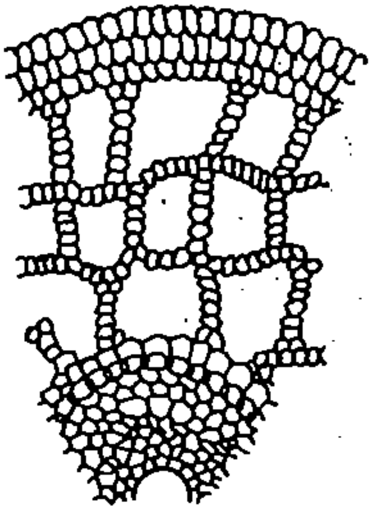


Fig 3.18: Transverse section of stem of *Hydrilla* (submerged hydrophyte)

The floating leaves in most species are quite similar in shape and features of adaptation. The leaves are peltate, usually circular in shape and have a strong leathery texture. The upper leaf surface is waxy and smooth as a result water glides off and does not adhere. The leaf margins are strong enough to resist tearing due to the pressure of wind or water currents. Despite the abundance of air tissues in the floating leaves their shape is maintained due to the presence of supporting mechanical tissues and chemical crystals like scleroids (Fig 3.19).

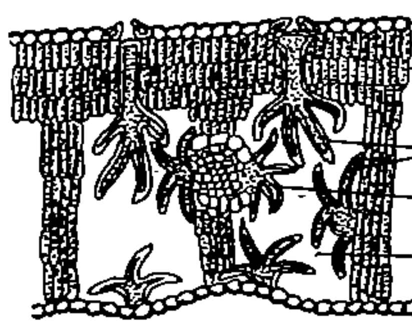


Fig 3.19: Transverse section of leaf showing presence of supporting mechanical tissues and scleroids.

You know that xerophytic plants which have adaptations to grow in dry or arid conditions are called xerophytes. There is no hard and fast line between the water status as habitats for meso and xerophytes and the term is only a relative one. Some biologists regard only those plants which actually suffer from deficiency of growth water as xerophytes. Deficiency of water adversely affects both directly and indirectly, the normal function and structure of plants. Xerophytes are only adapted to grow in dry habitats and assume characteristic dominance in deserts due to absence of other types of plants. But when better moisture conditions become available, the total biomass production in xerophytes increases. The scarcity of water from the viewpoint of water availability to plants may be of two types: i) dry habitats, and ii) wet habitats. Water is not available to plants on account of high concentration of soluble salts in the water or freezing of water in areas having sub-freezing ambient temperature. Wilting is another important factor which controls the moisture content of soil at which a plant fails to get sufficient moisture and begins to show permanent wilting. This depends upon the moisture content and texture of the soil. In coarse soils even at low moisture levels some water is available to plants and therefore, the wilting points of sandy soils is lesser than clay rich soils.

On the basis of their morphology, physiology and life cycle pattern, xerophytes are generally classified into the following three categories:

a) **Ephemeral annuals** also called drought evaders or drought escapers are common in arid zones. These annuals are able to complete their life cycle within a short period of 6-8 weeks during which moisture conditions are favourable. As the moisture gets depleted these annuals dry out leaving behind a crop of seeds to tide over the adverse dry period. They actually avoid the dry period and form seeds which are highly resistant to aridity. **Argemone mexicana, Solanum xanthocarpum** and **Cassia tora** are good examples of drought escapers.

b) **Succulents:** Plants adapted to hot and dry areas are called succulents. They have fleshy stem, leaves and roots which are swollen and serve as water storage organs. These plants are able to accumulate large amounts of water during the brief rainy season. To minimise water loss from the plants leaves either become very small or modify into thorns or are absent altogether to cut down water loss through transpiration. The root system is shallow, with wide horizontally spread stem and leaves are thick, swollen and leathery. Examples of succulents are **Opuntia sp., Euphorbia splendens** and various types of **cacti**, and **Agave**. In many cases stems become succulent as in **Opuntia** and **Euphorbia splendens**. They are also called fleshy xerophytes. In such xerophytes, cuticle is thick with a well developed two to three layered hypodermis.

c) **Non-succulent perennials:** These are actually the true xerophytes or drought resistants, because they possess a number of morphological, anatomical and physiological characteristics which enable them to withstand critical dry conditions. They exhibit rapid root growth and form an extensive root system to tap water from the soil in a most efficient manner. The leaf size is greatly reduced and in many xerophytic grasses, leaves roll on to reduce the leaf surface for restricting loss of water due to transpiration. Some of the examples are **Calotropis procera, Acacia nelotica, Saccharum munja.** In non-succulent xerophytes, root system is very extensive e.g. **Calotropis.** Important adaptations to minimise the loss of water through transpiration are:

   i) thick waxy coating on leaves.
   ii) thick cuticular and epidermal layers.
   iii) leaves small, sometimes scaly or survive for a short period only.
   iv) leaves modified into spines or in extreme cases stem devoid of leaves.
   v) dying back of leaves is a common phenomenon in many grasses.
   vi) rolling and folding of leaves as seen in many grasses.

II Ecological adaptation in animals to aquatic environment

a) In the aquatic environment animals are confronted with the problem of excess water. Freshwater and marine animals try to maintain water balance in quite different ways.

On account of the difference in the osmotic pressure between body fluids of aquatic organisms and their surrounding fluids aquatic organisms have developed osmoregulatory mechanism to deal with this problem. The salt content to the body fluids in freshwater animals is relatively high as compared to the surrounding water medium. Hence, the water tends to diffuse continuously into the body. Extra water from the body needs to be removed frequently. Most aquatic animals (e.g. protozoans and fishes) excrete the extra amount of water from the body by osmoregulation. Protozoa employ contractile vacuoles and other multicellular invertebrates and chordates use excretory organs such as nephridia and kidney (Fig 3.20).

In marine animals the situation is just the opposite. The concentration of salts in the body fluids is low as compared to the surrounding medium (i.e. hypotonic). Under these conditions the body tends to loose water. But through metabolic osmoregulation water is retained in the body and salt is excreted. Animals vary widely in their salinity tolerance. Organisms which have a narrow tolerance and cannot withstand salinity fluctuation are called **stenohaline.** Organisms which can survive under a wide range of salinity conditions are termed **euryhaline.** Usually animals inhabiting cooler fresh water and marine environments tend to have large body size except in a few cases such as diatoms and sea urchins which have relatively larger sizes in warmer waters.

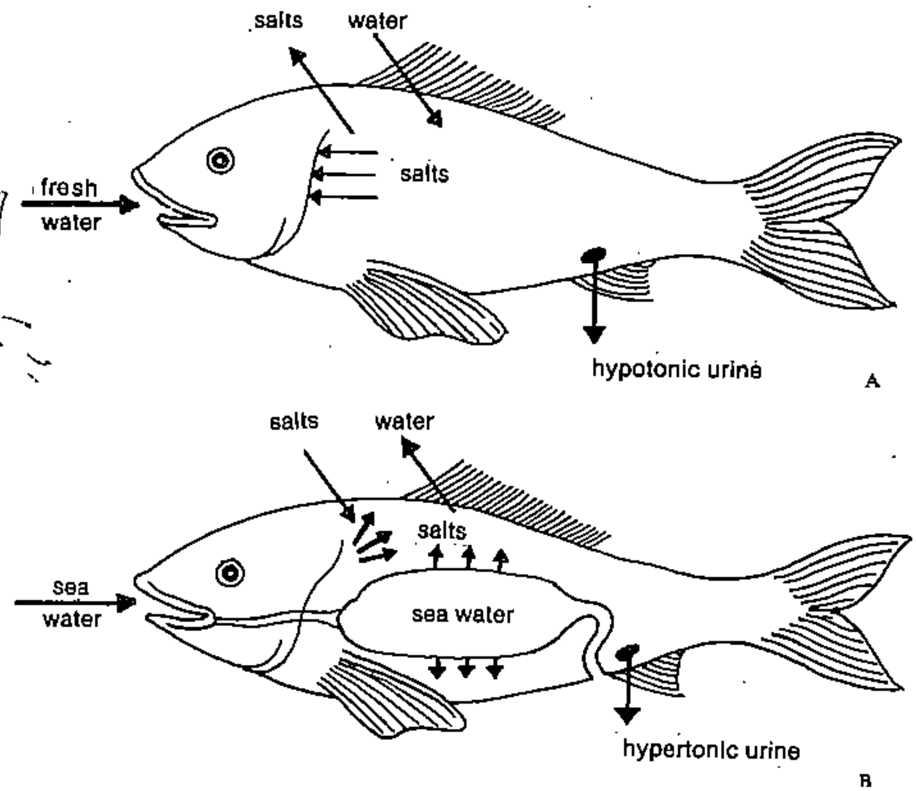


Fig 3.20: Osmoregulation in (A) fresh water fish, and (B) marine fish.

Ecological adaptations in animals to desert environment

In response to scarcity of water, animals adopt various strategies to conserve or prevent loss of water. Most of the desert animals have burrowing habit and are nocturnal, i.e., they become active after sunset to avoid warm day temperature. Some have impervious spiny skins, (e.g., hedge hog) and while others have the capacity to store large amounts of water (e.g. camel). Water is produced during fat metabolism in camels called metabolic water. Dry urine is discharged to conserve water. Besides, they undergo aestivation to escape from scorching heat. In grasslands and forests, water requirements of animals are met by the food, water wells and streams. The moisture contents and the amount of intake and output of water varies widely among the terrestrial animals and is greatly influenced by the habitat conditions.

SAQ 4

Tick mark (√) the correct statement given below:

i) The salinization results from the increasing
   a) alkalinity ( )
   b) sodium chloride ( )
   c) sodium bicarbonate ( )
   d) potassium chloride ( )

ii) Over-exploitation of ground water in coastal zones may cause intrusion of .... into fresh water.
   a) brackish water
   b) alkaline water
   c) salt water
   d) acid water

iii) Expansion of .... causes over-exploitation of ground water.
   a) agriculture ( )
   b) forestry ( )
   c) horticulture ( )
   d) cities ( )

iv) Some xerophytic plants resist drought by

a) evaporation of water ( )
b) accumulation of water ( )
c) absorption of water ( )
d) increasing concentration of salts ( )

v) Evaporation of ground water as well as irrigation water at the ground surface causes accumulation of

a) water ( )
b) salts ( )
c) minerals ( )
d) both water and minerals ( )

3.6 SUMMARY

In this unit you have learnt that:

- Water is a polar molecule and is absolutely essential for the continuance of life.
- Three-fourths surface of the earth is covered by water. Besides, the distribution of water in the biosphere varies widely and fresh water represents extremely small quantity.
- Water is the universal solvent and facilitates chemical reactions both outside and within living systems.
- Three types of waters can be distinguished on the basis of their salt content viz. fresh water, brackish water and marine water. The salinity of water depends on the amount of dissolved salts. All types of natural waters contain various amounts of different salts of Sodium, Potassium, Magnesium, (chloride, sulphate, phosphate, carbonate, bicarbonate, and nitrate).
- The hydrological or water cycle is a natural system for collecting, purifying and distributing water. The two processes such as evaporation and precipitation of water cycle are driven by the energy from the sun.
- Drought occurs when rainfall is 75% less than of normal rainfall. Plants and animals suffer adversely under drought conditions and only those adapted to endure extremely xeric conditions can survive.
- Water logging is another problem which is caused by irrigation of poorly drained fields resulting in the raising of the water table. Roots of plants may choke as water fills the air spaces in the soil. The adaptation of plants to soils impregnated with salt depends on root distribution above or below the layers of salt concentration.

3.7 TERMINAL QUESTIONS

1) How can water serve as an excellent transport system for living organisms?

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2) Why lakes do not freeze solid when temperature drops below 0°C?

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3) What attributes of water make it a good solvent?

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4) What role does solar energy play in global water cycle?

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5) What is salinisation of water and what harm does it cause?

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3.8 ANSWERS

SAQ 1

(i) One degree (ii) energy (iii) temperature (iv) continuance of life (v) bottom

SAQ 2

i) The salinity of fresh water is generally 0.50/00 (parts per thousand) that means if one litre of water is evaporated, it would yield 0.5 g of inorganic residue.

ii) An estuary has mixed fresh and salt water called brackish water.

iii) A high salinity of marine water is due to the presence of sodium chloride.

SAQ 3

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

SAQ 4

(i) b (ii) c (iii) d (iv) b (v) b

Terminal Questions

1) Water molecules do not break apart and cling together because of hydrogen bonding. Water molecules also stick to surface, particularly surfaces which are polar. Therefore, water can fill a tubular vessel and can flow so that dissolved and suspended molecules remain evenly distributed throughout a system. Thus, water serves as a very good transport system.

2) Water has its greatest density at 4°C. It expands and hence becomes lighter both above and below this temperature. This unique property prevents freezing.

3) The properties which make water a good solvent are its polarity and its hydrogen bonding capacity. Water dissolves many compounds because it breaks molecules into ions.

4) Water continuously circulates between the atmosphere and the earth's surface and this circulation of water is known as water cycle. All the vaporised water forms clouds which move by winds may pass over land where they are cooled enough to precipitate the water as rain or snow. The ground water is returned to the surface by springs, by pumps and by transpiration — the movement of water in plants from roots or leaves. Water again comes back to sea. This entire cycle of water flow from land to atmosphere is driven by solar energy.

5) The salinization results from, the increasing salt concentration of soil. When plants take water they need, the salts present in all natural water become concentrated. The problem of salinity continues to increase as irrigation increases. As a result of salinisation the productivity of cropland falls.

UNIT 4 ENVIRONMENTAL COMPONENTS : 3. SOIL

Structure

4.1 INTRODUCTION

In the previous units you have studied about environmental components such as water, heat and light. You have seen how these factors interact with each other and affect the distribution and ecology of living organisms. Now, you are going to study yet another important environmental component, that is, soil.

The soil is a dynamic, complex, constantly-changing part of the earth's crust that extends from a few centimetres deep in some places to several metres deep in others. It is a natural medium for plant growth and is essential for the existence of living organisms including humans.

The study of soil now ranks as a well developed, independent branch of science and is known as Pedology. In this unit, we shall discuss with you significant aspects of soil. The first part of the unit deals with the formation of soil, followed by the types of soil based on their mode of transportation. Then we take up certain basics such as soil texture, structure and profile, for discussion. Having learnt about them, you would find their implications in the different physical and chemical properties of soil. In the last part of the unit we would discuss with you the organisms inhabiting soil and their role in maintaining soil fertility.

Objectives

After studying this unit, you should be able to:

- define soil, and describe its nature and composition
- outline the process of soil formation
- list the different categories of soil particles and the various textural soil classes
- differentiate between different types of soils
- distinguish between light and heavy soils

- describe soil-water relationship in relation to plant growth
- explain the importance of permeability and aeration to plant growth and soil fertility
- discuss the chemical properties of soil particularly the cation exchange capacity, and nutrient availability and non-availability
- describe the role of soil biota in maintaining soil fertility.

4.2 WHAT IS SOIL?

The word soil is derived from Latin word 'solum' meaning earthy material in which plants grow. The soil is the consolidated outer layer of the earth's crust ranging in thickness from a mere film to three metres or more. It provides mechanical anchorage to plants, besides being a reservoir of water and plant nutrients. The soil also supports a rich and highly diversified micro-flora and fauna.

Typically, soil is a complex mixture of inorganic and organic materials. The inorganic materials, that is, the mineral constituents of soil are derived from parent material (the soil forming rocks) by fragmentation and weathering. The pore spaces formed between the mineral particles of soil are filled with water and gases. The organic components of soil comprise organic wastes, dead remains of plants and animals, and their decomposition products. Besides, a large variety of algae, bacteria, fungi and many small and large animals are invariably present in a fertile soil.

4.3 FORMATION OF SOIL

The processes which are involved in the formation of soils can be studied under the following headings:

4.3.1 Weathering of Rocks

The processes involved in the formation of soil are slow, gradual and continuous. The sum total of natural processes resulting in the disintegration of parent rocks is collectively known as 'weathering', and it involves physical, chemical and biological agencies.

Physical Weathering

Mechanical forces acting upon the rocks cause physical weathering. Temperature fluctuations cause expansion and contraction of rock surface resulting in the formation of cracks and fissures. During cold weather, the water present in rock crevices gets frozen and the formation of ice results in its expansion. The force of expansion causes breaking up of rock. Broken rock fragments roll down the slopes and break further into smaller pieces. Hails, rainfall and fast flowing streams are important agents of physical weathering. You might have seen rounded stone pieces of varying sizes on the bed of Ganga river at Rishikesh and Hardwar where fast flowing river reaches the plains from its place of origin at Gangotri in the Himalayas. Wind is another agent of physical weathering particularly when it carries sand particles which causes abrasion of rock surface, due to friction. In the Vindhyan hill forests, it is commonly seen that tree roots often penetrate through the rock crevices and in course of time, with the radial growth of roots, the rocks get disintegrated.

Chemical Weathering

The rocks while getting disintegrated may also undergo chemical change. Water is an important agent in bringing about chemical changes due to dissolution or reaction of one or more components of rock materials. Presence of dissolved materials and warm temperature favour chemical weathering. Some components of the rock may get dissolved and reprecipitated. Some minerals like feldspar and mica readily combine with water through the process of hydration and become soft and easily weatherable. Another very important process of chemical weathering is through hydrolysis in which water dissociates (particularly in the presence of carbon dioxide and organic acids) into H^+ and OH^- ions which act on silicates like orthoclase to produce silicate clays. Oxidation and reduction reactions and carbonation are other important means of chemical weathering.

It is important to realise that weathering of rocks is a continuous phenomenon, that helps in soil formation. It is, however, a very slow process, and may take hundreds or thousands of years to make a few centimetres of soil, depending on the nature of the parent rock material.

4.3.2 Mineralisation and Humification

As a result of physical weathering, the rocks are broken down into smaller particles. But this is not the true soil, and plants cannot grow well in the disintegrated rock material alone. The weathered material, however, undergoes further changes, that you would study in this section. You might have noticed that during weathering, mostly physical and chemical factors are involved, whereas for the further development of soil, that is mineralisation and humification, mainly the biological agents are involved.

During the early stages of soil formation, organic matter in the soil is not very high, as the vegetation and the soil fauna are not much developed. In such soils, algae, lichens, mosses, and other small form of plants grow and contribute organic matter through their death and decay. In due course of time, various types of plants, animals and microorganisms colonise such soils. They also contribute organic matter to the soil, in the form of wastes or their dead remains. This organic debris then breaks down into simpler products. This breakdown process, also known as decomposition is brought about by different kinds of microorganisms such as bacteria, fungi, and actinomycetes. They break the organic substances into various compounds such as polysaccharides, proteins, fats, lignins, waxes, resins and their derivatives. These compounds are further broken down into simple products such as carbon dioxide, water and minerals. This latter process is called mineralisation. The residual, incompletely decomposed organic matter left after mineralisation is called **humus** and the process of its formation as humification. Humus is an amorphous, colloidal and dark substance that is the source of energy and nutrients for most soil microorganisms. Humus is important, as it gives the soil a loose texture ensuring better aeration. Being colloidal in nature, it has a great capacity for imbibing and retaining water and nutrients. Humus, greatly improves the soil fertility.

4.4 TYPES OF SOIL

In the previous section you have seen how the mineral matter is derived by the weathering of the parent rocks, and the soil formation is a complex process, involving a series of steps. In this section you would study various types of soils categorised on the basis of their origin and relationship with the parent rock.

4.4.1 Residual Soils

Residual soils are formed at the same site where the weathering of the parent rock has taken place or soils formed *in situ* from the underlying rocks. These are also called sedentary soils. In these soils the surface layers are most weathered but the degree of weathering decreases with increasing depth, and the rock fragments become progressively larger and mostly chemically unaltered until they finally integrate with the underlying parent rock.

In India, the principal residual soil types are : the *reddish soils* of the Vindhyas and south of it covering most of the Peninsular India; and the *black soil* of south-west India. The red soils are poor in calcium, magnesium, phosphorus and nitrogen and coloured red by the presence of iron peroxide. The black soils, also called as black-cotton soils, are rich in clay, well supplied with potash, calcium, magnesium and iron. These are well suited to the cultivation of cotton and are characterised by the development of wide and deep cracks during the summer season.

4.4.2 Transported Soils

These soils are formed from the weathered material which is transported and deposited away from the site of origin. Depending upon the nature of the transporting agent, the transported soils are called.

i) Colluvial, ii) Alluvial, iii) Glacial and iv) Aeolian

i) Colluvial

These are the soils formed from the material transported by the pull of gravity. Fragments from cliffs or steep rocky slopes become dislodged from time to time and may accumulate below. This material is characteristically very coarse, consisting mostly of large fragments of rock and has a rather steep and unstable surface. The other kind of movement of weathered rock materials is due to landslides. These usually result from heavy rain or earth tremors and as a result the materials start cascading down a steep slope. Colluvial soils are devoid of any stratification and represent a random assortment of soil particles and rock fragments. Particles of different sizes, including various kinds of rocks and soils derived from slopes or cliffs are mixed indiscriminately.

ii) Alluvial

Materials of this category are deposited by running water in the form of *flood plains, river terraces, deltas and alluvial fans*. These deposits have two outstanding characteristics by which they can usually be recognised with ease. First, the individual particles tend to be rounded and smoothed by the action of running water. Second, the layers are usually distinct in that each contain particles of a particular range or size class depending upon the speed of the transporting water. Coarse materials are laid by swift water currents, whereas, fine particles are deposited by relatively calm waters.

Alluvial soils are found bordering rivers and slow moving bodies of water. When first formed, these deposits are so low that they are frequently flooded at high-water stages, and at such times they receive additional increments of fine sediment, especially if they are well vegetated. At this stage of development, they are called flood plains. As the stream cuts its channel deeper, the flood plain is left above the reach of high water and is called a terrace. Large streams are frequently bordered by a series of terraces, the oldest being at considerable heights above the present water level.

Where streams enter a lake or a sea, the deposit of silt and clay that settles down at the edge of the still water may build a delta which gradually lengthens until it extends beyond the mouth of the stream. The Sunderbans in West Bengal and Bangladesh are examples of deltas, which support mangrove type of vegetation.

Alluvial fans are formed where a stream descends from uplands, and a sudden change in gradient may sometimes occur as the stream emerges at the lower level. Deposition of sediments is thereby forced, giving rise to alluvial fans. They differ from a delta in their location and in the character of their debris. Fan material is often gravel and stony in nature and is well drained.

Among the transported soils, the alluvial soils of the Indo-Gangetic Plains are highly productive and have been under cultivation for several thousands of years. The parent material of the Indo-Gangetic alluvial soils is actually in the Himalayas. Mountain and hill washes contribute huge quantities of sediments brought down by the rivers and deposited in the plains below. Most of the alluvial soils are under intensive crop cultivation.

iii) Glacial

These are the soils which are formed by the grinding action of ice and snow. Moving, heavy ice-masses and glaciers push before them and gather within themselves large amounts of unconsolidated surface material. They also scoop up rock fragments which further scrape the surface. Sharp corners and edges of even the hardest rock fragments are ground smooth by this abrasive action. Glacial soils are found in Dehra Dun region and parts of Kashmir.

iv) Aeolian

Wind transported materials constitute this category. This can be further divided into dunes or loess. Dunes are found in three types of situations. Firstly, these may occur along the shores of water bodies like seas and lakes as a result of water currents eroding the land and depositing the resultant sand particles on the strand in bays and the wind moving the material back to the land. Secondly, dunes formed along the river valleys, where flood waters deposit sand on the flood plain which when dry is blown by the wind. In the third case, in dry regions, the weathering of sandstone and other rocks may produce sand that is easily blown away because of sparse vegetation. One interesting thing about dune sand is that it is composed of particles of uniform size and composition. The finer particles are blown further, whereas the heavier ones such as gravel remains at the same place. Dune soils are of not much agricultural value. Such soils are commonly found in parts of Rajasthan, south-west Punjab and parts of Gujarat.

Loess is a deposit of very fine unconsolidated and unstratified particles which have been picked up and transported some distance by wind and, therefore, is more fine-textured than dune soil. In some places, these deposits may attain a thickness of upto 70 metres. Sometimes loess is derived partly from volcanic ash also.

You have just studied about the various types of soils, based on their origin from their parent rock material. We would now advise you to have another look at Subsection 17.2.2 of FST-1 (in Block 4, Unit 17) to revise the types of soils found in the Indian sub-continent. While going through this subsection you should study Fig 17.3 carefully and note the regions having a particular soil type. Now, before we proceed further, how about trying a SAQ first?

SAQ 1

Complete the statements given below with the right word(s):

i) The components of soil are : ...., ..., ..., ... and ....

ii) .... of rocks, followed by .... and .... are the main events in the formation of soil.

iii) The soil consisting of recently weathered rock material is .... in organic materials.

iv) A dark soil usually is rich in ....

v) .... soils develop at the very place of their origin from the parent rock, whereas .... soils develop at places distant from their parent rock.

vi) Loess is comparatively more fine-textured than .... soils.

4.5 SOIL TEXTURE AND STRUCTURE

From the discussion of the previous section, you have seen that soils are predominantly composed of particles of various sizes derived from the disintegration or decomposition of parent rock material. These particles that we see today may have been produced in early geologic period and they continue to be produced even today and moved by agents like wind, water or ice over considerable distances.

In this section, we shall discuss various textural classes and structures of soil. Soil texture refers to the relative particle-size composition of the soil. The particle size composition of a soil is the percentage of the mineral matter by weight in each fraction. In a given sample of soil, there may be present different sized particles in various proportions. Depending on their size (in diameter) the International Society of Soil Science has given specific nomenclature to the various particle size classes which are as follows.

Table 4.1: Size classification of soil particles

S.No.	Type of soil particle	Size (diameter in mm)
1	Clay (colloids)	Less than 0.002
2	Silt	0.002 - 0.02
3	Fine sand	0.02 - 0.20
4	Coarse sand	0.20 - 2.0
5	Stone and gravel	2.0 and above

Soil mineral particles smaller than 0.002 mm are colloidal in nature and are called clay (see Table 1). They do not settle quickly when mixed with water, as they form a colloidal solution or sol. The clay fraction or the soil is most active physiochemically.

You have seen that based on the size, the soil particles are grouped into five categories. A soil may not necessarily be made up of one type of particles, that is, it may contain particles belonging to any of these categories, in varying amounts. Depending on the proportion of silt, clay and sand that the soil contains, the soils may be grouped into a number of classes such as sand, sandy loam, clay loam, clay etc. (see Fig 4.1)

A soil can be assigned to a textural class with the help of the triangular diagram as illustrated above. All possible combinations of sand, silt and clay are condensed into twelve major soil classes. The class to which a soil belongs can be closely approximated by examination in the field but for accurate determination, mechanical analysis is carried out to find out relative

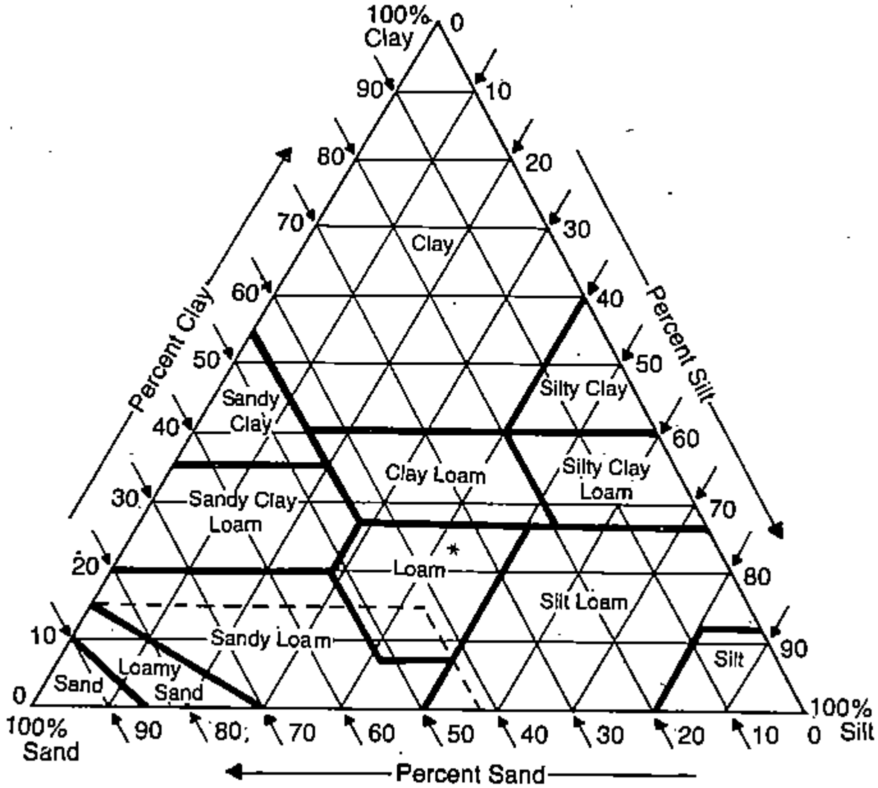


Fig 4.1: A soil textural triangle. To illustrate how the triangle works, assume that a sample of soil has been analysed and found to contain 47 per cent sand, 15 per cent clay and 40 per cent silt. Locate the 47 per cent value on the sand axis (bottom) on the triangle and draw a line parallel to the lines in the direction indicated by the arrow. Next, locate either the 15 per cent value for clay on the clay axis (left side of triangle) or the 40 per cent silt on the silt axis (right side of triangle) and draw another parallel line along either of the two axes in the direction indicated by the respective arrows. The two lines intersect in the loam area of the triangle, hence this soil is classified as a loam. (* Loam may be defined as a mixture of sand, silt and clay particles. A loam where sand is dominant is classified as a sandy loam, and in the same way there may occur silt loam, silty clay loam, and clay loam.)

amounts of particles of different sizes. The soil is assigned to a particular textural class after studying its mechanical analysis fraction. An experienced field surveyor can grade soils into these classes simply by feeling the soil when wet, between his fingers.

The term soil texture refers to different proportions of sand, silt and clay in a soil but the arrangement or the state of aggregation of the soil particles in soil mass is referred to as soil structure. The aggregation of sand, silt, clay into compound particles may be of (i) granular, (ii) crumb, (iii) platy, (iv) blocky, (v) subangular blocky, (vi) prismatic and (vii) columnar nature (see Fig 4.2).

The aggregation of soil particles is brought about by the colloidal fractions including sticky material of organic origin and very thin film of water molecules. Soil aggregates are called peds. The study of soil structure is important as it influences various physical properties of soil particularly aeration and water holding capacity.

4.6 SOIL PROFILE

You have already studied that weathering of rocks produces soil. The weathering process has been described in Section 4.3. Soil formation over a period of time results in vertical stratification of horizontal layers one over the other in the progressive state of maturity. The vertical section of a soil upto unweathered rock is made up of a succession of horizontal layers (horizons) of varying thickness but is reasonably differentiated on the basis of colour, texture, structure and chemical characteristics. Such a vertical section of soil from top mature soil to the underlying bed-rock is called a soil profile.

In a soil profile, the horizontal layers are named from top to bottom as A, B and C (see Fig 4.3). The top soil is called A-horizon and the sub-soil as B-horizon. The region of semi-

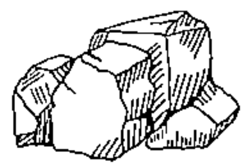
S.No.	Structure Type	Diagrammatic Structure	Aggregate Description
i	Granular		Relatively nonporous, small and spheroidal peds, not fitted to adjoining aggregates.
ii	Crumb		Relatively porous, small and spheroidal peds; not fitted to adjoining aggregates.
iii	Platy		Peds are plate – like. Plates often overlap.
iv	Blocky		Block-like peds bounded by other peds whose sharp angular faces form the cast for the ped. The aggregates often break into smaller blocky peds.
v	Subangular Blocky		Block-like peds bounded by other aggregates whose rounded subangular faces form the cast for the ped.
vi	Prismatic		Column-like peds without rounded caps. Other prismatic aggregate form the cast for the ped. Some prismatic peds break into smaller blocky peds.
vii	Columnar		Column-like peds with rounded caps bounded laterally by other columnar aggregates that form the cast for the peds.

Fig 4.2 : Various types of soil structure

broken parent rock is called C-horizon. In the A-horizon, the top fertile soil is very rich in organic matter representing different stages of disintegration and decomposition. A layer of organic matter comprising of loose fallen leaves, twigs and organic debris still intact or largely undecomposed, accumulated above the soil surface is referred to as Aoo layer. Below it is the Ao layer comprised of partly decomposed organic matter, where identity of the organic matter cannot be made out. Fully decomposed organic matter, i.e., humus enriches the soil by mixing with the mineral components to form soil aggregates or crumbs. This is referred to as the A_1 layer and is dark in colour. A_2 and A_3 have a decreasing quantity of humus and are less dark than the A_1 layer. In fact, in warm humid tropical soil the distinction of the A-horizon into different sub-horizons is not clear because of the rapid biological activity in soil and the consequent quick humification and mineralisation. The B-horizon is also subdivided into B_1, B_2 and B_3 with decreasing degree of maturity. B_1 is similar to the A_3 layer but some granular structures may be present, B_2 and B_3 horizons have soil blocks often formed due to aggregation of iron and aluminium. Horizon C represents weathered parent material which has not become true soil.

SAQ 2

i) What is the difference between soil texture and soil structure?

....

....

....

ii) A silt loam is finer in texture than a clay loam. True or False? [ ]

iii) In the A horizon:

a) different stages of decomposition of organic matter seen [ ]

b) microbial activity is low [ ]

c) the weathered material has not become true soil [ ]

d) the soil is lighter in colour than the C horizon [ ]

(Tick mark [√] the correct answer)

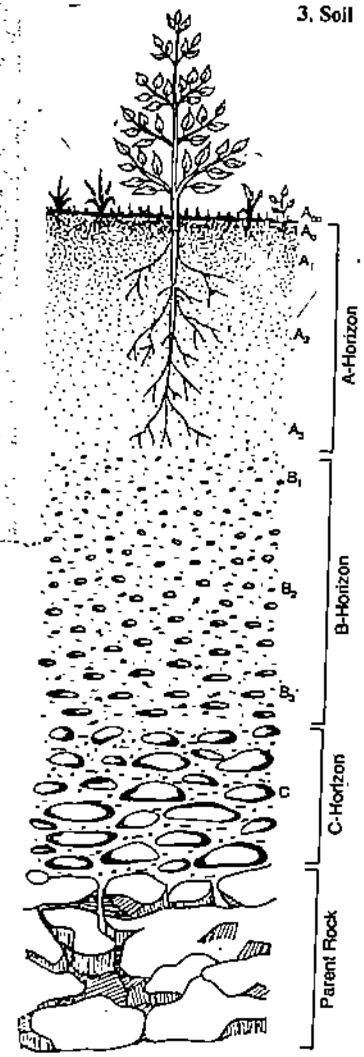


Fig 4.3: A soil profile. Various horizontal zones indicate the stages in soil formation.

4.7 PHYSICAL PROPERTIES

The physical properties of a soil have much to do with its suitability for the many uses to which man puts it. Properties like moisture storage capacity, aeration, and retention of nutrients are all intimately connected with the physical conditions of the soil. It is important to realise that the physical properties of soil exert a great influence on soil fertility and to what extent human use can alter these properties. Physical soil properties are not only important when soil is to be used as a medium for plant growth but also when soils are to be used as a structural material for making highways, dams, foundation for buildings as well as for the manufacture of bricks and tiles.

4.7.1 Light and Heavy Soils

The presence of silt and especially clay in a soil imparts to it a fine texture, and a slow water and air movement. Such a soil is highly plastic becoming sticky when wet, and hard and cloddy when dry unless properly handled. The expansion and contraction on wetting and drying, usually are great. And the water holding capacity of clayey and silty soils generally is high. In farming parlance, such smooth soils are known as heavy soils and the coarse sandy and gravel soils as light. This does not refer to their mass per unit volume, which may be greater for a sandy soil than a clay one, but to the power required to draw agricultural implements through the soil. This property is, therefore, a measure of cohesion between the soil particles, and although this is dependent on the particle size distribution in the soil, it is also dependent on the kind of particles present.

4.7.2 Soil Water

Soil water relationship is very important. In the first place the supply of large quantities of water is necessary to satisfy the evapo-transpiration requirements of growing plants. Furthermore, this water must be available when the plants need it and most of it must come from the soil. Second, water acts as a solvent, which together with the dissolved nutrients make up the soil solution.

Forms of Soil Water

Gravitational Water or Ground Water : After a heavy rain or irrigation, much of the water drains or sinks downwards. This is called gravitational water. This is of little significance in most soils because it drains downwards rather quickly under the influence of gravity.

Capillary Water : Some amount of water is retained against the pull of gravity in the minute spaces between the fine soil particles as thin films surrounding the particles and thicker ones where the particles touch each other, and a part of water is absorbed by the soil colloids. The downwards pull of gravity reduces these films to a minimum thickness. This form of soil moisture is in such a state that its movement as a liquid in any direction is so limited as to be practically negligible.

Hygroscopic Water: Even air-dried soil contains appreciable amount of water. If we heat apparently dry soil in a closed container, we can see drops of water deposited on the lid. This relatively small amount of moisture is termed as hygroscopic water. It is held so tenaciously by the soil colloids that it is not available to plants.

Retention of Soil Moisture

The movement of water into and within the soil, moisture storing capacity of soils and the availability of moisture to plants are governed by soil properties. Each of these factors is related directly or indirectly to the size and distribution of soil pores and the affinity of particles to moisture. To understand these aspects more clearly, we shall now discuss a few concepts given below.

Maximum Retentive Capacity: Let us take the example of a soil that is well granulated, silt loam, and has a uniform texture and structure. After heavy rain or irrigation, as water enters the soil, air is displaced and the soil pores whether large or small are filled with water. At this point the soil is said to be saturated and is at its maximum retentive capacity **(see Fig 4.4a,d).**

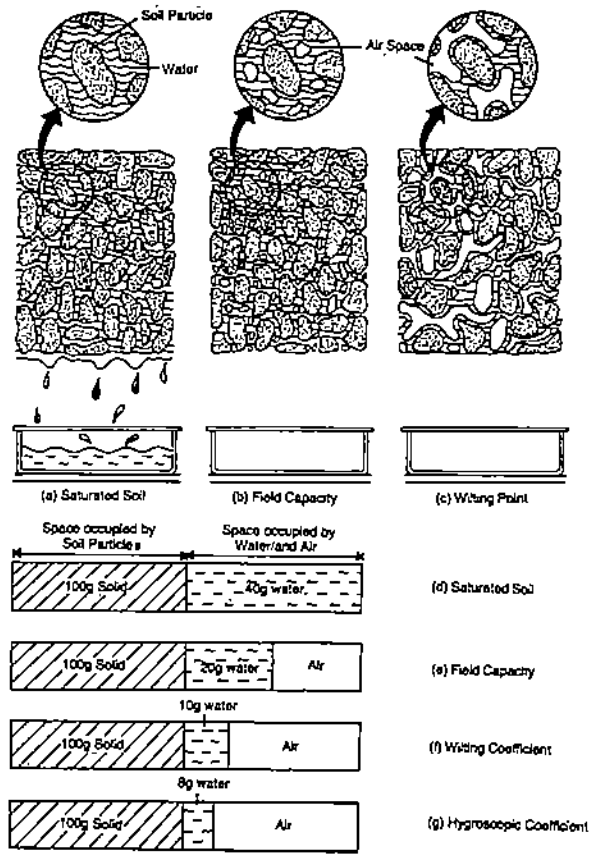


Fig 4.4 : Diagrams showing the volumes of solid (soil particles), air and water in a well granulated, silt loam at different moisture levels. Figures and show soil is completely saturated with water. Figures b, e show the situation after the draining of water from the macropores. The soil is then said to be at the field capacity. Plants will remove water from the soil quite rapidly until wilting coefficient (c & f) is approached, though there is still considerable moisture in the soil (see f). A further reduction in moisture content to the hygroscopic coefficient is illustrated in g. At this point water is held very tightly, mostly by the soil colloids.

Field Capacity : In the same soil as above, if we cut off the supply of water, that is, if there is no further rain, or we shut off irrigation water, there would be relatively rapid downward movement of some of the water. After a day or so, this rapid downward movement could cease. At this point we can find that the water from the larger pores or the macropores has drained out and its place is taken by air (see Fig 4.4b,e). The smaller pores or the micropores are still filled with water, and it is the main source from where plant roots absorb water. So the field capacity refers to the water content in the soil after gravitational water has drained away.

Wilting Coefficient : Plants absorb water from the soil and reduce the quantity of moisture in the soil as they lose water to the atmosphere by transpiration through their leaves. The second avenue of loss is evaporation directly from the soil surface. Both these losses are taking place simultaneously and are responsible for a markedly rapid rate of water dissipation from soils. If this water is not replenished, the soil dries out (see Fig 4.4c,f) and the plants show the effects of reduced soil moisture. During the day time, the plants tend to wilt when the temperature is high and/or there is strong wind, but recover and regain turgidity during the night. But if the soil is not supplied with water, ultimatly a time would come when the plants remain wilted both during day and night. Although the plants at this stage are not dead but remain in permanently wilted condition and will die if no water is added. The amount of moisture content in the soil at this stage is called the wilting coefficient or critical moisture (see Fig 4.4c,f). The water remaining in the soil is found in the micropores and around the individual soil particles and is not available to plants. Therefore, water must be replenished in the soil to revive the wilted plants.

Hygroscopic Coefficient : To have a more complete picture of soil moisture relations, let us take a soil sample and oven dry it for 24 hours at 11° C. Now if this soil is kept in an atmosphere which is completely saturated with water vapour, the soil will absorb some water, which makes a thin film around the soil particles. The water is held tightly and can move only in the vapour phase. The moisture at this point, absorbed by a unit weight of dry soil is termed the hygroscopic coefficient (see Fig 4.4g). As might be expected, soils high in colloidal materials will hold more water under these conditions than the sandy soils.

Soil moisture is sometimes expressed in terms of pF, which has a range from 0 to 7. The pF is the logarithm of capillary potential. The pF-0 represents saturated soil, 2.7 represents the field capacity, 4.2 the permanent wilting percentage, 5.5 the air dry level, and 7.0 the oven dry conditions. At the same pF, the actual amount of moisture content is higher in clay than in sand.

Available and Non-available Water

You have seen above that water is present even in the apparently dry soils (see Fig 4.4c), but it is of not much use as far as the plants are concerned. They cannot utilise the water that remains tightly adhered on to the surface of soil colloids. Therefore, water remaining in the soil at the time of permanent wilting is non-available to plants. For plant growth, only available water is important and not the total amount of soil moisture. The amount of available water varies in different soils. For example, a sandy soil may have a field capacity of 12 per cent, of which only one per cent is non-available. A clay loam has a field capacity of 35 per cent, and it may have about 10 per cent non-available water.

4.7.3 Permeability

Permeability is the ability of a soil to transmit water or air. Permeability or infiltration rate is measured in terms of the rate of water flow through the soil in a given period of time. Sandy soils are highly permeable because water drains rapidly. But soils with relatively small particle sizes are relatively less permeable. For example, water infiltration through a clay soil is extremely slow. This can cause water to accumulate at the surface or within the body of the soil resulting in water-logging. The amount of moisture capable of percolating completely through the soil is largely dependent upon the permeability of the middle and lower horizons of soil. When either of these is impermeable, the upper layers can quickly become saturated with water, resulting in runoff or lateral movement of water through the soil. Soil erosion is the normal consequence in sloping areas while flat sites may suffer from flooding to various degrees.

4.7.4 Aeration

A well -aerated soil is one in which gases are available to plant roots and other soil organisms, in sufficient quantities and in proper proportions to support their normal respiratory activities. It is important that oxygen which is necessary for soil biota is continuously renewed to support metabolic activities.

A soil which is considered well aerated must have the following two characteristics. First, sufficient space for air movement should be present. Second, there must be ample opportunity for the ready movement of gases into and out of the soil. Soil aeration is an important factor having far reaching influence on the metabolic activity of plant roots and other soil organisms. Continuous supply of oxygen in the soil is necessary to sustain soil organisms.

One of the most apparent effects of poor soil aeration is the reduction in the rate of organic matter decomposition, which you might recall is an essential process to maintain soil fertility. The reduced rate of break down of organic matter is due to the lack of oxygen rather than from the built up of carbon dioxide. Accumulation of organic matter in swampy areas shows that the lack of oxygen retards the decomposition of organic matter.

Aerobic soil organisms are unable to survive in the absence of gaseous oxygen. For example, bacteria that are responsible for the oxidation of nitrogen and sulphur are relatively ineffective in poorly aerated soils. This is also true for the symbiotic nitrogen fixers and some of the free living nitrogen fixers such as azotobacter.

Higher plants are also adversely affected by poor soil aeration because the root growth is curtailed; nutrient and water absorption is adversely affected; and certain toxic elements accumulate in poorly aerated soils.

4.8 CHEMICAL PROPERTIES

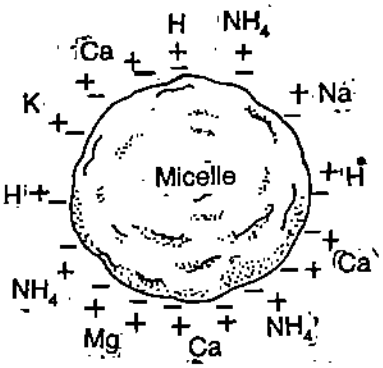


Fig 4.5 : Schematic representation of a clay or humus particle with hydrogen ions and mineral ions attracted by negative charges at its surface.

Soil is a highly dynamic system which supports complex chemical reactions. In this heterogeneous systems, the soil solution acts as the medium for complex chemical reactions. Soil colloidal components (clay and humus) bind the exchange cations on the surfaces.

Cation exchange is one of the most important soil reactions. Colloidal soil particles such as humus and clay usually bear electronegative charge. The charge may be the result of the adsorption of an excess of anions or the result of an imbalance in the atomic charges in the crystal lattice of clay micelle. To balance the negative charges, the particles tend to adsorb cations on their surface (see Fig 4.5). The balancing ions are called exchangeable cations and are in kinetic equilibrium with the soil solution.

4.8.1 Cation Exchange Capacity

The adsorption of a cation by a colloid nucleus or micelle and the accompanying release of one or more ions held by the micelle is termed as 'cation exchange'. The major cations are Ca^{2+}, Mg^{2+}, K^+, Na^+, and NH_4^+. Trace amounts of other cations such as Cu^{2+}, Mn^{2+} and Zn^{2+} are also present in the soil. Let us understand this with the help of an example. Assume that the clay micelle has one-half of its capacity satisfied with calcium ions, one-quarter with potassium ions, and one-quarter with hydrogen ions. The situation would be as shown in Fig 4.6.

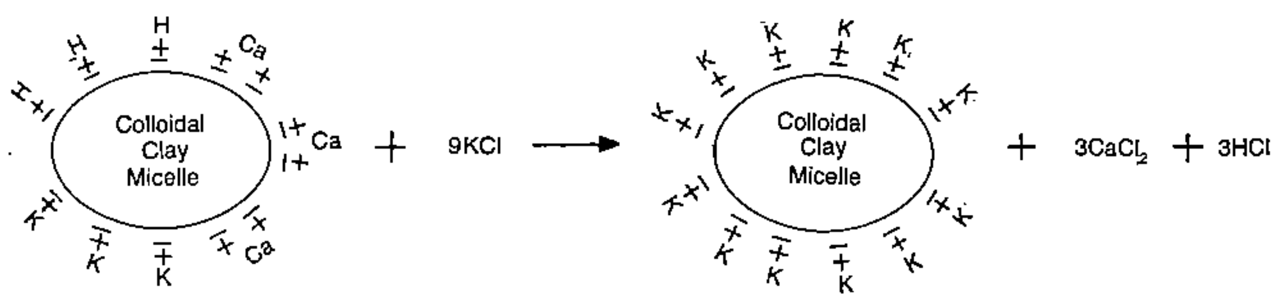


Fig 4.6: Depiction of cation exchange in a colloidal micelle.

Suppose that the soil is treated with a strong solution of potassium chloride. After some time, the potassium ions from potassium chloride will replace virtually all other cations and the micelle will get saturated with potassium. The calcium and hydrogen adsorbed on the micelle will be released and will enter the soil solution as chlorides. Since these cations (i.e., H+ and Ca^{2+}) are rather easily displaced, they are termed as exchangeable ions. The efficiency with which ions will replace each other is determined by (a) relative concentration or number of the ions, (b) the number of charges on the ions and (c) the speed of movement or activity of the different ions.

The capacity of soil colloids to adsorb cations can be determined easily. The commonly used method involve replacement of adsorbed cations by saturating the exchangeable sites with barium or ammonium ions, and then the amount of adsorbed barium or ammonium is determined. The cation exchange capacity is determined in terms of milliequivalent (m.e.) per 100 grams of soil. The total cation exchange capacity of the soil represents the total number of exchange sites both on humus and clay particles. If a clay has a cation exchange capacity of 1 milliequivalent (1 m.e./100g), it is capable of adsorbing and holding a milligram of hydrogen or its equivalent for every 100g of dry clay. You should note the term 'equivalent'. It indicates that other ions also may be expressed in terms of milliequivalents. For example, let us consider calcium. This elements has an atomic weight of 40 compared to 1 for hydrogen. Each calcium ion has two charges and thus is equivalent to $2H^+$. Therefore, the amount of calcium required to displace 1 milligram of hydrogen is 40/2 or 20 milligrams. This, then is the weight of 1 milliequivalent of calcium. If 100 grams of certain clay is capable of adsorbing a total of 250 milligrams of calcium, its cation exchange capacity is 250/20 or 12.5 m.e./100 g. The cation exchange capacity ranges from less than 5 for soils containing very little clay or organic matter to about 200 for soils richer in organic matter.

The composition of these cations exert a powerful influence upon both the chemical and physical attributes of a soil. In temperate and cold climates with moderate or high rainfall, H^+ ions are formed in abundance in the soil. They are of no direct use to the plants, and when they dominate the colloidal complex there is nothing to prevent the loss by leaching of important basic ions especially Ca, Mg and K and fertility is consequently low. This condition may arise as a result of the difference in the abilities of ions to replace each other, the order being H, Ca, Mg, K, NH_4 and Na. The degree of saturation with basic ions can always be reduced by cation exchange wherever there are enough H ions to bring about this displacement. Once displaced, the bases are carried away in drainage waters. Colloids are said to be unsaturated, when the adsorbed bases have thus been reduced to a very low level.

Cation Exchange Capacity = Exchangeable H + Exchangeable bases.

4.8.2 Nutrient Availability

You have seen that cation exchange plays an important part in nutrient availability to plants. Cation exchange functions in two ways as nutrients are released for the use of plants and microorganisms. In one case, the nutrients freed by cation exchange find their way into the soil solution. There they may ultimately contact the absorptive surfaces of roots and soil organisms or they may be removed by drainage water. Second, if the contacts of root hairs and microorganisms with the soil colloidal surfaces are close enough, there may be a direct exchange of cations between the colloidal particles and the root hairs or microbes. Under such a condition, the hydrogen ions, generated at the surface of root hairs or microorganisms, are thought to exchange with the adsorbed cations on the colloidal micelle without any of these ions having first been released to the soil solution.

Cation Saturation and Nutrient Absorption by Plants

The availability of adsorbed cations is not always so easy as the above explanation might suggest. This is because, several factors operate to expedite or retard the release of nutrients. First, there is the proportion of the cation exchange capacity of the soil occupied by the nutrient cation in question. For instance, if the percentage calcium saturation of a soil is high, the displacement of this cation is easy and rapid. Thus 6 milliequivalents of exchangeable calcium in a soil whose exchange capacity is 8 probably would mean ready availability. In another case 6 milliequivalents of Ca on the exchange complex in a soil having a total exchange capacity of 30 may represent an opposite condition. This is for this reason liming for alfa alfa crop (requires abundant calcium) should exceed 90 per cent saturation with calcium.

Influence of Associated Ions

The second important factor influencing the plant uptake of a given cation is the effects of the ions held in association with it. For instance, assume that suitable amounts of exchangeable calcium are held by two soils and that the accompanying cation in one case is dominantly hydrogen and in a second case mostly sodium. Since the strength of adsorption is in general of the order $H > Ca > Mg > K > Na$, it is obvious that in the first case Ca ions will be present in the soil solution in more quantity because they are held less tenaciously than the associated H ions. In the second case, the concentration of Ca ions in the soil solution will be relatively low since they are more tightly held by the soil colloids than are the sodium ions.

The Effect of Type of Colloid

Third, several types of colloidal micelle differ in the tenacity with which they hold specific cations. This undoubtedly will affect the ease of cation exchange. For instance, the tenacity with which Ca is held by montmorillonite (a type of clay) is much greater than that of kaolinite (another type of clay). As a result, it is suggested that a montmorillonitic clay must be limed to at least 70 per cent base saturation, before calcium will exhibit an ease and rapidity of exchange that will satisfy growing plants. A kaolinite clay, on the other hand, seems to liberate calcium much more readily, serving as a satisfactory source of this constituent at a much lower percentage of base saturation. Obviously, the liming programmes of the two soils will be different.

Effect of pH or Nutrient Availability

One of the greatest influence of pH on plant growth is through its effect on the nutrient availability. When base saturation is less than 100 per cent, an increase in pH is associated with an increase in the amount of calcium and magnesium in the soil solution, because calcium and magnesium are usually the dominant exchangeable bases. Many studies have shown that plant growth is promoted with increase in percentage of calcium in plants, which in turn is governed by the increasing pH or percentage base saturation. The general relationship between pH and availability of calcium and magnesium and other nutrients is shown in Fig 4.7.

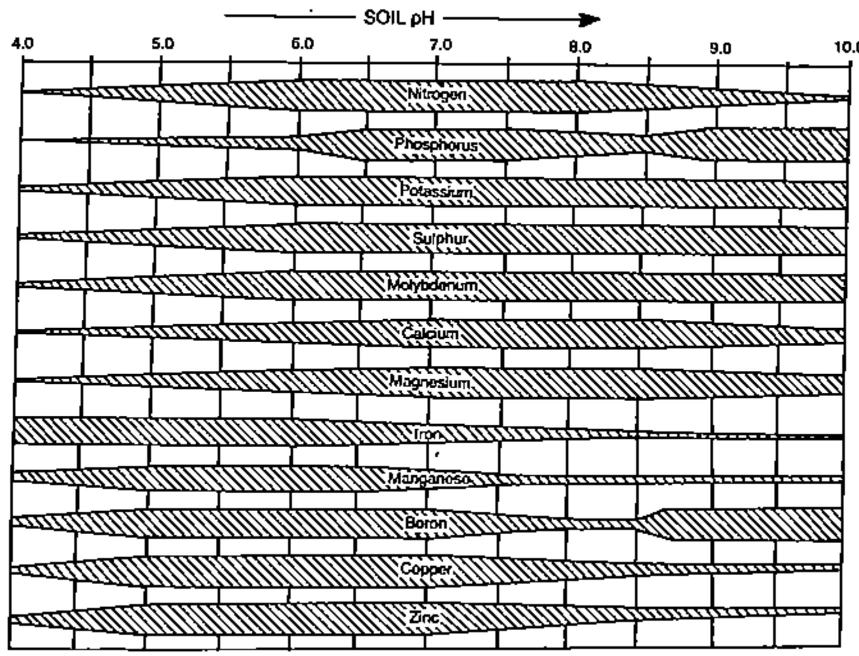


Fig 4.7: Relation of soil pH to the relative availability of nutrient elements required by plants.

Availability of molybdenum increases at higher pH (see Fig 4.7). At low pH, molybdenum forms insoluble compounds with iron and is rendered unavailable. Under these conditions, plants like cauliflower, clover and citrus will suffer from molybdenum deficiency but will show better performance when soil pH is increased. Potassium availability is usually good in alkaline soils that reflect the limiting leaching and removal of exchangeable potassium.

The availability or solubility of some plant nutrients decreases at higher pH. Iron and manganese which are generally deficient in calcareous soils are two good examples. Phosphorus and boron also tend to be unavailable in acid soils. On the other hand copper and zinc have reduced availability in both highly acidic and alkaline soils. The overall nutrient availability is good at close to pH 6.5.

Another aspect of soil chemistry not indicated in the Fig 4.7 is that at extremes of pH, the balance among nutrients becomes unfavourable, and certain nutrients become excessively soluble as to be toxic. For example, at low pH Al, Fe, Mn, Zn and Cu are excessively released to become toxic. The H and OH ions themselves are directly injurious below pH 4 or above 9.

4.9 SOIL BIOTA AND SOIL FERTILITY

A great diversity of organisms exist in soil, and they perform equally diverse functions. Many of their activities help in building of soil and contribute to its fertility. Salient features of their role in soil are discussed in this section.

4.9.1 Decay and Nutrient Cycling

Soil organisms are the chief agents of decay of organic matter. Decomposition and mineralisation of organic matter results in release of inorganic nutrients which can be absorbed by roots to sustain plant growth. In soil, the decomposers, that include a vast variety of bacteria, actinomycetes and fungi act on the organic matter. These organisms bring about the hydrolysis and oxidation of organic compounds through their enzymes. Complex organic compounds are broken down into simpler compounds until at last, carbon, hydrogen and oxygen are finally released as carbon dioxide and water. Other nutrients contained in the organic matter are released in inorganic form. You might recall that the conversion of nutrients present in the organic matter into inorganic form is termed as mineralisation. The whole process is as follows. Organisms like the fungi, ants, beetles, mites, slugs and snails, sometimes invade fragments of litter even before they fall on the ground. In subsequent transformations, each type of organic substance (carbohydrates, proteins and fats) as well as each stage in the breakdown of these substances, has its own specific set of saprophytes which act upon the organic material so that decay progresses by stages. For example, proteins are broken down successively into amino acids, ammonium salts, nitrites and nitrates, each step being the result of action of a different organism or group of organisms. Therefore, the process of decomposition consists of several overlapping cycles. As a result of decomposition of organic matter humus is formed, which is quite resistant to further alteration. You have already studied it earlier.

4.9.2 Production of Growth Substances

A wide variety of heterotrophic soil microorganisms including bacteria and fungi are known to produce 3-indole acetic acid and other growth promoting substances. This is very significant, as it governs the subterranean environment of plants. The occurrence of such growth regulating substances influence the growth and establishment of soil organisms on and around the plant roots.

4.9.3 Nitrogen Fixation

You have already studied in FST-I, Block 4, Unit 14, that nitrogen is an essential constituent of living organisms and there is an inexhaustible supply of it in the atmosphere in the free form. Majority of living organisms including humans are incapable of utilising gaseous nitrogen but need organic nitrogen for their nutrition. It is for this reason that the nitrogen fixation or availability of organic nitrogen is critical for the living organisms.

Free nitrogen is inert but certain groups of specialised organisms have the ability to utilise gaseous nitrogen from the atmosphere. The reduction of gaseous nitrogen or its conversion to organic nitrogen is called nitrogen fixation. The fixed nitrogen is readily utilised by other organisms. Incorporation of atmospheric nitrogen into nitrogen compounds by nitrogen fixers such as *Azotobacter* in aerated soils; *Clostridium* in unaerated soils; *Rhizobium* in the nodules of legume roots and by a number of blue green algae such as *Nostoc* and *Anabaena*, is the most important step to ensure nitrogen supply for the living organisms. The quantum of biological nitrogen-fixation has direct effect on soil fertility.

4.9.4 Soil Mixing

The larger soil organisms are responsible for considerable mechanical mixing and weathering of soil. The wedge-like action of roots and other underground plant organs, widens the fissures in rocks and the compacted soil so that they are more susceptible to other forms of weathering. Rodents, insects and worms turnover great amounts of soil, with the result that the material is repeatedly exposed to the physical and chemical agents of weathering. One of the most important organism in this regard is earthworm. These are important in many ways. The amount of soil that these creatures pass through their bodies annually may amount to as much as 15 tons of dry earth per acre, a startling figure! During the passage through the worms, not only the organic matter which serves the earthworm as food, but also the mineral constituents are subjected to digestive enzymes and to a grinding action within the animal. There is usually an abundant growth of grass around earthworm casts, this suggests an increased availability of plant nutrients therein. Thus the activity of earthworm not only mixes the soil, but also makes it fertile by increasing its aeration and drainage. They also bring the lower soil to the surface. They mix and granulate the soil by dragging into their burrows, large quantities of undecomposed organic matter such as leaves and grass, which they use as food.

Burrowing animals also bring great quantities of subsoil to the surface. In addition, these animals cut and bury the litter of which some is used for food and some as nesting material. The latter, together with their excreta buried below the surface, greatly increase the organic content which contribute to soil fertility.

4.9.5 Improvement of Soil Aeration

Soil organisms greatly improve soil structure and facilitate aeration. Root decay leaves the soil riddled with channels. and the burrowing of worms and other animals create innumerable passage ways which help in gaseous exchange, i.e., diffusion of oxygen and release of carbon dioxide from the soil. Growing roots often follow such channels on account of better aeration.

4.9.6 Improvement of Aggregate Structure

Bacteria and blue green algae, both of which are abundant in the soil, secrete mucilagenous excretions which cover their cells and colonies. Such muciliagenous materials along with other organic excretions of the cells are very effective in cementing soil grains into larger aggregates. A similar function is performed although in an entirely different manner by the soil fungi which bind soil particles together.

SAQ 3

Complete the following statements with appropriate words.

i) The physiochemically active fraction of soil is ....

ii) The soils that are smooth and contain large amount of clay and silt are termed as...................... soils, and the coarse soils containing high proportion of sand and gravel are called as...................... soils.

iii) .... by plants and...................... from soil surface are two major processes responsible for the loss of water at a rapid rate from the soil.

iv) .... water in the soil is the example of nonavailable water whereas .... water that is readily absorbed by plant roots.

v) Permeability of soil decreases with the .... percentage of .... size soil particles.

vi) In a soil, cation exchange capacity depends on the relative...................... of ions, number of .... on the ions and the .... of different ions.

vii) In some soils, there is build up of excessive H+ ions due to abundant rainfall, consequently there is .... of important basic cations resulting in the .... of soil fertility.

viii) The overall availability of nutrients for plants and soil micro-organisms is good in soils having pH of ....

ix) If the pH of a soil becomes very low, aluminium, iron and zinc, become excessively .... and ultimately prove .... to most of the soil biota.

x) ...., ... and .... are the main decomposers of organic matter in soil.

4.10 SUMMARY

- Soil is an important constituent of our environment. It is a complex system consisting of inorganic materials derived from parent rocks, organic matter of plant and animal origin, water, gases and supporting a wide variety of living organisms.
- Soil formation is a slow, gradual and continuous process involving hundreds of years. The basic framework of soil is made up of the weathered rock material. Processes like mineralisation and humification make the newly formed soil suitable for the growth and prosperity of living beings.
- Based on the sites of origin, the soils have been classified into two main categories, namely, residual and transported. Residual soils are ones which develop at the very site where their parental rock material is present, whereas transported soils are ones in which the rock materials are carried by various agencies to distant places where they develop

further. Depending on the agent involved in the transfer of weathered material, the transported soils are : colluvial (by gravity), alluvial (by water), glacial (by ice and snow) and aeolian (by wind).

- Soil is made up of particles of varying sizes, mixed in different proportions. Based on the diameter, soil particles have been classified into clay, silt, fine sand, coarse sand and gravel. Twelve main classes of soils are recognised depending on the relative proportion of soil particles of different sizes.
- The presence of soil particles, i.e., relative proportion of clay, silt and sand imparts a particular texture to the soil which greatly influences soil permeability to gases and moisture. The arrangement of soil particles into aggregates refers to the soil structure. A soil is said to be heavy, if it contains more of clay and silt. It is difficult to draw agricultural implements through such soils. On the other hand, soils having higher proportion of sand and gravel are termed as light, as agricultural implements can be easily drawn through them.
- Water in soil occurs in different forms. Gravitational water seeps through the soil under the influence of gravity, and is not available to plants. Capillary water is held in the soil pores and is utilised by the plants and other soil organisms. Hygroscopic water refers to the small amount of water that is tightly held on the surface of soil colloids, and is unavailable to plants.
- Permeability and aeration are important properties of a soil which influence the availability of water and gases. The growth of plants, particularly their roots are adversely affected in poorly aerated soils. Poor soil aeration retards absorption of water and nutrients by roots and leads to the build up of certain toxic substances in the soil.
- Cation exchange is an important chemical property of soil whereby nutrients such as Ca, Mg, K, Na, Cu, Mn, Zn and NH_4 present in soil are made available to the plants and other organisms of soil. The cation exchange capacity of a soil refers to the total number of exchange sites on the soil colloids which include humus and clay particles. The release of a particular nutrient in the soil depends on a number of factors such as proportion of cation exchange capacity of the soil occupied by a given cation; the influence of associated ions; the tenacity with which the colloid micelle holds the cation; and the soil pH.
- The diverse kinds of living organisms inhabiting the soil contribute immensely to soil fertility in different ways. Soil microbes carry out organic matter decomposition, help in nutrient cycling; production of growth substances and nitrogen fixation. Soil biota also improve aeration and contribute organic matter through their death and decay.

4.11 TERMINAL QUESTIONS

1) a) What does the term 'soil' mean to you?

....

....

....

....

b) If you pick up a handful of soil, list what all you find in it?

....

....

....

c) Soil formation proceeds in two steps or stages. What are they?

....

....

....

2) Fill in the empty columns in the table given below:

S.No.	Soil Type	Salient Features
I	RESIDUAL	i) .... ii) ....
II	TRANSPORTED	i) .... ii) ....
a.	Colluvial	i) .... ii) .... iii) .... iv) ....
b.	Alluvial	i) .... ii) .... iii) .... iv) ....
c.	Glacial	i) .... ii) .... iii) .... iv) ....
d.	Aeolian	i) .... ii) .... iii) .... iv) ....

3) a) Arrange the following categories of soil particles according to their diameter in a descending order. Fine sand, clay, stone and gravel, silt, coarse sand.

....

....

b) On what basis a soil is assigned to a textural class?

....

....

....

....

....

4) a) What types of soil water are recognised? Which of them is available to the plants?

....

....

....

....

....

b) How would you differentiate between heavy and light soil? Suggest a simple method.

....

....

....

....

c) List two major features of a well aerated soil.

....

....

d) Poorly aerated soils get degraded in due course of time. Why?

....

....

....

5) The proportion of sand, silt and clay in a soil determines (i) structure, (ii) water holding capacity, (iii) texture, (iv) nutrient potential, (v) fertility level. Tick mark [√] the correct answer.

6) a) What do you understand by cation exchange capacity of a soil? How it is expressed?

....

....

....

b) What factors govern the efficiency of replacement of ions from cation exchange complex of soil.

....

....

....

c) Name few elements which accumulate in toxic concentrations at low pH.

....

7) Clay particles will attract and hold which of the following ions to their surfaces?

(i) NO^-_3 (i) NH^+_4 (iii) $H_2PO^-_4$ (iv) Ca^{2+} (v) K^+

....

8) How does soil biota help in maintaining the soil fertility? Restrict your answer to the space provided below.

....

....

....

....

....

....

....

....

....

....

9) In order to grow good crops the soil is expected to perform certain functions. Which of the following are the required functions? (Tick mark [√] the correct answer).

   i) Store and exchange plant nutrients [ ]

   ii) Act as a reservoir and transport system for air and water [ ]

   iii) Provide anchorage for the plants [ ]

   iv) All of the above. [ ]

4.12 ANSWERS

Self-assessment Questions

1) i) mineral matter, organic matter, water, air, living organisms

   ii) weathering, humification, mineralisation

   iii) poor

   iv) organic matter

   v) residual, transported

   vi) dune

2) i) Soil texture pertains to particle size composition of a soil whereas soil structure refers to the arrangement of soil particles into aggregates.

   ii) False

   iii) a.

3) i) clay

   ii) heavy, light

   iii) transpiration, evaporation

   iv) hygroscopic, capillary

   v) increasing, small

   vi) concentration, charges, activity

   vii) leaching, loss

   viii) 6.5

   ix) soluble, toxicè

   x) bacteria, actionomycetes, fungi

Terminal Questions

1) a) **Hint :** It is the weathered outer crust of the earth that provides nutrients, water and shelter to living organisms that dwell and prosper in soil.

   Also see section 4.2 to formulate a crisp answer.

   b) minerals, organic matter, gases, water and various kinds of living organisms.

   c) i) Weathering of rocks

      ii) Mineralisation and humification

2)

S.No.	Soil Type	Salient Features
I	RESIDUAL	i) whole process of soil formation takes place at in situ or at the site of parent rock. ii) intensity of weathering is greatest near the surface, thus a gradation of weathered material can be seen in the soil profile.
II	TRANSPORTED	i) soil formed from the weathered material deposited away, from the site of origin, by transporting agencies. ii) no regular gradation in the soil profile is visible.
a)	Colluvial	i) weathered material transported by gravity. ii) composed of coarse materials; particles of various sizes mixed indiscriminately.

		iii) lack of stratification iv) found in hilly areas at base of mountains and slopes.
b)	Alluvial	i) weathered materials transported by running water. ii) individual particles are rounded and smoothed by and flowing water. iii) distinct layers deposited depending on the speed of water. iv) found bordering rivers and along flowing water bodies.
c)	Glacial	i) weathered material transported by moving ice and snow. ii) component particles have smooth surface due to abrasive action of ice and snow. iii) soils comprised of weathered and unweathered materials ranging from fine rock powder to massive boulders. iv) devoid of stratification.
d)	Aeolian	i) weathered material transported by wind. ii) composed of particles of uniform size and composition. iii) materials brought from great distances. iv) occurs along the shores of sea, lakes, rivers and in many dry regions.

3) a) Stone and gravel, coarse sand, fine sand, silt and clay.

b) Depending on the proportion of clay, silt and sand that a soil sample contains, it is assigned to a particular textural class. The triangular diagram helps to distinguish between the twelve textural classes.

4) a) Water exists mainly in three forms : gravitational, capillary and hygroscopic water. Of these, the capillary water is readily available to the plants.

b) Soils in which agricultural implements can be drawn easily are regarded as light soils and the soils which offer some resistance to the agricultural implements are designated as heavy soils.

c) i) Sufficient space for air movement, and

ii) ample opportunity for the easy movement of gases.

d) Lack of oxygen retards the decomposition of organic matter, which adversely affects nutrient cycling and soil fertility.

5) iii) Texture

6) a) It refers to the total number of exchange sites of colloids in soil. It is expressed in milliequivalents (m.e.) per 100 g of soil.

b) i) Relative concentration of ions, (ii) the number of charges of the ions, (iii) the speed of movement of ions.

c) Aluminium, iron, manganese, zinc and copper.

7) NH^{+}_{4}, Ca^{2+}, K^{+}

8) i) Soil biota constantly add organic matter in various forms to the soil.

ii) Different kinds of soil organisms carry out sequential reactions to breakdown the organic matter into its component simpler forms, so that they can be reused by plants and other organisms.

iii) Many soil organisms produce growth promoting substances that influence the growth of several other microorganisms in their vicinity, which in turn through their activities improve the soil.

iv) Numerous kinds of bacteria and blue green algae in soil fix atmospheric nitrogen by converting it into organic nitrogen.

v) Due to the burrowing activities of various animals, the soils are constantly upturned and mixed, this increases their aeration and drainage.

vi) Organisms like bacteria, blue green algae etc. also improve the aggregate structure of the soil.

vii) Death and decay of soil organisms is a source of organic matter in soil.

9) iv)

GLOSSARY

adaptable : able to change, making an organism more likely to survive

adaptation : a genetically determined characteristic that enhances the ability of an individual to cope with its environment; an evolutionary process by which organisms become better suited to their environment

aerosols : tiny solid and liquid particles suspended in the atmosphere

adsorption : the adherence of one particle, ion or molecule to the surface of another

anthropogenic : relating to humans

artesian well : perpendicular well producing a constant supply of water rising to the surface without pumping

bedrock : unweathered solid rock underlying soil

biogeocoenoses : term equivalent to ecosystem, used frequently by European and Russian scientists

biota : flora and fauna together

cation : an ion carrying positive electrical charge

cation exchange capacity : a measure of the total amount of exchangeable cations that a soil can hold, expressed in m.eq./100 g

chemosynthesis : a form of autotrophic nutrition in certain bacteria in which energy for manufacture of carbohydrates is obtained from inorganic materials instead of the sun

clay : soil particles less than 0.002 mm in diameter

covalent bond : a chemical bond between atoms formed by sharing of electrons

emigration : outward migration of a species or an individual from its normal area of occurrence

estuary : a coastal region such as inlets or mouths of a river where fresh water and salt water mix

fauna : a collective term for all the animal types that occur in a region

field capacity : amount of water that soil can hold against the pull of gravity

flora : a collective term for all the plant types that grow in a region

foot-candle (ft-c) : a standard measure of light. It is the illumination of a standard light source of one candle, one foot away, falling at all points on a square foot surface

food chain : a specific nutrient and energy pathway in ecosystems, proceeding from producer to consumer

geologic substratum : layer of the earth's crust

global warming : heating of the earth's atmosphere due to increasing concentration of carbon dioxide and other greenhouse gases

habitat : a specific site or place where a plant or animal naturally or normally lives or grows

heavy soil : a soil with a high content of the fine separates particularly clay, and hence difficult to cultivate

holocoenotic principle : the principle that the environment acts as a whole because the abiotic components, such as heat, light, temperature and the biotic components are integrated and do not act in an independent manner

humus/humic : a black or brown complex soil organic matter resulting from the decomposition of dead plants and animals or their parts. Humus increases soil fertility, aeration and water retention

hygroscopic water : water held tightly by surface adhesion to soil particles generally unavailable to plants

immigration : migration of a species or one individual to a new area

inorganic compounds : chemical compounds which normally do not contain carbon, as well as a few simple carbon containing substances, such as carbon dioxide and carbonates

leaching : the process of downward movement of soluble nutrients and other salts with moving water through soil profile

light soil : a coarse-textured sand soil, hence easy to till

loam : a textural class of soil with prescribed amounts of sand, silt and clay

mangrove : a tidal forest vegetation in saline swampy sea shore areas, in the tropics

marsh : water-logged ground which is dominated by emergent vegetation

metabolism : a general term for chemical reactions occurring in living cells, includes two major types of reactions : breakdown (catabolic) reactions and synthesis (anabolic) reaction

micelle : a complex soil particle with negative electric charges at its surface

organic compound : chemical compound containing carbon or of non-mineral origin

osmoregulation : the process by which living begins regulate the amount of water in their bodies and the concentration of various solutes and ions in their body fluids

ped : a unit of soil structure such as an aggregate crumb, prism, block etc.

pedology : the study of soil

pH : measure of acidity and alkanity on a 0-14 scale, with pH being neutral at 7. Numbers greater than seven, i.e., 8-14 pH being alkaline (basic), and less than seven, i.e., 6-0 pH being acidic

photon : a quantum of visible radiation; a "packet" of light energy

photoperiod : the duration of a period of light, such as the length of time in a 24-hour cycle in which daylight is present

photosynthesis : the process by which chlorophyll containing cells of plants utilize energy of the sun to synthesise simple carbohydrates from carbon dioxide and water. Oxygen is a by-product

phototaxis : locomotory movement of an organism or cell to the direction of illumination, e.g., movement of gamete in response to light

phototropism : in plants, a growth response to light stimulus

plankton : microscopic floating, aquatic plants (phytoplankton) and animals (zooplankton) in marine and fresh water situation which float freely in water

polar bond : chemical bond in which an electron is transferred from one atom to another, the resulting ions being held together by electrostatic attraction

pollution : an undesirable change in the physical, chemical or biological characteristics of air, land and water which affects life adversely, either directly or indirectly

precipitation : moisture falling on the earth's surface from clouds, it may be in the form of rain, hail, snow or sleet

productivity : amount of organic matter accumulated in the living component of an ecosystem in unit time, i.e., the rate of conversion of sunlight by plants into chemical bond energy

range of tolerance : range of physical and chemical factors within which an organism can survive

recycle : to pass through a cycle again, to return to an original condition

sand : a soil particle between 0.02-2.0 mm in diameter

silt : a soil particle between 0.002 and 0.02 mm in diameter

soil : the upper portion of earth's crust in which plants grow. It is composed of mineral matter, air, water, organic matter and various kinds of living organisms

soil aggregate : single mass or cluster of soil particles such as crumb, spheroid etc.

soil horizon : a layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil forming processes

soil profile : a vertical section of soil extending through all its horizons from the surface to bedrock

soil organic matter : the organic fraction of the sil that includes plant and animal residues at various stages or decomposition, and substances synthesised by various soil organisms

soil structure : the arrangement of soil particles into aggregates

soil texture : the relative percentage of sand, silt and clay in a soil

specific heat : the quantity of heat in calories which unit mass of that substance requires to raise its temperature by one degree celsius

succession : a natural ecological process by which different groups or communities colonise successively the same area over a period of time in a definite sequence

taiga : the northern boreal forest zone, a broad band of coniferous forest south of the arctic tundra

topography : the physical geography of the earth

tundra : treeless area in arctic and alpine regions, varying from a bare area to various types of vegetation consisting of grasses, sedges, ferns, dwarf shrubs, lichens and mosses

water-logging : refers to a condition when a ground is completely saturated with water or it has standing water

weathering : all physical and chemical changes produced in rocks at or near the earth's surface by atmospheric agents

wilting coefficient : the minimum water content of the soil at which plants can obtain water

wilting point (or permanent wilting point) : the moisture content of soil at which plants wilt and fail to recover even when placed in a humid autmosphere

xerophyte : a plant able to inhabit places where water supply is scanty or where there is physiological drought.

FURTHER READINGS

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Limnology, R.G. Wetzel, W.B. Saunders Co., New York, 1975.

Dear Student,

While studying these units you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions in order to improve the course. Therefore, we request you to fill and send us the following questionnaire which pertains to this block.

QUESTIONNAIRE

LSE-02
Block-1

Enrolment No. | | | | | | | | | |

1) How many hours did you need for studying the units?

Unit Number					
No. of hours					

2) How many hours (approximately) did you take to do the assignments pertaining to this block?

Assignment Number		
No. of hours		

3) In the following table we have listed 4 kinds of difficulties that we thought you might have come across. Kindly tick (√) the type of difficulty and give the relevant page number in the appropriate columns.

Page Number	Types of difficulties			
	Presentation is not clear	Language is difficult	Diagram is not clear	Terms are not explained

4) It is possible that you could not attempt some SAQs and TQs.
In the following table are listed the possible difficulties. Kindly tick (√) the type of difficulty and the relevant unit and question numbers in the appropriate columns.

Unit No.	SAQ No.	TQ No.	Type of difficulty			
			Not clearly posed	Cannot answer on basis of information given	Answer given (at end of Unit) not clear	Answer given is not sufficient

5) Were all the difficult terms included in the glossary. If not, please list in the space given below.

6) Any Other Suggestion(s)

To,

The Course Coordinator (LSE-02; Ecology)
School of Sciences
Indira Gandhi National Open University
Maidan Garhi
New Delhi - 110 068

UGBY/ZY - 06
Ecology

Block

2

ECOSYSTEM : FUNCTIONING, TYPES

BLOCK 2 ECOSYSTEM : FUNCTIONING TYPES

In the first block, we have discussed the concept of ecosystem and its components. The various non-living components have been described in isolation in Units 2, 3 and 4. We, from our study of ecosystem, know that the biotic components depend on the abiotic components of the environment. In this block, we aim to draw together information and principles from the earlier units so that you begin to understand how the ecosystem functions on the whole. From the previous block you would have also got the idea that our earth can be considered as a vast ecosystem. Since this complete system is much too big and complex to be studied at one time, it is therefore, more convenient to divide it into two basic categories — the terrestrial and aquatic ecosystems. In this block, these two major types of ecosystems will be reviewed in order to bring out the differences in their structure and functions.

The first Unit of this block explores some of the ecological topics that are not extensively discussed so far. First, we have dealt with the components of ecosystem. This is followed by trophic levels and ecological pyramids. Then energy input in the ecosystem is considered. Next the concept of production, that is, primary production – net and gross; secondary production; and ecological efficiency are introduced. Then, the topics — energy flow and energy budget are taken up. The unit concludes with a discussion on ecosystem control and feedback.

Organisms are made up of matter and they need a constant supply of nutrients to grow, reproduce and regulate various bodily functions. Unit 6 discusses the flow of nutrients from the living to non-living components of the ecosystem and back in perpetual cycles. The two basic types of biogeochemical cycles — gaseous, represented by carbon and nitrogen; and the sedimentary, represented by phosphorus and sulphur have been explained. The crucial role of micro-organisms in releasing the nutrients bound in living matter for reuse and the impact of human activities on nutrient cycles have been discussed. Finally, the overall nutrient budget and cycling in tropical forests have been compared to cycling in temperate forests.

The Unit 7 of this block deals with types of terrestrial ecosystem. Here, you would study the different biomes in detail. It will be discussed as to how these biomes have been affected by some of the human activities. Then, we will talk about the Chipko Movement and social forestry in the present day context.

Finally, in this block we will discuss about the global waters which cover about three quarters of the earth's surface. You will study that aquatic ecosystems are categorised into fresh water, marine, and brackish water ecosystems. We will describe at length the oligotrophic, mesotrophic, eutrophic lakes and impoundments. Besides, you will study the difference between the biota of lakes, rivers, estuaries and marine ecosystems.

Objectives

After studying this block you would be able to :

- define and apply the terms and principles related to various aspects of ecosystem functioning;
- outline the course of various nutrients like carbon, nitrogen, sulphur and phosphorus in biogeochemical cycles;
- describe the concept of biomes viz. grasslands, forests, deserts and relate the importance of these biomes to human welfare;
- explain the general ecological features of aquatic ecosystem with their classifications.

Study Guide

We advise you to give a quick look to the Study Guide given in Block-1, before beginning this block. Just like the previous block you would find a questionnaire at the end of this block too, wherein we have sought your help to let us know your difficulties and suggestions for improving this block. It would be useful to keep a record of the time you spend studying each unit of this block. Also have a look at the questionnaire, this will give you an idea, as to which points you need to note down while reading the units.

UNIT 5 ECOSYSTEM FUNCTIONING

Structure

5.1 INTRODUCTION

As you know from your study of Block-4, FST-1; and Block-1, LSE-02, that an ecosystem consists of the community of organisms in a given area together with the abiotic (non-living) components of the environment. The term ecosystem is applied to both small and large ecological systems. Thus we might consider a small pond or even a tree as an ecosystem. On a much larger scale, we can examine a crop field, a grassland, forest, ocean, or even our planet on the whole as an ecosystem.

Ecosystems have both structure and function. The structure of an ecosystem is determined by the components that make up the system, while ecosystem function is determind by the manner in which these components interact in a complementary way. Let us examine these interactions in more detail.

In this unit you would find certain terms and concepts that you have studied before (in the above units). Here, these concepts have been elaborated further, or they are used as a background material for explaining other concepts. Before, you start going through this unit, we advise you to give a quick glance to the units mentioned below: i) Unit-14, Block-4, FST-1; ii) Unit-1, Block-1, LSE-02.

Objectives

After studying this unit you would be able to :

- explain why ecosystem is taken up as a unit of study;
- identify the various components of an ecosystem and state the functional role of producers, primary consumers, secondary consumers and decomposers in an ecosystem;
- summarise the concept of limiting factors and tolerance range;
- recognise different types of ecological pyramids, and realise the usefulness and limitations of ecological pyramids in describing ecosystem dynamics;
- describe gross primary production, net primary production and secondary production;
- explain food-chain, food web, and flow of energy through the ecosystem;

- define and use in proper context the terms 'ecological efficiency', 'energy budget', and 'ecological feedback'.

5.2 ECOSYSTEM AS A UNIT OF NATURE

An ecosystem can be visualised as a functional unit of nature representing complex interactions between living and non-living components. The study of any ecosystem involves systematic description of the components and understanding of the close relationship between the biotic and the abiotic components. Why consider ecosystem as a unit of study? This, perhaps, is the question arising in your mind presently. If one wishes to study the various aspects of relationships of living and non-living components of the environment, it would be easy to understand and interpret these relationships in a smaller component of the biosphere, that is the ecosystem. We shall elaborate this further with the help of an example. Let us consider a village ecosystem (see Fig. 5.1). It is depicted here by the area enclosed within the dotted lines. The boxes within the village ecosystem represent three sub-systems namely: producers or crop plants, cattle and humans. The solid lines connecting the boxes represent the interactions. Solar energy, fertilisers and pesticides are the major inputs brought from outside the village ecosystem. These inputs determine the quantum of output, that is, foodgrain, fodder and other animal products which are exported from the village. So, you see that, the village ecosystem could be considered as a model to study the organisms and their environment as an integrated unit.

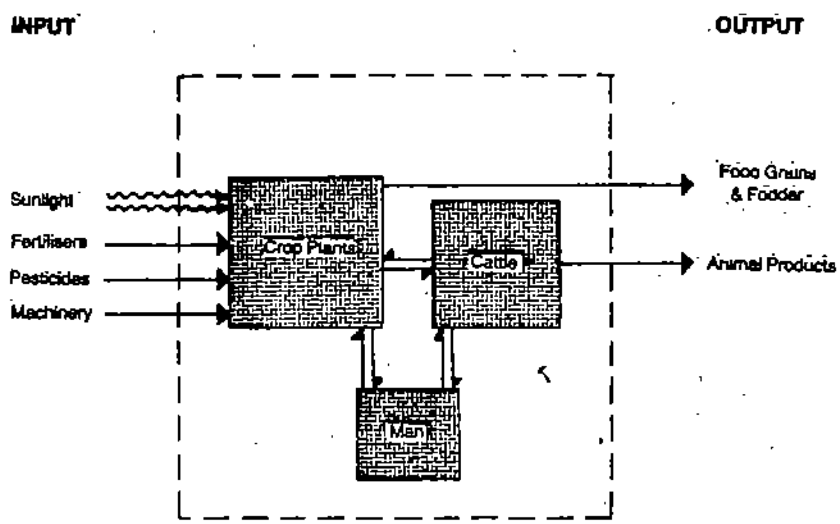


Fig. 5.1 : A model of village ecosystem

Ecosystems are conceptual models and these models can be applied at any scale, from a bowl of water to the whole earth. Ecosystems represent enormous contrast in size and complexity. For the purpose of study, an ecosystem can be delineated in almost any way convenient to the interest of the investigator. In the case of some ecosystems such as lake, river or pond, distinct boundaries can be recognised but in the case of other ecosystems, such as a grassland, forest, village or town, boundaries are not so sharp however, they can be delineated according to the object of study or any other practical consideration.

5.3 COMPONENTS OF ECOSYSTEM

All ecosystems possess both biotic and abiotic components. Let us now examine these two components.

a – without, bios – life

5.3.1 Abiotic Components

Three broad categories of abiotic components can be visualised.

i) **Inorganic Substances :** There are about forty elements that are required in various processes of living organisms. Some of these are macronutrients which the plants need in relatively large amounts, and others are micronutrients, that are required in trace amounts. There are nine macronutrients : carbon, hydrogen and oxygen (the three elements found in all organic compounds), and nitrogen, potassium, calcium, phosphorus, magnesium, and sulphur. Some examples of micronutrients are : iron, chlorine, copper, manganese, zinc, molybdenum and boron.

ii) **Organic Substances :** These include carbohydrates, proteins, lipids and their derivatives which are derived from the waste products of plants and animals or are the remains of dead plants and animals. Organic fragments of different sizes and composition formed as a result of decomposition of organic residues are collectively called organic detritus. Decomposing organic matter releases nutrients along with the formation of a dark, amorphous, colloidal substance called humus which is important for the fertility of soil (also see Unit-4, LSE-02). New humus is added as old humus gets converted into mineral elements.

Detritus is derived from latin word 'detere' meaning wear away.

iii) **Climatic Factors :** This includes temperature, rainfall, humidity, and light, and their daily and seasonal fluctuations. These abiotic constituents are very important for the survival and continuation of living beings and the ecosystem.

5.3.2 Biotic Components

We categorise the biotic components of an ecosystem into three categories on the basis of how they obtain energy and nutrients.

i) **Producers :** Producers, also called **autotrophs**, are largely green plants that can make food from simple inorganic materials. Food refers to complex organic compounds such as carbohydrates, fats and proteins. Green plants accomplish food making through the process of photosynthesis. In this process, green plants use carbon dioxide, water and some minerals, to produce carbohydrates first, and later various other organic compounds such as fats and proteins. Oxygen is given off by plants as a byproduct of photosynthesis. During photosynthesis, radiant energy of sunlight is converted into chemical energy and is stored in the chemical bonds of the compounds made by the plants (see the equation given below).

Producer = Primary Producer
aut, auto-self; trophos-feeding

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{Sun}}{\text{Light Energy}} \xrightarrow[\text{(in green plants)}]{\text{Chlorophyll}} \underset{\text{Glucose (sugar)}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

The major **primary producers** of aquatic ecosystems (freshwater and marine) are various species of algae (see Fig. 5.2). In terrestrial ecosystems, the major primary producers are predominantly herbaceous and woody plants. Some photosynthetic prokaryotic organisms such as blue green algae and a few bacteria are also called primary producers. Besides the green plants there are certain chemosynthetic bacteria that are also autotrophic. But they obtain the energy for the synthesis of organic compounds (amino acids, proteins) from sources other than solar energy. Some of these sources are : ammonia (NH_3), methane (CH_4), and hydrogen sulphide (H_2S). You can surely make a long list of animals that obtain their food from green plants. Can you also name a few organisms that depend on the chemosynthetic bacteria for nutrition? We give you a few examples of the same. Organisms like crabs, molluscs and giant worms, that are present at or near the oceanic floor where sunlight cannot penetrate, get their food from chemosynthetic bacteria.

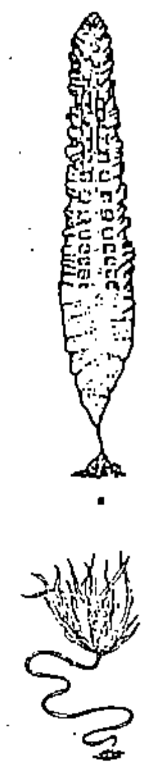


Fig. 5.2 : Marine algae
a) *Laminaria agardhii*
b) *Nereocystis luetkeana*

ii) **Consumers :** These are also called as **phagotrophs or heterotrophs.** The organisms grouped under this category cannot manufacture their own food but obtain their energy and nutrients by feeding on other organisms. Some eat primary producers (green plants) to get their food supply and are called **herbivores.** In terrestrial ecosystem typical herbivores are insects, birds and mammals. Two important groups of herbivores mammals are rodents and ungulates. **Primary consumers** also include parasites (fungi, plants or animals) of plants (see Fig. 5.3). In aquatic ecosystems (freshwater and marine) the typical examples of herbivores are : small crustaceans and molluscs. Most of these organisms such as water fleas, copepods, crab larvae, mussels and clams are filter feeders and extract the minute, primary producers from water.

Phago – eat

heteros – other different:
trophos – feeding

Herbivores = Primary Consumers
herba – grass, green crops;
vora – devour, eat

Ungulates are hoofed, grazing animals, such as horses, cattle and sheep that are adapted for running on the tips of their digits

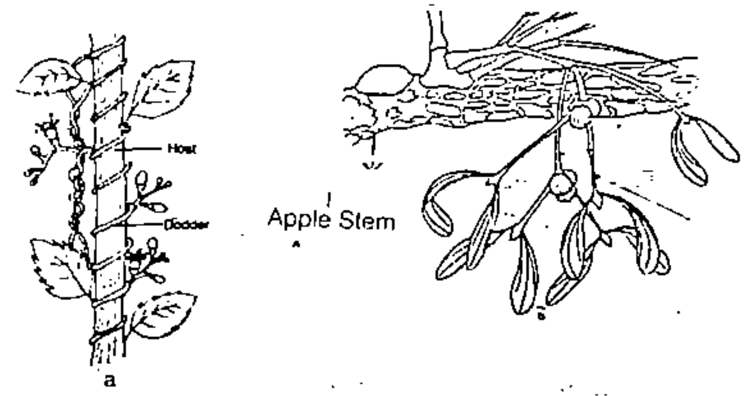


Fig. 5.3 : Some Parasites of Plants a) Dodder (*Cuscuta* sp.) b) Mistletoe (*Viscum* sp.)

Carnis-flesh
secondary consumer=carnivore

Besides, there are animals which depend on herbivores for food and are called **secondary consumers** . Since secondary consumers feed on herbivores, they are therefore, carnivores. There are also animals that feed on secondary consumers. They too are carnivores, and are known as **tertiary consumers.** Secondary and tertiary consumers may be : a) **predators** which hunt, capture and kill their prey; **b) carrion feeders** which feed on corpses; or **c) parasites** in which they are much smaller than the host, and they live on it while the host is alive. They depend on the metabolism of their host for their energy supply.

There are some animals that have quite flexible food habits as they eat plants, (therefore are herbivores) and animals (therefore are carnivores). They are known as **omnivores** of which man himself is a good example.

Omnis – all

Sapros – decomposed, rotten; trophos – feeding

iii) **Decomposers :** Also known as **saprotrophs.** Mostly, these are microscopic and are heterotrophic in nature. Decomposer organisms obtain their energy and nutrients by degrading dead organic matter. When plants and animals die, their bodies are still a source of energy and nutrients, as are their waste products such as urine and faeces which they discard throughout their life times. These organic remains are decomposed by micro-organisms, namely fungi and bacteria which grow saprophytically on these remains. They secrete digestive enzymes from their bodies on the dead and wasted materials, subsequently absorbing the products of digestion. The rate of digestion is variable. The organic matter of animal wastes such as urine, faeces and corpses is consumed within a matter of weeks whereas fallen leaves and branches may take years to decomposes. During the decomposition of wood, fungi act and produce an enzyme cellulase, that softens the wood. This enables the small animals to penetrate and ingest the material. Fragments of decomposing material are called detritus, and many small animals feed on these, contributing to the process of breakdown. They are called **detritivores.** Because of the combined activities of the true decomposers (fungi and bacteria) and detritivores (animals), in the breakdown (decomposition) of materials, they are sometimes collectively referred to as decomposers. Although, strictly the term decomposer relates to saprophytic organisms. Some typical terrestrial detritivores are : earthworm (see Fig. 5.4a), woodlice, millipedes (see Fig. 5.4b) and other smaller (< 0.5 mm) animals such as mites, springtail and nematodes.

Decomposer organisms secrete digestive enzymes from their bodies into the dead organic material and absorb the digested food. This is in contrast to consumers which eat and digest it internally.

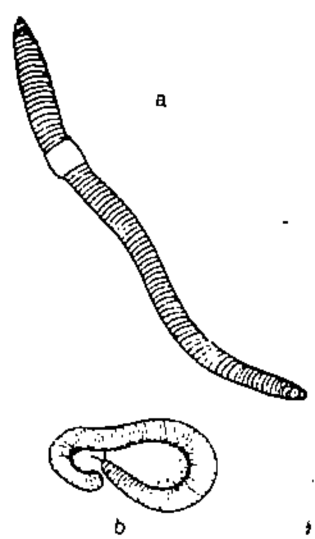


Fig. 5.4 : Detritivores.
a) Earthworm, b) Millipede

The important end result of the decomposer activity is that inorganic nutrients, originally bound up in the tissue of organisms are converted into simple forms that are usable once again by the producer organisms. Apart from processing and clearing the organic wastes, decomposers are vitally important for regenerating ecosystem fertility by releasing nutrients for utilisation by plants, that were locked up in the organic matter.

5.4 TOLERANCE RANGE AND LIMITING FACTOR

In the above section you have studied the biotic and abiotic components of the ecosystem and their functional roles and relationships. You have also seen how important these components are for the survival and well-being of the organisms and ultimately the whole ecosystem. These components are required in certain minimum and maximum limits for the optimal functioning of the organisms.

5.4.1 Tolerance Range

Organisms are able to survive only within certain maximum and minimum limits with respect to each environmental factor such as water, light and temperature. These are called the tolerance limits and the range in between these limits is the tolerance ranges (see Fig. 5.5). Different organisms have different tolerance ranges (see Fig. 5.6). Beyond the maximum and minimum limits of this range, no member of a particular species can survive. For example, fish generally tolerate a narrow range of water temperature. If the water cools below the range of tolerance, they die or move to warmer waters.

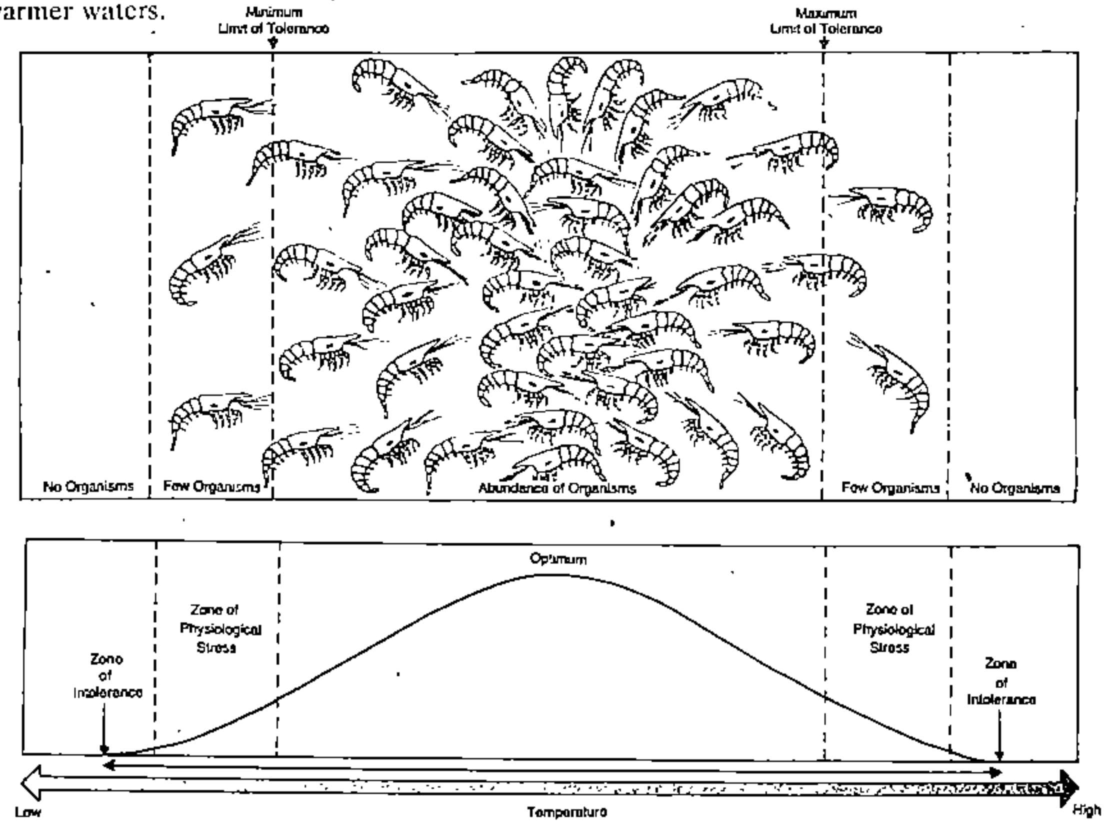


Fig. 5.5 : Range of tolerance for a population of organisms of the same species, to an environmental factor – in this case temperature. The organisms shown here are scarlet prawns.

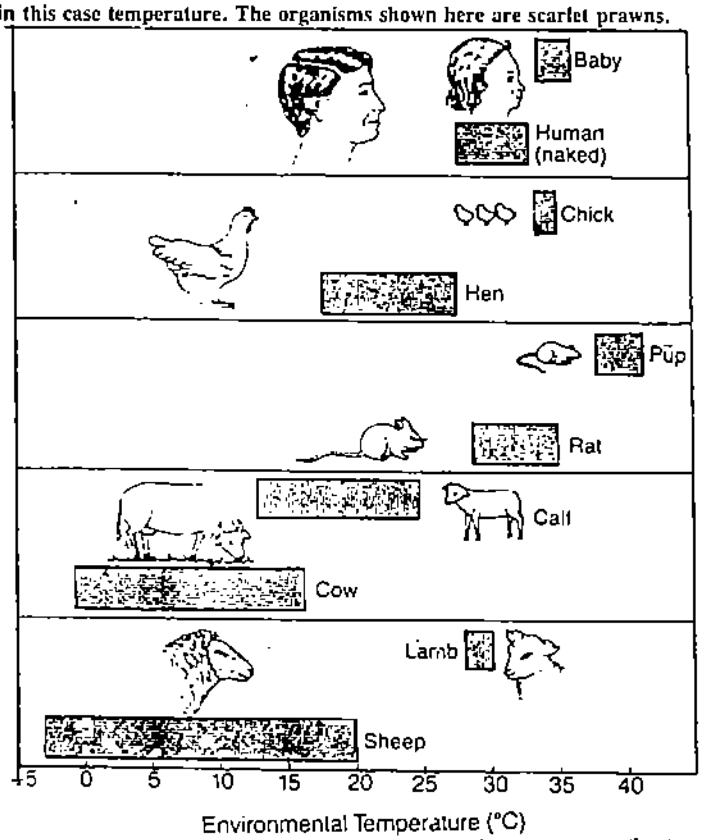


Fig. 5.6 : Tolerance to temperature varies with species. Each bar represents the temperature range that the organisms can tolerate.

Note : The young ones of a species have narrower range of tolerance than the adult.

5.4.2 Limiting Factor

In all ecosystems one factor, usually abiotic, limits the growth of organisms and is therefore called a limiting factor. The limiting factor is one that outweighs all the other factors that are necessary for the growth of organisms. It is the primary determinant for growth because it lies beyond the minimum and maximum limits of the range of tolerance. For example, phosphorus is a limiting factor in certain aquatic ecosystem. It is the first to be used up. When phosphorus is reduced, the growth of algae is impaired. So, this is an example, where phosphorus is in short supply and is thus a limiting factor.

As mentioned above, just as the shortage of any abiotic factor impairs the survival of organisms in an ecosystem, so can an excess. Any factor that is in excess may be detrimental for the living organisms, directly or indirectly. You may be wondering, how? Let us consider an example of a power plant from where the hot water pours into a nearby stream. As a result, the temperature of water in the area nearby shoots up from 10° C to 30° C. This sudden thermal shock is fatal for many fish and other aquatic organisms. The above example, illustrates the direct effect of excess of a factor.

How the factors indirectly affect living beings is illustrated by the following example. If we over-water or flood a patch of land having trees, on a prolonged basis, then the excess water saturates the soil by displacing air needed by the trees from the soil pores, thus creating anaerobic conditions. As a result, the roots get deprived of oxygen leading to the death of the trees. The excess of the water thus indirectly affects the survival of trees adversely.

SAQ 1

a) In the following statements, put a tick (√) mark on the correct ones and a cross (×) 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. ☐

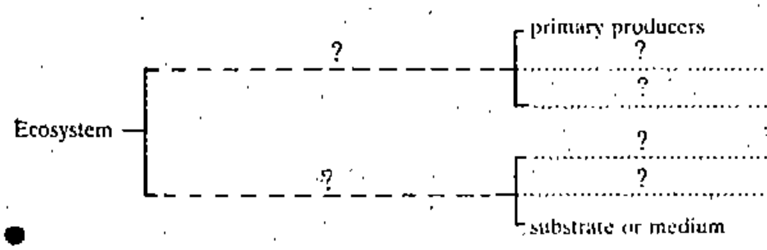
iii) Ecosystems represent enormous contrast in size and complexity. ☐

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 :

biotic components, energy, consumers, abiotic environment, inorganic elements, decomposers.



c) Can you give two examples of limiting factors not mentioned in the text?

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5.5 TROPHIC LEVEL

In an ecosystem, the various biotic components are related to each other and form food chains (see FST-1, Unit-14, Section 14.3). If we group all the organisms in a food chain according to their general source of nutrition, we can assign them different trophic (feeding) levels (Fig. 5.7). The producer organisms belong to first trophic

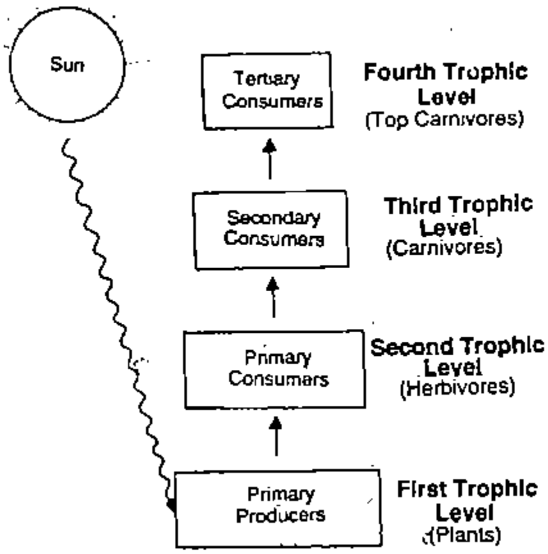

Fig. 5.7 : Diagrammatic representation of trophic levels in an ecosystem.

level, primary consumers (herbivores) to the second trophic level, secondary consumers (carnivores) to the third trophic level and tertiary consumers (top carnivores) to the fourth trophic level. Man, who is an omnivore may belong to more than one trophic level (see Fig. 5.8). There are usually four or five trophic levels, and seldom more than six — its reasons you would study in Section 5.9 of this unit.

Trophic Level				
Fourth Trophic Level			Man	Tertiary Consumer
Third Trophic Level		Man	Fish	Secondary Consumer
Second Trophic Level	Man	Hen	Insect	Primary Consumer
First Trophic Level	Wheat	Grass	Weed	Primary Producer

Fig. 5.8 : Three food chains drawn separately to show that an organism can occupy different trophic levels. In this diagram, the position of man in different food chains illustrates this point. The arrows indicate the direction of food chain.

The study of trophic level gives us an idea about the energy transformation in an ecosystem. It provides a useful conceptual basis to include all organisms that share the same general mode of feeding into one group and they together are said to belong to the same trophic level. This feeding level concept implies that organisms obtain food through the same number of steps from the producer. One thing should be clear to you, that is, the trophic levels are numbered according to the steps an organisms is away from the source of food or energy, that is the producer.

5.6 ECOLOGICAL PYRAMIDS

The ancient Egyptians constructed elaborate tombs called pyramids. The base of the pyramid is broad and it supports the upper levels of the structure, and it narrows to a point at the top. A similar situation is seen when we study and depict the trophic relationships in an ecosystem. The different trophic levels of an ecosystem are related to one another and can be summarised in the form of ecological pyramids. The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or high-level consumers; other consumer trophic levels are in

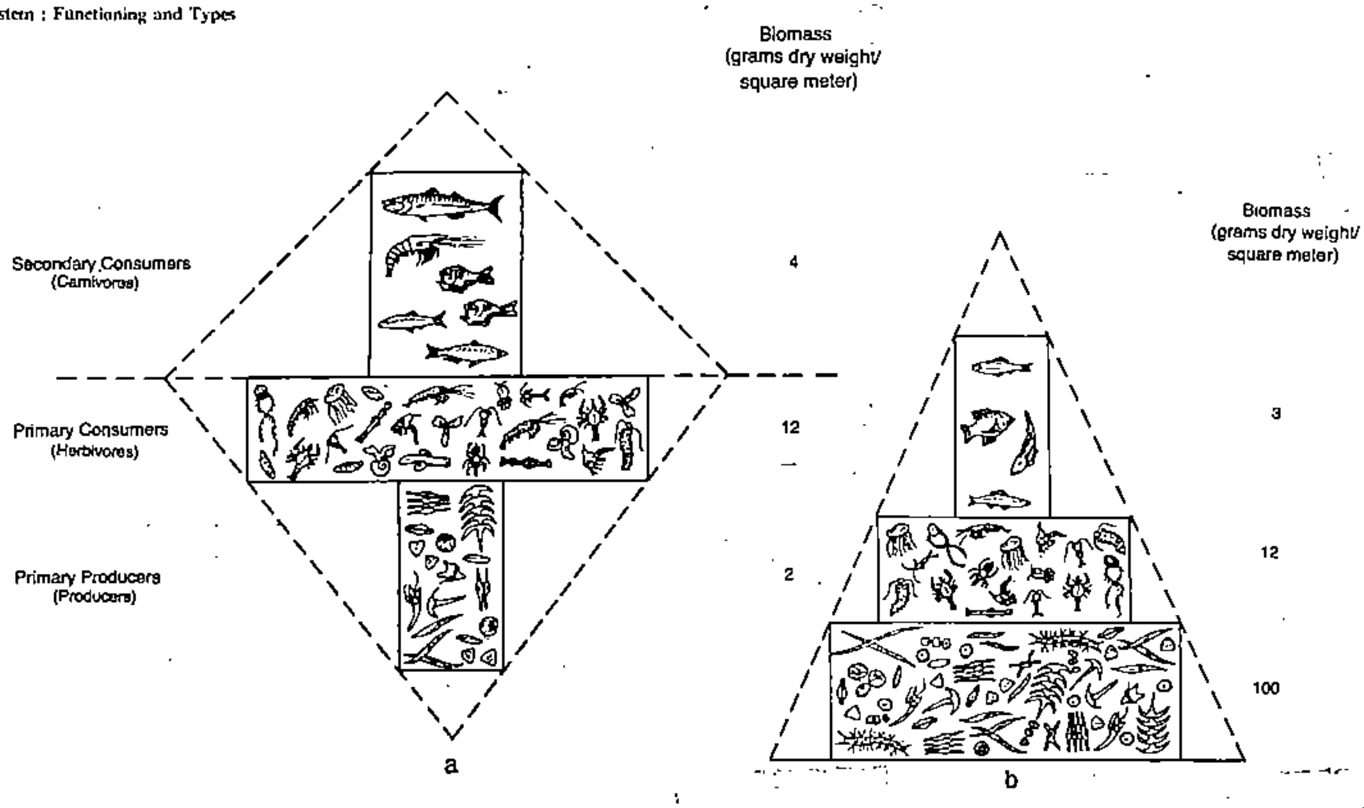

Fig. 5.12 : Pyramid of biomass in an open ocean ecosystem at two different times of the year a) during winters, b) during spring season. The numerical figures as indicated above are hypothetical and the organisms drawn are not to the same scale.

For constructing the pyramid of biomass, the time of sampling is very important. You could ask why? Let us discuss this point with a specific example, that is of ocean. In open ocean, the producers are microscopic phytoplankton and consumers range from microscopic zooplankton to massive organisms like whales. Here, the biomass of consumers may temporarily exceed that of primary producers, if sampling is done when the number of phytoplankton is low such as in winters. During such sampling periods, the pyramid of biomass would look as shown in Fig. 5.12a. However, if the samples are taken during spring when phytoplankton populations are immensely large, or if several generations of phytoplankton are included, the pyramid shape would look like as shown in Fig. 5.12b. From this example, it should be clear to you that the time of sampling is very crucial. In the same ecosystem, we can get an inverted pyramid at one time of the year and an upright pyramid in a different season.

5.6.3 Pyramid of Energy

When we wish to compare the functional roles of the trophic levels in an ecosystem, an energy pyramid is probably the most informative. It overcomes some of the objections pertaining to the pyramid of numbers and biomass. An energy pyramid more accurately reflects the laws of thermodynamics, with loss of energy being depicted at each transfer to another trophic level, hence the pyramid is always upright (see Fig. 5.13). Energy pyramids in the case of aquatic ecosystem are also upright, even where the pyramid of biomass is inverted. In energy pyramids, a given trophic level, always has a smaller energy content than the trophic level immediately below it. This is due to the fact that some energy is always lost as heat in going from one trophic level to the next. Each bar in the pyramid indicates the amount of energy utilised at each trophic level in a given time; annually per unit area. The unit of measurement is kcal/m^2/yr.

The first law of thermodynamics states that energy may be transformed from one form to another but can be neither created nor destroyed.

The second law of thermodynamics states that the conversion of energy from one form to another is never 100 per cent efficient, that is, some energy is always wasted in energy conversions.

A pyramid of energy must be based on determination of the actual amounts 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 their body tissues. The energy inputs and outputs are calculated so that energy flow can be expressed per unit area of land (or volume of water) per unit time. Though, these calculations are a bit difficult than for the other pyramids, the advantages of energy pyramid are many: i) It takes into account the rate of production, in contrast to the pyramids of numbers

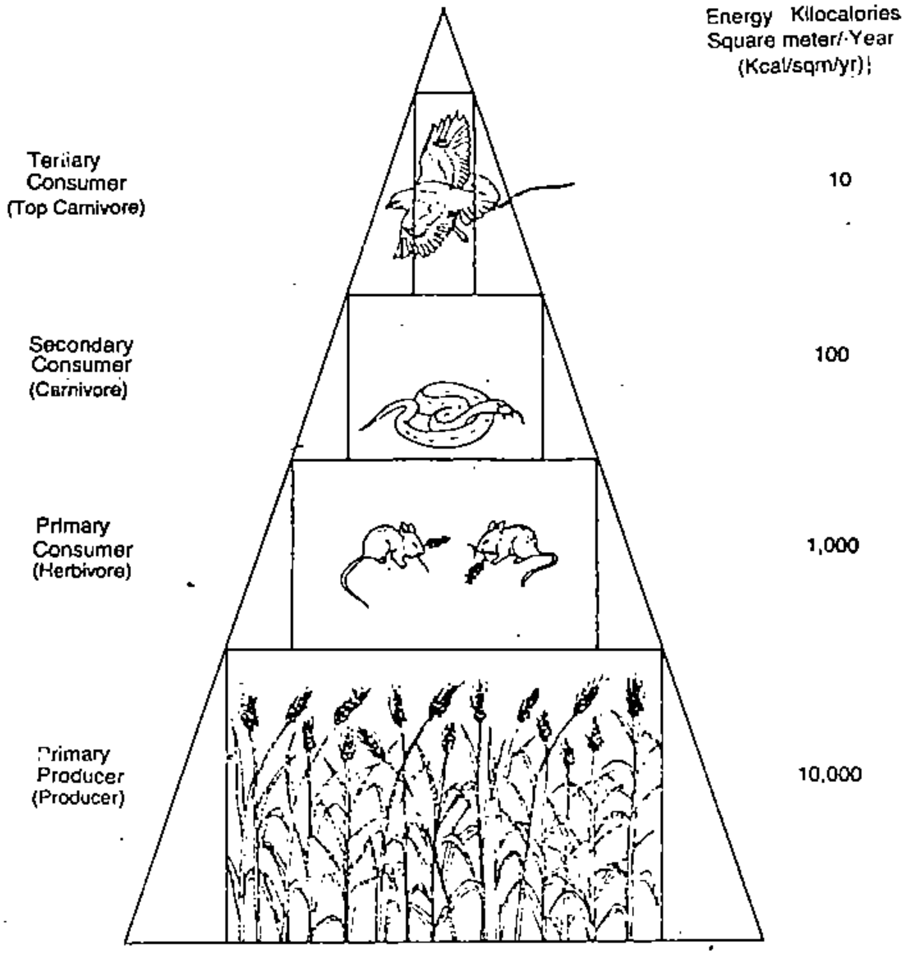

Fig. 5.13 : Pyramid of energy. The cumulative energy content of primary producers is always higher as compared to the energy in the next trophic level and so on and so forth, over a period of time. The numerical figures as indicated above are hypothetical, the organisms are not drawn to the same scale.

and biomass which indicate the standing states of organisms at a particular moment in time. Each bar of a pyramid of energy represents the amount of energy per unit area or volume that flows through that trophic level in a given time period. ii) Weight for weight, two species do not necessarily have the same energy content. Comparisons based on biomass may, therefore, be misleading. iii) Apart from allowing different ecosystems to be compared, the relative importance of populations within one ecosystem can be compared and inverted pyramids are not obtained. iv) Input of solar energy can be added as an extra rectangle at the base of a pyramid of energy

5.6.4 Limitations of Ecological Pyramids

The pyramid of energy is a significant improvement over the previous two types of ecological pyramids, yet all of them overlook one or another important aspect. Some of these limitations are discussed below.

i) Some species practise more than one mode of nutrition or belong to two or more trophic levels. This is particularly true in the case of consumers of higher trophic levels. Man is an example. He gets his food from primary producers as well as from higher trophic levels. Such organisms which feed at more than one trophic level are extremely difficult to depict in ecological pyramids.

ii) Saprophytes play a vital role in ecosystem but they are not represented in ecological pyramids.

iii) Detritus such as litter and humus is an important source of energy and exerts considerable influence on ecosystem function, yet it is not depicted in ecological pyramids.

iv) Ecological pyramids do not provide any clue to seasonal and diurnal variations.

v) The rate of transfer from one trophic level to another is not reflected in the ecological pyramids.

SAQ 2

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

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

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c) Why is a pyramid of numbers are sometimes inverted?

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d) In what terms is the biomass expressed?

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e) Why are energy pyramids never inverted?

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5.7 ENERGY INPUT IN ECOSYSTEM

Survival and functioning of ecosystem is dependent on the input of energy. Continuous availability of energy is essential for supporting diverse ecosystem processes. For any ecosystem, the ultimate source of energy is sunlight. And as you know, it enters the ecosystem through the producers. When a primary consumer (herbivore) eats a producer, and is itself eaten by secondary consumers, we can say that energy is flowing through the ecosystem. You have already studied some aspects of solar energy input in Subsection 2.2.2, Unit 2, Block-1 of this course. The information provided therein, would serve you as a base material for understanding this and the subsequent sections of this unit.

As you already know that the amount of solar energy received at the outer boundary of earth's atmosphere is at the rate of 2cal/cm^2/min. This quantity is fixed and known as solar constant. You have also learnt that about 30 per cent of the sunlight reaching the earth's atmosphere is reflected back into space, about 51 per cent is absorbed as heat by ground, vegetation or water, and about 19 per cent is absorbed by the atmosphere. Only a small fraction of sunlight, that is, about 0.02 per cent reaching the atmosphere is used in photosynthesis. Nevertheless, it is this small fraction on which all the organisms of the ecosystem depend. The actual amount of solar flux received at the surface of the earth is dependent on various climatic, geographic and other environmental factors. On an average the total amount of solar energy that reaches the earth's surface is about 3,400 kcal/m^2/day. It varies significantly from one place to another, for example, it decreases with latitude and its input also varies during different seasons at any given location. The solar flux values for fourteen different stations in India are given in Table 5.1, and it varies from 361 to 543 cal/cm/day.

Table 5.1

Mean total radiation of sun and sky, on a horizontal surface (in cal/cm^2/day) (After Ramdas and Yegnanarayanan, 1954)

TRIVANDRUM	487
BANGALORE	467
MADRAS	530
DHARWAR	480
BOMBAY	499
POONA	506
AHMEDABAD	543
JODHPUR	534
JAIPUR	495
ALLAHABAD	511
CALCUTTA	486
DELHI	489
JULLUNDUR	496
SRINAGAR	361

5.8 CONCEPT OF PRODUCTION

You have just studied that ecosystems are unable to function, unless there is a constant input of energy from an external source that is sun. Solar energy enters the biotic components of the ecosystem through primary producers. And you know that the plants store solar energy in the form of chemical bond energy through the process of photosynthesis. In the following subsections you would study about this stored solar energy in the plants and its availability to the next trophic levels.

5.8.1 Primary Production

Energy accumulated by plants during photosynthesis is called **production** or more specifically **primary production.** It is the first and the basic form of energy stored in an ecosystem. Production is defined technically as the amount of biomass or organic matter produced per unit area in a given period. It can be expressed in terms of weight (g/m^2) or energy ($kcal/m^2$). The **rate** at which energy accumulates is known as **primary productivity.** It is expressed in terms of $kcal/m^2/yr$ or $g/m^2/yr$.

In case of plants, primary production is generally differentiated into two distinct categories, namely **gross primary production (GPP)** and **net primary production (NPP).** Gross primary production refers to the total amount of solar energy fixed into organic matter by primary producers through photosynthesis. A considerable portion of the solar energy fixed by plants (GPP) is utilised by plants themselves in respiration (R) to get the energy needed for their metabolism and for other vital functions. The amount of energy left after respiratory consumption (R) is incorporated into new body tissue (growth) or is used for producing new individuals (reproduction). The amount of biomass or organic matter accumulated by plants per unit area in a given period is called net primary production. The overall relationship between GPP and NPP can be written as :

$$GPP - R = NPP \quad or \quad GPP = NPP + R$$

From this equation, you might have noticed that whatever energy is fixed by plants (GPP) some of it is used for their own maintenance (R) and only remaining (NPP) is available for the next trophic level. So net primary production is the only energy available for the next trophic level.

The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter. Of this total, about 115 billion tons are produced on land and about 55 billion tons in the oceans, despite the fact that the oceans occupy about 70% of the earth's surface. We the human beings harvest about 1.2 billion tons per year as plant food.

Production efficiency : The maximum amount of solar energy harvested by plants is about 5 per cent but the average for green plants, on the whole is only a small fraction of sunlight, i.e., 0.02 per cent reaching the atmosphere. The production efficiency, that is the ratio of net primary production to gross primary production (of green plants) is on the average rather high. It varies between 40 to 85 per cent. The most efficient are those plants which have low maintenance requirement due to minimum non-photosynthetic (non green) tissues, such as in grasses, algae and phytoplankton. Algae and crops like corn have an efficiency of about 80 to 85 per cent, submerged aquatic plants 60 to 75 per cent, deciduous forests about 42 per cent.

Different ecosystems have different productivities (see Fig. 5.14). Productivity of ecosystems depends on a variety of factors such as sunlight, temperature, rainfall and the availability of nutrients. Those situations that provide the best circumstances for plant growth are the most productive. Warm, moist, sunny areas with high levels of nutrients in the soil are ideal. Some areas have low productivity because one of the essential factors is missing. Deserts have low productivity because water is scarce, arctic areas too have low productivity because temperature is low, and open oceans also have low productivity because nutrients are in short supply. Coral reefs and tropical rain forests have high productivity. Marshes and estuaries are highly productive since waters running into them are rich in the nutrients and they also get enough light.

You have just seen that some ecosystems have consistently high production. Such high production usually results from an additional input of energy subsidy to the system. The energy subsidy, as you have learnt may be in the form of high ambient temperature, rainfall, or inflow of nutrients. Some agricultural systems also have high productivity, e.g., sugarcane has a productivity of 1,700 to 1,800 g/yr; corn 10,000 g/yr; and some tropical crops up to 3,000 g/yr. Can you now think of the energy subsidies that are linked to high production? In agricultural system energy subsidy includes the use of fossil fuels for land preparation and the use of fertilisers and pesticides.

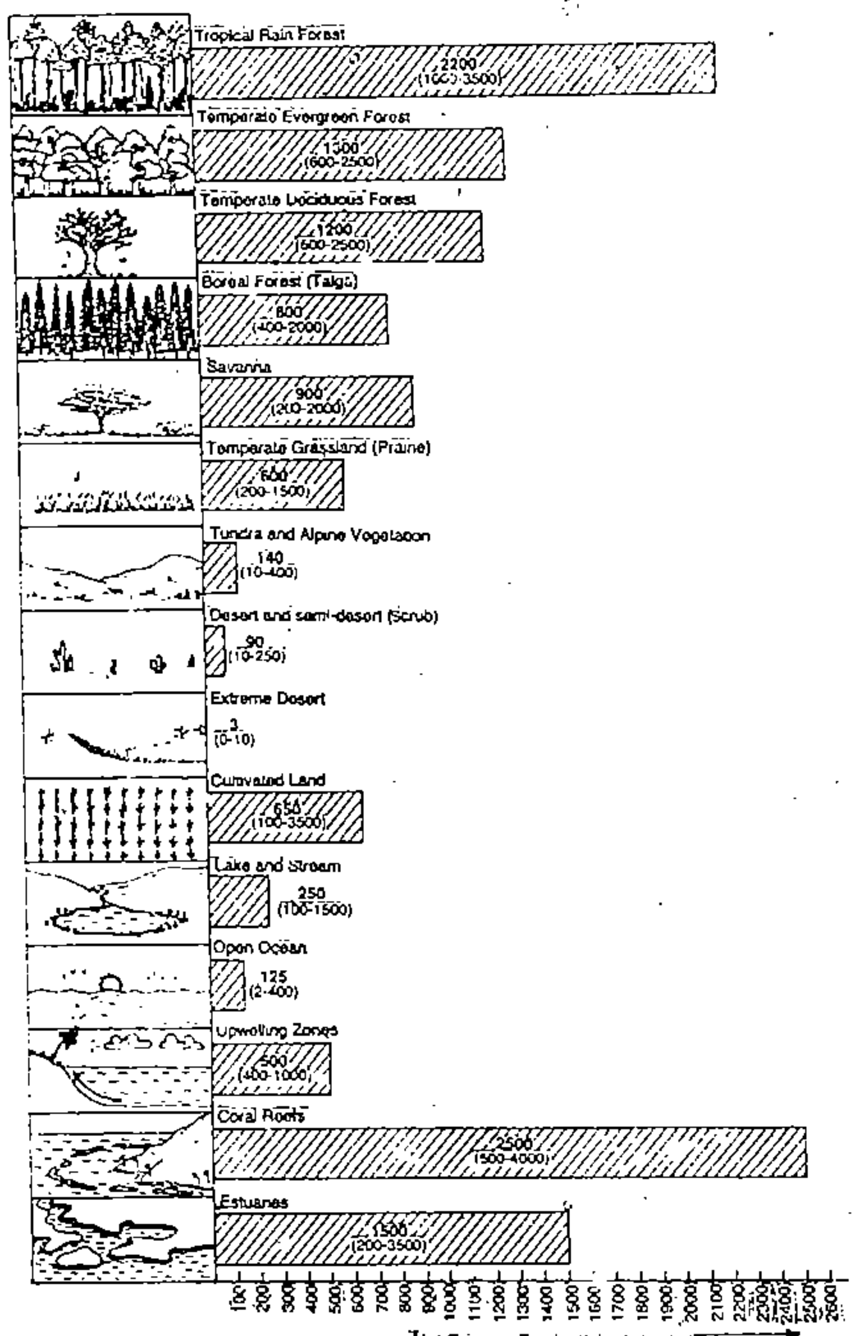


Fig. 5.14 : Comparative productivities of different ecosystems of the world. The numerical figures written in bold are the average values and the ones written in parentheses represent the range of productivity (Data from R.H. Whittakar, Communities and Ecosystems, 1975).

5.8.2 Secondary Production

You have seen that net primary production is the only energy available to consumers or heterotrophs including man. Herbivores such as cow or deer graze upon grass and utilise primary production. The food is processed in the stomach of animals. Digested material is assimilated in the body and the unutilised material is excreted. Some of the assimilated energy is used up in respiration to provide energy for the metabolic needs of body such as maintenance and repair of tissues. The remaining part is utilised for producing new tissues for reproduction. Production of animal biomass on account of growth as well as addition of new individuals of animals is referred to as secondary production. And secondary productivity is the **rate** of formation of new organic matter by heterotrophs.

Very little of the plant matter that is consumed is actually converted to animal tissue. In terms of energy content, the conversion is only about 10 per cent. This energy loss is shown in Fig. 5.15, where a rabbit has 0.1 kcal of secondary production for every

1 kcal of food eaten. What happens to the other 90 per cent? Fig. 5.15 shows that most of this difference is used in respiration to power the animal's movements and maintain its body functions. A certain amount is not assimilated at all and is therefore excreted in the faeces. Thus relatively little energy is left for the production of new body tissues.

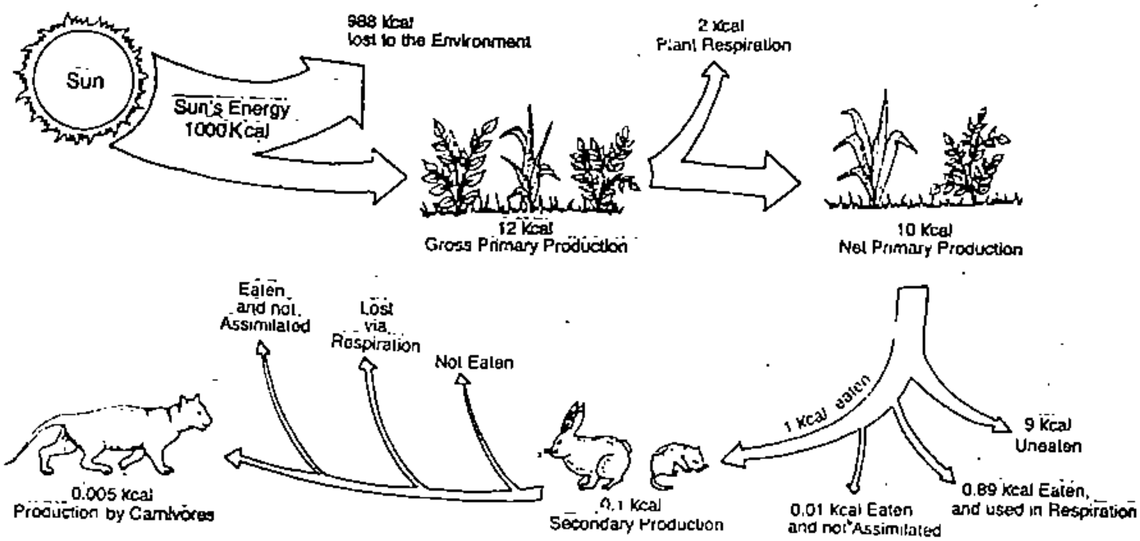


Fig. 5.15 : Energy relationships in an ecosystem. The average values for energy transfer are illustrated, the actual values vary from system to system.

To put this concept on a familiar level, let us consider an adult human. A person eats daily, yet a healthy adult does not gain weight at all. To summarise, although there are large variations from ecosystem to ecosystem, as a generalisation, for every 10 kcal of plant tissue available to herbivores, about 1 kcal will be eaten, and only about 0.1 kcal will be stored in the form of body weight.

It must be clear to you that in contrast to primary production, secondary production is usually not differentiated into 'gross and net' categories because heterotrophs consume only already manufactured food.

Just as net primary production is limited by a number of variables, so is secondary production. The quantity, quality (including the nutrient status and digestibility), and availability of net production are the three limitations.

5.9 ENERGY FLOW

As you know our world is a solar-powered system, and green plants are the entry gates of energy into ecosystem. In Unit 2, Subsection 2.2.5, Block-1, LSE-02 you have already learnt that out of the total incoming solar energy, only a very small fraction is absorbed by plants. And on this small fraction of sunlight trapped by plants is built the entire living world. In this section we shall discuss with you as to how the different biotic components of an ecosystem are related in terms of energy.

From your study of the First block of this course plus the Fourth block of FST-1, you have sufficient background information on this topic. One thing you should remember is that any organism derives its energy from the 'food' it consumes. And you know that all organisms cannot make their own food and only the producers have the capacity to do so. Therefore, various organisms in an ecosystem must fulfil their energy needs by relying on producers directly or indirectly. In other words we can say that energy flows from the first trophic level, that is, from producers to the subsequent trophic levels. In an ecosystem energy is transferred in an orderly sequence. See Fig. 5.16 carefully before you proceed further.

Have you noticed the following two points in the figure? i) The flow of energy is in one direction only, and ii) some energy is lost as heat at every successive step.

Now let us consider the first point, that is, the direction of flow of energy. Energy flows from lower (producer) to higher (herbivore, carnivore, etc.) trophic level. It never flows in the reverse direction, that is, from carnivores to herbivores to green plants. Organisms at each trophic level depend on those at lower trophic levels for the energy to sustain themselves and reproduce. For example, we cannot convert energy directly from the sun into food. We depend on green plants to make such transformation for us. This is in accordance with the first law of thermodynamics, that energy cannot be created nor destroyed but may be transformed from one form into another. For example, the energy of visible light is transformed into chemical energy of the glucose molecule synthesised by green plants through photosynthesis. The living organisms including plants utilise glucose in respiration, which releases chemical energy, and a part of which is ultimately dissipated as heat, that is, the third form of energy.

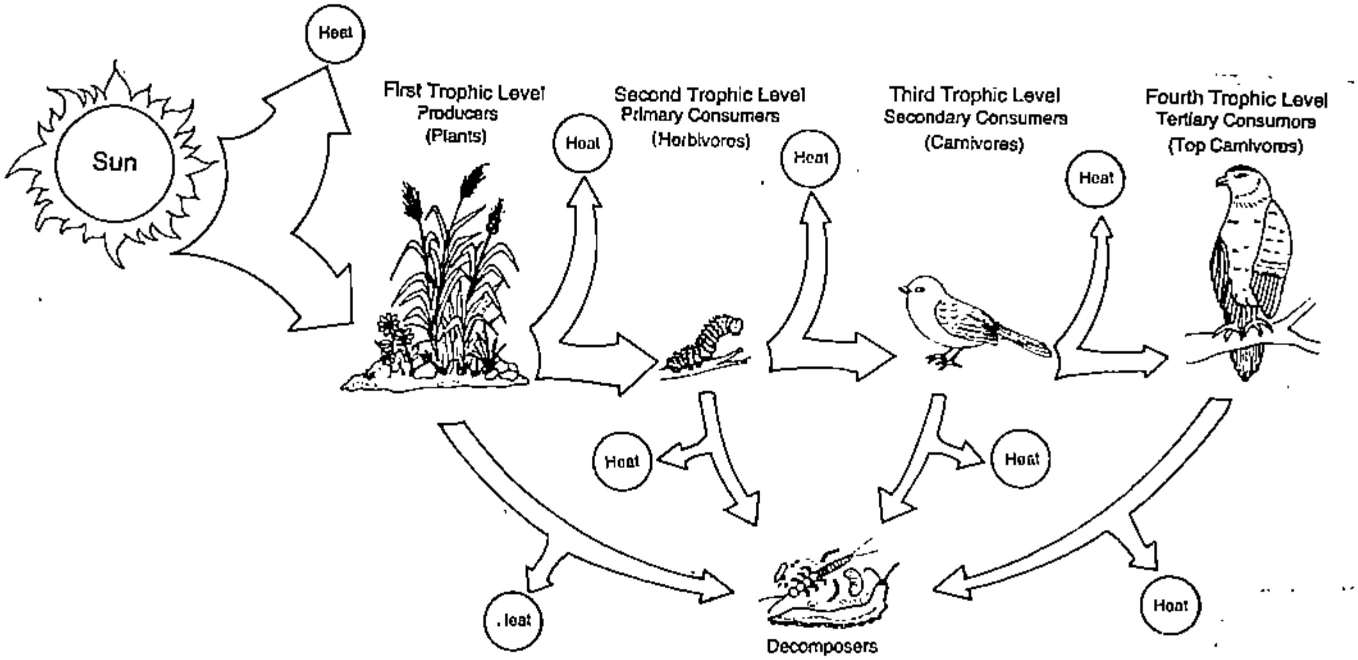


Fig. 5.16 : Energy flow through an ecosystem. Producers capture a small amount of solar energy and make it available for the subsequent biotic components of the ecosystem, whether they are herbivores, carnivores, top carnivores or for that matter even the decomposers.

Let us now take the second point that is the loss of some energy at each trophic level. You might recall that the second law of thermodynamics states that when energy is transformed from one form into another, some of it is converted into unusable energy, such as heat. Let us understand this with another example. When you slide a box along the floor, some of the energy you are putting into pushing the box is being converted into heat energy, due to friction. And this heat energy escapes into the surrounding environment. In the same way when the energy stored in muscle cells is used to contract arm muscles, some of the useful energy is lost as body heat from the body. Since heat energy cannot be used to do useful work, more energy must be supplied to a biological system from outside to compensate the inevitable energy loss. In order to continue to function, organisms and ecosystems must receive energy supply on a continuing basis.

Related to the various aspects of energy flow in an ecosystem is the question — why only a few links in the food chain? The unavoidable loss of usable energy between feeding levels explains why food chains are relatively short — at the most four or five links. From your study of pyramids of energy you have seen that how the amount of energy decreases from the first trophic level onwards. At the fourth or the fifth level very little energy is left to support another trophic level. In general, there is about 90 per cent loss of energy mainly as heat as we proceed from one trophic level to the next higher level. In other words, only 10 per cent energy of a particular trophic level is incorporated into the tissues of the next trophic level. Thus, if 1,000 kcal of plant energy were consumed by herbivores, about 100 kcal would be converted into herbivore tissue, 10 kcal to the carnivores and 1 kilocalories to the top carnivore tissues. Considering these aspects it is clear that in human communities, consumption of food derived from animals such as meat, eggs and dairy products have high energy cost as compared to foods obtained directly from plants.

In energy terms it is more economical to eat bread made from wheat than to feed the wheat to hens and then eat the eggs and chicken meat (also see Fig. 5.17). This is because eating wheat as bread avoids using any part of its energy to keep the chickens alive and active. The crux of the whole discussion is the shorter the food chain, the greater is the availability of usable energy.

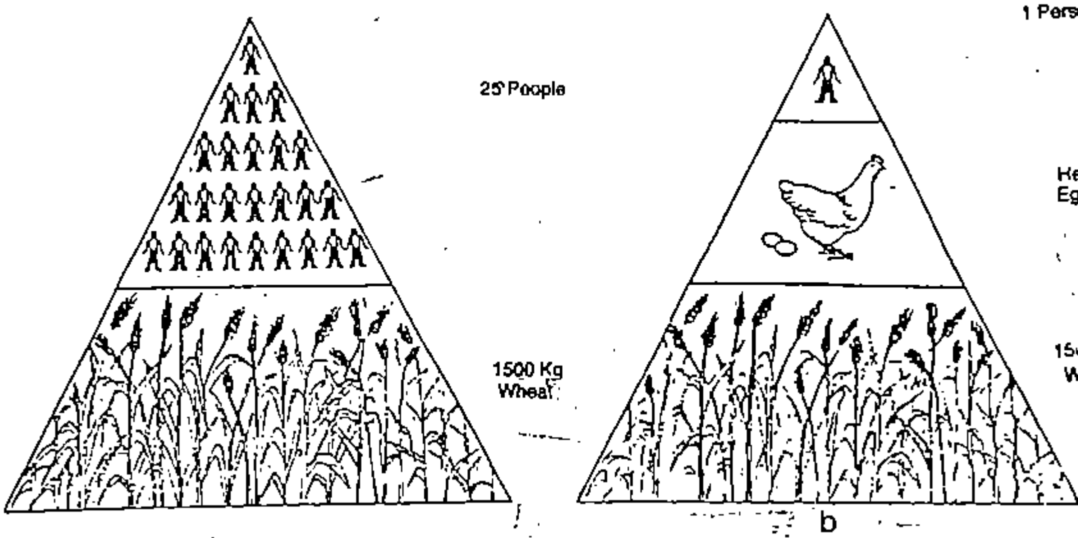


Fig. 5.17 : The relative energy efficiency of different types of foods for human consumption

This principle has also been practised by many animals in nature to fulfil their energy needs. The example of baleen whale (Fig. 5.18) we shall discuss here. These whales

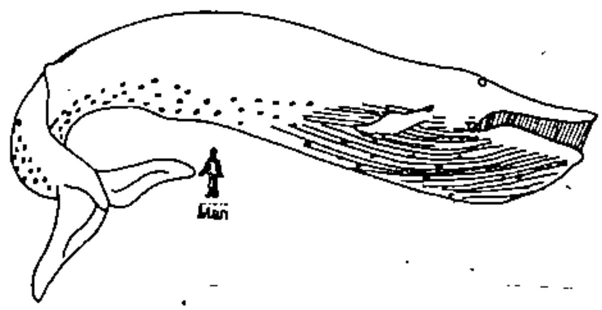


Fig. 5.18 : The largest mammal — the baleen whale

are typically found in the open oceans, often in areas where obvious food sources are insufficient to supply the energy needs of so large an animal. This animal has a special adaptation that allows it to feed on microscopic zooplankton and tiny fish. A large sheet of horny material called baleen, composed of a substance similar to our fingernails hangs down from the roof of the mouth. These toothless animals can scoop up a huge mouthful of water and then strain the water out through the fringed edge of the baleen, trapping in its mouth enormous numbers of tiny plants and animals that are then swallowed. In this manner a large carnivore is able to feed on primary consumers of very small size in an ecosystem that is very poor in sizeable prey organisms, and thus fulfil its energy requirements.

Energy Budget

We have seen that all living things must take in and use energy to maintain their bodies, to grow, to obtain more energy and to reproduce. Each individual has an 'energy income' of all the energy that it acquires during a specified period. It also has an 'energy budget', its allotment of different amounts of energy for various activities. Similarly energy budget for ecosystem as a whole can be prepared. One such example is given below (see Fig. 5.19). From such studies one can know as to how much energy input there is in an ecosystem and its subsequent transformation from one trophic level to another. The energy values are generally expressed in terms of caloric. Let us now discuss the Fig. 5.19 that you have just seen. It shows that most of the energy input is in the form of solar radiation while the output of energy is represented by the waste heat dissipated from the system. It may be observed that the total energy input amounts to 410486 kcal/m^2/yr (410,000 kcal/m^2 solar energy and 486 kcal/m^2/yr in the form of organic matter imported into the system) matches with the output of

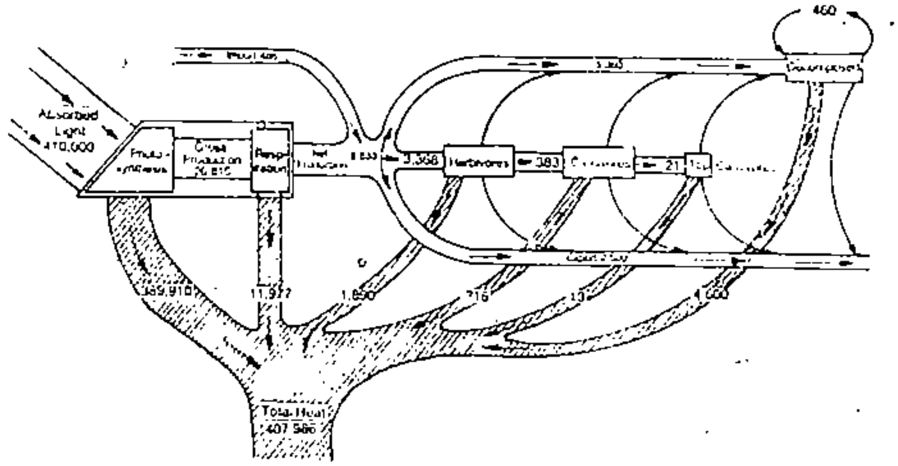


Fig. 5.19 : Energy flow diagram for Silver springs, Florida. All the energy figures are expressed as kcal/m²/yr. (After Odum, 1957).

energy (407986 kcal/m²/yr) lost as waste heat and (2500 kcal/m²/yr exported from the system in the form of organic matter).

SAQ 3

a) Explain the statement : "The ultimate source of energy for our planet is sun".

....

....

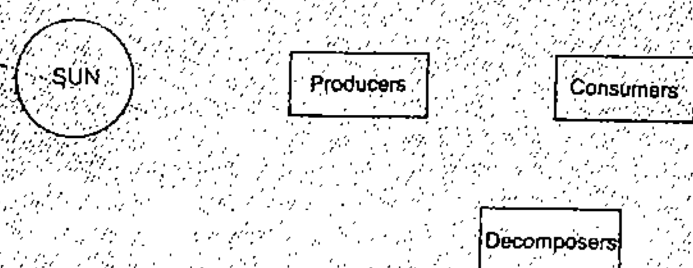
....

....

b) In the following diagram use pen/pencil to indicate the following aspects :

i) direction of flow of energy.

ii) relative amount of energy available to each trophic level.



c) Energy enters an ecosystem by way of the :

i) producers

ii) consumers

iii) detritivores

iv) scavengers

(Tick the correct answer)

d) The rate at which light energy is converted to the chemical energy of organic molecules is the ecosystem's :

i) net primary productivity

ii) gross primary productivity

iii) net secondary productivity

iv) gross secondary productivity

(Tick the correct answer)

e) About how much of the chemical energy within producer tissues becomes chemical energy within herbivore tissues?

i) 1%

ii) 10%

iii) 30%

iv) 50%

(Tick the correct answer)

f) Rank the following types of ecosystem in terms of their net primary productivity, with 1 being the most productive and 8 the least productive.

Desert and semi-desert area	[ ]
Savanna	[ ]
Open ocean	[ ]
Estuary	[ ]
Temperate deciduous forest	[ ]
Tropical rain forest	[ ]
Coral reef	[ ]
Extreme desert	[ ]

5.10 FOOD CHAIN AND FOOD WEB

You are familiar with the concept of food chain and food web that you have studied earlier in FST-1, Unit 14. Based on that we would discuss these in more detail in the following sections.

5.10.1 Food Chain

In a food chain, the food energy is transformed from a given source through a series of species, each of which eats the one before itself in the chain. This repeated series of eating and being eaten is always initiated with green plants, which convert radiant energy into chemical energy which is stored in food. A very simple food chain is :

Sun ⟶ grass ⟶ goat ⟶ man

In the previous sections, you have also studied that at each transfer a proportion of the food energy is lost as heat. This limits the number of links or steps in a food chain, usually to four or five. In aquatic ecosystems, microscopic green plants called phytoplankton and algae play the same role as grasses in a pasture or trees in a forest.

Based on the kinds of organisms that constitute the first trophic level, three types of food chains can be distinguished. These are : i) grazing food chain, ii) detritus food chain, and iii) auxiliary food chain.

i) **Grazing Good Chain :** Grazing food chains are quite familiar to most of us. Cow or deer grazing in a field represents a grazing food chain. Similarly, eating of phytoplanktonic algae by zooplankton and fish is another example of grazing food chain. In most ecosystems, only a small proportion of the total community energy flows through grazing food chains. Also at each step, significant amount of organic matter is shunted to detritus food chain through death, decay and excretion by living organisms.

   The grazing food chains in forest and ocean represent two extreme types. Ocean food chains are among the longest, up to five links, in contrast to forest types which mostly consist of three or rarely four links. One of the reasons for the longer length of grazing food chains in aquatic ecosystems is the small size of the phytoplankton and zooplankton that chiefly comprise the first two trophic levels. If there are many small herbivores at level two, this means that the carnivores at level three also can be relatively small and numerous, and an additional carnivore level can be accommodated before the last level, represented by a relatively small number of large carnivores.

ii) **Detritus Food Chains :** Detritus food chains begin with dead organic matter which is an important source of energy. A large amount of organic matter is contributed by the death of plants, plant parts, animals and their excretion products. These types of food chains are present in all ecosystems but they are over dominating in forest ecosystems and shallow water communities.

Various species of microscopic fungi, bacteria and other saprophytes play a prominent role in decomposing organic matter to obtain energy needed for their survival and growth. In this process they release various nutrients, locked in dead organic matter, which are used readily by the green plants. Detritus food chains are interconnected with grazing food chains and other auxiliary food chains through certain specific common organisms to permit crossing over of energy and material flow from one circuit to another. For example, cattle do not assimilate all of the energy stored in plants, undigested residues in faeces become available for the decomposers and the detritivores.

Detritus food chains are located mainly in the soil or in the sediments of aquatic ecosystems. They form an essential component of natural ecosystems and are necessary for self-sustenance and for maintaining ecological balance. Detritus food chains can be of great practical value for modern man for sewage treatment and control of water pollution.

Most of the natural ecosystems possess both grazing and detritus types of food chains. Their relative importance however, varies from one ecosystem to another. In terrestrial and shallow water ecosystems, detritus food chains dominate because a major proportion of the annual energy flow passes through this circuit. In case of tidal marshes, almost 90 per cent of the primary production is routed through the detritus food chains. In deep water aquatic systems rapid turnover of organisms and high rate of harvest are responsible for the dominance of grazing food chains.

iii) **Auxiliary Food Chains :** In addition to grazing and detritus food chains there are other auxiliary food chains operated through parasites and scavengers. Some parasitic food chains may be quite complex and may involve unrelated organisms. A deer fed upon by internal roundworms and external ticks or a man with malarial parasites in his blood are examples of parasitic food chains. Other parasitic relations are quite involved as parasites are transmitted through a variety of vectors or through unrelated intermediary host organisms. Like the other food chains, the ultimate source of energy for all auxiliary food chains is solar energy orginally harvested by plants.

5.10.2 Food Web

In nature no food chain is isolated or is simple as described in the above examples. A plant may serve as a food source for many herbivores simultaneously, e.g., grass plants can support deer, cow, grasshopper or rabbit. Similarly, a herbivore may be food source for many different carnivorous species (see Fig. 5.20). Also food

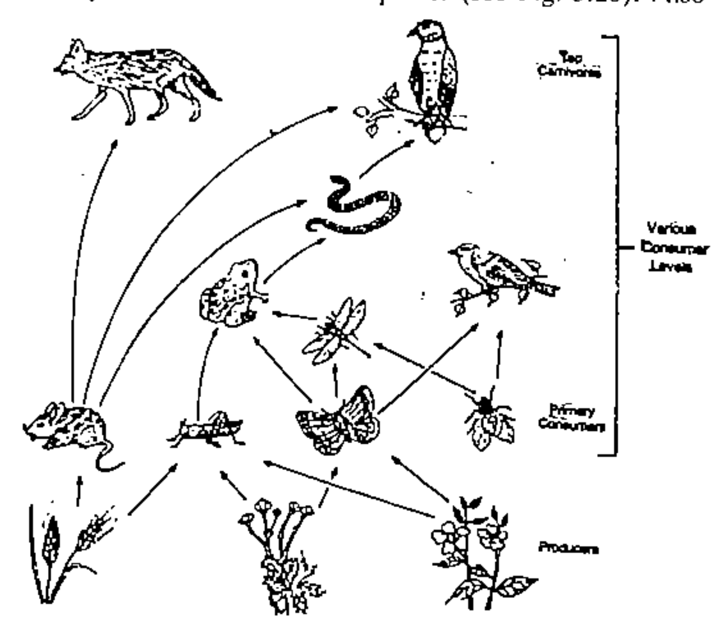


Fig. 5.20 : A simplified version of a food web.

availability and preferences of herbivores as well as carnivores may shift seasonally (e.g., we eat mangoes in the summer and oranges in the winter).

In an ecosystem, when all interconnections between food chains are mapped out, they form a food web (see Fig. 5.20). A food web illustrates, all possible transfers of energy and nutrients among the organisms in an ecosystem, whereas a food chain traces only one pathway in the food web.

The food web for most communities is very complex, involving innumerable kinds of living organisms. With many interlocking food chains the community remains stable even if one or more of these relations are altered. For example, in a stream-side ecosystem if the grasshoppers become scarce or their population is wiped out because of some calamity, the frogs preying on grasshoppers are not forced to die or move out of that place. They can instead feed on other organisms such as flies or butterflies (see Fig. 5.20). Obviously, then a food web introduces a strong element of stability into an ecosystem. Larger the number of components involved, the more stable the ecosystem is.

5.11 ECOSYSTEM CONTROL

In this section, let us discuss about yet another important aspect of ecosystem functioning, that is, how it maintains its ecological balance. By now, it must be obvious to you that an ecosystem is a dynamic system, wherein a lot of events take place. For example, animals eat and in turn are eaten, moisture and nutrients flow in and out of the system, and weathers change. In spite of all these happenings the ecosystems persist and recover from the slight disturbances. This capacity of an ecosystem to self-regulate or self-maintain is called **homeostasis.** Isn't this ability of ecosystems to recover from certain perturbations remarkable? Let us take a simple example to see that how is this balance maintained in spite of the slight disturbances in the ecosystem. Consider a grassland, when there is a drought, plants do not grow well. The mice that eat the grass become malnourished. When this happens, their birth rate decreases. And also the hungry mice retreat to their burrows and sleep. By doing so, they need less food and are less exposed to predators, so their death rates decrease. Their behaviour protects their own population balance as well as that of the grasses which are not being consumed while the mice hibernate. Such a mechanism is known as feedback regulation and is very important to maintain the ecological balance. It is the prime regulatory mechanism for the ecosystem as a whole. You may know that there are several kinds of organisms comprising an ecosystem. So all the organisms in an ecosystem are part of several different feedback loops. A feedback loop may be defined as relationship in which a change in some original rate, alters the rate of direction of further change. In the above example, we had deliberately taken a very small group of living beings, that has primarily the mice and the plants.

Homeo = same;
Stasis = standing

Now we take up, another parameter of ecosystem balance. One factor that affects the stability or persistence of some ecosystems under small or moderate environmental stress is species diversity — the number of species and their relative abundance in a given ecosystem. High species diversity tends to increase long-term persistence of the ecosystem. It is because with so many different species and the linkages between them, risk is spread more widely. An ecosystem having a good variety of species has more ways available to respond to most environmental stresses. For example, the loss or drastic reduction of one species in an ecosystem, with complex food web usually does not threaten the existence of others, because most consumers have several alternative food supplies. In contrast, the highly specialised agricultural ecosystem, planted with only one type of crop such as wheat or rice is highly vulnerable to destruction from a single plant disease or insects. Therefore, the essence of the whole discussion is that most balanced ecosystems contain many different species.

The discussion so far, might have led you to conclude that the ecosystems have the ability **to cope up with any disruption.** You should realise that **this ability is limited.** Extremities like fires (destroy the landscape), over-exploitation (e.g., rampant deforestation, mining) or excessive simplification (monoculture, plantation, cropfields) or too severe and prolonged stresses (like drought, pollution) seriously hamper the control mechanism, resulting in ecosystem degradation. The lesson is obvious. We should check and control our actions, so that, we do not overload the ecosystem.

SAQ 4

a) In your food chain,
   i) Who is the producer? ....
   ii) Who are the consumers? ....
   iii) Who is the herbivore? ....
   iv) Who are the carnivores? ....
   v) Who are the decomposers? ....
   vi) Who is the autotroph? ....
   vii) Who are the heterotrophs? ....
   viii) Who are the predators? ....

b) Food chains are ordinarily found in food webs. Why does a food web tend to be more stable than a food chain?

....

....

....

c) If some birds were eating wheat in the fields and farmers killed the birds.
   i) the natural ecosystem would be unaffected
   ii) a natural ecosystem might be disrupted
   iii) the biosphere would tend to stabilise
   iv) the biosphere would tend to be disrupted
   v) both ii and iv.

   (Tick mark the correct answer)

d) 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

   (Tick the correct answer)

e) A detritus food chain begins :
   i) always in the ocean
   ii) with a producer
   iii) with decaying organic matter
   iv) with air pollution

   (Tick the correct answer)

f) A natural food web :
   i) contains only grazing food chains
   ii) contains several trophic levels
   iii) is usually unstable
   iv) all of these

   (Tick the correct answer)

g) In what way are decomposers like producers?
   i) either one may be the first member of a grazing food chain

ii) both produce oxygen for other forms of life

iii) both require a source of nutrient molecules and energy

iv) both supply organic food for the biosphere

(Tick the correct answer)

h) Most food chains are composed of

i) 1 or 2 species

ii) 3 or 4 species

iii) 9 or 10 species

iv) more than 16 species

(Tick the correct answer)

5.12 SUMMARY

In this unit we have examined various aspects of ecosystem functioning. So far you have learnt that :

- Ecosystems are considered functional units of nature having no specified size or limits.
- Ecosystems comprise different biotic and abiotic components which are functionally coordinated and operate in an integrated, holistic manner.
- Every organism has a capacity to tolerate a certain range of a particular environmental factor. This range is known as the tolerance range. At the extremities of the tolerance range the factor becomes limiting.
- The concept of trophic level tells us as to which organisms share the same general source of nutrition.
- Trophic relationships of an ecosystem can be represented graphically in the form of ecological pyramid. The base of the pyramid represents the producers and the successive tiers represent the subsequent higher trophic levels.
- Ecological pyramids are of three types : one – pyramid of number depicts the number of individual organisms at each trophic level; second – pyramid of biomass represents total weight of the living organisms at each trophic level, third pyramid of energy shows the amount of energy utilised at successive trophic levels.
- Ecological pyramids give useful information about the functional structure of an ecosystem, but they also have some limitations. Important among them are : a) decomposers are not represented; b) organisms which take food from different trophic levels are not accounted for; c) one gets no idea about the seasonal and daily variations and also about the detritus litter as an energy source; d) the rate of transfer from one trophic level to another is not known.
- Energy is transferred in an orderly sequence, i.e., from sun to producers, to consumers, to decomposers. Energy flow is always downhill and unidirectional. Heat is constantly lost during the process of energy transfer as expressed in the first and the second laws of thermodynamics. In an ecosystem, energy flow can be quantified. Energy budget refers to the energy entering and leaving an ecosystem in a given span of time.
- Ecosystems are solar-powered systems. Green plants capture solar energy and store in the form of organic substances. Gross primary productivity of an ecosystem is the rate at which organic matter is produced during photosynthesis. Net primary productivity represents the rate at which some of this matter is incorporated into plant bodies. Net primary productivity is less than gross primary productivity because of the losses resulting from plant metabolism. Increase in the weight of consumers which depend on organic food is termed as secondary production.
- Productivity varies from one kind of ecosystem to another and from one time to another. The availability of water, the amount of minerals and many other factors in addition to incident radiation limit productivity in different ecosystems.

- Energy passes from one trophic level to the next. Approximately 90 per cent of the energy is lost at each transfer. On the average, about 10% of the energy entering a particular trophic level is available to the next level in an ecosystem. Therefore, the biomass that an ecosystem can support at each trophic level declines rapidly. The loss of energy at each trophic level, limits the number of trophic levels in a food chain to four or five.
- Organisms of various trophic levels are related to each other through feeding relationships, that can be represented in terms of food chain. Three main types of food chains can be distinguished namely grazing, detritus and auxiliary food chains. The relative importance of these chains may vary in different ecosystems.
- Ecosystems are highly dynamic entities. They have evolved effective homeostatic mechanism for self-regulation through feedback control.

5.13 TERMINAL QUESTIONS

1) a) Fill in the blank spaces with appropriate words.

All ecosystems have the same three categories of organisms; ...., which use abiotic sources of energy and nutrients to synthesise organic molecules; ...., which acquire energy and nutrients by digesting the organic molecules of living organisms; and ...., which obtain energy and nutrients by digesting the organic molecules of dead organisms, their excretions and other organic (but no longer living) materials. Of the three categories, an ecosystem could persist without ....

2) a) Discuss the concept – range of tolerance. Can you think of any examples in which the range of tolerance was exceeded in ecosystems you are familiar with? What happened during these incidents?

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b) What is a limiting factor? What is the limiting factor in most terrestrial ecosystems?

....

....

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....

....

3) a) Which of the following pyramid can never assume an inverted shape?

pyramid of biomass, pyramid of number, pyramid of energy.

....

b) Which trophic level remains unrepresented in ecological pyramids?

....

c) Why pyramid of biomass in some aquatic ecosystems like lakes and oceans acquires an inverted shape?

....

....

....

....

....

4) a) The net primary productivity of an ecosystem is the total amount of producer tissue formed per unit area per unit time, or the .... productivity, minus the chemical energy used in .... The amount of chemical energy decreases with each step in a food chain, since each organism uses some of the energy to ...., a process that converts chemical energy to ...., and this form of energy is lost from the food chain.
(Fill in the blank spaces with appropriate words)

b) Productivity can be expressed in terms of $kcal/m^2/yr$ or $g/m^2/yr$. Discuss the differences and the similarities between these two expressions.

....

....

....

c) What influences productivity?

....

....

d) Which ecosystems have high net productivity?

....

....

....

....

e) What is secondary production? How does it differ from primary production?

....

....

....

....

....

5) a) Fill in the blank spaces with appropriate words :
Energy enters an ecosystem primarily as .... and leaves an ecosystem primarily as .... Within the ecosystem, it is transferred from organism to organism in the form of .... energy.

b) Can energy be recycled through an ecosystem? Yes or No?

c) Assume that a plant converts 1 per cent of the light energy it received from the sun into plant material and that an animal stores 10 per cent of the food energy that it eats. Starting with 10,000 calories of light energy, how much energy is available to a person who eats :

i) Wheat.......................calories
ii) hen.......................calories
iii) frog.......................calories

d) A group of explorers is stranded on a barren island. All they have in their stores are some hens and some wheat. To make these resources last as long as possible, should they :

i) eat the wheat and when it is finished, kill and eat the hens, or

ii) feed the wheat to the hen, collect and eat the eggs laid and when the wheat is gone, kill and eat the hens, or

iii) kill and eat the hens first and when they are finished eat the wheat?

Choose the correct choice and write its number in the box provided below.

[ ]

Also justify your answer, in not more than 4 to 5 lines.

....

....

....

....

....

e) Is there one or more than one food web in any ecosystem?

....

f) During the 1970s, shark-killing expeditions became a fad. Why are sharks important in the food chain of the ocean, and what do you suppose might happen to other fishes if a large number of sharks disappeared?

....

....

....

6) In what way food web relationships promote ecosystem stability? Support your answer with a suitable example.

....

....

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....

....

....

5.14 ANSWERS

Self-assessment Questions

i) a) i) √
ii) ×
iii) √
iv) ×
v) ×

b)

- biotic components
  - primary producers
  - consumer
  - decomposers
- abiotic components
  - energy
  - inorganic elements
  - substrate or medium

c) Write from your own experience

Hint : i) water in a desert

ii) salinity in an aquatic ecosystem

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

goat, rat (second trophic level)

lion, cat (third trophic level)

b) **Hint** : e.g., bear.

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

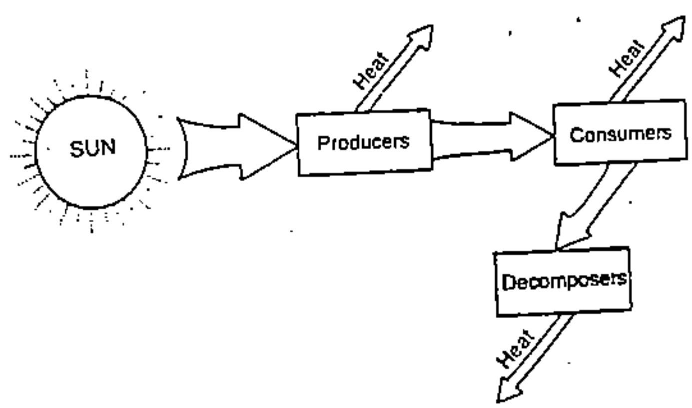
c) In situations where the number of producers is less than the subsequent trophic levels, we get an inverted pyramid, e.g., a large number of insects feeding on a single tree.

d) g/m^2.

e) In energy pyramids, a particular trophic level always has a smaller energy content than the trophic level immediately below it. This is because some energy is lost while transfer from one trophic level to the next. Since the amount of energy decreases from the first trophic level onwards, therefore the energy pyramids are always upright and never inverted.

3) a) 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 which on the whole can be considered as a large ecosystem, is sun.

b)



c) i)

d) ii)

e) ii)

f) desert and semi-desert areas (7)

savanna (5)

open ocean (6)

estuary (3)

temperate deciduous forest (4)

tropical rain forest (2)

coral reefs (1)

extreme desert (8)

4) a) Your choice.

b) **Hint :** If one population of a food chain suffers a decline; then this particular food chain could disappear.

c) v)

d) iv)

e) iii)

f) ii)

g) iii)

h) ii)

Terminal Questions

1) producers, consumers, decomposers, consumers.

2) a) Every living organism can tolerate certain range of a particular environmental factor. Beyond this range the organism is unable to survive, e.g., one of the factors that influence the life in lakes is pH. Due to acid rain, the pH of the lakes becomes low, consequently most of the living organisms perish. The water of such lakes appear transparent as the lake becomes devoid of life. (Recall from FST-1, Unit 16, Sub-section 16.2.1)

Another example is the accumulation of hazardous wastes in the bodies of organisms like birds, man, etc. who are at the top of the food chain. (See FST-1, Unit 16, Sub-section 16.2.1)

b) Living organisms are dependent on certain environmental factors for their survival and well being. If any of these factors is in short supply, or even in an excess, it becomes a limiting factor. In most terrestrial ecosystems, water is a limiting factor.

3) a) pyramid of energy

b) decomposers

c) In lakes and sea, most primary producers are single-celled algae which are very small and short-lived. These producers have rapid turnover as compared to the animals of secondary and tertiary trophic levels, e.g., various kinds of fish. These organisms of secondary and tertiary trophic levels are large in size and outweigh the producers. So if we calculate the biomass of various trophic levels in conditions when the biomass of producers is less than the consumers, the pyramid assumes an inverted shape.

4) a) gross, respiration, do work, heat

b) Similarities – both are the units to measure primary productivity.

Differences – primary productivity in terms of weight is expressed as $g/m^2/yr$, and in terms of energy is expressed as $kcal/m^2/yr$.

c) Productivity is influenced by a variety of factors such as sunlight, temperature, rainfall and availability of nutrients.

d) Ecosystems like coral reefs, tropical rain forests and estuaries have high net productivities.

e) Secondary production refers to the production by consumer organisms. In primary production, the solar energy is trapped by producers resulting in the increase of their biomass; whereas in secondary production, the consumers utilise the stored energy of plants, for building their bodies.

5) a) Light, heat, chemical

b) No

c) i) 10 calories
ii) 1 calorie
iii) 0.1 calorie

d) If we sustain the population of men as well as hen or the stored wheat, the stock would exhaust faster. So first, hens be eaten and then wheat. This will enable the wheat stock to last longer.

wheat ⟶ hen ⟶ man .... (1)

wheat ⟶ man .... (2)

In food chain (2) since man is nearer the producers therefore, the energy loss would be minimum and they can be sustained on the available wheat stock for a longer period.

e) One food web

f) Disappearance of shark would lead to a massive increase in the number of small fish. This would exert tremendous pressure on the phytoplankton population. In times, when the phytoplankton number is very low, there won't be enough food for the fish, and result would be increased mortality of small fish. Thus the entire food chain would be disrupted.

6) A food web shows the feeding interrelationships which exist between various food chains found within an ecosystem. A food web, has a number of alternative routes for energy flow, which help in promoting ecosystem stability. Give an example of your choice.

UNIT 6 NUTRIENT CYCLES

Structure

6.1 INTRODUCTION

You have already learnt in the earlier units (Units 1 and 5) that all ecosystems have certain common basic features of structure and function. They all have living and non-living components through which there is a flow of energy and exchange of materials. Birth, growth, death and decay are the four pillars that keep life going on the planet. The soil does not offer an endless supply of minerals to land living organisms nor do fresh water and sea to their inhabitants. Yet in the millions of years during which life evolved and flourished on land, the soil has not been exhausted of the nutrients required by plants. Similarly, the atmosphere has not run out of its oxygen or carbon dioxide. Shortages of these substances are prevented because they are circulated and recycled in a community in a delicately balanced cycle of events.

In this unit we will consider the dynamics of major nutrient elements in the biosphere. We will study the various chemical forms in which they occur in nature and the way they cycle. You will learn specifically about the cycling of carbon, nitrogen, sulphur and phosphorus through the abiotic and biotic components of the ecosystem. The role of decomposers in liberating the nutrients back into the environment for their reuse is crucial in the cycling of these nutrients. The nutrient cycles are delicately balanced and each step is critical for their normal functioning. However, man is seriously influencing the rate and quantum of these nutrient cycles through his activities. Suitable examples are provided to show the impact of human activities on the nutrient cycles.

A study of this unit will help you to understand that a community of plants and animals in an ecosystem survives primarily by a combination of material cycling and energy flow.

Objectives

After reading this unit you will be able to:

- define and use in proper context the term biogeochemical cycle and explain the importance of the concept,
- distinguish between gaseous and sedimentary cycles,
- outline the course of carbon, nitrogen, sulphur and phosphorus cycles,
- describe the importance of micro-organisms in nutrient cycling,
- differentiate between nutrient cycling in tropical and temperate forest,
- identify the consequences of human intervention in nature in terms of nutrient cycles.

6.2 BIOGEOCHEMICAL CYCLING

You have studied in Unit 5 that energy flows through ecosystems enabling the organisms to perform various kinds of work, and is ultimately lost as heat. It is gone for ever in terms of usefulness to the system. On the other hand, nutrient materials never get 'used up'. They can be recycled again and again indefinitely. For example, when we breathe, we inhale several million atoms that may have been inhaled by say, Akbar or any other person you may care to choose from history. First let us explain what we mean by mineral nutrients. As you have learnt in Unit 5, of more than 100 chemical elements, about 40 are present in living organisms. Some are needed in relatively large amounts and so are called **macronutrients** while some are needed in only trace amounts and so named **micronutrients** (see Table 6.1).

Table 6.1

Relative amounts of some chemical elements that make up living things

	Element	Main Reservoir
Major Macronutrients (> 1% dry organic weight)	Carbon	Atmosphere
	Hydrogen	Hydrosphere
	Oxygen	Atmosphere
	Nitrogen	Atmosphere and Soil
	Phosphorus	Lithosphere
Relatively Minor Macronutrients (0.2 – 1% dry organic weight)	Calcium	Lithosphere
	Chlorine	Lithosphere
	Copper	Lithosphere
	Iron	Lithosphere
	Magnesium	Lithosphere
	Sulphur	Lithosphere and Atmosphere
	Sodium	Lithosphere
	Potassium	Lithosphere
Some Micronutrients (< 0.2% dry organic weight)	Aluminium	Lithosphere
	Boron	Lithosphere
	Bromine	Lithosphere
	Zinc	Lithosphere
	Cobalt	Lithosphere
	Iodine	Lithosphere
	Chromium	Lithosphere

Individual nutrients can exist in combination with other elements forming different compounds. But living organisms may not be able to obtain the essential nutrients from all those compounds. For example, plants can use carbon only in the form of carbon dioxide (CO_2). Similarly all organisms need nitrogen but most of them are incapable of utilising the gaseous N_2 present in the atmosphere unless it is available in form of soluble nitrates (NO_3^-) or ammonia (NH_3).

The mineral nutrients move from the non-living to the living and then back to the non-living components of the ecosystem in a more or less circular manner. This is known as **biogeochemical cycling** (bio for the living; geo for atmosphere, water, rocks and soil and chemical for the elements and processes involved). We generally call them **nutrient or mineral cycles.** You should, however, remember the important role of

a) green plants which organise the nutrients into biologically useful compounds,

b) decomposers which ultimately return them to their simple elemental state,

c) air and water which transport the nutrients to long distances between the abiotic and biotic components of the ecosystem.

You should also get familiar with the two important terms associated with biogeochemical cycles :

a) the different **reservoirs** or **pools** of nutrients like the atmosphere and rocks. These are large and the relative size of these pools is important when one assesses the effect of human activities on nutrient cycles.

b) the **compartments** of the cycles through which the nutrients move. They are relatively short-term stores of nutrients in comparison with reservoirs; for example, the plants and animals through which the nutrients move and in which they are stored for short periods in a cycle.

Fig. 6.1 shows a model. The reservoirs are the atmosphere and rocks; the major compartments are sea and sediment, freshwater and soil. These include the primary producers and consumers and dead organic matter in the decomposer system.

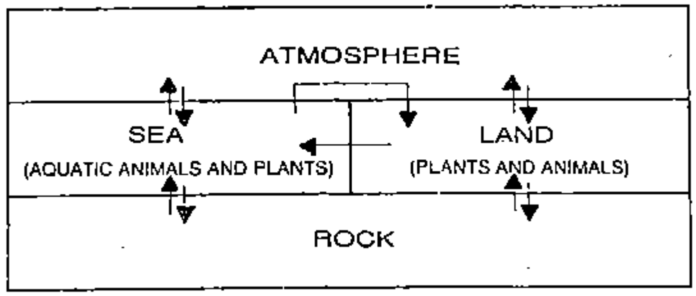


Fig. 6.1 : A model of the biogeochemical cycle. The arrows indicate the outgoing and incoming of minerals.

Now let us study two types of biogeochemical cycles.

Types of Biogeochemical Cycles : There are two basic types of biogeochemical cycles; **gaseous** and **sedimentary.** In the gaseous type of biogeochemical cycle there is a prominent gaseous phase. Cycling of carbon and nitrogen represents gaseous biogeochemical cycles. In sedimentary cycles the main reservoir is the lithosphere from which the nutrients are released largely by weathering of rocks. The sedimentary cycle is exemplified by phosphorus and sulphur.

When we describe biogeochemical cycles we often say that a cycle is **perfect** or **imperfect.** A perfect nutrient cycle is one in which the nutrients are replaced as fast as they are used up. Most gaseous cycles are generally considered perfect. In contrast, sedimentary cycles are considered relatively **imperfect,** as some nutrients are lost from the cycle into the soil and sediments and become unavailable for immediate cycling i.e., there are more stages in which short-term or long-term stagnation occurs. Most significant of the stagnation stages is sedimentation in oceans and deep continental lakes. So if portions of nutrients, such as phosphorus or sulphur are lost, they are unavailable to organisms for comparatively longer periods. Human beings have so speeded up the movement of many nutrients that the cycles tend to become imperfect or rather acyclic resulting in too much of nutrients at one stage or too little at another. We will discuss this in detail when we come to the phosphorus cycle.

Factors or processes which promote nutrient loss from the compartments of biogeochemical cycles to the reservoir can impoverish ecosystems over long run. For example, continuous cultivation and cropping without the use of fertilisers is bad for the soil. Small particles and nutrients wash with runoff waters or leach down to groundwater and rivers through subsoil to the sea, where they may get buried with sediments which may eventually be incorporated into rocks.

Agriculture, forestry operation (e.g. deforestation), and other activities can profoundly affect the rates of nutrient cycling. For instance, burning of fossil fuels contributes towards the build up of carbon dioxide in the atmosphere. We will learn more of this as we discuss each cycle individually

SAQ 1

Identify the correct statements that describe the terms biogeochemical cycle, reservoir and compartment from those given below :

i) A place where there is long-term accessible storage of minerals in rocks.

ii) A place where short-term accessible storage of nutrients occurs, within the mineral cycle.

iii) A place where there is long-term storage of nutrients from which the nutrient cycles are replenished.

iv) Cycles occurring between the organisms, soil and air and between the organisms, air and sea.

6.3 CARBON CYCLE

Carbon is the basic constituent of all organic compounds. Next to water, carbon is the most significant element constituting 49 per cent of the dry weight of organisms. The carbon cycle is essentially a perfect one, that is, carbon is returned to the environment about as fast as it is removed. The source of all carbon in living organisms, dead organic material and fossil deposits is carbon dioxide found in the atmosphere.

Table 6.2 : Carbon in major biospheric compartments

Major Compartments in the Biosphere	Carbon in 10^9 tons
Atmosphere	711
Terrestrial	3,100
Oceans (mostly as carbonates)	39,000
Fossil fuels	12,000

Source : Data from 1981 report of the Council on Environment Quality.

The atmosphere has an average concentration of about 0.032 per cent or 320 ppm of CO_2. Apart from the atmospheric pool, a considerably large amount of CO_2 is found dissolved in the oceans. It is estimated that the oceans contain more than 50 times as much carbon as there is in the atmosphere. The oceanic reservoir tends to regulate the amount in the atmosphere. Table 6.2 shows the major biosphere compartments involving carbon. The cycling of carbon involves the atmospheric reservoir, from where it is taken up by the producer to consumer and from both these groups to the decomposer and then back to the reservoir (Fig. 6.2). Let us now consider each stage of the cycle.

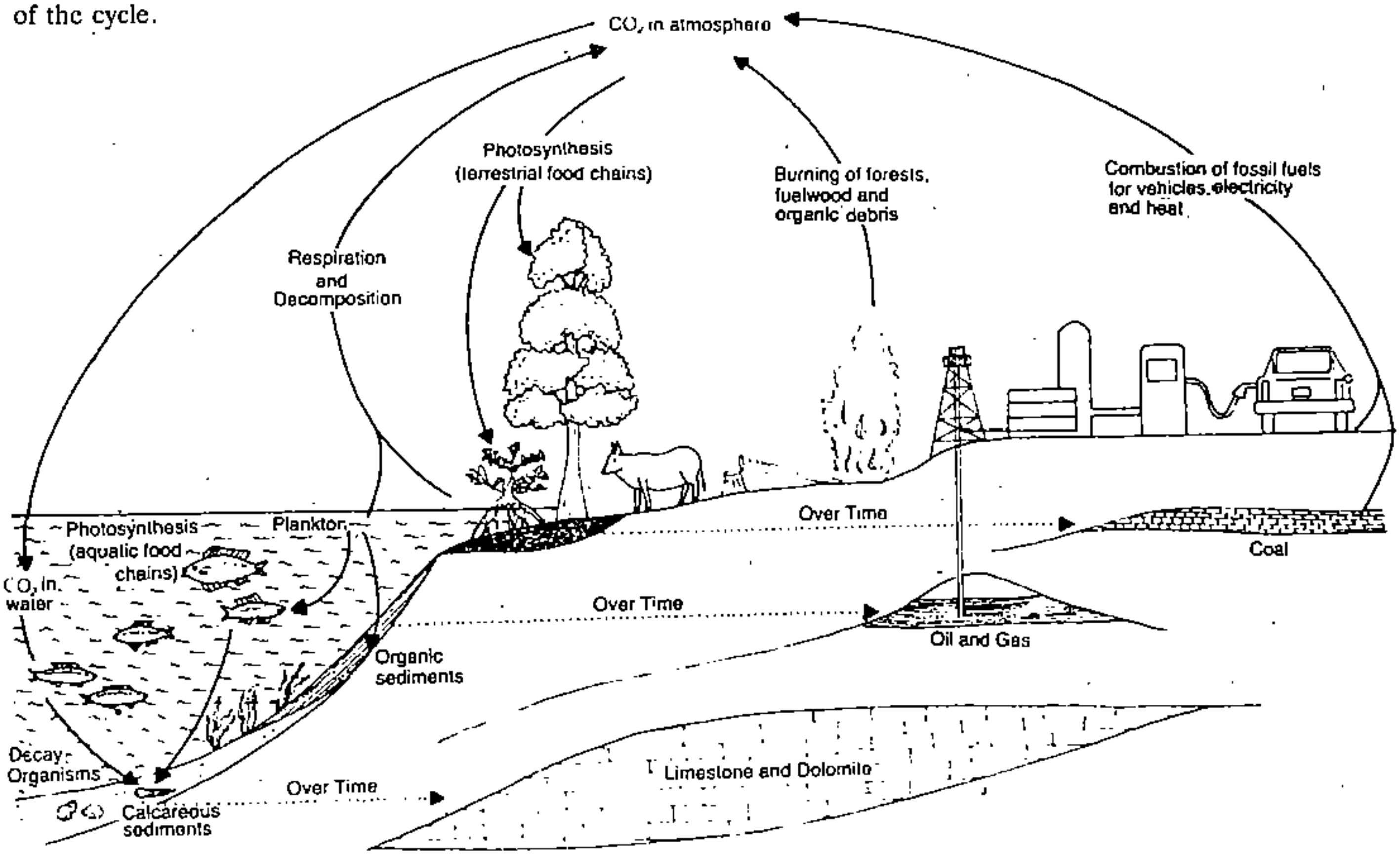


Fig. 6.2 : Simplified carbon cycle

Through photosynthesis, green plants pick up carbon from carbon dioxide they take in from the atmosphere. As much as 4 to 9 $\times 10^{13}$ kg of carbon is fixed in the biosphere through photosynthesis annually.

Respiratory activity in the producers and consumers accounts for the return of a considerable amount of carbon as CO_2 to the atmosphere. The most substantial return, however, is through the activity of decomposers in their processing of the waste materials and dead remains of other trophic levels.

Burning of wood, forest fires and combustion of organic matter also are additional man-made sources for releasing CO_2 into the atmosphere.

Turnover Rate : Rate of replacement of a substance or a species when losses to a system are replaced by addition.

The rate of release of carbon depends on environmental conditions such as soil, moisture, temperature and precipitation. In tropical forests most of the carbon in plant remains is quickly recycled, for there is little accumulation in the soil. The **turnover rate** of atmospheric carbon over a tropical forest is about 0.8 year. In drier regions such as grasslands, carbon is stored as humus. In swamps and marshes where dead material falls in water and is not completely decomposed, carbon is stored as humus or peat and circulated very slowly. The turnover rate here is of the order of 3-5 years.

More than 99 per cent of the **total carbon** is present in the earth's crust as deposits of coal, petroleum, peat and limestone. These as you know are deposits of plant and animal remains. On weathering of carbonate rocks, burning of fossil fuels and volcanic activity, the bound carbon is returned to the atmospheric-aquatic reservoir.

A number of aquatic plants occurring in alkaline water release calcium carbonate ($CaCO_3$) as a byproduct of photosynthesis. For example 100 kg of Elodea cannadensis can precipitate 2 kg of $CaCO_3$ in 10 hr of sunlight under natural conditions. This pure $CaCO_3$ mixes with clay to from limestone over a number of years.

In aquatic environments, the phytoplankton utilises the CO_2 that is dissolved in the water, or is present as bicarbonates and carbonates and convert this CO_2 into phytoplankton biomass. The phytoplankton is used as food by the aquatic food chain. The CO_2 produced in respiration is reutilised by the phytoplankton to produce more biomass. The carbon bound in the shells of snails and foraminifera as carbonates is deposited in the sediments when these animals die. In this manner a significant portion of the carbon gets buried in the sediment and is removed from circulation. This may later surface as limestone rock or coral reef.

The atmospheric gaseous CO_2 remains in dynamic equilibrium with the CO_2 dissolved in oceans. The interchange between the two phases occurs due to diffusion, the direction of which depends on the relative concentrations of carbon dioxide. Carbon dioxide dissolves in water easily and some of it enters the aquatic phase through precipitation. A litre of rain water contains about 0.3 ml of gaseous CO_2. The CO_2 dissolved in the water, in soil or in oceans forms carbonic acid (H_2CO_3). The carbonic acid dissociates into hydrogen and bicarbonate ions (H^+ and HCO_3^-). The bicarbonate ions can further dissociate into hydrogen and carbonate ions. All these steps are fully reversible as shown in the following equation.

$$\text{Dissolved } CO_2 + H_2O = H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^{-2}$$
$$\updownarrow$$
$$\text{Atmospheric } CO_2$$

The direction of the reaction depends on the concentration of the critical component. For example, a local depletion of CO_2 would result in the movement of CO_2 from the dissolved phase into the atmosphere. Similarly the assimilation of bicarbonate ions (HCO_3^-) through photosynthesis by aquatic plants would tend to shift the equilibrium in the other direction. The equilibrium system actually is not as simple as it seems. It depends on several factors, pH of the water being one. At higher pH values i.e., alkaline conditions more carbon is present as carbonates; in acidic conditions more carbon is in the dissolved phase.

It may now be apparent to you that what seemed like a simple cycle is actually quite complicated. However, it is important to recognise that there are limited avenues by which carbon is utilised and a much larger number by which it is restored to the atmosphere.

Human Impact on Carbon Cycle

Human activities have greatly influenced the carbon cycle. The discharge of CO_2 into the atmosphere is steadily increasing owing to burning of fossil fuels and destruction of forests. At the beginning of the Industrial Revolution about 1800, it is believed that CO_2 concentration in the atmosphere was 290 ppm (parts per million) which is equal to 0.29 per cent. In 1958 when accurate measurements were first taken, the concentration of CO_2 was already 315 ppm, while in 1988 it had risen to 350 ppm. A major concern over the increasing concentration of CO_2 in the atmosphere is its possible effect on the average ambient global temperature. Carbon dioxide is one of the gases that helps to produce the **'greenhouse effect'** (recall FST-1 Block 4, Unit 16). Rise in the ambient global temperature would have pronounced ecological effects. The warming would cause icecaps to melt and ocean levels to rise, as a result the continental coastal regions would be flooded. The rise in temperature would also change the rainfall and vegetation patterns which would disrupt agricultural production. This has been verified by comparing with predictions of climatic patterns of the past through computer modelling studies.

SAQ 2

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) Fill in the blanks using suitable words from the text.

Increasing carbon dioxide concentration in the atmosphere can lead to a rise in ...., as carbon dioxide is one of the ....gases. This rise could cause .... to melt resulting in a flooding of the ....

6.4 NITROGEN CYCLE

You have already learnt that nitrogen is an essential constituent of protein — the building block of all living cells. It is also a major constituent of the atmosphere (79 per cent). Although organisms live in an atmosphere rich in gaseous nitrogen yet the organisms cannot use this nitrogen. It can be utilised only after gaseous nitrogen has been 'fixed' into some chemically usable form. The transformation whereby molecular nitrogen is converted into a variety of nitrogenous compound and its release again into the atmosphere, is what constitutes the nitrogen cycle (Fig. 6.3).

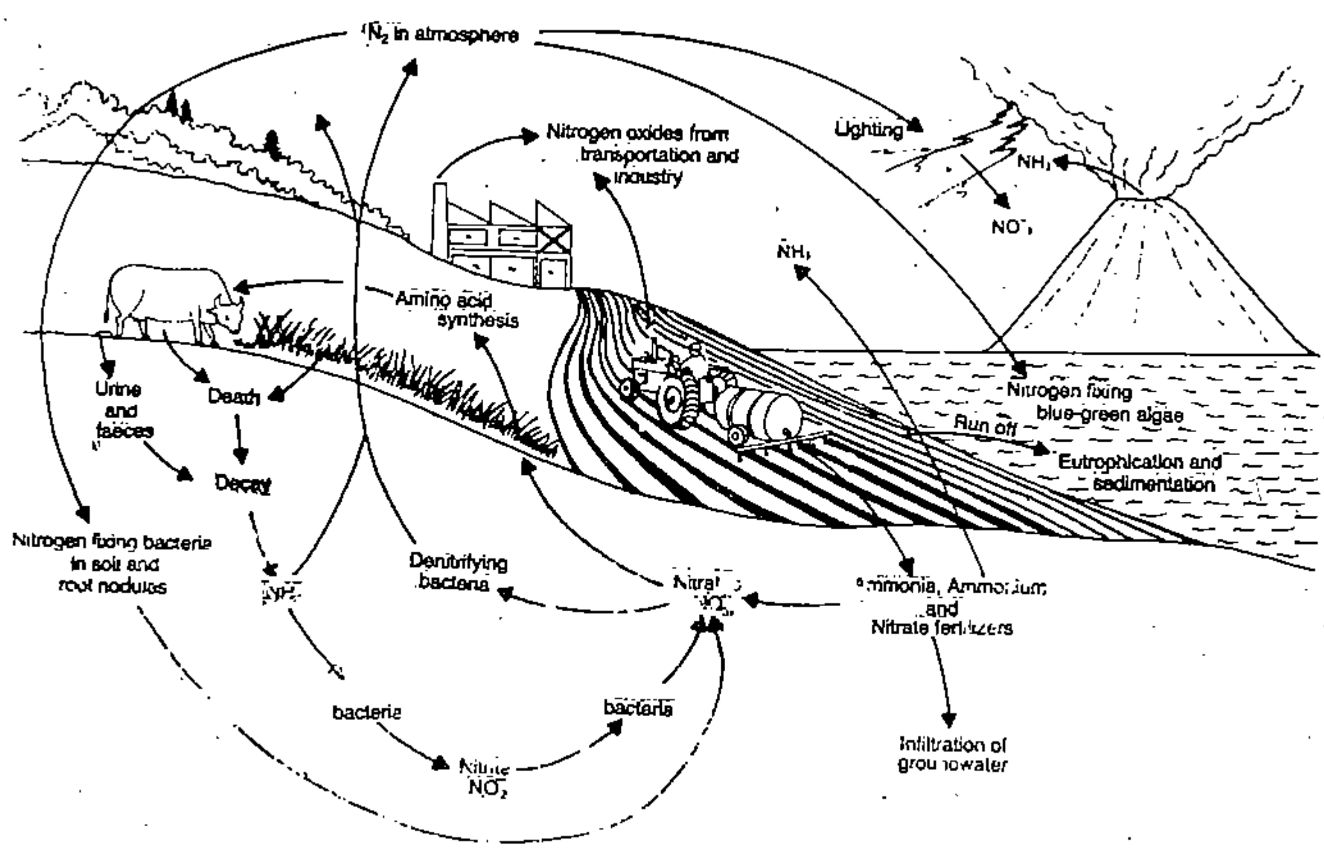


Fig. 6.3 : Nitrogen cycle. A simplified diagram representing major steps in the circulation of nitrogen involving various organisms and different forms of inorganic and organic nitrogen.

The largest reservoir of nitrogen is the atmosphere but the critical pools are represented by its organic and inorganic forms that can be used by plants and animals.

Nitrogen Fixation

As we have said before, atmospheric nitrogen cannot be used by plants or animals. It has to be first **fixed.** The term **nitrogen fixation** refers to the oxidation or reduction of atmospheric nitrogen to nitrates (NO_3^-) and ammonia (NH_3) which can be used by living organisms. In nature nitrogen fixation into these compounds occurs primarily in two ways :

i) **High energy fixation :** Through cosmic radiations, lightning, volcanic activity and meteorite trails which provide the high energy needed to combine atmospheric N_2 with oxygen and hydrogen of water. The resulting ammonia and nitrates are brought to the earth by rainwater.

ii) **Biological fixation :** Approximately 63% of all nitrogen fixed is through biological fixation. Nitrogen fixing organisms are primarily **prokaryotes; bacteria and blue green algae.** Nitrogen fixation requires activation of molecular nitrogen by splitting nitrogen into two atoms of free nitrogen $N_2 \rightarrow 2N$. This is an energy requiring step, which in biological fixation requires 160 kcal/mole. The actual fixation step, in which two atoms of nitrogen combine with three molecules of H_2 to form two molecules of ammonia (NH_3) releases 13 kcal/mole. Therefore, the net energy requirement for nitrogen fixation is 147 kcal/mole.

Except for the photosynthetic ones, all nitrogen fixing organisms need an external source of carbon compounds to provide the energy for this endothermic reaction. **It is an interesting fact that nitrogen fixation regulated by two enzymes nitrogenase and hydrogenase in nature requires low energy. In contrast, industrial nitrogen fixation requires very high temperature (400° C) and pressure (2×10^7 Pascal).** Table 6.3 illustrates the kind of organisms known to fix nitrogen. Symbiotic nitrogen fixation occurs largely in terrestrial situations whereas, fixation by free living organisms occurs in both terrestrial and aquatic situations.

Table 6.3 : Examples of symbiotic and free living nitrogen fixing organisms

Symbiotic	
HOST PLANT	N_2 FIXING ORGANISMS
Legumes (pea, alfalfa, pulses like arhar, beans, clover, etc.)	*Rhizobium*
Non-legumes (*Alnus, Myrica, Casuarina, Hippophae, Elaeagnus, Coriaria, etc.*)	Actinomycetes
Tropical grasses (*Paspalum, Digitaria*, maize, sorghum)	*Azotobacter, Spirillum* *Klebsiella*
Cycads	Blue green algae
Ferns, (*Azolla*)	Blue green algae (*Anabaena*)
Lichens	Blue green algae
Free-living	
Aerobic bacteria — (*Azotobacter*)	
Anaerobic bacteria — (*Clostridium*)	
Anaerobic — photosynthetic bacteria — (*Chromatium, Rhodospirillum, Chlorobium*)	
Blue green algae — (*Nostoc*)	

i) **Symbiotic Nitrogen Fixers**

Of the symbiotic nitrogen fixing bacteria, species of *Rhizobium* form root nodules in legumes and are the most studied nitrogen fixers and the best understood. Species of *Rhizobium* are host specific to particular species of legumes. The rhizobia penetrate the root hair and once inside the root, the bacteria rapidly multiply and form swollen, irregular – shaped bodies in roots of legumes.

Some non-legume woody plants also have root nodules and fix nitrogen symbiotically. The organisms that cause the formation of nodule and fixation of nitrogen are actinomycetes (a kind of primitive fungus). Some examples of non-legumes are species of *Alnus, Elaeagnus Myrica, Araucaria, Ginkgo, Casuarina.* Unlike legumes, which are largely tropical in origin, these nitrogen fixers orginate in the temperate zone.

Nitrogen fixation by blue green algae or cynobacteria may take place in free living forms or in symbiosis with fungi as in certain lichens, mosses, ferns and at least one seed plant. The fronds of the small free floating aquatic fern *Azolla* contain small pores filled with symbiotic blue green algae *Anabaena* that actively fix nitrogen. For centuries this fern has played an important role in the rice fields of China. Before the rice fields are planted, the water filled paddy fields are covered with the aquatic fern which fixes enough nitrogen for the crop as it matures. This practice permits rice to be grown without further addition of nitrogen fertilisers.

Symbiotic nitrogen fixers are more efficient than free living ones.

ii) **Non Symbiotic Nitrogen Fixers**

There are certain groups of free living bacteria both aerobic and anaerobic and blue green algae that fix nitrogen. Aerobic nitrogen fixing bacteria such as *Azotobacter* and anaerobic form *Clostridium* are widely distributed in soils as well as in fresh and marine waters. In fact accumulating evidence indicates that many soil and water bacteria are capable of nitrogen fixation and because they occur in abundance the total amount of nitrogen fixed is considerable.

The N_2 fixed in the soil and root nodules is used by the plants to form numerous nitrogenous compounds mainly proteins which then enter the food chain. Nitrogen is returned to the soil in the form of organic compounds through manure, dead plants, and animals and micro-organism. But most of this nitrogen is insoluble and not immediately available for plant use. The organic nitrogenous compounds have to be changed to inorganic compounds to be used by plants. This is done by two processes — ammonification and nitrification.

Ammonification

Many heterotrophic bacteria, actinomycetes and fungi in soil and water, metabolise the organic nitrogen and release it in an inorganic form as ammonia. This process is known as **ammonification** or **mineralisation.** This is an energy releasing reaction. For example, glycine-based protein releases 176 kcal/mole. This energy is used to maintain the life process of the organisms that accomplish the transformation.

Nitrification

Ammonia or ammonium salts, are converted into nitrate in a process termed **nitrification**, to be useful to most autotrophic and heterotrophic organisms. This process occurs in warm moist soil with near neutral pH and takes place in two steps :

i) ammonia salt or ammonia is oxidised and converted into nitrite by *Nitrosomonas*

$$2NH_3 + 3O_2 \longrightarrow 2NO_2^- + 2H^+ + 2H_2O \quad 65 \text{ kcal/mole}$$

ii) Nitrite is further oxidised and converted into nitrate by *Nitrobactor*

$$2NO_2^- + O_2 \longrightarrow 2NO_3^- \quad 17 \text{ kcal/mole}$$

Because the ammonium ion has a positive charge it tends to be retained on the clay particles which are negatively charged as soon it is formed, till it is oxidised. The nitrate ion being negatively charged moves freely through the soil and readily travels down to the root zone.

These nitrifying bacteria obtain their energy from this oxidation process. Now let us see how nitrogen is converted back into its gaseous form.

Denitrification

Nitrates are readily leached from the soil and also lost through denitrification the process by which molecular or gaseous nitrogen (N_2) as well as nitrous oxide (NO) and nitric oxide (N_2O) and nitrogen dioxide (NO_2) are formed from NO_3^- by bacteria (such as *Pseudomonas*) and fungi. They use the nitrate as a source of oxygen in the presence of glucose and phosphate. Denitrifing bacteria prefer anaerobic or partially aerobic habitats such as estuaries, bogs, lake bottoms and water-logged soils. The bacteria reduce the nitrates to nitrites which are finally converted to free nitrogen.

Figure 6.4 shows the processes involved in N_2 cycle namely fixation, assimilation, denitrification, decomposition, leaching, runoff in rainwater, etc., along with some estimates of annual global movements. The magnitude of the two flows is directly related to human activities — emmissions into the atmosphere and industrial fixation that is largely added to farms in the form of nitrogen fertilisers are also shown.

The total annual nitrogen fixation is estimated to be 92×10^6 metric tonnes, whereas total amount denitrified and returned to the atmosphere is only 83×10^6 metric tonnes. The extra nitrogen added each year in the biosphere causes disbalance of nearly 9×10^6 metric tonnes and is being largely built up in groundwater, reservoirs, rivers, lakes and the ocean.

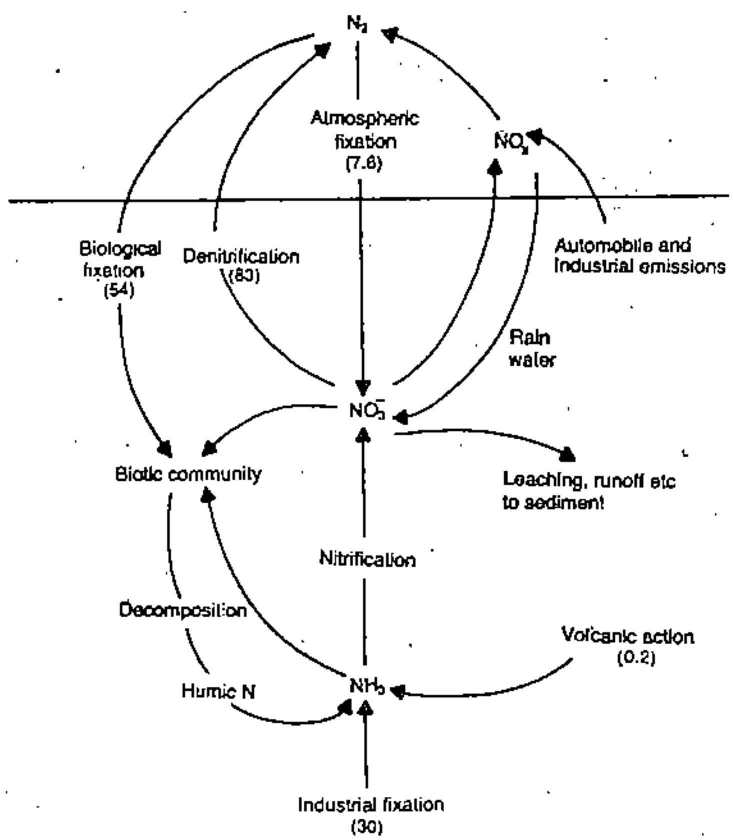


Fig. 6.4 : Estimates of the magnitude of key flows in the nitrogen cycle. Numbers in parentheses are in 10^6 metric tonnes per year (Data from Delwich 1970 Scientific American)

The self-regulating feedback shown in Fig. 6.4 makes the nitrogen cycle a relatively perfect one when a large area or the biosphere as a whole is considered. Some nitrogen is lost to the ocean sediments and gets out of circulation but this is compensated by nitrogen entering the air by volcanic gases. Let us now assess the impact of human activities on this cycle.

Human Impact on Nitrogen Cycle

Human activities are profoundly affecting the cycling of nitrogen in nature. Over 30×10^6 metric tons/yr. of N_2 is fixed in the commercial production of fertilisers, an amount almost equal to that fixed biologically. The use of N_2 fertilisers affect the distribution of N_2 on earth. Much of the nitrogen in the harvested crops becomes animal and human waste in sewage waters and eventually enters the aquatic ecosystem through runoff and leaching. Nitrogenous compounds leached into the groundwater may be abundant in irrigation and drinking water where they can cause serious health hazards. Nitrogenous compounds entering the lakes have fertilising effect resulting in algal blooms and promote **cultural eutrophication.** You already have an idea what eutrophication means (from Unit 26 Block 4 of FST-1). Excessive growth of phytoplankton in eutrophic lakes produces huge quantities of biomass and finally collapse due to nutrient exhaustion. The dead organisms are consumed by detrivores which use up the oxygen supply. This problem of cultural eutrophication is, however, more severe in the case of phosphorus additions rather than nitrogen. When fossil fuels are burned we add nitrogenous compounds to the air. Large quantities of nitrogen oxide (NO) are released from vehicles and most of the NO is converted to NO_2 by combining with ozone (O_3) in the atmosphere. NO_2 is a toxic gas for humans and a cause of smog. It combines with water to form nitric acid, HNO_3, which forms 30% of the strong acids in the acid rain. You will read mo about acid rain in Section 6.5.

Now that you have learnt about the biogeochemical cycles where the main reservo are in gaseous phase, we will discuss two sedimentary cycles namely phosphorus ar sulphur. These are different from the earlier two gaseous cycles because the main reservoirs and major reactions involving their transformation are largely confined to the sediment.

SAQ 3

a) Tick mark the correct answer.

The main reservoir of nitrogen in the biosphere is the

i) atmosphere   iii) oceans

ii) rocks   iv) organisms

b) Fill in the blanks using suitable words :

Nitrogen is available to producers in the form of .... from detrivores, ... from the nitrogen fixers, and .... from the nitrifying bacteria. Nitrogen is available to consumers and detrivores chiefly in the form .... Nitrogen leaves an ecosystem as .... formed by denitrifying bacteria.

6.5 SULPHUR CYCLE

The sulphur cycle is mostly sedimentary except for a short gaseous phase (Fig. 6.5). The large reservoir of sulphur is in the soil and sediment where it is tied up in organic (coal, oil and peat) and inorganic deposits (pyrite rock and sulphur). It is released by weathering of rocks, erosional runoff and decomposition of organic matter, and is carried to terrestrial and aquatic ecosystems in salt solution. The smaller reservoir is in the atmosphere. Sulphur can circulate on a global scale along with carbon, oxygen and nitrogen because of its gaseous phase.

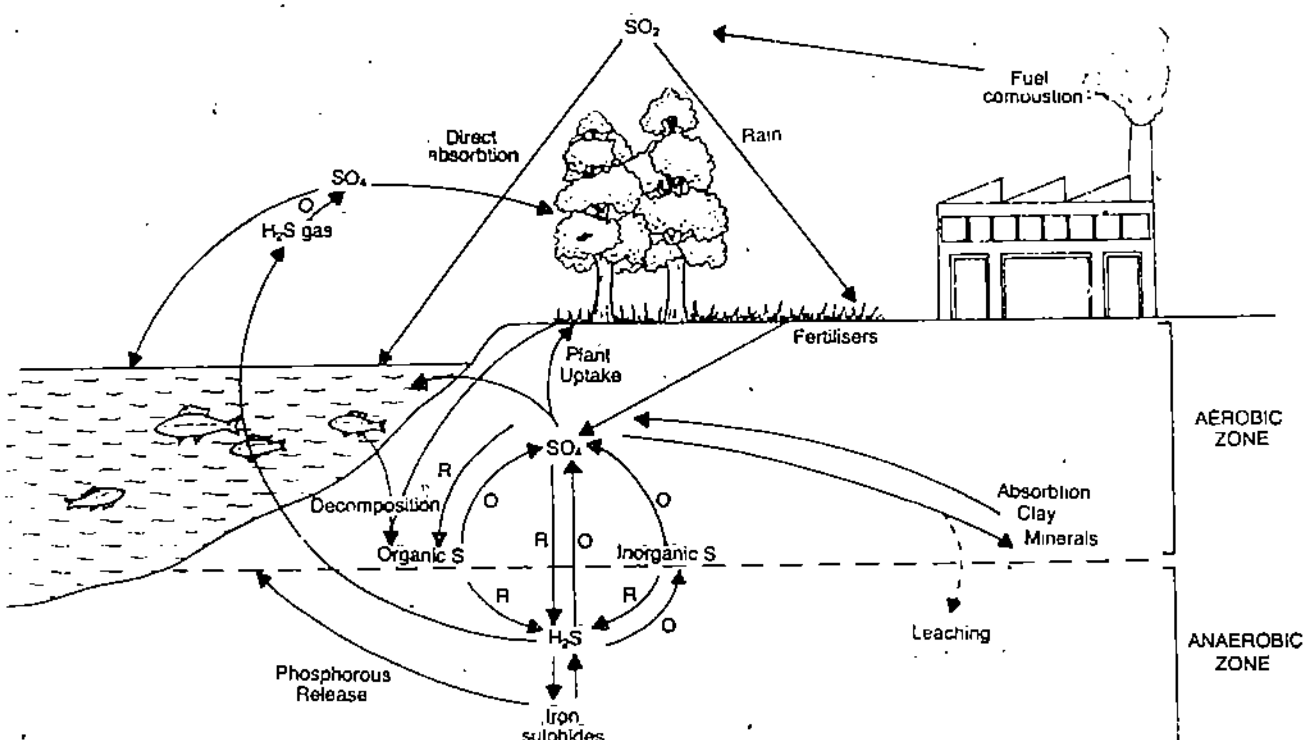


Fig. 6.5 : The Sulphur cycle linking air, water and soil. The centre circular arrows show oxidation (O) and reduction (R) reactions that bring about key transformations between available sulphate (SO_4) pool, organic sulphur and iron sulphide deep in the sediment and soil.

Sulphur enters the atmosphere as hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) from several sources like combustion of fossil fuels, volcanic eruptions, and the surface of oceans and gases released by decomposition. Hydrogen sulphide also oxidises into sulphur dioxide (SO_2). Atmospheric SO_2 is carried back to the earth dissolved in rainwater as weak sulphuric acid (H_2SO_4). Sulphur in the form of sulphates (SO_4^{-2}) is taken up by plants and incorporated through a series of metabolic processes into sulphur bearing aminoacids. From the producers the amino acids are taken up by the consumers.

Sulphur bound in living organisms is carried back to the soil, to bottoms of ponds and lakes and seas through excretions and decomposition of dead organic material by bacteria and fungi. The oxidation-reduction transformations have been summarised in Table 6.4. These are carried out by specialised bacteria that obtain their energy from these transformations.

Table 6.4 Role of some microbes in the sulphur cycle (O—represents oxidation while R—represents reduction reactions)

Microbes	Reactions, transformations
Colourless, green and purple sulphur bacteria	$H_2S \xrightarrow{O} S \xrightarrow{O} SO_4$
Desulphovibrio (anaerobic) bacteria	$SO_4 \xrightarrow{R} H_2S$
Thiobacillus (aerobic)	$H_2S \xrightarrow{O} SO_4$
Aerobic Heterotrophs	Organic S $\xrightarrow{O} SO_4$
Anaerobic Heterotrophs	Organic S $\xrightarrow{R} H_2S$

Look at Fig. 6.5 again. From the reactions shown in the figure and the table you can see some parallel with the nitrogen cycle, since the sulphate is used as a hydrogen acceptor by the heterotrophic sulphate reducing bacteria just as the denitrifying bacteria use nitrite and nitrate.

Species of colourless sulphur bacteria such as *Beggiatoa* oxidises hydrogen sulphide to elemental sulphur and species of *Thiobacillus* oxidise it to sulphate. For some species oxidation processes can occur only in the presence of oxygen; for others oxygen is not necessary. These bacteria are chemosynthetic autotrophs. They obtain their carbon from the reduction of CO_2.

$$6CO_2 + H_2S \longrightarrow C_6H_{12}O_6 + 6H_2O + 12S$$

These bacteria are again comparable to the chemosynthetic autotrophic nitrifying bacteria that oxidise ammonia to nitrite and nitrite to nitrate. The green bacteria apparently are able to oxidise H_2S to elemental sulphur S, whereas purple bacteria can carry the oxidation to sulphate stage.

$$6CO_2 + 12H_2O + 3H_2S \longrightarrow C_6H_{12}O_6 + 6H_2O + 3SO_4^{-2} + 6H^+$$

The sulphate may be recirculated and taken up by the producers or used by sulphate reducing bacteria. The sedimentary aspect of the cycle involves the precipitation of sulphur in the presence of iron (Fe) and calcium (Ca) as highly insoluble ferrous sulphide (FeS) and ferric sulphide (Fe_2S_3) also known as pyrite; or relatively insoluble calcium sulphate ($CaSO_4$) thus contributing to the reservoir of sulphur. From this it enters the cycle through weathering and erosion. Not as much sulphur is required by the ecosystem as nitrogen and phosphorus. Nonetheless sulphur cycle is important in the general pattern of production and decomposition. For example when iron sulphides are formed in the sediments, phosphorus is converted from insoluble into soluble form as shown in the Fig. 6.7, and phosphorus enters the pool available to the living organisms. This is an excellent example of how one cycle regulates another.

Human Impact on Sulphur Cycle

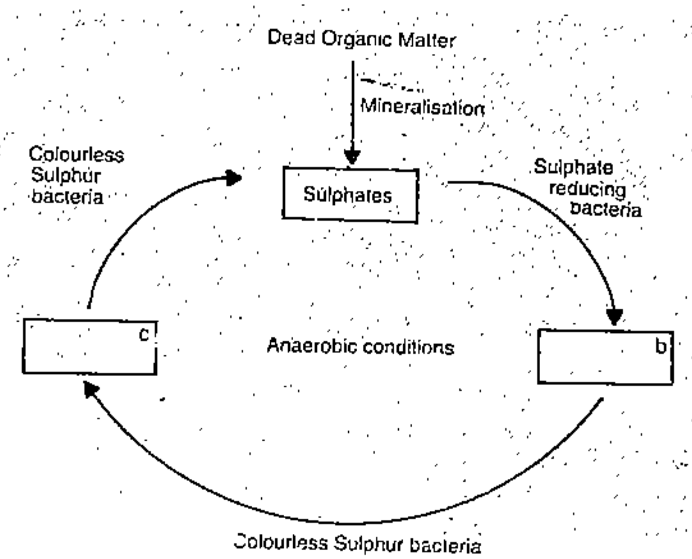
On account of combustion of large amounts of fossil fuels sulphur dioxide is emitted. Globally some 147 million tonnes of SO_2 are poured into the atmosphere each year. Normally oxides of nitrogen (NO_2 and N_2O) and sulphur (SO_2) are only transitionary steps in their respective cycles and are present in most environments in low concentrations. Combustion of fossil fuel, however, has greatly increased the concentration of these oxides in air especially in urban and industrial areas to a point where the biotic components are adversely affected. SO_2 is damaging to photosynthesis, it is one of the most potent phytotoxic pollutant. Furthermore it interacts with water vapour to produce H_2SO_4 and ultimately returns to earth as **acid rain.** (You have already read about the effects of acid rain in FST-1 Block 4 Unit 16). Acid rain affects the land, vegetation and aquatic systems in a variety of ways. Important plant nutrients like, calcium, magnesium and potassium are progressively leached out of the soil, aluminium and zinc accumulate. Useful micro-organism in the soil are replaced by harmful disease causing fungi.

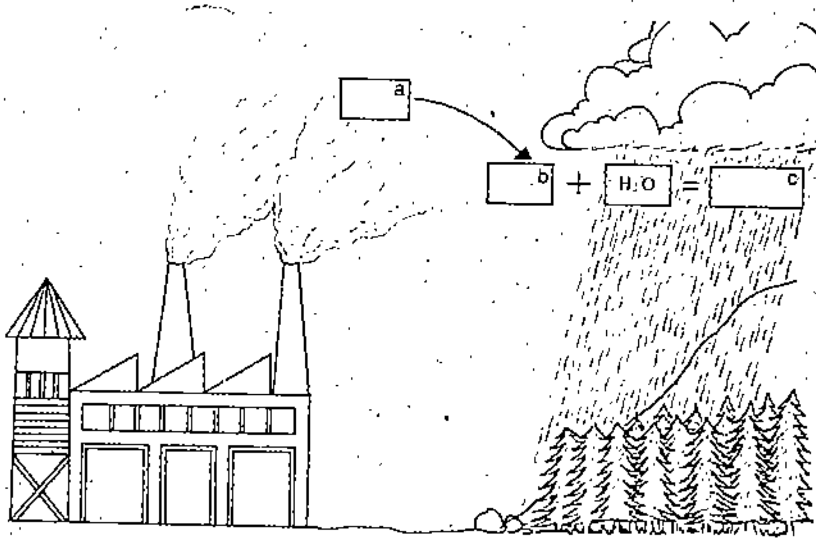
Theoretically normal rain has a pH of 6.5, slightly more acidic than saliva and milk. Acid rain is precipitation..........rain, snow sleet, fog that contains dilute solutions of sulphuric and nitric acids.

Acid rain is no longer a local problem, of urban areas. Its impact is greatest on lakes or streams and already acidic soils that lack pH buffers such as carbonates, calcium salts and other bases.

SAQ 4

Complete the diagrams (i) and (ii) which explain the subcycles of the sulphur cycle.





6.6 PHOSPHORUS CYCLE

Phosphorus is a very important nutrient because of its role in the form of phosphate, in reactions that store and release energy. The availability of phosphates often becomes a limiting factor in ecosystem productivity. The reservoir pool of phosphorus is in crystalline phosphate rock and the compartments in phosphorus cycling involve organisms, soil and shallow marine sediments.

The natural form in which phosphorus is available is inorganic phosphate. Through erosion and weathering of rocks, inorganic phosphate is made available to plants that absorb it from soil or in the case of aquatic plants from the water. Once taken up by the plant the phosphate may become part of ATP (adenosine triphosphate), nucleic acid or some other organic compound. The phosphate may be returned to the soil or sediment when the plant dies and decomposes. Phosphorus may also be passed to the consumer or get incorporated into the cell body of the decomposers.

In consumers the phosphorus may be incorporated into the bones and teeth and thus it remains bound for a long period of time. Some of it is excreted as waste and is immediately available to the decomposer. It may by a short loop be converted back to inorganic phosphate and be assimilated by the plants (see Fig. 6.6). On the other hand, it may be tightly bound to iron, calcium and aluminium as insoluble compounds and be washed off or lost in sediments.

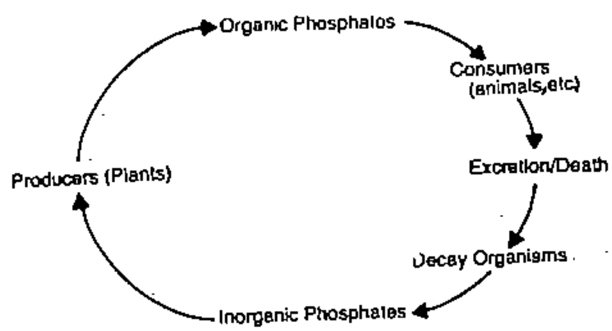
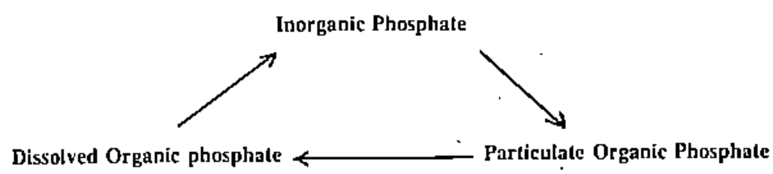


Fig. 6.6 : A short loop in the cycling of phosphorus in the terrestrial ecosystem

In marine and fresh water ecosystems the phosphorus cycle moves through three compartments.



Inorganic phosphates are taken up rapidly by the phytoplankton which in turn may be ingested by zooplankton or detritus feeding organisms. Zooplankton in turn may excrete as much phosphorus daily as stored in their biomass. More than half the phosphorus excreted is inorganic which is again taken up by the phytoplankton thus keeping the cycle running.

The rest of the phosphorus in aquatic systems is in the form of organic phosphates that may be utilised by bacteria, that in turn may be consumed by microbial grazers which then excrete the phosphorus they ingest.

Part of the phosphorus is deposited in shallow sediments and part in the deep water because phosphorus is precipitated largely as calcium compounds much of which become immobilised for long periods in the bottom sediments from where it is later recirculated by upwelling. Figure 6.7 shows the phosphorus cycle in terrestrial and aquatic ecosystems.

Phosphorus is the key limiting factor in aquatic systems. The turnover rate may actually determine the productivity in many aquatic systems. For example, excess phosphates can stimulate explosive growth of algae and photosynthetic bacteria populations, resulting in disruption of aquatic ecosystems.

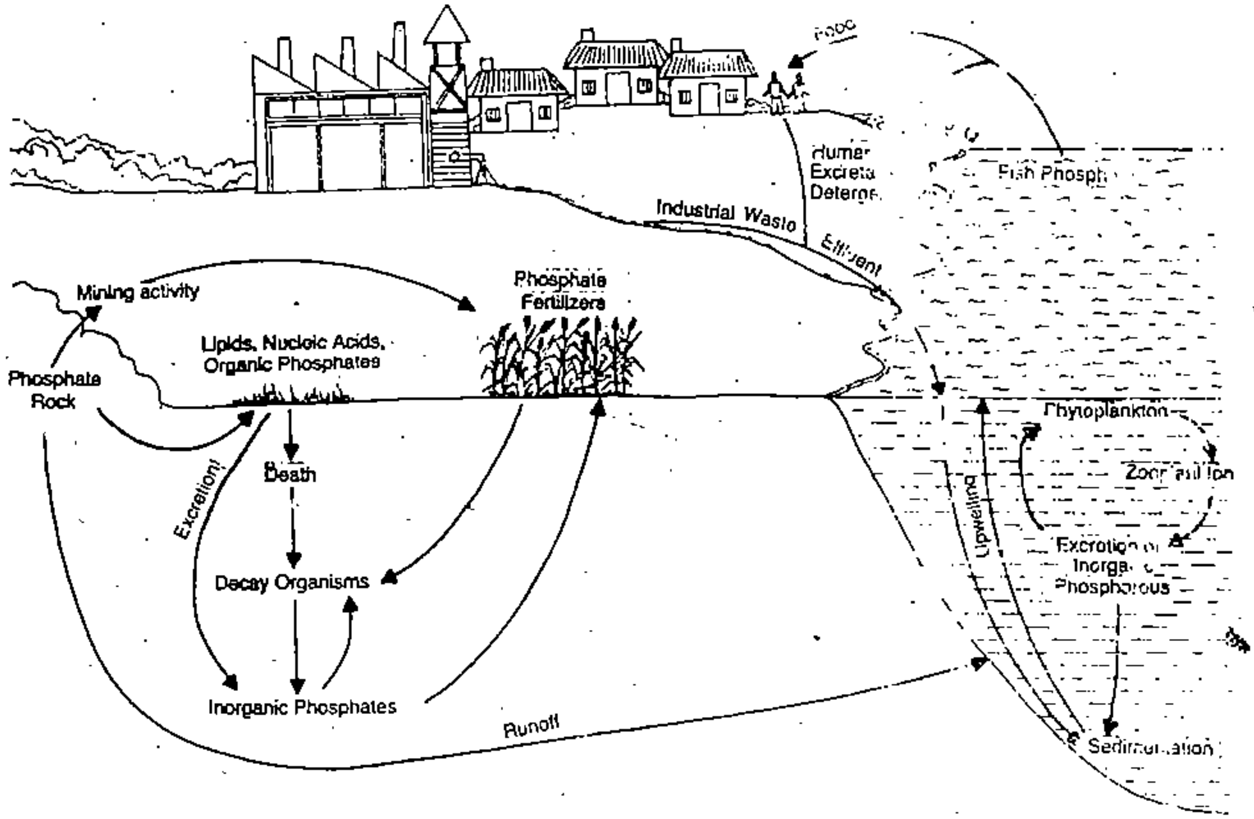


Fig. 6.7 : The phosphorus cycle in terrestrial and aquatic ecosystems. The rate of cycling of phosphorus is extremely important for growth and activity in living things.

Human Impact on the Phosphorus Cycle

Like other biogeochemical cycles, human activities have altered the phosphorus cycle. Human beings mine phosphate rocks and guano deposits to make phosphorus available for production of fertilisers, detergents, animal feed, medicines, pesticides and numerous other products. This mining exposes phosphate deposits made over millions of years.

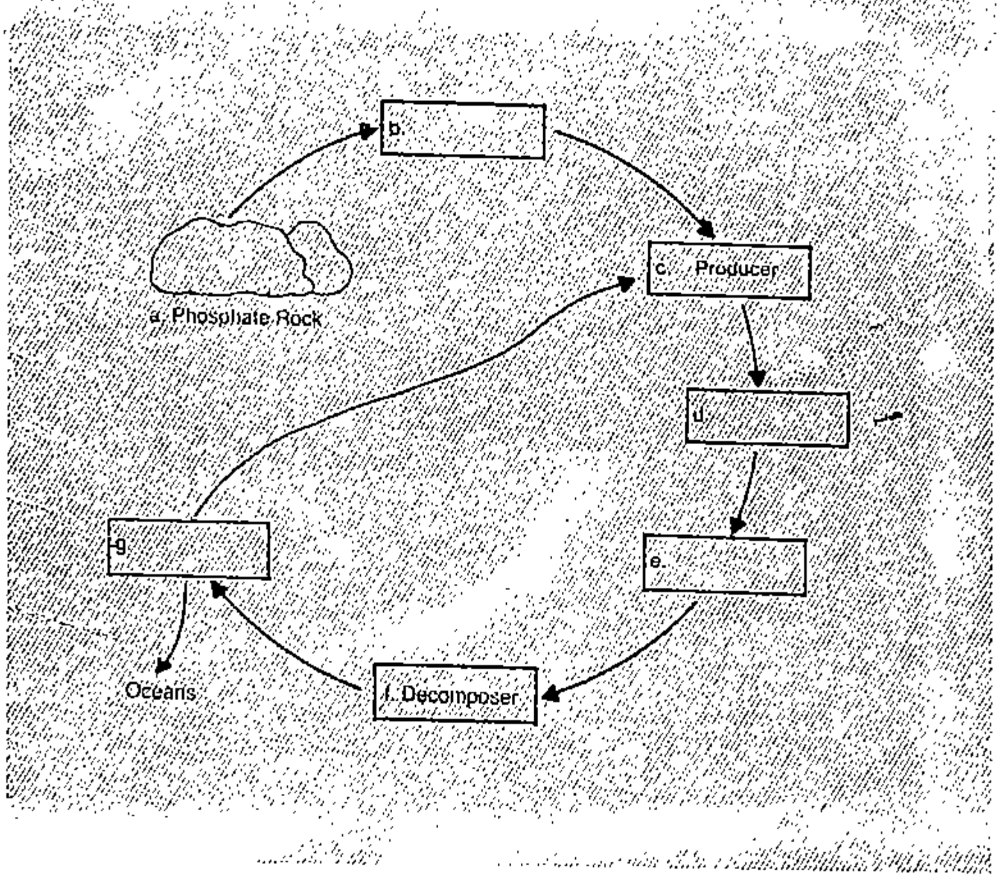
Phosphates are removed from soil through cropping of vegetation and to replace it phosphate fertilisers have to be added. Because of the abundance of calcium, iron and aluminium in the soil much of the phosphates get immobilised as insoluble salts. Thus more fertilisers have to be added. This results in high concentration of phosphates in agricultural runoffs. Similarly concentration of phosphorus in detergents, wastes of food processing plants, animal feed lot, sewage, etc., add to a considerable quantity of phosphorus poured in natural waters. This problem becomes acute in urban areas.

As said earlier, in aquatic ecosystems the phosphorus is taken up rapidly by the vegetation resulting in a sudden explosive growth of algae. Like nitrogen, this leads to **cultural eutrophication** of the water body. The producers cloud the water and forms a scum on the surface, blocking sunlight for the submerged plants. This is one example of the result of accumulation of nutrients at one stage of the nutrient cycle. It is important to note that the means of returning phosphorus to the cycle are inadequate to compensate for the loss. Sea birds have traditionally played an important part in returning phosphorus to the cycle via their droppings (for example guano deposits off the coast of Peru) but apparently not at the rate at which it has occurred in the past.

Unfortunately human activities appear to hasten the rate at which phosphorus is lost and thus make the cycle 'less perfect'. You could think our present use of phosphorus which is washed out into the rivers and finally into the oceans as an accelerated 'pouring' of phosphorus from the source to the sink.

SAQ 5

a) Complete the following diagram showing the stages in the phosphorus cycle



6.7 NUTRIENT BUDGETS AND CYCLING IN FORESTS

In this unit we have so far considered the movement of individual nutrients with major emphasis on their global, biological and chemical aspects. We will now study the nutrient dynamics in terms of input, output and flows of nutrients technically called nutrient budget with particular reference to forest ecosystem.

6.7.1 Nutrient Budgets

Nutrients are constantly being added and removed by natural and artifical processes (see Fig 6.8). The measure of the input and outflow of nutrients through the various components of an ecosystem form its **nutrient budget.** The nutrient budget of an ecosystem can be considered under two sections.

a) **Internal budget :** This is concerned with the circulation of nutrients through various biotic and abiotic compartments of a given ecosystem. In other words the input and output that occurs along the producer ⟶ consumer ⟶ decomposer food chain and the exchanges between the reservoirs and sediments within the ecosystem.

b) **External budgets :** In contrast the external budgets pertain to the input and output of the entire ecosystem in relation to other ecosystems. For instance volcanic eruptions throw materials into the atmosphere or spread lava over a terrain, thus distributing nutrients over large areas. Wind and water transport nutrients to long distances and serve as carriers for their actions such as weathering of rocks or wind that carries nutrients between different ecosystems. Animals feed in one ecosystem defecate or die in another, or trees grow in one ecosystem and are burnt elsewhere. Humans are without question the most powerful agents that affect the internal and external nutrient budgets.

6.7.2 Nutrient Cycling in Tropical and Temperate Forests

From this study of the nutrient cycles you must have realised the importance of the role of green plants that take up nutrients from the substratum and air, representing

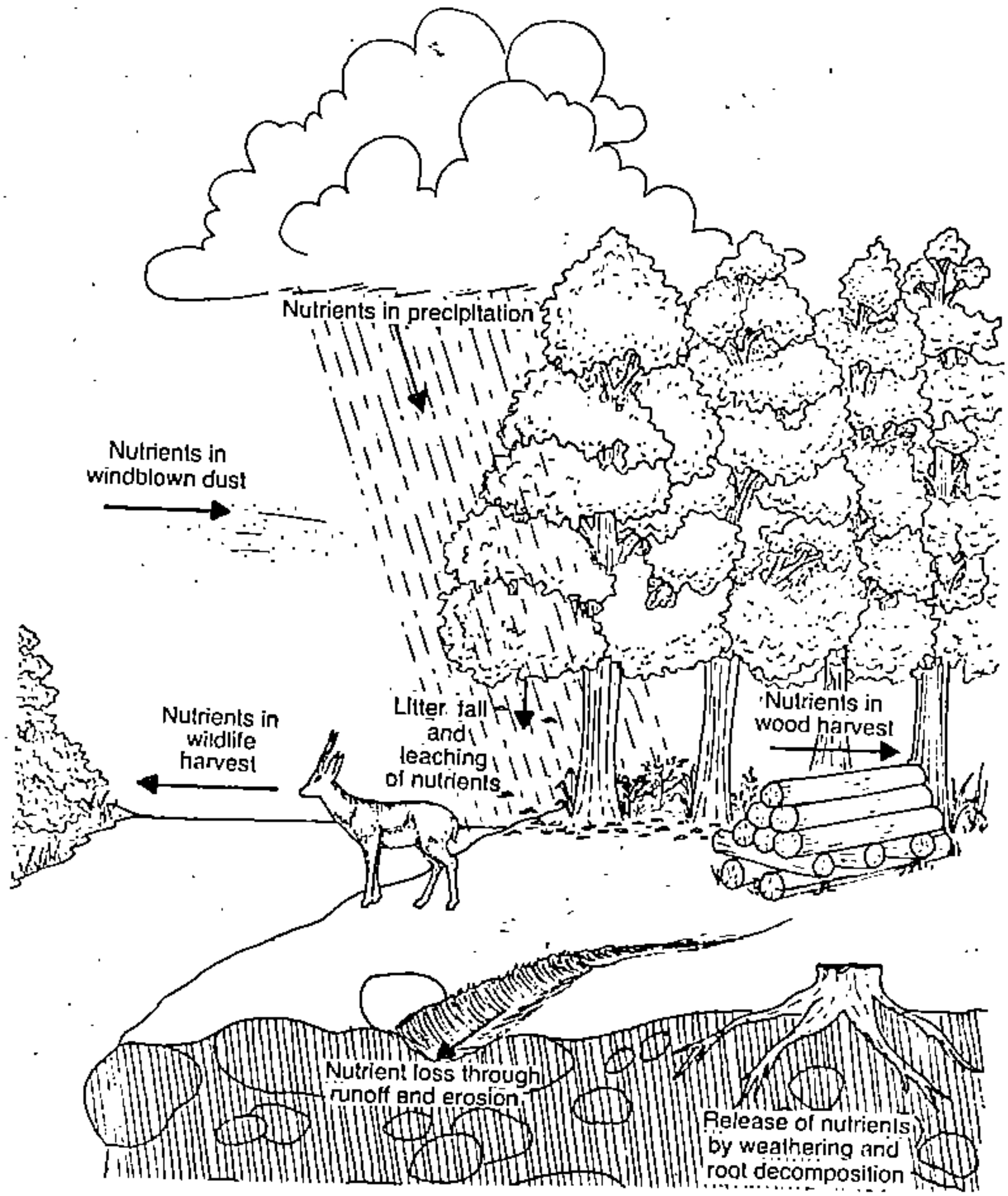


Fig. 6.8 : Nutrient budget in forest ecosystem. Input of nutrients is through precipitation, dust, litterfall and, through weathering and root decomposition. Outflow is through wood harvest, hunting, runoff, erosion and leaching.

the abiotic components and decomposers that release the nutrients back into the abiotic pools for reuse by the plants.

In tropical forests a large percentage of the total nutrients are held in the biomass and not in the soil, but in the temperate regions a large portion of organic matter and available nutrients is at all times in the soil and sediments. Figure 6.9 shows the contrast in the distribution of organic carbon matter in a northern coniferous and a tropical rain forest. Interestingly both ecosystems contain the same amount of organic carbon but more than three fourths is in vegetation in the tropical forest.

Recycling of nutrients in the organic structure of the tropical forests is aided by a number of nutrient conserving, biological adaptation. These adaptations depend on the geology and basic fertility of the region and some of the mechanisms that are especially well developed in tropical rain forests are:

Recycling of nutrients within the organic structure means that nutrients move within the plant in the leaves and woody tissue. Watever nutrients are washed away from the leaves by air, water or lost from the plant in litter is quickly taken up by the plants again so that very little nutrients remain in the soil.

i) Root mats consisting of many fine feeder roots which penetrate the surface of the litter and quickly recover nutrients from leaf fall and rain before they are leached away. Root mats also inhibit the activity of denitrifying bacteria, thus preventing loss of nitrogen.

ii) Mycorrhizal fungi associated with root systems act as nutrient traps and help in the recovery and retention of nutrients. This symbiosis is also present in temperate forests of areas that are basically poor in nutrients.

iii) Evergreen leaves have thick waxy cuticles that retard loss of water and nutrients, also leaves have pointed tips or 'drip tips' that drain off water fast, thereby reducing leaching of leaf nutrients.

iv) Algae and lichens that cover surfaces of many leaves pick up nutrients from rainfall some of which becomes available to the leaves immediately. Lichens also fix nitrogen.

v) Thick bark inhibits diffusion of nutrients out from the phloem and subsequent loss by stem flow i.e., rain running down the trunks of trees.

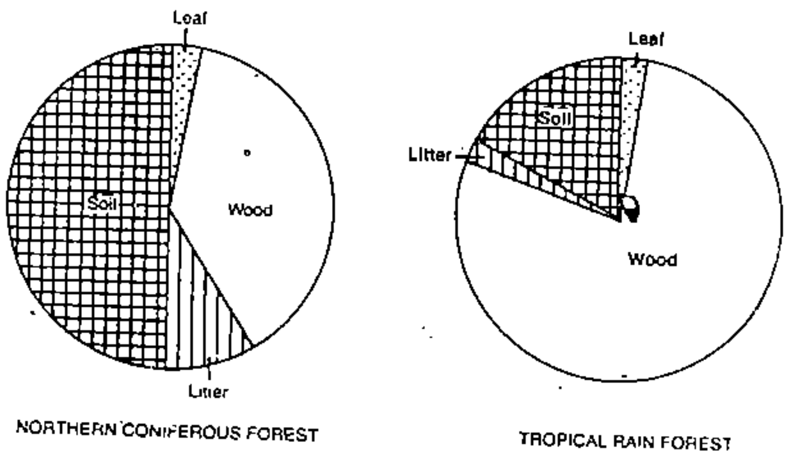


Fig: 6.9 : Distribution of organic carbon accumulated in abiotic (soil and litter) and biotic (wood and leaf) compartments of a tropical and a temperate forest. Note that the tropical forest has a much larger percentage of organic carbon in plant biomass.

Although soils of tropical forests are generally poor in nutrients they are able to maintain high productivity under natural conditions due to these nutrient-conserving mechanisms that almost bypass the soil by having a **plant to plant cycling.** When such forests are cut or cleared for agriculture these mechanisms are destroyed and productivity declines very rapidly. Forest removal takes away the land's ability to hold nutrients as well as to combat pests in the face of year round high temperatures. Crop production declines and in a few years the land is abandoned.

Soils in temperate forest have relatively large nutrient pools and when these forests are cleared, the soil retains nutrients and may be cultivated for many years by ploughing one or more times a year, planting short season annual plants and applying inorganic fertilisers. During winter, freezing temperatures help hold in nutrients and combat disease and pest.

It is for these reasons that agricultural practices suitable for temperate areas may be inappropriate for tropical areas and should not be applied unmodified in the tropics.

6.8 SUMMARY

In this unit you have studied that :

- Nutrients circulate from the environment to organisms and back to the environment in perpetual cycles referred to as biogeochemical cycles or nutrient cycles. There are two types of cycles: gaseous, where the major reservoir is the atmosphere, these are represented by carbon and nitrogen and sedimentary cycles, represented by sulphur and phosphorus with major reservoirs in the earth's crust.
- The carbon cycle involves the assimilation and respiration of carbon dioxide by plants, its consumption as carbohydrates in plants and animal tissue and its release through respiration and decomposition and combustion. Carbon is also withdrawn from the cycle into long-term reserves. The equilibrium of carbon dioxide between the sea, atmosphere and land is being disturbed by rapid release of carbon dioxide into the atmosphere by burning wood and fossil fuels. Increased carbon dioxide in the atmosphere has the potential to raise the ambient global temperature of the earth with serious ecological implications.

- Nitrogen cycle is characterised by fixation of atmospheric nitrogen by nitrogen fixing organism and industrial processes, its assimilation by plants in the form of nitrate and ammonium ion. Involved in the nitrogen cycle are the processes of ammonification, nitrification and denitrification. Human intrusion into the nitrogen cycle involves release of oxides of nitrogen into the atmosphere which cause air pollution and smog. Excessive nitrates released into the aquatic ecosystems cause cultural eutrophication.
- Sulphur cycle is a combination of gaseous and sedimentary cycles. It involves a long-term sedimentary phase in which sulphur is tied up in organic and inorganic deposits from where it is released by weathering and decomposition and taken up by the plants as inorganic sulphates. Sulphur enters the atmosphere as SO_2 released during fossil fuel combustion and as H_2S released during decomposition of organic matter. Sulphur dioxide, soluble in water is carried to earth as sulphuric acid in acid rain.
- The phosphorus cycle is wholly sedimentary with major reservoirs in phosphate rocks. It is released by weathering and taken up by plants as inorganic phosphates. Major part of the phosphates added as fertilisers are immobilised in the soil but great quantities used in detergents and in wastes are carried in the sewage effluents. These ultimately become part of shallow sediments of the sea and a large portion is lost into the deep sediments. Phosphorus is carried back to the terrestrial ecosystems through fish meal and bird droppings but the amount returned is not enough to compensate the loss.
- Green plants, by taking up nutrients and decomposers by releasing the nutrients for reuse, play an important role in nutrient cycling. Nutrients are constantly being added or removed from the ecosystems. A measure of the inflow and outflow forms the nutrient budget of an ecosystem.
- In tropical forests a large portion of the nutrients are held in the biomass and not in the soil. This is due to the plant to plant recycling of nutrients aided by various nutrient-conserving biological adaptations. Therefore, if tropical forests are cleared the soil's ability to hold nutrients is lost, making it unsuitable for long-term agriculture.
- In temperate forests a large portion of the nutrients are in the soil rather than in plant biomass. Therefore, if these forests are cleared, the soil still retains nutrients and may be farmed for many years.

6.9 TERMINAL QUESTIONS

1) What are the two types of biogeochemical cycles and what are their distinguishing features?

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2) 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.

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3) Describe briefly how carbon and sulphur cycles are affected by human activities.

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4) a) Why is phosphorus considered an example of an imperfect cycle?

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b) Phosphorus is often one of the limiting factors in aquatic ecosystems yet heavy discharge of phosphates into a clear lake 'kill' it. Comment.

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5) Explain why removal of tropical forests often reveal poor quality agricultural land.

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6.10 ANSWERS

Self-assessment Questions

1) ii) compartment; iii) reservoir
   iv) biogeochemical cycles

2) a) iv)
   b) ambient global temperature;
   greenhouse gases; icecaps;
   continental coastlines

3) a) i)
   b) ammonium (ion);
   ammonium (ion);
   nitrate;
   amino acid;
   dinitrogen (N_2)

4) i) b) H_2S; c) S.
   ii) a) SO_2; b) SO_3; c) H_2SO_4

5) i) b) weathering; d) organic phosphate
   e) consumer; g) inorganic phosphate

Terminal Questions

1) 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 principal reservoir lies in the earth's crust and is released into the ecosystem by, weathering, mining and erosion. Examples are phosphorus and sulphur.

2) 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.

3) **Hints :**

i) burning of wood and fossil fuels (coal, oil, gas) adds more CO_2 to the atmosphere which may lead to rise in global temperatures. Higher temperatures can cause increased melting of polar ice, milder winters and changed rainfall patterns.

ii) clearing of forests would remove carbon-sinks.

iii) increased release of SO_2 in atmosphere due to burning of fossil fuels and heavy industry. SO_2 is a toxic component of smog and forms H_2SO_4 with water vapour and falls to earth as acid precipitation.

4) a) because more phosphorus is lost from the cycle in deep sediment than is returned to the cycle.

b) addition of phosphates to lakes leads to cultural eutrophication i.e. algal blooms and most of the oxygen requiring organisms die, as the oxygen in the water is used up by detrivores for the process of decomposition.

5) **Hints :**

i) nutrients at any time are circulating in the biomass rather than residing in soil.

ii) various biological adaptations in tropical plants conserve the nutrients.

UNIT 7 TYPES OF ECOSYSTEMS : TERRESTRIAL ECOSYSTEMS

Structure

7.1 INTRODUCTION

In the previous units you have studied what our ecosystem is and what constitutes this system. As you know the world itself is very vast, and it represents a big ecosystem called biosphere . In an ecosystem there is continuous functional interaction between the living organisms and the non-living materials. The interrelations between organisms and environment on the land constitute "Terrestrial Ecology". However, due to variation in the topographic features of valleys, mountains and slopes, certain differences are bound to occur. These differences are reflected in both the material and biotic diversities. Altitudinal and latitudinal variations cause shifts and differences in the climatic patterns. Due to varied climate the plant and animal life existing in different terrestrial areas diversify which result in differentiation of biomes as segments within the large biosphere. In the present unit we shall discuss various types of biomes. Besides, you will learn about the importance of the forests, consequences of deforestation, chipko movement, importance of grasslands and the phenomenon of desertification.

Objectives

After reading this unit you will be able to :

- explain the concept of biome and identify various biomes of the world,
- differentiate between the major types of terrestrial ecosystems such as grassland, forests and deserts,
- relate the importance of forests to human welfare,
- identify the causes and consequences of deforestation,
- describe the concept of social forestry and chipko movement,
- describe the distribution and classification of Indian grasslands, economic and ecological importance of grasslands, ecological features of Indian deserts and understand the process of desertification,
- understand and explain the concept of wasteland and methods of their rehabilitation.

7.2 BIOMES OF THE WORLD

As you know, the land mass constitutes $\frac{1}{4}$th of our planet. A large variety of plants and animal communities have developed in relations to climatic and edaphic variations.

As one attempts at combining plant and animal distribution into one system the classifications given earlier were found to be inadequate because plant and animal distributions do not coincide. Another approach was to accept plant formations as the biotic units and to associate animals with plants. This approach is fairly workable because animal life depends on plants. These broad integrated natural biotic units are called biomes. Thus a biome is a large community unit characterised by the kinds of plants and animals present. Each biome consists of a distinctive composition of plant and animal species, the climax communities in each are of uniform life form of vegetation such as grasses or coniferous trees. It also includes stages in the development of the community towards its final form, which may be dominated by other life forms.

On a local and regional scale, communities are considered as gradients in which the combination of species varies as the individual species respond to environmental gradients. On a larger scale one can consider the terrestrial and even some aquatic ecosystems as gradients of communities and environments on a world scale. Such gradients of ecosystem are ecolines.

Apart from gradual changes in vegetation other ecosystem also changes significantly. As one goes from highly mesic and warm temperatures to xeric situations or cold temperatures, productivity, species diversity, and the amount of biomass decreases. There is a corresponding decline in the complexity and organisation of ecosystems, in the size of plants, growth form and in the number of strata in the vegetation.

The following three major biomes recognised by ecologists as forests, grasslands and deserts occur as belts around the world (Fig. 7.1).

Fig. 7.1 : Three major types of biomes, i.e., forest, grassland and desert.

SAQ 1

a) Write answer of the following questions in the space given below.

b) Compare your answers with those given at the end of the unit.

i) What is biome?

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ii) What do you mean by ecoline?

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iii) Name the major types of biomes.

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7.3 FORESTS

Now let us see as to what a forest is. The word forest is derived from the Latin word 'foris' meaning outside, the reference being to village boundary fence and must have included all uncultivated and uninhabitated land. Today a forest is any land managed for the diverse purpose of forestry whether covered with trees, shrubs, climbers etc. or not. The forest biomes include a complex assemblage of different kinds of biotic communities. Optimum conditions of temperature and ground moisture responsible for the growth of trees contribute greatly to the establishment of forest communities. The nature of soil, climate and local topography determine the distribution of trees and their abundance or sparseness in the forest vegetation. Forests may be evergreen or deciduous. They are distinguished on the basis of leaf into broad-leafed or needle-leafed coniferous forests in the case of temperate areas. Characteristics of different types of forests are described below.

7.3.1 Types of Forests

The forest biomes of the world have been classified into the three major categories: coniferous forest, tropical forest and temperate forest (Fig. 7.2). All these forest biomes are generally arranged on a gradient from north to south or from high to lower altitude. We shall discuss each category in detail.

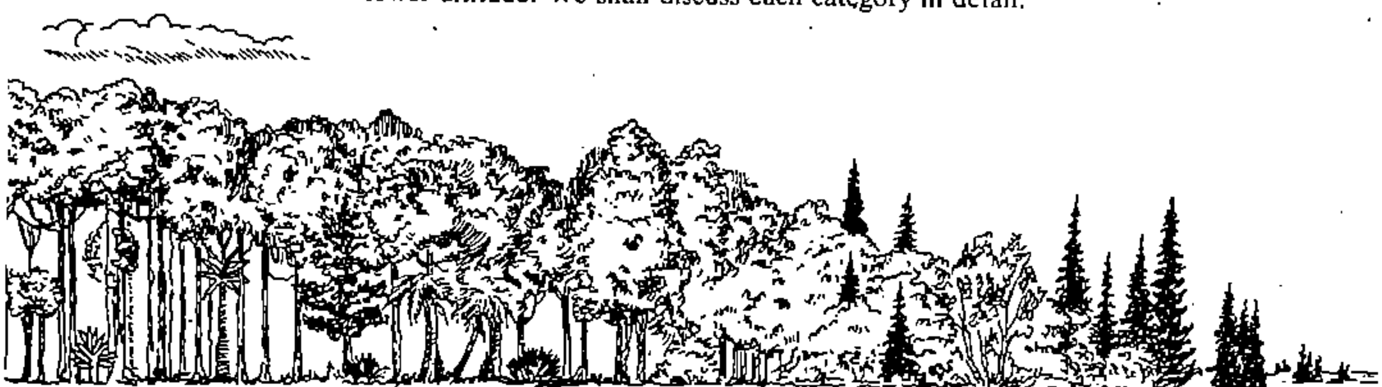

Fig. 7.2 : Types of Forests

i) **Coniferous forest :** Cold regions with high rainfall and strongly seasonal climates with long winters and fairly short summers are characterised by boreal coniferous forest which is transcontinental. For example, adjacent to Tundra regions either at latitude or high altitude is the northern coniferous forest, which stretches across both north America and Eurasia just south of Tundra (i.e. Canada, Sweden, Finland and Siberia). The term *taiqa* is applied to the northern range of coniferous forests. This is characterised by evergreen plant species such as Spruce (*Picea glauca*), fir (*Abies balsamea*) and pine trees (*Pinus resinosa*/*Pinus strobus*) and by animals such as the lynx, wolf, bear, red fox, porcupine, squirrel, and amphibians like *Hyla, Rana,* etc.

   Boreal forest soils are thin podozols and are rather poor both because the weathering of rocks proceeds slowly in cold environments and because the litter derived from conifer needle is broken down very slowly and is not particularly rich in nutrients. These soils are acidic and are mineral deficient. This is due to movement of large amounts of water through the soil, without a significant counter upward movement of evaporation, essential soluble nutrients like calcium, nitrogen and potassium which are leached sometimes beyond the reach of roots. This process leaves no alkaline oriented cations to encounter the organic acids of the accumulating litter. The productivity and community stability of a boreal forest are lower then those of any other biome.

ii) **Temperate deciduous forest :** The temperate forests are characterised by a moderate climate and broad-leafed deciduous trees, which shed their leaves in fall, are bare over winter and grow new foliage in the spring. These forests are characteristic of north America, Europe, Eastern Asia, Chile, part of Australia and Japan, with a cold winter and an annual rainfall of 75-150 cm. and a temperature of 10-20°C. The precipitation may be fairly uniform throughout year. In Himalayas occur Temperate vegetation including pines, fir and juniper trees with an undergrowth of scrubby rhododendrons at elevations of 2743-3658 metres.

Trees are quite tall about 40-50 m in height and their leaves are thin and broad. The predominant genera of this biome are maple (*Acer*), beach (*Faqus*), oak (*Quercus*), hickory (*Carya*), basswood (*Tilia*), chestnut (*Castnea*), and cotton wood (*Populus*). In some locations, coniferous vegetation may be quite predominant and that includes white pines (*Pinus strobus*), and willow (*Salix*). Soils of temperate forests are podozolic and fairly deep.

The animals inhabiting the temperate forests are deer, beers, squirrels, gray foxes, bobcats, wild turkey and woodpeckers. Common invertebrates include earthworms, snails, millipedes, coleoptera and orthoptera and vertebrates like amphibians such as toad, salamander, cricket and frog, reptiles, such as turtle, lizard and snake, mammals such as racoon, opossum, pig, mountain lion, etc. and birds like horned owl, hawks, etc. The range of animal size and adaptations is wide; the larger animals include such as deer and black deer. The dominant carnivores are large including the wolf and mountain lion although smaller carnivores such as fox and skunk are also common. Plants and animals of temperate forest allow a profound seasonality in behaviour, some even hibernate throughout the winter.

iii) **Temperate evergreen forest :** Many parts of the world have a mediterranian type of climate which is characterised by warm, dry summers and cool, moist winters. These are commonly inhabitated by low evergreen trees having broad leaves. In a woodland, trees are essentially lacking although shrubs may range up to 3-4m in height. Fire is an important hazardous factor in this ecosystem and the adaptation of the plants enable them to regenerate quickly after being burnt. The characteristic animals of temperate evergreen woodland chaparral are mule, deer, brush rabbit, wood rat, chipmunk, lizard, etc.

iv) **Temperate rain forests :** The temperate rain forests are colder than any other rain forest and exhibit a marked seasonality with regard to temperature and rainfall. Rainfall is high, but fog may be very heavy which may actually represent a more important source of water than rainfall itself. The biotic diversity of temperate forests is high as compared to temperate forest. However, the diversity of plant and animals is much low as compared to their warmer counterparts. The animals of temperate rain forests are similar to those of deciduous forests, but show a somewhat high diversity.

v) **Tropical rain forests :** Tropical rain forests occur near the equator. Tropical rain forests are among the most diverse communities on the earth. Both temperature and humidity remain high and more or less uniform. The annual rainfall exceeds 200-225 cm and is generally distributed throughout the year.

The flora is highly diversified : a sq km may contain 300 different species of trees — a diversity unparalled in any other biome. The extremely dense vegetation of the tropical rain forests remains vertically stratified with tall trees often covered with vines, creepers, lianas, epiphytic orchids and bromeliads. Under the tall trees there is a continuous evergreen carpet, the canopy layer, some 25 to 35 metres tall. The lowest layer is an understory of trees, shrubs, herbs, like ferns and palms, all of which become dense where there is a break in the canopy. Soils of tropical rainforests are red latosols, and they may be very thick. The high rate of leaching makes these soils virtually useless for agricultural purposes, but if they are left undisturbed, the extremely rapid cycling of nutrients within the litter layer which is formed due to decomposition can compensate for the natural poverty of the soil.

The common vertebrates of tropical rain forests are the arboreal amphibian *Rhacophorus malabaricus*, aquatic reptiles, chameleons, agamids, geckos and many species of snakes and birds, social birds being dominant, and a variety of mammals. Nocturnal and arboreal habits are most common in many mammals such as insectivores, leopard, jungle cats, anteaters, giant flying squirrels, monkeys and sloths.

vi) **Tropical seasonal forests :** Tropical seasonal forests occur in regions where total annual rainfall is very high but segregated into pronounced wet and dry periods. This kind of forests is found in South East Asia, central and south America, northern Australia, western Africa and tropical islands of the pacific as well as India. In exceedingly wet tropical seasonal forests, commonly known as monsoon forests, the annual precipitation may be several times that of the tropical rain forests. Teak is often a major large tree in the best known tropical seasonal forests of India (central India) and south east Asia. Bamboo is also an important climax shrub in these areas.

vii) **Subtropical rain forests :** In regions of fairly high rainfall but less temperature differences between winter and summer and broad-leaved evergreen subtropical biome is found. The vegetation includes mahogany, gumbolimbo, bays, palms, oaks, magnolias, tamarind, all laden with *epiphytes* (of pineapple and orchid families), ferns, vines and strangler fig *(Ficus, aureus)*. Animal life of subtropical forest is very similar to that of tropical rainforests.

7.3.2 Importance of Forests

In Units 17 and 18 (Block IV) of FST 1 you have already studied that forests are renewable resources which provide us a wide variety of commodities.

For man, forests have been a source of recreation and the development of his culture and civilisation. Apart from the source of fuelwood, they are raw materials to various wood industries like pulp and paper, composite wood, rayon and other man-made fibres, matches, furniture, shuttles and sport goods. Indian forests also provide many other minor products such as essential oils, medicinal plants, resins and turpentines, lac and shellac, katha and catechu, bidi wrappers, tasser silk, etc.

India and other tropical countries have particularly abundant timber and heartwood resources. Timber accounts for 25% of all photosynthetic materials produced on the earth and about half of the total biomass produced by a forest. Forests have great biological importance as reservoirs of genetic diversity apart from playing an important role in regulating earth's climate.

Forests provide habitat, and food as well as protection to wildlife species against extremes of climate and help in balancing carbon dioxide and oxygen of the atmosphere. Forests enhance local precipitation and improve water holding capacity of soil, regulate water cycle, maintain soil fertility by returning the nutrients to the soil through litter. Forests check soil-erosion, landslides and reduce intensity of flood and droughts. Forests, being home of wildlife are important assets of aesthetic, touristic and cultural value to the society.

Sometimes back, a movement known as 'Chipko Movement' was launched by the village folk to save the tree from felling. Chipko Movement — the movement to hug trees is probably the world's most well-known grassroots ecodevelopment movement. The genesis of the Chipko Movement has both an ecological and an economic background. The Alaknanda valley in which the movement originated was the scene of an unprecedented flood in 1970. The tragic aftermath of this flood left a deep impression on the hillfolk and with it, soon followed the appreciation of the vital ecological role that forests play in their lives.

The non-violent, action-oriented Chipko Movement has greatly helped to unite the people and focus attention on the mismanagement of forest resources. Its Gandhian character of defending without inflicting violence has brought it considerable. sympathy. The Chipko Movement has not only helped to preserve our biosphere but it also inculcates social and political awareness among women and men as well.

Due to continuing deforestation we are faced with a major ecological and socio-economic crisis. To reverse this trend of deforestation a National Wastelands Development Board was established in May, 1985, with the aim of bringing under productive use wastelands in the country through a massive programme of afforestation and tree planting. While doing so, it was aimed at restoring the disturbed ecological balance and providing employment opportunities in rural areas. It was thought that this would lead to development of afforestation movement. Initially this programme was taken up with the object of bringing five million hectares of land every year under fuelwood and fodder plantations.

The first major source of fuelwood can be our farm lands, and the second major source of fuelwood can be the vast tract of barren and wastelands amounting to nearly 80 million hectares, which are idle at the moment. It includes about one million hectares along the country's roads, rail lines, canals and drains. This entire land may not be available for tree planting as large areas have been encroached upon for various purposes. Even if 15 per cent of the country's barren and wastelands can be planted with fuelwood species, there would be 12 million hectares of land under fuelwood plantations. These lands would yield about another 96 million tonnes of fuelwood per annum, assuming an annual yield of eight tonnes per hectare.

Two biomass research centres set up by the Department of Science and Technology, at the National Research Institute, Lucknow and at Kamraj University, Madurai, are investigating to identify tree species that can give high yields in saline and alkaline soils. For example, in the Kutch disrict of Gujarat, with a total area of 3.2 million hectares of barren and uncultivable land, energy plantations of prosopis and other species can be easily raised.

Exploitation of our forests for commercial purposes and for food and fodder cannot be stopped completely because of symbiotic relationship between forest and mankind. However, commercial exploitation can be minimised and illegal smuggling of forest assets can be curbed and put to an end by effective laws in this behalf.

The early forest legislation, namely, Forest Act of 1927 was aimed at preservation of forest and eco-balancing. This legislation which had its origin in old British colonial era looked at forest as a source of revenue and not as a decisive elements in environmental preservation. The Wildlife (Protection) Act of 1972 and Forest (Conservation) Act of 1980 are steps in this direction. The objective of this Act is to restrain the use of forest for non-forest purpose, which reveals that the law only regulates, and does not totally prohibit forest destruction.

After studying the various aspects with regard to importance of forest, we will discuss the human pressure on forests and the extent of deforestation.

7.3.3 Deforestation and its Causes

Indiscriminate felling of trees as a result of urbanisation, industrialisation, mining operations, and use of wood for domestic and other purposes, have caused heavy depletion of forests as shown in Table 7.1. India, alone is losing more than 1.5 million hectares of good forest cover each year. If the present state of depletion is allowed to continue unabated, the country will be heading towards nightmarish situation of zero forest in about 20 years. Also all the tropical forests in the world will probably disappear in next 50 to 75 years.

Table 7.1 Diversion of Forest Land for Non-forest Purposes

Year	Loss of Forest land (hectares)
1980	Nil
1981	2,672.04
1982	3,246.54
1983	5,702.01
1984	7,837.59
1985	10.608.07
1986	11,963.11
1987	72,780.50
1988	18,765.35
1989	20,365.05

India is losing forests at an extremely rapid rate. The data released in mid 1984 by the National Remote Sensing Agency (NRSA) shows that India lost 1.3 million hectares of forests every year in the approximately seven year period between 1972-75 to 1980-82.

The NRSA study classifies the forest cover into three categories (Table 7.2) : closed forests, open or degraded forests and mangrove forests. Closed forests diminished from 14.12 per cent to 10.96 per cent, degraded forests increased from 2.67 per cent to 3.06 per cent and mangrove forests decreased from 0.099 per cent to 0.081 per cent. Thus, during the two periods India lost 10.4 million hectares of closed forests and 63,000 hectares of mangroves and 1.29 million hectares of closed forests got converted into degraded forests.

Table 7.2 Vital Forest Statistics

Type of Forests	1972-75	1980-82
Forest cover (million hectare)	55.52	46.35
Closed forests (million hectare)	46.42	36.02
Open forests (million hectare)	8.77	10.06
Mangrove forests (million hectare)	0.33	0.26
Forest cover (% of total land area)	16.89	14.10

The problem of deforestation is one of the main environmental problems facing the country. There are various reasons attributed to this phenomenon of deforestation. The indiscriminate deforestation by agricultural practices, land mining, road construction, etc., which result not only in an immediate lowering of ground water level, but also in long-term diminishing of rainfall. Forests recycle moisture back into their immediate atmosphere by transpiration where it again precipitates as rain. Due to deforestation, this natural reuse cycle is broken and water is lost through rapid run off. Forests are also necessary to check the floods and soil erosion and are important for wildlife, human recreation, fresh air and water sheds.

Much of the mining activity in India is being carried out in forest regions. The obvious result is deforestation and erosion. Underground mining also significantly denudes forests because timber is used for supporting the roofs of mine galleries. In Goa, mining leases are spread over 43 per cent of the forest area. Because mining leases do not bind the mine owners to undertake any soil conservation measures or refill the worked over mines, a large number of abandoned mines are lying in bad shape and are under extensive gully erosion.

7.3.4 Consequences of Deforestation

The destruction of natural vegetation cover causes the loss of top soil. It is virtually irreplaceable and takes nature, 1000 years to build 2.5 cm. of topsoil. 12000 million tonnes of India's top soil is washing down the rivers every year, skimming 15 cm. of soil off 1,000 lakh hectares due to deforestation and run off. The country loses 300-500 lakh tonnes of foodgrains every year as a result of soil erosion. The entire Himalayan ecosystem is threatened with severe imbalances as snow-lines have thinned and perennial springs have dried up. Rajasthan's already poor land is getting further degraded, turning large portion of the state into wasteland. Chronic drought conditions occur in areas like Tamil Nadu and Himachal Pradesh where they were unknown.

Deforestation results not only in an immediate lowering of groundwater levels but also in long-term lowering of rainfall. Forests recycle moisture back into their immediate atmosphere by transpiration where it again falls as rain. Due to deforestation, this natural reuse cycle is broken and water is lost rapidly as run off.

7.3.5 Social Forestry and Forest Conservation

Social forestry is a term used by the National Commission on Agriculture in 1976 to denote tree-raising programmes to supply firewood, fodder, small timber and minor forest produce to rural populations. Social forestry programmes have mainly three components; a) farm forestry, encouraging farmers to plant trees on their own farms by distributing tree or subsidised seedlings, b) wood lots planted by the forest departments for the needs of the community, especially along roadside, canal banks and other such public lands, and c) community wood lots planted by the communities themselves on community lands, to be shared equally by them.

Social forestry programmes have been launched by several states to promote afforestation on essentially non-forest lands that is, on private farms and village commons. Several state governments in our country have stepped up thier own afforestation efforts and are also planning to hand over large tracts of degraded government forests lands to industrial firms for afforestation.

Since 1976, social forestry programmes have been taken up in Bastar, Madhya Pradesh. Derelict patches of forests near villages are being rehabilitated by planting fruit and other economically valuable species. In 1983 a new approach to social forestry was taken up in Bastar, as well as in other parts of Madhya Pradesh. Under the Hitagrahi scheme, the 60 poorest families of a village were selected, and each given a hectare of derelict land for growing fruit trees. The forest department provides saplings, fencing and any other required materials. Thus the incentive given to the landless farmers by the forest department has brought about tremendous increase in social forestry.

Certain forest conservation and management processes have to be employed in the forests to maintain them. To get the desired quality of timber or pulp for paper industry, monoculture forests of fast growing trees such as poplars, certain conifer, teak and eucalyptus have been cultivated by man. Existing forests are strongly manipulated in order to increase their yield of desired benefits. It includes weeding (the elimination of species which might compete with the seedlings of the desired species), thinning (eradication of individuals of the same species) and brashing (removal of leafless lower branches especially in conifers). Chemical technology may be applied to forestry to control insect parasites and pathogenic fungi. Forest Management also includes the controlling of forest fire. Silviculture is a branch of forestry which is concerned with the establishment, development, care and reproduction of monocultures of valuable timber trees such as teak, sal, sheesham, kel etc.

SAQ 2

a) Fill in the blanks and complete the following statements :

b) Compare your answers with those given at the end of the unit.

i) The forest biomes comprise a complex assemblage of different kinds of ....

ii) Forests may be evergreen or ....

iii) Tropical rain forests occur near the ....

iv) The genesis of the Chipko Movement has both an ecological and an ....

v) Exploitation of our forests for commercial purposes and for food and fodder cannot be stopped completely because of symbiotic relation between ....

vi) The study of National Remote Sensing Agency classifies the forest cover into three categories such as ....

vii) Due to deforestation the natural water reuse cycle is broken and water is lost through rapid ....

SAQ 3

Answer the following questions briefly.

i) Mention at least two effects of deforestation.

....

....

....

....

ii) What is social forestry? (Answer in the space given below)

....

....

....

7.4 GRASSLANDS

The grassland biome is found where rainfall is about 25-75 cm per year, not enough to support a forest, but more than that of a true desert. Typical grasslands are vegetation formations that are generally found in temperate climates. In India, they are found mainly in the high Himalayas. The rest of India's grasslands are mainly composed of steppes and savannas. Steppe formations occupy large areas of sandy and saline soils in western Rajasthan, where the climate is semi-arid, average rainfall is less than 200 mm a year with a dry season of 10 to 11 months, and a large variation in rainfall. The soil is always exposed, sometimes rocky but more often sandy with fixed or mobile *dunes*. Forage is available only during the brief wet season. The grass layer is sparse and consists mainly of annual grass species.

In the central and eastern parts of Rajasthan, where the rainfall is about 500 mm per year and the dry season is of six to eight months, dry savanna grazing ecosystems have developed. The light shade cast by the sparse population of trees like *Prosopis cineraria* favours the growth of the grasses which in the best-watered areas can reach up to a height of 100 cm to 120 cm.

The major difference between steppes and savannas is that all the forage in the steppe is provided only during the brief wet season whereas in the savannas forage is largely from grasses that not only grow during the wet season but also from the smaller amount of regrowth in the dry season.

Under heavy grazing pressure, the quality of grasslands also deteriorates rapidly. In arid to semi-arid tracts, active growth of vegetation is triggered each year by the advent of the monsoon during June or early July. The biomass increases to its peak value around September to October. Fruiting is completed by September and subsequently the plants dry up. In subtropical parts of northern India which receive winter rains, there is usually a second flux of growth in December and January.

7.4.1 Types of Grasslands

Grasslands exist in both temperate and tropical regions where rainfall is relatively low or uneven. Based on climatic conditions there are six types of grasslands found in the different regions of the Indian subcontinent (Fig.7.3). Here we will discuss only four major types of grasslands.

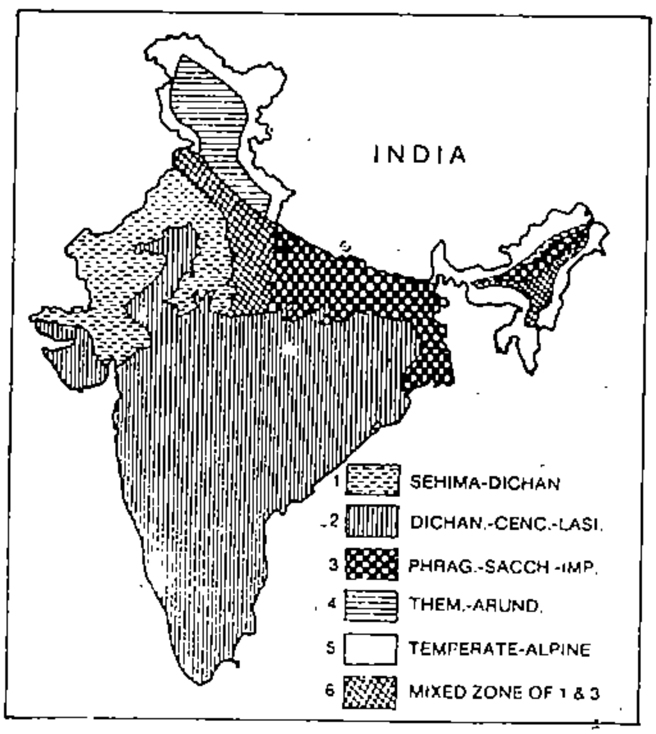

Fig. 7.3 : Types of grazing land

1) *The Sehima-dichanthium type* covers the whole of peninsular India (dry subhumid zone except Nilgiri). The thorny bushes of the savanska range land, are *Acacia catechu, Mimosa rubicaulis, Zizyphus* and sometimes fleshy *Euphorbia*, along with low trees of *Anogeissus latifolia, Soymida febrifuga* and other deciduous species. The floristic list includes 24 perennial grasses and 129 other herbaceous species of which 56 are legumes. Sehima is more prevalent on gravel and the cover may be 27%. *Dichanthium* flourishes on level soils and may cover 80% of the ground.

2) The *Dichanthium-cenchrus-lasiurus* type (semi-arid zone) extends to the northern portion of Gujarat, Rajasthan (excluding Aravallis), western Uttar Pradesh, Delhi and Punjab. The topography is broken up by hill spurs and sand dunes. Eleven perennial grasses, 45 other herbaceous species (including 19 of the leguminosae) are listed. To this list may be added shrubby growth of *Acacia senegal, Calotropis gigantia, Cassia auriculata, Prosopis cineraria, Salvadora oloides* and *zizyphus Nummularia* which make the savanna rangeland look like scrub.

3) The *Phragmities-sacchrum-imperata* type (moist subhumid zone) covers the Ganga alluvial plain in Northern India. The topography is level, low lying and ill-drained. There are 19 principal grass species and 56 other herbaceous ones including 16 legumes. *Bothriochloa pertusa, Cynodon dactylon* and *Dichanthium annulatum* are found in transition zones. The common trees and shrubs are *Acacia arabica, Anogeissus, latifolia, Butea monosperma, Phoenic sylvestris* and *Zizyphus. nummularia.* Some of these are replaced by *Borassus sp* in the palm savannas especially near Sunderbans.

4) The *Themeda — Arundinella* grass cover extends to the humid montane regions and moist sub-humid areas of Assam, Manipur, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh and Jammu and Kashmir. The savanna is derived from the humid forests on account of shifting cultivation and sheep grazing.

7.4.2 Economic Importance

After the land, people and cattle, the second major component of the grazing ecosystem is the vegetation. Its herbaceous layer and non-ligneous organs of the woody shrubs and trees constitute the fodder. The richness of the fodder depends upon its chemical constituents especially protein and minerals like phosphorus, potassium and calcium, lignin, silica, etc. The young and green succulent shoots of grasses and forbs of the leguminosae family, constituting the ground cover or the lower stratum of grazing land, provide the best choice for grazing material.

India teems with animals of all shapes and sizes from the lumbering black buffaloes to the ever nervous sheeps and there are millions of them. India with just a fortieth of the total land area of the world supports more than half of its buffaloes, 15 per cent of its cattles, 15 per cent of its goats and 4 per cent its sheeps. The livestock wealth plays a crucial role in Indian life; it is a major source of fuel, draught power, nutrition and raw material for village industries. But this huge mass of livestock needs fodder for sustenance while there is not enough of it. Only about 13 million hectares in the country are classified as permanent grazing lands. On top of it, they exist in a highly degraded state. The animals scrounge for whatever they can get on millions of hectares of fallow and uncultivated land and uncultivable wastelands, as well 36 million hectares of tropical forest lands. In all, almost all accessible vegetation in more than half the total land area of the country is grazed by livestock — which snap up almost everything except non-palatable weeds.

Grassland biomes are important to maintain the crop of many domesticated and wild herbivores such as horse, mule, ass, cow, pig, sheep, goat, buffalo, camel, deer, zebra, etc. which provide food, milk, wool, hide or transportation to man.

In India, most of the grasslands represent the serial stages in succession and they are not maintained by grazing and fire. However, they would develop into forest communities. A team of scientists at Indian Grasslands and Fodder Research Institute, Jhansi and Central Arid Zone Research Institute, Jodhpur, is mainly entrusted with such responsibility. Some species are more palatable to the livestock and are very sensitive to grazing and thus overgrazing usually results in their disappearance from the area. Now some unpalatable weeds and shrubs start to grow and turn the area into man-made desert.

Overgrazing has certain other ecological effects — the mulch cover of the soil reduces microclimate becomes more dry and is readily invaded by xerophytic plants. Due to absence of humus cover, mineral soil surface is heavily trampled when wetness produces puddling of the surface layer, which in turn reduces the infiltration of water into the soil and accelerates its run off, producing drought. These changes contribute to the reduction of the rate of energy flow, and the disruption of the stratification and periodicity of the primary producers results in a breakdown of the biogeochemical cycles of water, carbon and nitrogen. Water and wind erosion completely breakdown a very dry grassland microclimate. Further, intensive grazing results in increased areas of bare soil, which creates a new habitat for burrowing animals such as mice, jack-rabbits, gophers, prairie dogs, locusts etc., which render large areas of forage lands sterile.

In the management of grasslands, fire plays an important role. Under moist conditions fire favours grass over trees whereas in dry conditions fire is often necessary to maintain grasslands against the invasion of desert shrubs. Burning of *Cynodon daotylon* increases forage yields.

Thus you can realise the importance of the grassland and now after having read about this biome you would like to know what desert biome is and where it occurs? But before that you try SAQ.

SAQ 4

Write answer of the following questions in the space provided.

1) Where does the grassland biome occur?

....

....

2) Where do dry savanna grazing ecosystems develop?

....

....

....

3) State the one major difference between steppes and savanna.

....

....

....

4) How does overgrazing affect ecology of that area?

....

....

7.5 DESERTS

Deserts are formed in regions with less than 25 cm of annual rainfall, or sometimes in hot regions where there is more rainfall, but unevenly distributed in the annual cycle. Lack of rain in the mid latitude is often due to stable high pressure zones; deserts in temperate regions often lie in "rain shadows", that is, where high mountains block off moisture from the seas. These areas thus receive meagre rainfall. Along with low rainfall there are fluctuations in temperature. The climate of these biomes is modified by altitude and latitude. At high altitudes and at greater distance from the equator the deserts are cold hot as in other places. Deserts are found in Australia, Arabia, Turkestan and Argentina. Thar desert in Western India and Pakistan, Gobi desert of Mongolia, South Africa, Iran are also well known deserts.

The perennial plant species like creosote bush *(covillea)*, inesquite organ cactus, ferrocactus are scattered throughout the desert biomes. In shallow depressed areas with salt deposits (sarcobatus), geesewood, seepwood and salt grasses are common. The annuals wherever present germinate, bloom and reproduce only during the short rainy season, and not in summer and winter. This is an adaption to desert condition.

Animals such as reptiles and some insects are adapted to deserts, because their impervious integuments and dry excretions enable them to get along on the small amount of water. Mammals as a group are poorly adapted to deserts but some species have become secondarily adapted. A few species of nocturnal rodents, for example, excrete very concentrated urine and do not use water for temperature regulation, and can live in the desert without drinking water. Other animals such as camel must drink periodically but are physiologically adapted to withstand tissue dehydration for appreciably long periods of time.

Because water is the dominant limiting factor, the productivity of a given desert is almost directly dependent on the rainfall. Where soils are suitable, irrigation can convert deserts into some of our most productive agricultural land. Whether productivity is continuous or is only a temporary 'bloom' depends on how well man is able to stabilise biogeochemical cycles and energy flow at the increased irrigation rates. As the large volume of water passes through the irrigation system, salts may be left behind that will gradually accumulate over the years until they become limiting, unless means of avoiding this difficulty are devised.

7.5.1 Desertification

What is desertification? It is 'the diminution or destruction of the biological potential of the land which can ultimately lead to desert like conditions'. In arid and semiarid regions, where restoration of the fragile ecosystem is very slow, mining adds significantly to other desertification pressures.

Seven thousand years ago the Thar desert received abundant rainfall, hosted shrubs and trees including the jamun, was crisscrossed with rivers and lakes and was home of a thriving civilisation. Today, however, it is a barren desert. There have been expressed fears that the Thar is spreading. But the main problem faced by this desert area which stretches across parts of Rajasthan, Gujarat, Punjab and Haryana, is desertification in areas where there was some vegetation.

Recognised as a worldwide environmental problem, desertification threatens the future of about 628 million people around the world. An area twice the size of Canada — or 20 million sq km — is in imminent danger of being turned into a desert.

The cause of this process is not climatic changes, droughts, etc. but human actions. Increase in population and lack of alternative employment opportunities have left the people living in the Thar with no choice but to continue grazing cattle even in its inhospitable conditions. The Thar desert has seen unprecedented growth in its population in the last 70 years — from 3.57 million in 1901 to 10.24 million in 1971. A commensurate rise in the cattle population has put unbearable pressure on the restricted grazing area that exists in the desert. In 20 years the cattle population shot up from 10.27 million in 1951 to 16.44 million in 1971. Additionally there has been an increase of 25.3% in the net sown area between 1951-71, therefore, decreasing the grazing lands. Development activities such as road building, urbanisation, canal and rail track construction have increased leading to a further spread of the desert. Deforestation — in this case the felling of few trees that exist for fuel — has also added to the overall thrust of the desert.

According to studies conducted by the Central Arid Zone Research Institute (CAZRI) in Jodhpur, 9,290 sq km or 4.35% of western Rajasthan has already been desertified and a further 76.15% on 1,62,900 sq. km is vulnerable to desertification. The Thar desert already covers 3,17,000 sq. km and supports a population of 19 million, a density of 61 persons per sq. km compared to three persons per sq. km in arid regions elsewhere in the world — making it probably the most densely populated desert in the world.

Unless swift conservation measures are taken and proper employment opportunities are found for the local people, the increasing density of the human and cattle population in this desert area will inexorably lead to further desertification.

7.5.2 Indian Deserts

The Indian desert forms the east end of the greatest desert district of the world, extending from the Atlantic coast of Africa including the Sahara, part of Arabia, South Persia and Baluchistan. The climate of this region is characterised by excessive drought, the rainfall being scanty and irregular. The winter rains of northern India rarely penetrate into the region, and there is thus only rainy season. The cold season starts from about the middle of November to the middle of March. This season is characterised by extreme variations of temperature and the temperature is frequently below freezing point at night. During April, May and June the heat is intense, trying and scorching winds prevail with great dessicating action being frequent. The relative humidity of the atmosphere is always low.

A considerable portion of Western Rajasthan is covered by blown sand chiefly consisting of well-ground quartz grains, but also flakes of horn blonde and felspar, as well as fragments of the local rocks. In addition, grains of carbonate of lime have been found, some of which are casts of minute foraminifera, proving that some of the sand, at least, has been carried by the wind from the distant hills in Kutch. The action of the wind on the sand results in the formation of dunes of various shapes (Fig.7.4). Where a dune is advancing, its leeward slopes are invariably steep and without vegetation, if the motion is rapid enough. Another characteristic action of the wind on the surface of the sand is the sorting of the sand particles, resulting in the formation of wind ripples. Where these ripples are formed they have constant forward motion as long as the wind is strong enough. Under such circumstances, germination of seeds is impossible.

Fig. 7.4 : Formation of sand dunes of various shapes

Now it is clear that the climate of Indian desert is hostile to all vegetation, only plants possessing special adaptations being able to establish themselves. These adaptations are in general of two types, having two distinct objects in view : to enable the plant to obtain water, and to retain it when obtained. The bulk of the vegetation consists of a kind of scrub made up of shrubs and perennial herbs, capable of great drought resistance. There are a few trees and these are stunted and generally thorny or prickly thus protecting themselves against plant feeding animals. Of the latter, there are vast herds of camels, cattles, sheep and goats, forming the chief wealth of the rural population, and appearing to thrive in spite of the arid nature of the desert.

The proper desert plants may be divided into two main groups. Those depending directly upon rain and those depending on the presence of sub-terranean water.

The first group consists of two types: the 'ephemerals' and the 'rain perennials'. The ephemerals are delicate annuals, apparently free from any xerophilous adaptations, having slender stems and root-systems and often large flowers. They appear almost immediately after rain, develop flowers and fruits in an incredibly short time, and die as soon as the surface layer of the soil dries up. The rain perennials are visible above the ground only during the rainy season, but have a perennial underground stem. Bulbous monocotyledons of which *Dipcadi erythroeum* is a representative from this region, and also various cyperaceae grow. By far the largest number of indigenous plants are capable of absorbing water from deep below the surface of the ground by means of a well-developed root system, the main part of which generally consists of a slender, woody tap root of extraordinary length. Generally, various other xerophilous adaptations are resorted to such as reduced leaves, thick hairy growth, succulence, coatings of wax, thick cuticle, protected stomata, etc., all having for their object a reduction of transpiration. The plants belonging to this category are more or less woody perennials. A few annuals occur, however, such as the rare *Monsonia heliotropiodes*.

Among reptiles there occur two species of testudines *(Loricata)*, 18 species of lizards, and 18 species of snakes, of the lizards, some species like *Calotes versicolor, Uromastix dardwickii* are predatory on the desert locust inhabiting localised areas in Thar desert. Among predominant predatory birds are two species of the vultures, namely, *Gyps bengalensis* and the white vulture, *Neophron*.

The mammalian fauna of Indian deserts includes many species, some of which are rat-tailed bat, longer hedgehog, Indian hairy-footed gerbil, wild boar, jungle cats, panthers, etc

SAQ 5

Tick mark the correct answer in the space provided.

1) Which animal drinks water periodically and is physiologically adapted to withstand tissue dehydration for long period?
   a) Lion ☐
   b) Tiger ☐
   c) Camel ☐
   d) Elephant ☐

2) Which biome experiences intense heat and scorching wind with a great desi cating action during April to June?
   a) Tundra biome ☐
   b) Desert biome ☐
   c) Forest biome ☐
   d) Grassland biome ☐

3) How much area is covered by Thar desert?
   a) 5,17,000 sq km ☐
   b) 6,00,150 sq km ☐
   c) 2,50,000 sq km ☐
   d) 3,17,000 sq km ☐

4) When did Thar desert host shrubs and trees including Jamun?
   a) 10,000 years ago ☐
   b) 8,000 years ago ☐
   c) 7,000 years ago ☐
   d) 5,000 years ago ☐

5) On which animal Calotes and Uromastix are predatory in Thar desert. ?
   a) desert locust ☐
   b) desert gerbil ☐
   c) desert dragonflies ☐
   d) desert snakes ☐

7.6 SUMMARY

In this unit you have learnt that :

- Biomes are recognisable community units formed as a result of interaction of regional climates with regional substrate. Some of the biomes are recognised as forest biome, desert biome, grassland biome.
- Grassland biome is found where rainfall is about 25-75 cm every year. Grassland biomes are important to maintain the crop of many domesticated and wild herbivores such as horse, buffaloes, camels, deers, zebras, which provide food, milk, wool, leather, transportation to man.
- Forests occupy approximately 40% of the land. The forest biomes are classified as coniferous forest, temperate deciduous forest, temperate evergreen woodland forest, temperate rain forest, tropical rain forest, tropical seasonal forest, sub-tropical forest etc.
- The data released by NRSA in 1984 showed that India lost 1.3 million hectares of forest every year.
- Social forestry is a tree-raising programme to supply firewood, fodder, small timber and minor forest produce to rural population.
- The Chipko Movement—the movement to hug trees is a grassroot eco-development movement.
- Desert biomes occupy 17% of land occurring in the regions with annual rainfall of less than 25 cm.
- Desertification is the process of the diminution or destruction of the biological potential of land that can ultimately lead to desert like conditions.

7.7 TERMINAL QUESTIONS

1) Describe a biome and state the changes brought about by destruction of forest biome in global ecology.

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2) Explain the ways in which the social forestry benefits rural masses.

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3) State the ways through which deforestation can be checked.

....

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4) What do you understand by 'Chipko Movement'? State your opinion with regard to contribution it has made in checking the felling of the trees.

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....

5) State why maintenance of grassland biome is essential in our country.

....

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....

6) Describe how the Thar deserts have been formed.

....

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....

7.8 ANSWERS

SAQ 1

i) A biome is a large community unit characterised by the kinds of plants and animals present.

ii) The terrestrial and even some aquatic ecosystems are considered as gradients of communities and environments on a world scale. Such gradients of ecosystems are called ecolines.

iii) There are three major types of biomes such as forests, grasslands and deserts.

SAQ 2

i) Biotic communities
ii) Deciduous
iii) Equator
iv) Economic background
v) Forest and mankind
vi) Closed forests, open or degraded forests and mangrove forests
vii) Run off

SAQ 3

i) The destruction of forest cover causes (a) loss of top soil, (b) soil erosion, (c) perennial springs to have dried up, (d) chronic drought conditions. (e) lowering ground water levels and in long-term lowering of rainfall, (f) disruption of natural cycle, (g) floods, etc.

ii) Social forestry is a tree raising programmes to supply firewood, fodder, small timber and minor forest produce to rural populations.

SAQ 4

1) The grassland biome occurs where rainfall is about 25-75 cm per year, not enough to support forest.

2) In places where the rainfall is about 500 mm per year and the dry season is of 6-8 months dry savanna grazing ecosystems develop.

3) The major difference between steppes and savanna is that all the forage in the steppe is provided only during the brief wet season whereas in the savanna forage is largely from grasses that grow only during the wet season but also from the smaller amount of regrowth in the dry season.

4) Overgrazing causes reduction of the mulch cover, microclimate becomes dry and is readily invaded by xerophytic plants. Besides, due to absence of humid cover, mineral soil surface is heavily trampled when root produces puddling of the surface layer, which in turn reduces the infiltration of water into the soil and accelerates its run off, causing drought.

SAQ 5

i) c
ii) b
iii) d
iv) c
v) a

Terminal Questions

1) For biome refer to answer 1 of SAQ 1. The destruction of natural cover causes the loss of top soil. The entire Himalayan ecosystem is threatened due to thinning of snow lines and drying up of springs. Because of deforestation the natural reuse cycle is broken and water is lost rapidly through run off. Deforestation causes floods, soil erosion and changes the climate. Thus deforestation can change global ecology.

2) The main aim of the social forestry is to supply firewood, fodder, small timber and minor forest produce to rural populations. Social forestry programmes have mainly three components. (a) farm forestry to encourage farmers to plant trees on their own farms (b) woodlots planted by the forest departments for the needs of the community particularly along road side, canal banks and other such lands (c) community woodlots planted by the communities themselves on community land to be shared equally by them.

3) Deforestation can be checked by enacting effective laws and gearing up awareness among masses. Chipko Movement is as a result of mass awareness towards environment.

4) The movement to hug trees is a grassroot ecodevelopment movement. You have to write your opinion whether this movement has significantly checked the deforestation or it has been mere slogan.

5) India teems with animals. The livestock wealth plays a crucial role in Indian life. But this huge mass of livestock needs fodder for sustenance. Therefore, grassland biomes are important to maintain crop of many domestic and wild herbivores such as horse, mule, ass, cow, sheep, goat, buffalo, camel, etc. Due to overgrazing microclimate becomes dry, reduces the infiltration of water into the soil and accelerates its run off, producing drought.

6) Seven thousand years ago, Thar desert received abundant rainfall, hosted shrubs and trees including Jamun, was crisscrossed with rivers and lakes. Today it is a barren desert. The cause of this desertification is not climatic changes, drought, etc. but human actions which include deforestation; overgrazing by cattles, etc.

UNIT 8 TYPES OF ECOSYSTEMS : AQUATIC ECOSYSTEMS

Structure

8.1 INTRODUCTION

In Unit 1 you have learnt that ecosystems are classified into terrestrial and aquatic. In the previous unit you have studied in detail the characteristic features of the various terresterial ecosystems. In this unit we will be discussing the aquatic ecosystems.

You have studied in the previous units the general structure and functions common to all ecosystems and how the ecosystems operate as self-sufficient interacting systems in the biosphere. Ecosystems consisting of water as the main habitat are known as aquatic ecosystems. There are three kinds of aquatic ecosystems : Fresh water, saline and brackish water ecosystems. Freshwaters are again of two types, the static water ecosystems are called lentic systems and flowing water ecosystems are called as lotic systems. You will read about these in this unit.

Objectives

After studying this unit, you should be able to :

- describe the general ecological features of the aquatic ecosystems and their classification;
- explain the process of spring and fall overturn;
- compare oligotrophic, mesotrophic and eutrophic lakes and impoundments;
- differentiate between lentic and lotic freshwater ecosystems;
- define wetlands and differentiate between marine ecosystems and estuaries;
- explain the difference between the biota of lakes, rivers estuaries and marine ecosystems.

8.2 AQUATIC ECOSYSTEMS

Global waters cover about three quarters of the earth's surface either as fresh water where salt content is less than 0.5 per cent or as saline water where the salt content is more than 3.5 per cent or as brackish water where salt content is intermediate between fresh water and saline water. On the basis of their salt content aquatic ecosystems can be divided in saline water bodies and fresh water bodies. The salt content of fresh bodies is very low, always less than 5 ppt (parts per thousand). As against this the water bodies containing salt concentration equal to or above that of sea water (i.e., 35 ppt or above) are called as saline water bodies or marine water bodies. Seas and oceans of the world come under this category. Estuaries and brackish water bodies have salt content somewhere in between 5 to 35 ppt. Because of their salt content estuaries and oceans bear different kinds of organisms and will be discussed separately under sections 8.5 and 8.6. It is on this basis, that aquatic ecosystems are categorised into 1) **Fresh water ecosystems** — lakes, ponds, swamps, pools, springs, streams, and rivers 2) **Marine ecosystems** — shallow seas and open ocean and 3) **Brackish water ecosystems—estuaries, salt marshes, mangrove swamps** and forests.

8.2.1 Classification of Aquatic Organisms

After discussing the common types of the aquatic ecosystem let us now study in brief the ecological classification of aquatic organisms. In the present unit we will provide you a sample of diversity of organisms that exists in various types of aquatic ecosystems in which we focus on their distinctive characteristics. The aquatic organisms of all the three types of ecosystems i.e., marine, fresh water or brackish, are classified on the basis of their zone of occurrence in the aquatic system and their ability to cross these zones.

The organisms in the aquatic ecosystem are unevenly distributed but can be classified on the basis of their life form or location into five groups as shown in Fig. 8.1. The five groups are given as under :

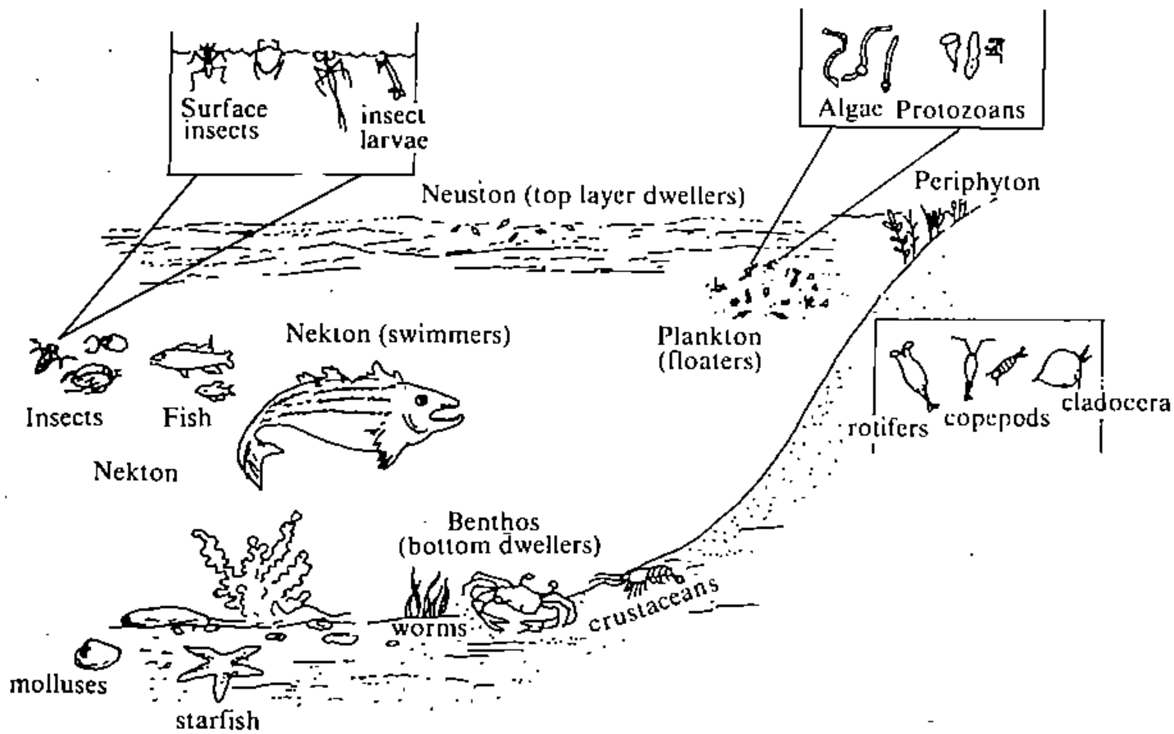


Fig. 8.1 : Life Styles of Aquatic Organisms

i) **Neuston :** These are unattached organisms which live at the air-water interface such as floating plants and several types of animals (see Fig. 8.1). Some spend most of their lives on top of the air-water interface, such as water striders, while other spend most of their time just beneath the air-water interface and obtain most of their food within the water, e.g., beetles and back-swimmers.

ii) **Periphyton :** These are organisms which remain attached or clinging to stems and leaves of rooted plants or substances emerging above the bottom mud. Usually sessile algae and their associated group of animals fall in this group.

iii) **Plankton** : This group includes both microscopic plants (phytoplankton) and animals (zooplankton) found in all aquatic ecosystems, except certain swift moving waters. The locomotory power of the planktons is limited so that their distribution is controlled, largely, by currents in the aquatic ecosystems. Planktons are divisible into :

1) Plants (chiefly algae) known as *phytoplankton* ; and
2) Animals (primarily crustaceans and protozoans) known as *zooplankton.*

Most phytoplanktons and zooplanktons are capable, however, of at least some movement. Certain zooplanktons are extremely active and move relatively large distances, considering their small size, but they are so small that their range is still largely controlled by currents.

iv) **Nekton** :This group contains animals which are swimmers. The nektons are relatively large and powerful as they have to overcome the water currents (see Fig. 8.1). The animals range in size from the swimming insects, which may be only about 2 mm long, to the largest animals that have lived on earth namely the blue whale.

v) **Benthos** :The benthos or the benthic organisms are those found living in or on the bottom or benthic region of the water mass. They exhibit a variety of adaptations to the environment. The reason for this is that the bottom is a more heterogeneous habitat than either the open water or the surface and this diversity is reflected in the organisms. Practically every aquatic ecosystem contains well developed benthos. The adaptations of the organisms in the benthic community reflect the composition of the bottom, its stability or tendency to shift, and its depth.

You should realise however, that each system has certain unique characteristics. Despite there being a common factor – water in all aquatic ecosystems and similar limiting factors and life forms — there are three types of as a typical aquatic , ecosystems, namely, the fresh water marine and brackish water system. All vary is size, depth, gradient of light penetration, temperature, amount of dissolved oxygen, etc., which are responsible for a particular type of environment and biota and hence a specific type of ecosystem.

8.2.2 Factors Limiting the Productivity of Aquatic Habitats

Sunlight and oxygen are the two most important limiting factors of the aquatic ecosystems. This distinguishes them from the terrestrial ecosystems where moisture and temperature are the main limiting factors. We will now consider some of the important limiting factors which exert controlling influence on productivity of aquatic ecosystems, namely sunlight, transparency, temperature and oxygen.

i) **Sunlight** : Sunlight is a major limiting factor for water bodies, since light rapidly diminishes as it passes down the column of water. The upper layers of the aquatic ecosystems, up to which light penetrates and within which photosynthetic activity is confined forms the photic zone. The depth of this zone depends on the transparency of water.

ii) **Transparency** : Transparency affects the extent of light penetration. It is indirectly related to turbidity. Suspended particulate matters such as clay, silt and phytoplankton make the water turbid, consequently limiting the extent of light penetration and this photosynthetic activity in a significant way.

iii) **Temperature** : The water temperature changes less rapidly than the temperature of air because water has a considerably higher specific heat than air, that is larger amounts of heat energy must be added to or taken away from water to raise or lower its temperature. Since water temperatures are less subject to change, it follows that aquatic organisms have narrow temperature tolerance. As a result, even small changes in water temperatures are a great threat to the survival of aquatic organisms than comparable changes in air temperatures are in terrestrial organisms.

iv) **Dissolved oxygen** : Oxygen in the terrestrial ecosystems occurs in the atmosphere along with other gases in a certain fixed concentration however, in aquatic ecosystems it is dissolved in water, where its concentration varies constantly depending on factors that influence the input and output of oxygen in water. In fresh water the average concentration of dissolved oxygen is 0.0010 per cent (also expressed as 10 parts per million or 10 ppm) by weight, which is 150 times lower than the concentration of oxygen in an equivalent volume of air.

Oxygen is found in waters in dissolved form. It enters the aquatic ecosystem through the air water interface and by the photosynthetic activities of aquatic plants. Therefore, the quantity of dissolved oxygen present in an ecosystem depends on the rate at which these two processes occur. For example, the turbulence that occurs in waterfalls as well as wave activity that occurs in open water, increase the rate of oxygen transfer from air to water (unless the water is already saturated with oxygen). The transfer of oxygen is also affected by the surface area of the waterway. A wide shallow section of a river has a larger surface area of oxygen transfer than a narrow deep segment. Further, the quantity of oxygen that is produced per unit area due to photosynthesis is related directly to the density of aquatic plants that are present in water.

Dissolved oxygen escapes the water body through air-water interface and through respiration of organisms (fish, decomposers, zooplanktons, etc). The amount of dissolved oxygen retained in water is also influenced by temperature as oxygen is less soluble in warm water. Warm water also enhances decomposer activity. Therefore, increasing the temperature of a waterbody increases the rate at which oxygen is depleted from water.

In certain instances, large populations of decomposers remove nearly all the dissolved oxygen in surface waters (such as lakes, streams and rivers) through respiration. Such situations are more likely to occur during late summer, when low stream flow and high water temperatures reduce the level of dissolved oxygen even more. When the dissolved oxygen level falls below 3-5 ppm, many aquatic organisms are likely to die.

The limiting factors discussed here apply in general to all aquatic ecosystems — lakes, ponds, rivers, streams, estuaries, oceans and seas.

SAQ 1

i) State whether the following statements are true or false :

a) Unlike terrestrial ecosystems, the temperature changes in aquatic ecosystems are not very sharp.

b) Organisms living in aquatic ecosystems are not adapted to gross temperature changes.

c) Oxygen occurs in the aquatic ecosystems in its dissolved form.

d) Light is the major limiting factor in aquatic ecosystems.

ii) Match the terms used for defining groups of aquatic organisms given in column A with their definitions given in column B.

Column A	Column B
a) Neuston	a) The group of plants and animals which are found living in or on the bottom of an aquatic ecosystem.
b) Nekton	b) Plants or animals that cling to rooted water plants above the bottom mud.
c) Benthos	c) Animals and plants of minute size which float in the aquatic ecosystems seas, rivers, ponds and lakes. These organisms are incapable of independent movement and depend on water currents for movement.
d) Plankton	d) Aquatic animals that swim strongly and are able to overcome water currents.
e) Periphyton	e) Organisms associated with the surface film of water.

8.2.3 Classification of Freshwater Ecosystems

Fresh water ecosystems depend on the terrestrial ecosystems for large quantities of organic and inorganic matter which are constantly added into them by the communities growing on nearby land.

The fresh water ecosystems can be conveniently divided into two main divisions

i) Lentic (from 'lenis', calm) or standing or basin series ecosystems. Examples of this division are lakes, pools, ponds, swamps, marshes etc.

ii) Lotic (from 'lotus', washed) or running or channel series ecosystems. Examples of this division are rivers, streams, springs etc.

These two fresh water ecosystem have been extensively treated in the following two sections, i.e., Sections 8.3 and 8.4.

8.3 LENTIC ECOSYSTEMS

Lakes are inland, depressions containing standing water. They vary considerably in area and depth. The largest lake in the world, the lake Superior in North America has a surface area of 83,000 km^2 and a maximum depth of 307 metres (5,000 feet). Whereas the deepest lake, in the world, lake Baikal in Siberia is nearly half the area of Lake Superior, i.e., 31,500 km^2. It has, however, more than twice its depth (706 metres).

Fresh water lakes of this earth hold 125×10^3 km^3 of water and have inflow as well as outflow. In addition they have various patterns of circulation within their boundaries and so their water is not totally static. However, they do lack the constant linear or turbulent flow of the rivers.

8.3.1 Lakes, Impoundments and Wetlands

Lentic ecosystems include all those systems which have a static body of water. Lakes, impoundments and wetlands are all lentic ecosystems. Let us see how do they differ from each other.

Lakes : Most lakes occur in regions which have recently been subjected to geological changes; say within the past 20,000 years. However, a few lakes, such as lake Baikal in Russia and Lake Tanganyanitia in Africa are ancient and are estimated to have originated twenty million years ago.

Lakes arise in several ways. Some, like the tectonic lakes, are formed in basins created by geological activities such as warping and faulting of the earth's crust. Most of the Himalayan lakes are tectonic in origin. Some are formed in crater depressions of extinct volcanoes and are called crater lakes, for example lake Kounsaranag in Kashmir. Others may be a result of glacial activity. For example most lakes of North America originated due to glacial erosions and deposition, whereby glacial abrasions of slopes in high mountain engraved basin which later became filled with melting snow and rain. Still others have been formed by deposition of silt, drift-wood and other debris in beds of slow moving streams. Lakes may also arise by landslides blocking off streams and valley.

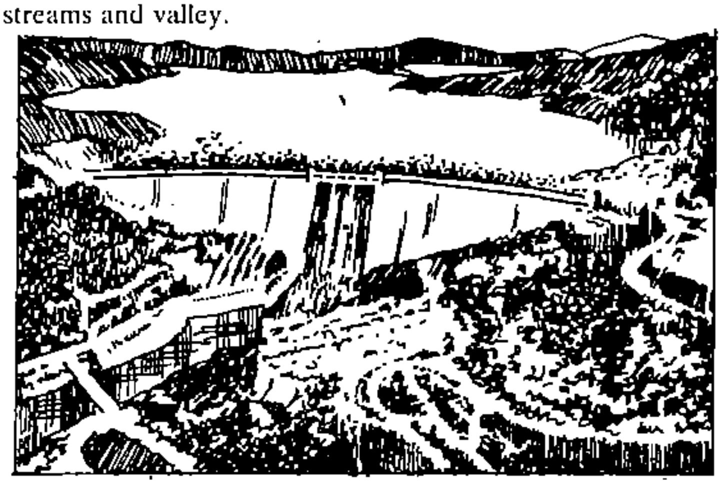


Fig. 8.2 : A reservoir formed behind Shastri Lake showing two possible means of releasing water from impoundments

You should be aware that lakes are not evenly distributed on the earth but are grouped in certain regions called 'lake districts'. However, in a given area all natural lakes have the same geological origin and same characteristics, though they may represent several stages of succession due to varying depths at the time of origin.

Impoundments : We have so far discussed natural lakes. In addition to these there are a number of lakes both small and large artificially created by man called reservoirs or impoundments (Fig.8.2a). These have been built to fulfil specific requirements — hydroelectric power generation, fisheries, water supply, irrigation, industries, recreation, control of floods, etc.

Impoundments may be called offstem or onstem depending on how they have been created. Onstem reservoirs — these are located in upland areas and are formed by damming a stretch of river or stream in a suitable river valley. In India only these types of impoundments are found. Offstem reservoirs are built in low land areas by pumping water some distance from a river or from an underground source.

Wetlands : Wetlands are permanently or periodically water covered areas. They can be defined as submerged or saturated lands either artificially or naturally, and either periodically or permanently up to a depth of six metres by water which may be fresh brackish or saline.

These wetlands may be classified into two categories :

Inland wetlands which occur inland and contain fresh water e.g. bogs, swamps, etc.

Coastal wetlands which occur near the coast and contain saline or brackish waters, e.g. mangrove swamps, mangrove forests. You will read about these in Section 8.6 in greater detail.

8.3.2 Characteristics of Lake Ecosystems

The environment of static waters of lakes and ponds sharply contrasts with those of lotic ecosystems. Light penetration in lakes is usually up to a certain depth which as you know is affected by turbidity. Temperature and dissolved oxygen also vary with depth. Dissolved oxygen in stagnant water is generally less compared to lotic systems because only a relatively small surface of the water body is in direct contact with air. Decomposition of organic matter usually takes place at the bottom of the lake. The oxygen content usually decreases with depth. The gradations of temperature, sunlight and oxygen are directly responsible for **vertical zonation** or stratification, occurring in lakes. They are also responsible indirectly for horizontal zonations of lakes as they profoundly influence the distribution of lake organisms which contribute to the characteristic horizontal zonations.

A) **Thermal Stratification :** Shallow lakes show no thermal stratification as their waters are well mixed, resulting in uniform temperature throughout. However lakes with depths of more than 15 metres exhibit fairly pronounced temperature stratification.

a) ***Summer Stratification*** : Thermal stratification is fairly pronounced during the summer seasons in most lakes of the temperate (cold) regions but is rare in lakes of tropical (hot) and subtropical regions where it occurs only in very deep lakes. This is so, because the rate of mixing of layers is very fast in case of tropical lakes whereas, the temperate lakes retain well defined layers showing different temperatures. These layers do not mix rapidly. Therefore the temperate lakes exhibit clear stratification with respect to temperature.

   Let us understand how thermal stratification develops in water bodies and why it is maximum during the summer seasons. In lakes the top one metre of the water surface directly absorbs around 90 per cent of the total solar radiation falling on it and is considerably more heated in the process. Consequently, the lower sub-surface layers receive progressively less radiation and remain relatively cool. Thus, the lake becomes thermally stratified, with its water forming layers due to temperature differences or thermal gradients (see Fig. 8.3)

   Thermal stratification is maximum during the summer season, primarily due to two reasons. Firstly, due to the fact that solar intensity increases during this period and it heats the surface layer greatly while the lower layers remain comparatively cool. Secondly, the thermally stratified layers offer resistance to mixing by wind. The fairly pronounced stratification of lakes developed in summer is called summer stratification or stagnation. The various stratified layers which are formed as a result (Fig.8.3) can be delineated as follows (Fig.8.3.a,b).

i) **Epilimnion :** This forms the uper layer of the lake and consists of freely-circulating warm water which is well lighted though poor in nutrients. Most of the phytoplanktons grow in the epilimnion which is well aerated both due to photosynthetic oxygen production by plants and mixing by wind.

ii) **Metalimnion :** This zone lies below the epilimnion and above the hypolimnion and thus forms the intermediate layer which is non-circulating. The metalimnion is characterised by steep and rapid fall in water temperature with increasing depth. Within the metalimnion is present the 'thermocline', the plane at which the temperature drops most rapidly — at least 1 celsius for each metre of depth.

iii) **Hypolimnion :** This zone forms the bottom layer which is deep, cold and non-circulating. The hypolimnion is generally rich in nutrients though its oxygen content is low due to its utilisation by decomposition process which as you know generally occurs here and uses up oxygen. Temperature fall here is gentle.

Stratification of certain temperate lakes is not limited to the summer season as they undergo stagnation or stratification in winter also which is called winter stratification or stagnation and is described below (Fig.8.3 a,b).

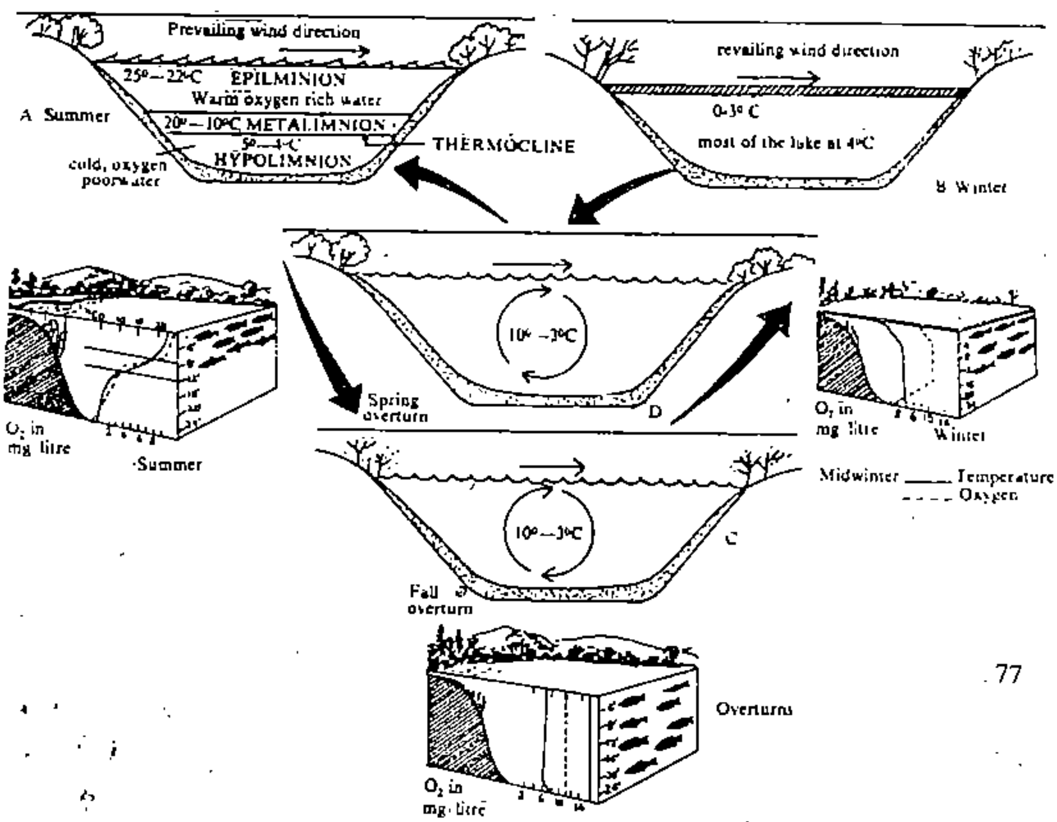


Fig. 8.3 : Showing seasonal stratification of temperature and oxygen as well as distribution of aquatic life in a temperate lake. The distribution of temperature and oxygen in a lake affects the distribution of fish and other aquatic life. The narrow fish outline depicts the cold water species (trout). The broader outline represents the warm water species namely bass

a) Shows the three well defined layers due to summer stratification — epilimnion, thermocline in metalimnion, and hypolimnion b) shows the seasonal stratification in winter c) and d) show the fall and spring overturns, respectively, when stratification is destroyed and fishes occur at almost all depths.

b) ***Winter Stratification*** : During extremes of winter the surface layer of the lake freezes or attains a temperature close to 0° Celsius. Under these conditions an inverse stratification develops. The water beneath the ice absorbs solar radiation passing through the ice and so remains relatively warm. When this warm water attains a temperature of 4°C it becomes dense and heavier. Consequently it sinks to the bottom where it mixes with bottom water of the lake which is warmed by heat conducted from the bottom mud. The result is higher temperature at the bottom, though the overall stability of water remains undisturbed. That is, the less dense surface water in the form of ice or at 0°C floats on the top of the warm, heavier water which is at an appropriate temperature of 4°C. Both of these layers remain stratified and do not mix during the winter season so that the lake is said to have undergone, winter stagnation or stratification.

c) ***Overturn*** : The summer or winter stratification is seasonal. Circulation of lake water occurs twice a year, in the spring and autumn (fall) seasons by a process called overturn. This circulation is important for lakes which undergo stratification as it allows thorough mixing of oxygen, phytoplankton and nutrients within the the lake. Let us now understand the process of overturn both in the spring and autumn seasons.

Spring overturn : In spring and early summer season the increased solar radiation melts the ice cover, which, as it attains a temperature of 4° Celcius, becomes dense and heavy and sinks to the bottom, displacing the lower water which moves up. This circulation of water is further helped by the prevailing summer winds and is called spring overturn (Fig.8.3.c,d)

Autumn (fall) overturn : In autumn or early winter the air temperature falls, resulting in the cooling of the surface waters. When the surface water cools to 4°C it becomes dense and heavy and sinks to the bottom displacing the bottom warm water which rises to the surface. This mixing of the surface and bottom layers is further facilitated by strong winter winds and is called 'fall overturn' (Fig.8.3c and 3c,d).

B) Light Stratification

As you have already read, the penetration of light in water bodies is limited depending on the transparency of water and its ability to absorb light. On the basis of light penetration lakes become vertically stratified into two basic layers (1) the upper trophogenic zone, corresponding roughly to the photic zone about which you have read in section 8.2.1 in which photosynthesis dominates and the lower, and (2) tropholytic zone where decomposition is most active and which corresponds to the aphotic zone (Fig. 8.3).

Between these two zones is the **compensation depth** — the depth at which light intensity is such that the photosynthetic production is just enough to balance respiratory losses and beyond which light penetration is so low that it is no longer effective. Generally compensation depth occurs where light intensity is about 100 foot candles or approximately one per cent of full noon sunlight incident to the surface.

C) Oxygen Stratification

In most lakes, oxygen stratification nearly parallels that of temperature during the summer season (Fig.8.3a). The amount of oxygen is greatest on the surface, gradually decreasing with depth. The surface layer has the maximum oxygen content due to two main reasons. First, being well lighted, maximum photosynthetic oxygen is produced here. Secondly, being in intimate contact with the atmosphere, it permits free diffusion of oxygen into it from the air. The oxygen content, beneath the surface water decreases, as both these oxygen sources disappear. At the bottom the oxygen content decreases further due to utilisation of oxygen by decomposers occurring here.

8.3.3 Biota of Lakes

Lakes exhibit life zones. So far you have been reading about the vertical zonation of lakes. The lakes can be divided into horizontal zones as well. This division is on the basis of life forms existing in lakes. The penetration of sunlight in the lake influences the vertical gradient of sunlight, temperature and oxygen. The horizontal gradation of lakes is affected by distribution of organisms in the waters. This results in definite zones which are shown in Fig.8.4 and are as follows :

i) **Littoral zone** : This is the shallow water zone, near the shore, where light penetrates to the bottom. Rooted plants can grow only in this region.

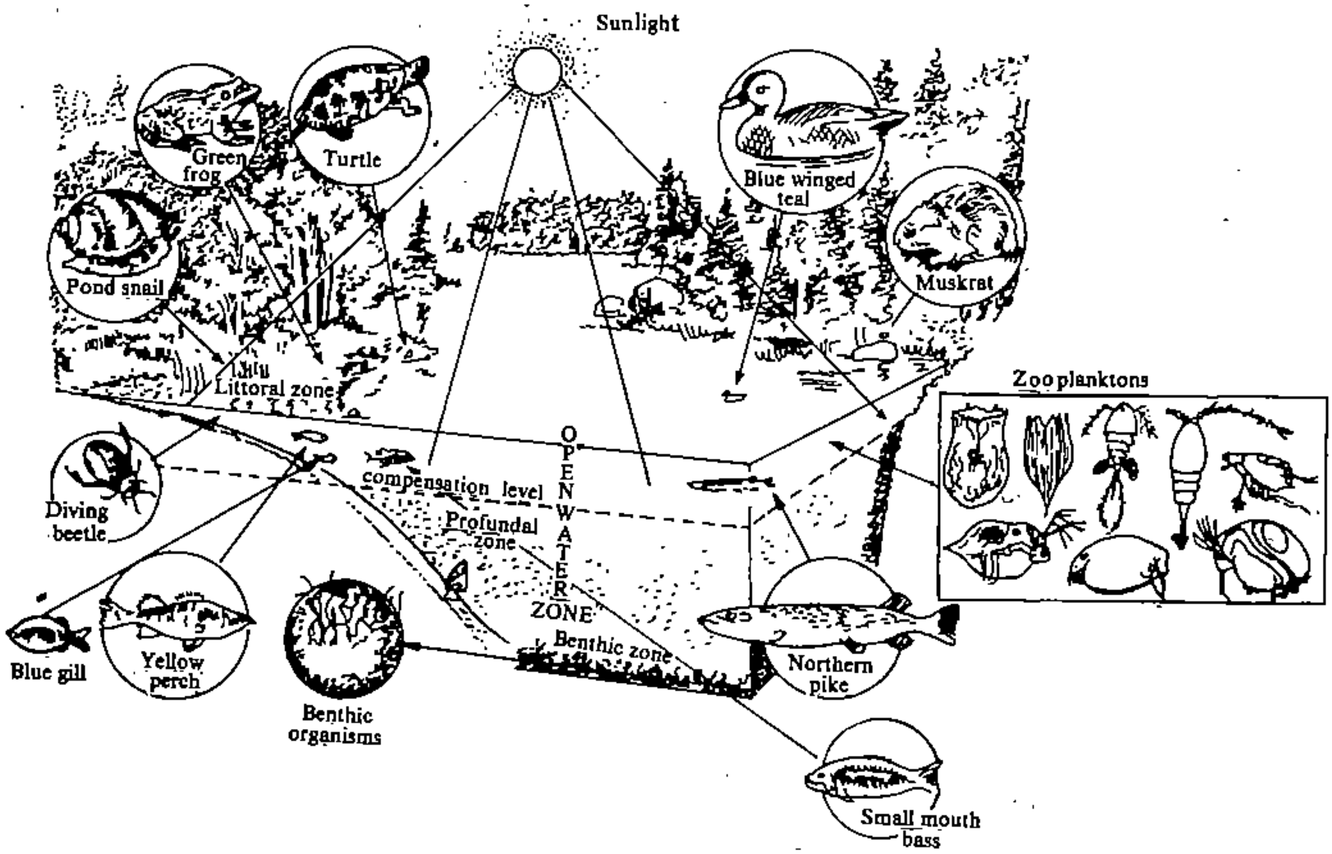


Fig. 8.4 : Four major life zones in a lake in summer showing the representative animals in each zone.

ii) **Open Water Zone :** This extends beyond the littoral zone and is too deep for light to penetrate till the bottom and for rooted plants to grow. This zone is divided on the basis of light penetration and distribution of organisms into :

a) limnetic region which is photic

b) profundal region which is aphotic

iii) **Benthic Zone :** This forms the floor of the lake and underlies the littoral and limnetic zone.

Let us now see how the types of plants and animals occurring in the various horizontal zones are classified.

LITTORAL ZONE

A) Plants of the littoral zone

Two types of plants occur here:

i) Non-rooted phytoplanktons which include all kinds of algae occurring in the limnetic as well as those found only here. Certain species of green algae, blue green algae and diatoms remain attached to plant surfaces and are collectively called periphyton (Fig.8.5 a)

ii) All rooted or benthic flowering plants, attached to the substratum which occu in concentric zones within the littoral region. A general representative arrangement of rooted plants proceeding from the shallow towards the deeper lake area includes the following three sub-zones. (Fig.8.5b).

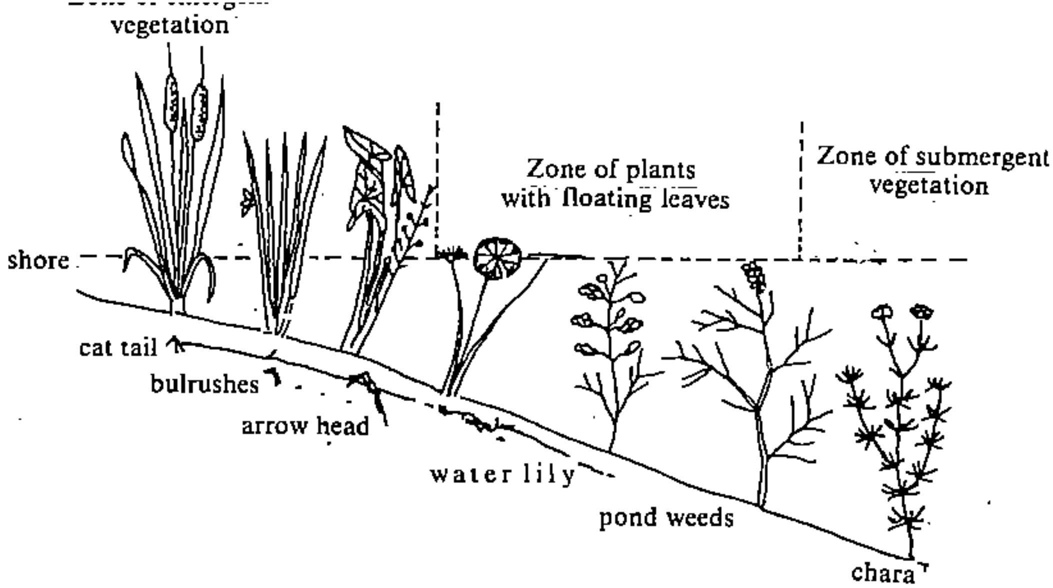


Fig. 8.5 : Some plants of littoral zone a) Floating vegetation of the littoral zone b) Rooted plants showing zonation in the littoral region of the lake

a) **Zone of emergent plants :** consisting of plants whose roots and stems remain submerged in water and whose upper leaves and stems protrude above the water level e.g. cat's-tail, arrowheads, etc. This is followed by

b) **Zone of plants with floating leaves :** containing plants ecologically similar to the previous types of plants though the photosynthetic area of these plants is much more wide. Water shields, and water lilies abound here.

c) **Zone of submerged vegetation :** includes plants which are completely or largely submerged in water. Plants of this zone have highly divided leaves to overcome the tearing of leaves by strong water currents for maximum absorption of nutrients as their root system is poorly developed. Pond weeds are usually prominent in this zone.

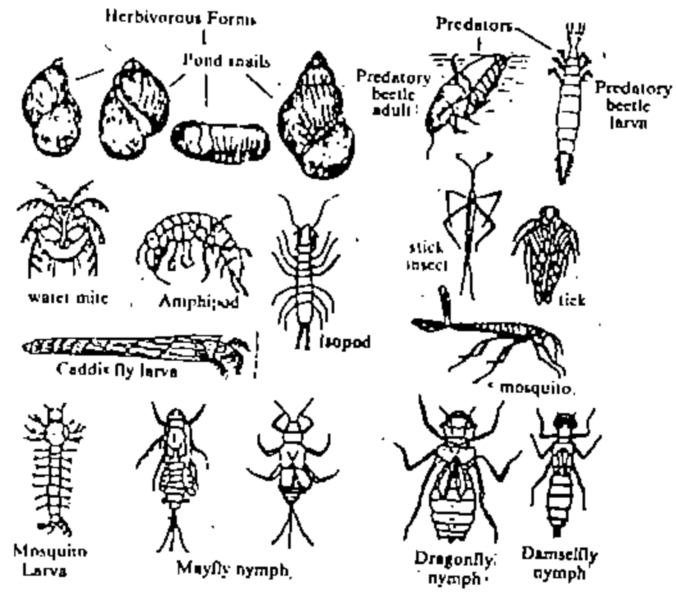


Fig. 8.6 : Some representative invertebrate animals of the littoral zone

B) Animals of the littoral zone

Animals of this zone may be herbivores, carnivores or detritus feeders and are as diverse as plants (Fig.8.6).

Many of them such as rotifers, protozoans, insect larvae, hydras and bryozoa are neuston as they spend their lives attached to the stem or leaves of rooted plants. Others such as snails, flatworms, and many types of insect nymph and larvae spend their lives moving about the plants. Zooplankton here include species also found in the limnetic as well those that are not. The latter include larger forms that rest on the rooted vegetation, while they are not actively swimming. The nekton here is rich in small swimming insects particularly such as diving beetles, back swimmers, water boatman, etc., many of which occur also in streams. Many species of fishes like mirrows, sunfish and northern pike are restricted to just this zone, while others move freely between here and the open water zone. Vertebrates living on the lake shore are found here and include amphibians, e.g., frogs; reptiles, e.g., turtles and snakes and mammals like beavers and musk rat. Benthos found in or on the floor underlying the littoral zone are diverse. Most of them are detritus feeders, though some are carnivores.

OPEN WATER ZONE

A) Plants of the open water zone

In this zone plants are restricted to the limnetic one and generally consist of phytoplankton (Fig.8.7) such as dinoflagellates, blue green algae and green algae. Of these the single celled planktonic algae are the main producers for the lake as a whole.

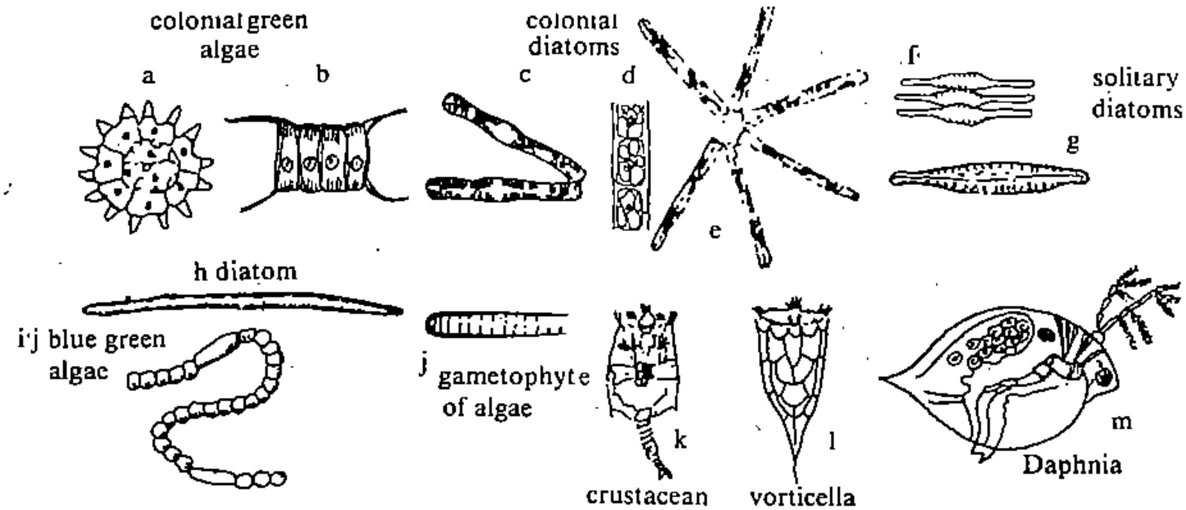


Fig. 8.7: Plankton of the limnetic region of the open water z one of lakes: (a,b) colonial green algae, (c,d,e,f) colonial diatoms; (g,h) solitary diatoms (i,j) blue green algae (k,l,m) protozoa.

The profundal region of the open water zone has no green plants as it is dark and so cannot support photosynthesis.

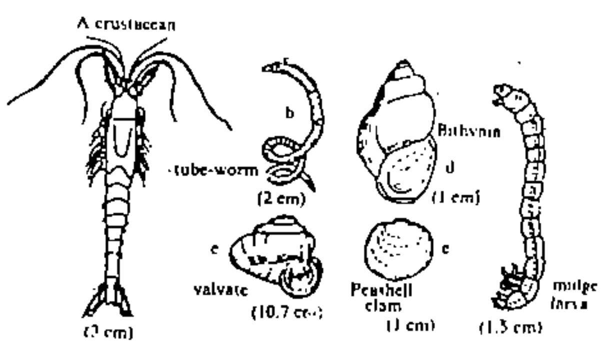


Fig. 8.8 : Representatives of benthic invertebrates found in the profundal region of lakes (a) Mysis, a mysid crustacean; (b) Tubifex, the tubeworm of sludgeworm; (c) Valvata; (d) Bithynia; (e) Musculium, the Pea-shell clam, (f) Chironomus, the bloodworm, a midge larva.

B) Animals of the open water zone

The limnetic region of this zone contains certain fishes as well as a rotifers, zooplankton such as crustacean and protozoan (Fig.8.6). In the profundal zone occur chemosynthetic autotrophs as well as heterotrophs. The latter may be carnivores or detritus feeders. Further the larger fishes of the lakes are restricted to the profundal zone which also has a well developed series of decomposer population present from top to the bottom. The bottom which underlies the open water zone contains benthos whose diversity is low. Benthic animals found here are larvae of several insect species such as midges and burrowing flies as well as clams, snails, tube worms and ecomposers (Fig.8.8).

8.3.4 Types of Lakes

Lakes of the world exhibit a great diversity of shape, size and combination of properties. However, on the basis of nutrient status and primary productivity they can be divided into three categories (1) **Oligotrophic** (nutrient poor) lakes (Fig.8.10a), (2) **Eutrophic** (nutrient rich) lakes (Fig.8.10b) and (3) **Mesotrophic** (medium nutrient) lakes.

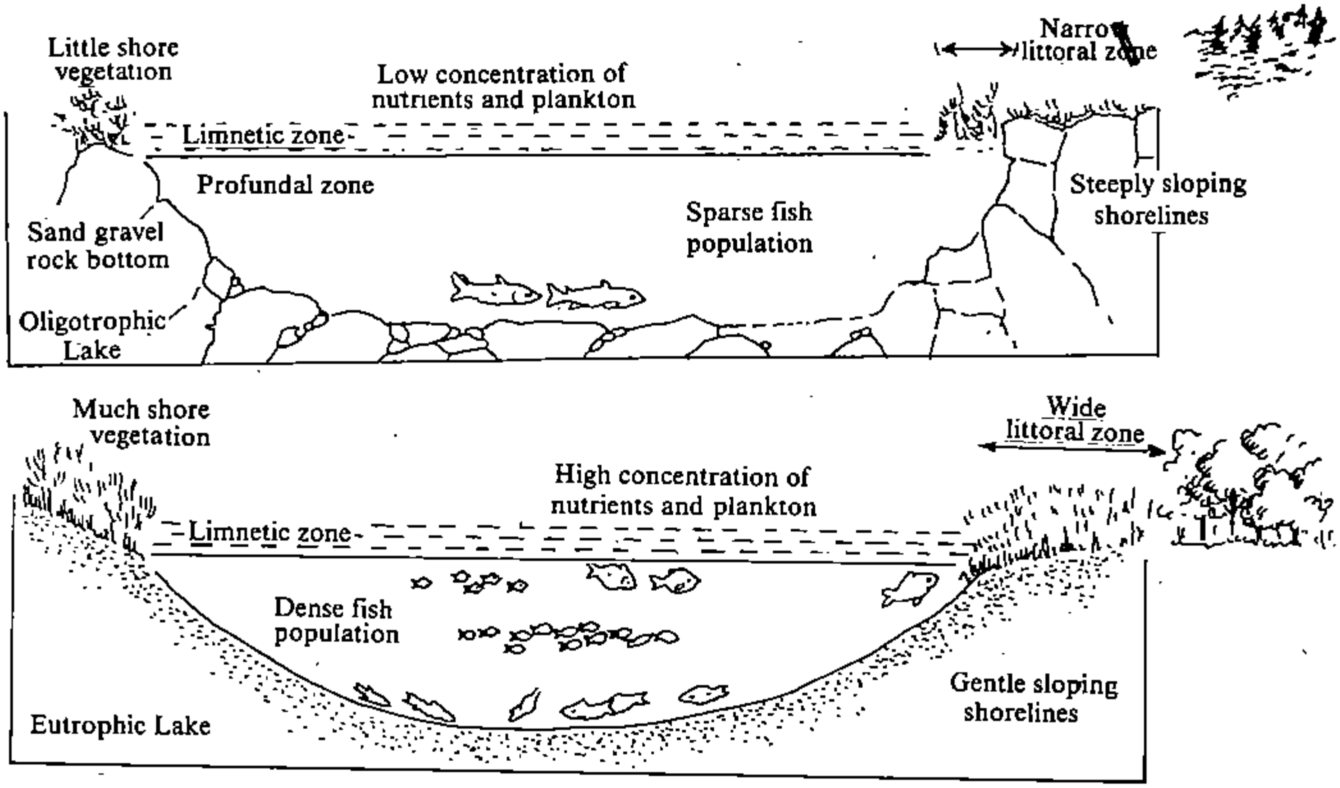


Fig. 8.9 : A summary of the biota of lakes and their zones of occurrence

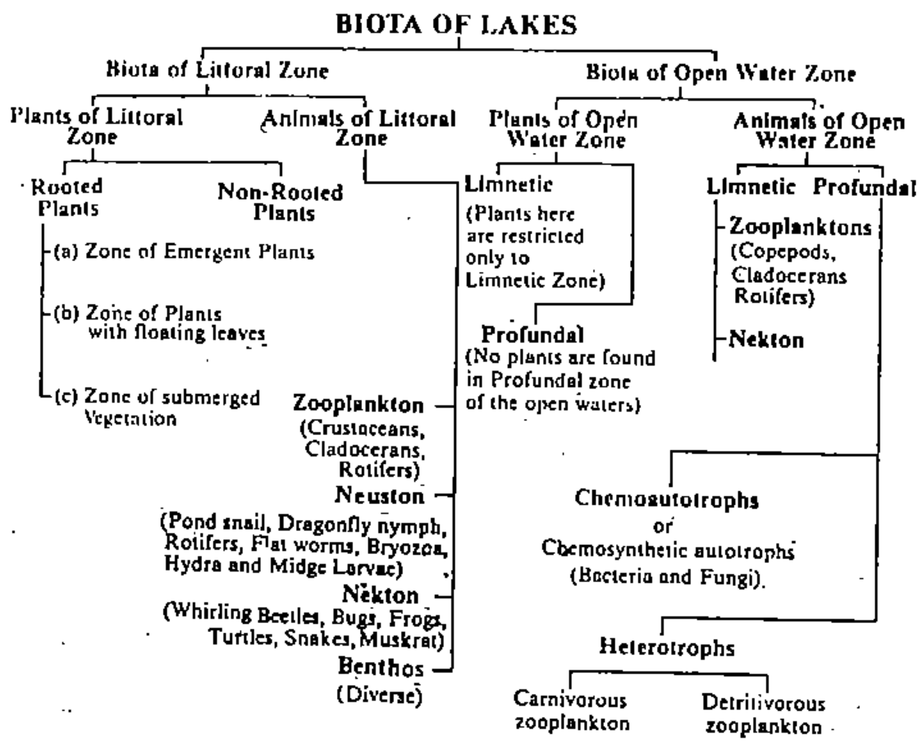


Fig. 8.10: Comparison of oligotrophic and eutrophic lakes. (a) The oligotrophic lake is deep and has relatively cool water in the epilimnion. The hypolimnion is well supplied with oxygen. Organic water that drifts to the bottom falls through a relatively large volume of water. The watershed surrounding the lake is largely oligotrophic, dominated by coniferous forests on thin and acid soil. (b) The eutrophic lake is shallow and warm, and oxygen in the deeper water is nearly depleted. The amount of organic detritus is large relation to the volume of water. The watershed surrounding the lake is eutrophic consisting of nutrient-rich farmland and deciduous forest.

Eutrophication

The nutrient content of lakes thus acts as a limiting factor for organisms as the quantity and diversity of organisms in a lake is dependent on the rate at which nutrients are cycled within it (see Unit 16, section 16.2.2 of the 4th block of FST course). Some lakes are eutrophic from their formation but most lakes were originally oligotrophic and have become eutrophic, naturally, over many thousands of years. The process of aging of lakes through nutrient enrichment is called 'eutrophication'. Many lakes today are undergoing eutrophication at a very rapid pace due to human interventions. Activities such as industrialisation, intensive agriculture, etc. result in the rapid addition of nutrients such a nitrogen, phosphates etc. from agricultural run off, sewage drainage and industrial effluents. This eutrophication which is caused by cultural activities is called 'cultural eutrophication'.

Fig. 8.9 : Comparison of oligotrophic and eutrophic lakes

Criteria	Oligotrophic	Eutrophic	Mesotrophic
1) Depth surface area ratios.	Oligotrophic lakes are deep often with steep sides. Their surface to volume ratio is low (surface area is small compared to depth).	Eutrophic lakes are shallow and their surface to volume ratio is high (surface area is large relative to depth)	Mesotrophic lakes are intermediate between the oligotrophic and eutrophic lakes. (surface area and depth are proportional).
2) Nutrient status	These lakes are poor in nutrients particularly nitrogen, phosphorous and organic matter.	These lakes are rich in nutrients such as nitrogen, phosphorous and organic substances.	They are mildly eutrophic and have characteristic features intermediate between the Oligotrophic and eutrophic lakes.
3) Primary Production	Primary productivity in these lakes is low.	Primary productivity is high in these lakes due to presence of excess nutrients	They contain moderate quantities of nutrients and have moderate primary productivity.
4) Species diversity	The number of organisms occurring here are low, though their species diversity is high.	The number of organisms, that is, biomass is high, though species diversity is low.	
5) Oxygen content	Oxygen content in such lakes is high and extends to the bottom.	Oxygen content here is low on the whole. It is particularly low in the bottom layers either seasonally or throughout the year. In some cases anaerobic conditions develop in bottom layers of the lake resulting in the elimination of aerobic organisms especially fishes.	Oxygen contents is medium.
6) Transparency of water body	Waters of oligotrophic lakes are transparent, appearing blue to green in sunlight.	Waters of eutrophic lakes are cloudy, due to excess algal and plant growth. In the summer season the lake waters assume a pea soup or green paint colour due to increased algal growth or blooms.	Medium turbidity

SAQ 2

i) Fill in the blanks using appropriate words :

a) On the basis of thermal stratification in temperate lakes during summer, the lakes have been divided into three zones : i)............. ii) .... and iii) ....

b) In any lake between the trophogenic zone and tropholytic zone, there exists a thin surface where light intensity is such that the photosynthetic production is just enough to balance the losses due to respiration. This depth at which this zone is situated is known as ....

c) On the basis of the biotic forms occurring in different lakes the lakes have been divided into three horizontal zones : i)................, ii)................, and iii) ....

d) In order to be called as wetland an area has to be covered by at least .... metres of water which may be fresh, brackish or saline.

c) Open water zone of the lakes has been divided into two regions:
i)................ ii)................ (littoral, hypolimnion, six, open water, epilimnion, benthic, compensation depth, limnetic, epilimnion)

ii) State whether the following statements are true or false.

a) There are no photosynthetic plants in the profundal region of the open water zone of lakes.

b) Impoundments are artificially created lakes.

c) Eutrophic lakes are shallower and warmer than oligotrophic lakes.

d) Summer and winter stratification are seasonal phenomena and are punctuated by overturns twice a year.

8.4 LOTIC ECOSYSTEMS — RIVERS

The lotic or flowing water habitats include rivers, streams, brooks etc. The most outstanding features of such habitats is the continuously flowing water which moulds the characteristics of the water bed and influences the distribution of organisms within.

In order to differentiate between the lotic and lentic habitats let us see how rivers (lotic habitats), differ from lakes that represent the lentic habitat.

- The rivers have a continuous — one directional flow with the entire volume of water flowing unidirectionally. In large rivers, the flow may be from one climatic zone to another.
- The volume of river water keeps changing, causing variation in its velocity.
- The water level of the rivers exhibit wide range of fluctuations.
- Generally as a rule the depth of rivers is small as compared to lakes.
- River waters usually flow in a narrow channel, though occasionally their channels may expand, to form river lakes.
- The physical, chemical and biological conditions of the river gradually change with distance along the main channels in a definite direction.
- The material transported or eroded by the rivers at any point, is transported by them downstream with no supporting for return, thus causing their permanent removal.
- In rivers prolonged stagnation is absent. Rivers in comparison to lakes depend more on the surrounding land for nutrients, manufacturing little basic food materials themselves.

The two most important points are that :

1) Rivers are open or heterotrophic systems whereas lakes are closed or self contained systems except for some gains or losses from inflowing or outflowing streams; and

2) Nutrients in a lake may be used several times whereas in rivers, at any point, plants and animals must avail of temporarily available nutrients.

8.4.1 Characteristics of River Systems

The basic function of the rivers is to convey surplus rain water from land to sea. Annually the rivers carry fresh water, equivalent to 25 cm of rain, evenly distributed over the whole land surface.

The point of origin of the river is the 'source'; the path it takes, is the 'course'; the streams which pin it along the course are the 'tributaries'; and the channel within which it flows is the 'bed'. Its point of entry into the sea or lake or estuary is called its mouth (Fig.8.11).

Classification of the river zones

The course of a river can be classified in two ways (A) firstly by its physical characteristics and (B) secondly by the presence or absence of fish species which indicate differing physical, chemical and biological features of the river.

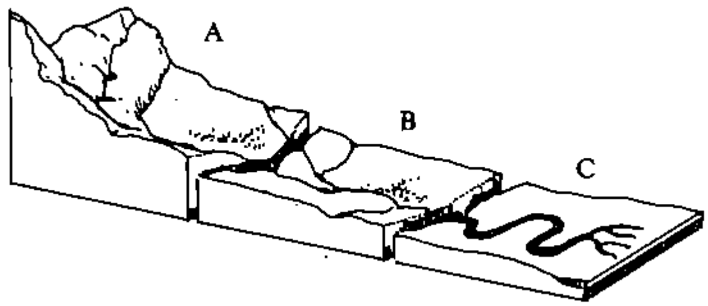


Fig. 8.11 : Three phases in the flow of water downhill from mountain headwater stream to wider lower elevation streams to rivers which empty into oceans. A. The upper course, B. The middle course and C. The lower course.

A) Classification of the river course on basis of physical characteristics

The river is divided into three parts (Fig.8.11)

i) **The upper or mountain course :** Here the water is fast flowing and runs through a 'V' shaped valley with unstable banks. The fast flowing water has great erosive powers, particularly after rains, being able to move large stones and roll them along. Angular stones washed into the river are rubbed against one another, to form rounded pebbles.

ii) **The middle course :** The middle course of the river occurs over the foothill belt where the velocity of water is comparatively less which moves a little slowly. However, the waters are still fast enough to transport sand, silt and mud in suspension, and to roll pebbles along its bed. In this part of the river course, the valley is broad with stable sides, so that the river cannot erode the land, as much as it does in the mountain course. Most of the transportation of silt is achieved by this part of the river.

iii) **The lower course :** The lower course of the river occurs in the plains, across which it meanders or zigzags slowly. The river here loses much of its velocity and thus much of its ability to carry heavier sand and silt in suspension. It, therefore, deposits part of its silt load as sand banks or shingle beaches and builds up large flat plains by spreading alluvium over a wide flood plain or delta.

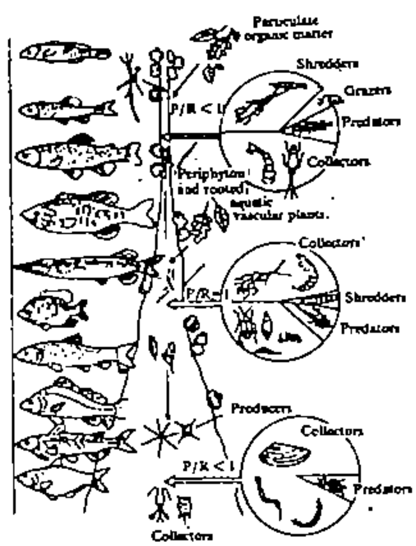


Fig. 8.12 : The lotic ecosystem classified on the basis of fish species found in different zones.

B) Classification of the river zones on the basis of presence of certain fish species

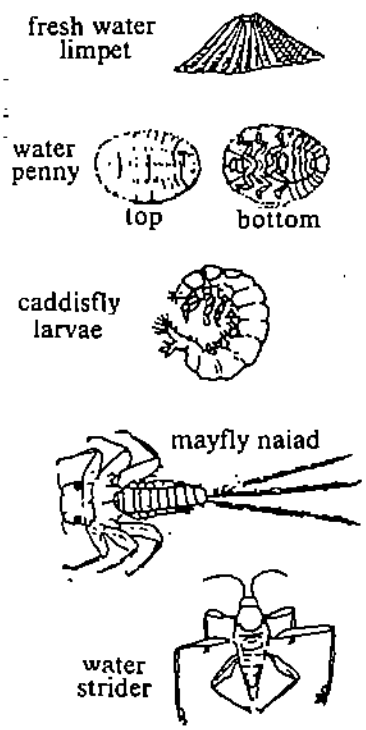
A river is classified by this method into four zones (Fig.8.12).

i) **Head stream of Highland brook zone :** This is formed by a number of small streams, which originate from a marsh, a spring or a glacier. This is a small shallow zone with an irregular course. It is formed after torrential rain with no pools and has a low water temperature. The only plant life forms are mosses or liverworts. Fish are absent in this zone.

ii) **Trout beck zone :** This is larger and more constant than the head stream. The greater volume of torrential water carves channels into exposed rock floor (bed rock). Compared to the head stream the water is deeper and current more rapid and is capable of carrying matter in suspension. A typical trout beck has a steep slope gradient and its sides are lined with coarse pebbles and rough boulders. It deposits grit in the sheltered part of the course where flow is less. There is little plant growth in the trout beck zone due to the presence of strong current and rocky conditions here. The water in this zone is oxygen-saturated and cold. Areas of fast water alternate with irregular pools. The fish occurring here are the powerful swimming brown trout, the miller's thumb and the stone loach.

iii) **The mirrow reach or grayling zone :** This zone has a less steep gradient, than the trout beck. The river here still flows swiftly, though the current is not fast and conditions are not torrential. Erosion is thus comparatively less. Some silt may be deposited in the quieter-flowing areas. In areas with moderate currents filamentous algae may grow in summers. Other plants can gain a foothold where silt is deposited with further silt accumulating among their roots. The presence of these quiet areas with water plants is characteristic of this stretch. The water is still well oxygenated though its temperature is more variable. Areas of fast flowing water or riffles now alternate more regularly with long pools. Fish characteristic of this zone are mirrow and in some regions grayling. The fish of the trout beck zone are also found here and so is the eel and in some rivers young offspring of salmon.

iv) **Coarse fish reach or lowland course zone :** This zone corresponds to the lower course of the river. Here the river is deep and slow moving. Its sluggish flow results in the deposition of silt forming muddy bottom on which many hydrophytes can grow. In this zone compared to other zones, the oxygen content is less and the temperature is more variable. Although some of the fish, characteristic of the upper reaches of the river may be present in this zone, but conditions here are not suitable for them to complete their life cycle successfully. For example, salmon and trout require silt-free gravel in which to lay their eggs and cold, well oxygenated water for their young offspring. Conditions are now more suitable for other fish species such as cyprinids, the roach, the chub and the bream. These fishes can tolerate low concentration of dissolved oxygen and higher water temperature and need water plants on which they can lay their eggs. In the lowest reaches of a river running into an estuary the sea occurs to flow under, during the summer months.



Some organisms occuring in rapidly flowing water.

Fig. 8.13 : Some organisms. occurring in rapidly flowing waters

The courses described above do not occur in all rivers. The first zone depends obviously on the existence of fairly high hills, not permeable to water such as the chalk hills or the later zones may be absent in some cases, while in others a torrential zone may run into the sea with no slackening of current.

8.4.2 Biota of Rivers

The biota of both the rapidly flowing and the slowly flowing sections of the river are very distinct and so studied separately. Let us study the biota characteristic of each habitat.

i) **RAPIDLY FLOWING WATERS**

In the rapidly flowing section of the river, the water current is the dominant feature. Everything that is not attached or weighed is swept away, including organisms and sediments alike. The substratum tends to be either gravel or rock whose fragments are smoothed and rounded by the water. The habitat itself is diverse, as different microhabitats occur here — a) on the surface of rock fragments b) between rock fragments and c) beneath rock fragments.

The differences in these microhabitats are due to the differences in the force of water currents occurring in each of them. As a result each microhabitat houses different types of organisms.

a) **Animals :** In the exposed rock surface habitats only those organisms are found which have an efficient mechanisms for staying in one place. In fact despite adaptations for staying put, many individuals of species do get swept away

Animals found here (Fig.8.13) include fresh water limpet, larvae or water penny (riffle beetles), fresh water sponges and caddis flies, all specially adapted to this environment.

The microhabitat formed in the spaces between rock fragments is slightly sheltered. Here occur the stone fly and dragonfly both of which are flattened and have behavioural adaptations to hold them in place.(i.e. clinging by instinct to hard surface and orienting themselves along the current). In addition to these, the larvae of insect hellgramite is found here, which avoid being swept away by being large and covered with spines.

In the Microhabitat beneath rocks, where current is weak, occur animals which though they have basic adaptations for staying in the rapidly flowing water, are not as highly adapted as members of the two other microhabitats. Animals found here are annelids, flatworms, clams, some snail species and other insect larvae

In the rapidly flowing habitat, nekton occur only in areas where current is not too strong and include cold water fish species such as trout or salmon. In areas where the current is very strong nekton are absent and in such cases, the benthos may be many and varied and may form the entire community.

b) **Plants :** Among the plants only small, well attached forms, such as sessile algae can survive here. Thus, due to the presence of only a few plants, the nutrient base for animals here is organic detritus washed into the river from the drainage area.

ii) SLOW MOVING WATERS

The habitat of a slowly moving part of the river is very different from the one just described. Here the water flow is comparatively slow and so current is less. As a result the erosive power of the water is greatly reduced, resulting in the deposition of smaller sediments on the bottom, instead of being carried away by the stream. The organisms due to changed habitats are also different (Fig.8.14) and are as follows:

a) **Animals :** Zooplankton are common here and include an assemblage of protozoa and smaller crustacean, such as water flies, and copepods. Neuston occurring here are several insects such as water striders, water boatman, backswimmers and predaceous diving beetles, all of which spend most of their time at the surface of the stream. The nekton are numerous and include large crustaceans like the fresh water shrimp and many types of insects and fishes such as carp and catfish all of which are different species from those of the fast water regions. The benthos here include the snowbugs, mayfly naiads and dragonfly naiads which occur on the surface of the benthic region and the tubeworms, naiads of burrowing mayflies and rotifers which bury into it.

b) **Plants :** Plant life is abundant in this habitat and includes rooted vascular plants such as pond weeds and grasses, firmly attached aquatic mosses and multicellular filamentous algae. Minute floating plants such as duck weeds may cover most of the surface of the slow moving streams especially in the slowest backwaters. Motile algae, such as diatoms and flagaellates may abound in the open water.

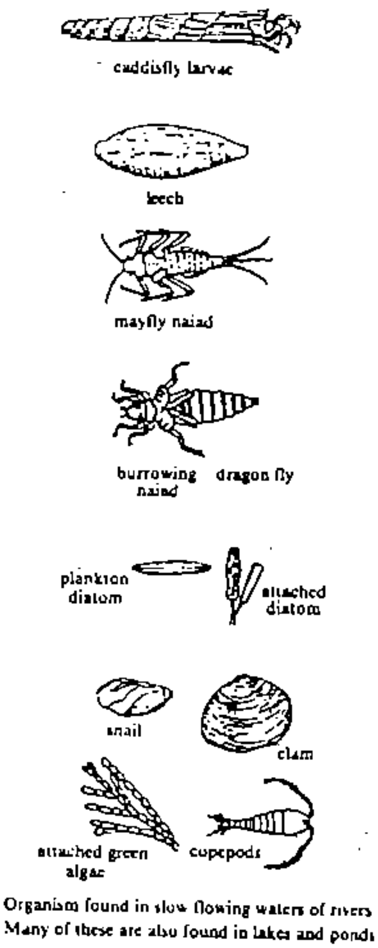


Fig. 8.14 : Some organisms found in slow flowing river. Many of them are also found in lakes and ponds

As plants are more in this habitat the productivity is comparatively higher than that of the rapid waters and so the community here is relatively less dependent on nutrients from outside.

While in the fast-water streams the main controlling factor is the current, in the slow-water streams the main limiting factor is the concentration of dissolved oxygen. In this ecosystem a large quantity of oxygen can be withdrawn by the high level of animal activity coupled with active detritus food chain. In addition, the low level of turbulence means that less oxygen is incorporated into the water at the surface. Thus, the concentration of dissolved oxygen in a slow moving stream can be substantially less than saturation and so the community must be much more tolerant of low oxygen conditions as a result. For example the salmon and trout occurring in fast water need high oxygen levels while the most common fishes of slow water are often low oxygen concentration tolerant species such as carp and catfish.

SAQ 3

i) Tick mark (✓) the correct statements and cross mark (×) the incorrect statements :

a) In the rapidly flowing water, those animals are found which have efficient mechanisms for staying put.

b) Slow moving waters, have much greater diversity of neuston and nekton than rapidly flowing waters.

c) The main factor limiting the growth of organisms in slow moving waters is concentration of dissolved oxygen.

d) The basic function of rivers is to convey surplus rain water from the land to sea.

ii) Fill in the blank spaces using appropriate words :

a) Based on the presence of certain *fish species* river ecosystems have been categorised into .... zones. On the basis of their **physical characteristics** they have been divided into ....courses.

b) In fast moving waters the limiting factor is the speed of water ....

c) Compared to static water bodies, the water level of the rivers exhibits a .... range of fluctuations.

d) Rivers, in comparison to lakes, depend more on surrounding........................ for nutrients.

8.5 MARINE ECOSYSTEMS

Marine ecosystems cover 70 per cent of the earth's surface and have an average depth of 3,750 m (the greatest known depth being 10,750 metres in the Marianas Trench). Marine ecosystem as you know is one of the largest reservoirs of water, living things and essential nutrients needed by both the marine and land organisms. The total biomass in the marine ecosystems far exceeds that of all fresh water ecosystems put together.

8.5.1 Salient Features of Marine Ecosystems

Marine ecosystems are of great ecological significance and have certain salient features which we have briefly elaborated below :

Physico-chemical factors

1) **Salinity** : The sea is salty and its salinity is fairly constant, averaging about 3.5 per cent usually written as 35 (parts per thousand). Sodium chloride is the main salt being 27 per cent while the rest are calcium, potassium and magnesium salts. Odum (1971) gives the following percentage of thousands/kg. as shown in Table I.

Table 8.1 : Chemistry of the Sea Water

Positive ions (cations)		Negative ions (anions)	
Sodium	10.7	Chloride	19.3
Magnesium	1.3	Sulphur	2.7
Calcium	0.4	Bicarbonate	0.1
Potassium		Carbonate	0.007
		Bromide	0.07

2) **Light** is a limiting factor in the ocean as it contributes significantly to organic production and distribution of marine life. The ocean is divisible as shown in (Fig. 8.16) on the basis of the light penetration into two horizontal zones :

i) The lighted **photic** or **euphotic zone** extending from the sea surface up to a depth of 200 metres, where sufficient light reaches to support photosynthesis. This photic zone, also called the epipelagic one, is characterised by sharp gradients or light, temperature and salinity. The amount of light reaching the lower level of this zone rarely exceeds 0.0001% of what is received at the surface. Below this is the

ii) **aphotic** or lightless zone which distinguishable into three further sub-zones (a) *mesopelagic* which extends from 200 metres to 1,000 metres. This zone is in semi-darkness as very little light penetrates it. Here temperature gradient is more even and gradual, without much seasonal variation. Further this zone contains a minimum of oxygen and a maximum of nitrates and phosphates.

Next is the (b) *bathypelagic* zone which extends from 1,000 metres to 2,000 metres and where darkness is virtually complete, for humans though some fishes and crustacean do respond to dim light.

The third and the lower most zone is the (c) *abyssopelagic* zone where permanent darkness prevails and where temperature is uniform at 3°C and hydrostatic pressure is enormous.

3) **Temperature** like salinity remains almost constant in the oceans in contrast to the land or terrestrial ecosystems ranging from about 2°C in the polar seas to 32°C or more in the tropics. The annual variation in any part of the sea is usually not more than 6°C.

4) **Concentration of Nutrients :** The marine environment is low in concentrations of dissolved nutrients, which since they occur in very little amount are measured in parts per billions (ppb) in contrast to salts, such as sodium chloride which is measured in parts per thousand (ppt). This low quantity of nutrients acts as a major limiting factor in determining the size of marine populations (see Table8.1)

5) **Dissolved Gases :** The marine environment serves as a gigantic reservoir of dissolved oxygen and carbon dioxide, which respectively help regulate the composition of the air we breathe and the temperature of the atmosphere.

6) **Alkalinity :** The sea is alkaline, as the electrical dissociation force of cations exceeds that of anions. Further it is buffered and has a pH of 8.2 normally, and so resists changes in pH.

7) **Pressure :** Water pressure increases with depth which varies in the ocean from 1 atmosphere at the surface to 1000 atmosphere at the greatest depth. Pressure changes in the sea are several times greater than those on land and so have a pronounced effect on the distribution of life. Since organisms are limited to surface waters, where pressure is not so great, others are adapted to life at greater depths.

8) **Continuity :** The sea is a continuous body of water. All the oceans : Pacific, Indian, Arctic and Antarctic are connected together. However, temperature, salinity and depth seem to act as barrier to free movement of marine organisms.

9) **Depth :** The sea is very deep varying in different regions. Generally life extends to all depths but is confined more to the continental shelf and islands.

10) **Currents :** The sea is in continuous circulation by means of currents. These may be either, wind driven surface currents of deeper currents, resulting from variations in temperature and salinity.

11) **Waves and tides :** The sea is dominated by several kinds of waves and tides, which are produced by the pull of moon and sun.

12) **Circulation of nutrients in the coastal zone :** Circulation of nutrients from the sea bottom to the upper surface, occurs in the coastal regions by two processes (i) upwellings — where the winds cause the surface waters to be blown offshore, which are replaced then by the cold nutrients rich waters from the deep (Fig.8.15) (ii) outwellings — where the sea is enriched by nutrient rich estuarine waters entering it.

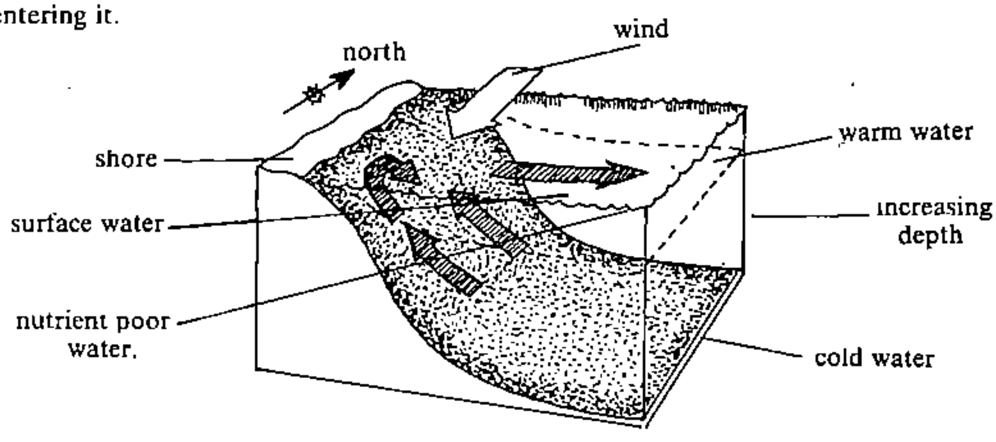


Fig. 8.15 : Coastal upwellings in Northern Hemisphere. During upwelling the sea water rich in nutrients moves above the nutrient poor upper surface waters. The circulation of nutrients along the coast favours dramatically the number of producers and then consumers. Thus, the regions of upwellings are full of marine organisms.

Organisation of the Marine Ecosystems

You have read in Unit 15 of Block 4 of the Foundation Course in cience and Technology that oceans like lakes, exihibit zonations. We will first describe the various zones or regions of the oceans and then later deal with the biota occurring in them.

The marine habitat is distinguishable into two different zones (1) Benthic zone — which forms the basin or floor of the ocean, regardless of depth (2) Pelagic zone — which represents the free water zone, filling the basin see (Fig.8.16).

i) **Benthic Zone :** The benthic zone is divisible into sub zones horizontally. These are depicted in a cross section portion of the marine habitat, adjacent to a continent in Fig.8.16.

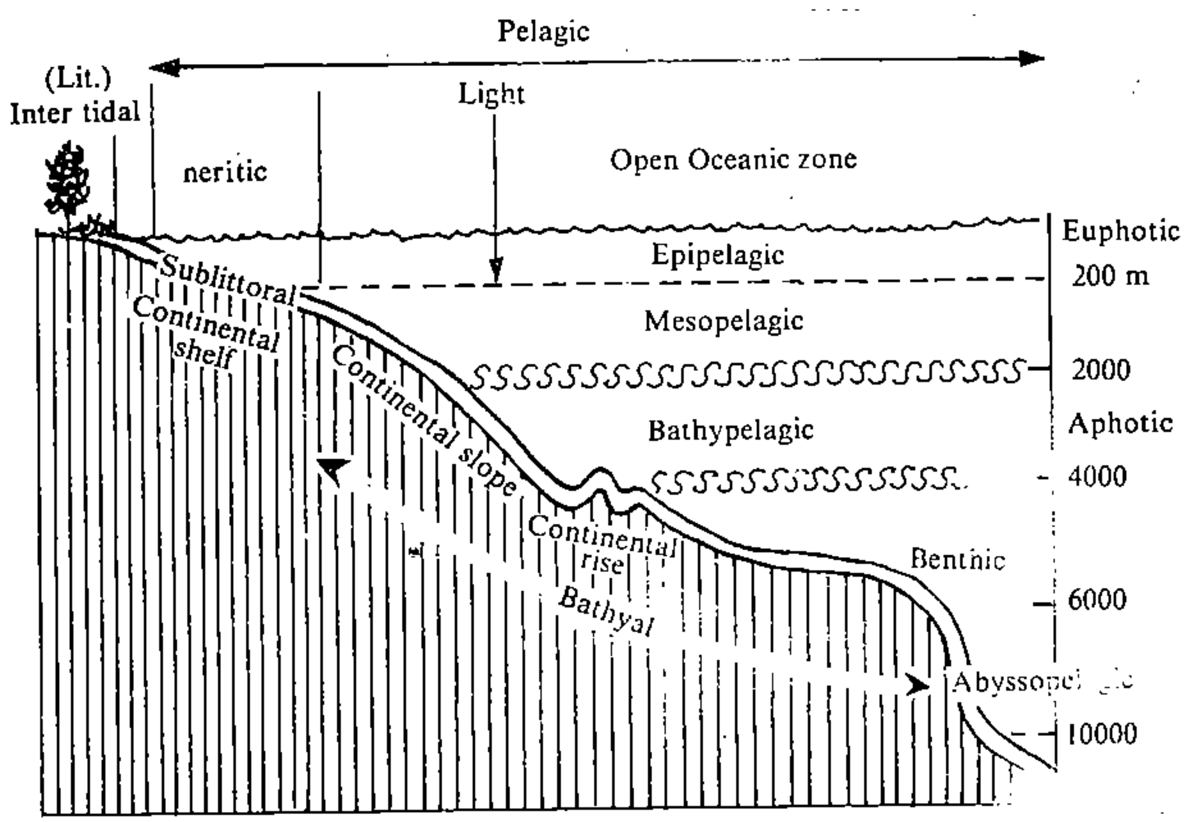


Fig. 8.16 : Organisation of the Marine Ecosystem

The shape of the benthic zone is roughly the form of an inverted hat. The upper most portion is called the (i) supra littoral zone, comprising the beach down to the edge of the ocean. Beyond this is the (ii) littoral zone which represents the area between the upper and lower tide levels and is, therefore, also known as intertidal zone. Littoral zone is the shore of the ocean. Next to this is the (iii) sublittoral or continental shelf which extends from the littoral zone to the beginning of the continental slope. The continental shelf is the underwater extension of the continent and extends to a depth of 125 to 200 metres. After the continental shelf, a rapid descent occurs and this is called the (iv) continental slope. The continental slope after some distance forming the (v) continental rise which may be geologically active. This region has canyons and trenches which are subject to underwater eruptions and avalanches. The region of the continental slope and rise together comprise the bathyal zone. The bathyal zone which is 200 metres deep descends rapidly to a depth of 3,000 or 4,000 m. From this the bottom drops for further several thousand metres and levels off around 6,000 m to form the broad flat (vi) abyssal plains where temperature is never above 4°C.

Pelagic Zone : The waters contained in the sea basin, constitute the pelagic zone (Fig.8.16) which is divided into (i) the neritic zone situated above the sublittoral zone or the continental shelf starting from the edge of the littoral sea and extending up to the edge of the continental shelf, to a depth of 200 m. Beyond this is the (ii) deep, open sea of the oceanic zone which is divided on the basis of light penetration as discussed in earlier sections the physico-chemical property of light of the oceans.

The upper illuminated zone of the open ocean is also called epipelagic zone. So the euphotic pelagic ocean is named a epipelagic one. The aphotic pelagic province has been divided into the following three horizontal zones : mesopelagic, bathypelagic and the abyssopelagic zone. There is no light in the bathypelagic and abyssopelagic zones. The mesopelagic zone is comparatively less dark but light is not sufficient to carry out photosynthesis.

8.5.3 Biota of Oceans

Life in the sea is not particularly abundant, though the diversity of organisms is very high (Fig.8.17). Almost every major group of animals and every major group of algae occur somewhere in the oceans, with the exception of vascular plants and insects. These two have a few marine representatives though they are abundant in estuaries. On the basis of depth-wise differences in life forms, the expanse of marine ecosystems has been divided into littoral, neritic, pelagic and benthic zones. Let us now read about biota of each one of these.

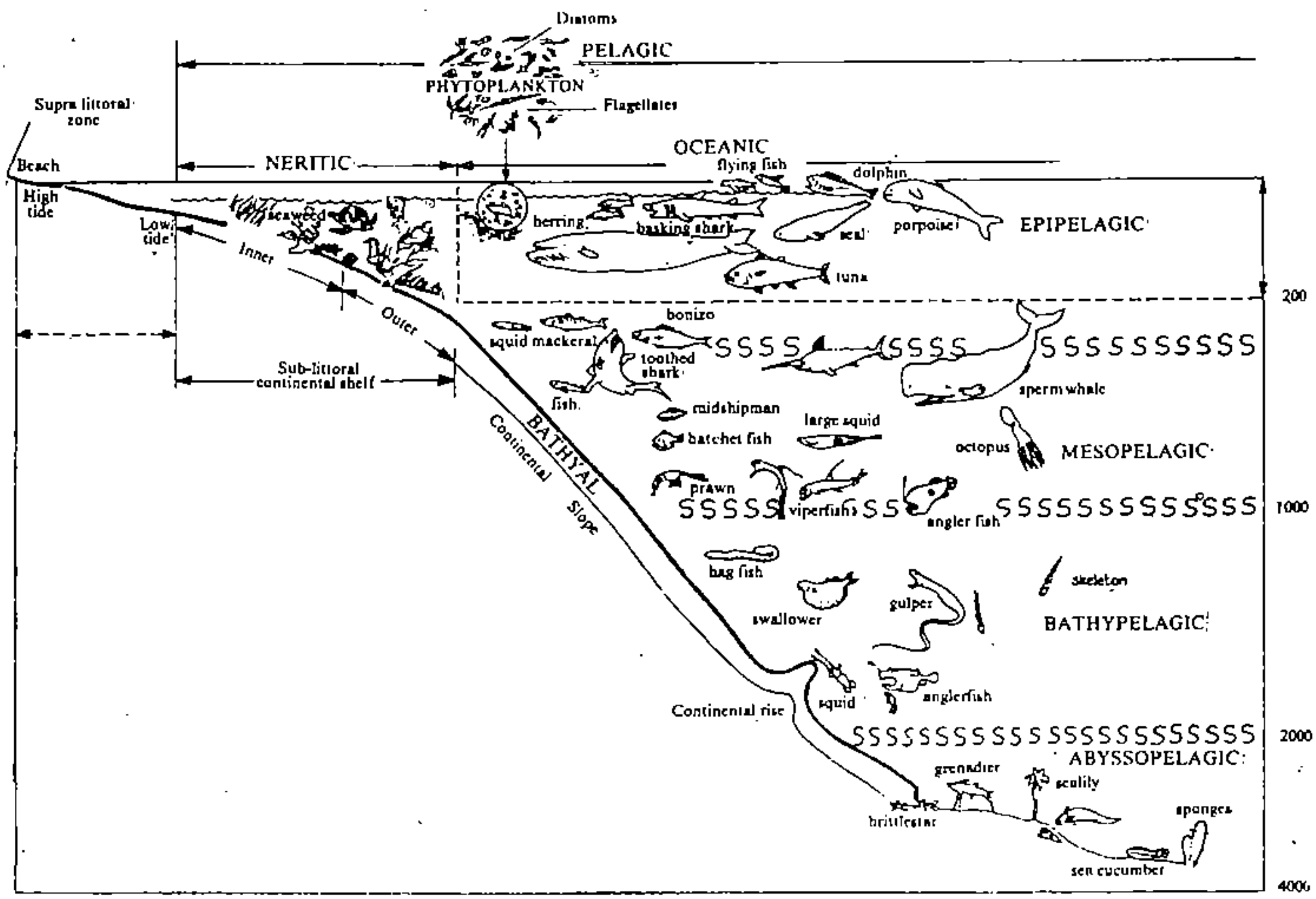


Fig. 8.17 : Representatives biota of marine ecosystem occurring in each zone or region (organisms not drawn to scale)

i) **Biota of Littoral Zone :** This zone is the shore region of the marine ecosystems and is subject to violence of waves and tides, fluctuation of water level and variability of temperature, light, salinity and moisture. In common language supra littoral zone is termed as a beach. Considerable light penetrates the bottom of this zone which is exposed and submerged twice a day except for tide pools. Thus, animals living here exist in a difficult environment and so must be either resistant to periodic drying or able to burrow to water level. This zone is thus also called intertidal zone.

This intertidal zone or the littoral zone is a region of high productivity with a simple community, many of whose members may be exceedingly abundant.

There is no typical littoral zone, there are two types of beaches ; a rocky intertidal beach (Fig.8.18a) is different from a sandy beach or a mud flats (Fig.8.18b). However, all have certain things in common. The wave action is stronger here than anywhere else in the sea. The turbidity is high and the substrate erodes rapidly. There are few species of plants. Those that occur are attached securely to the substrate and may be present in large numbers. The energy requirements of the animal community here depends on the large amount of detritus washed in by the waves. Common animals found here are snails, clams, barnacles, crustaceans, annelids sea anemones and sea urchine. The animals here exhibit zonation with respect to tides — (Fig.8.18) Animals more resistant to desiccation usually occurring at higher levels than those that are less resistant.

ii) **Biota of the Neritic Oceanic Zone :** This zone constitutes 75 per cent of the total oceanic area and is relatively rich in species and high in productivity owing to factors such as penetration of light to considerable depths and high concentrations of nutrients (Fig.8.17).

Communities in this region are both richer and more diverse compared to those of the open ocean (Fig.8.17). No other region has such a variety of life, not even the tropical rain forests. The most productive phytoplanktons are the dinoflagellates and diatoms, though red, brown and green algae attached to the bottom in the shallow regions may be significant. The zooplanktons are usually similar to those of the pelagic zone though some purely open-sea species are replaced by neritic species. Temporary zooplanktons are more numerous here than in the open sea.

Nekton in the ocean over neritic zone or the continental shelf are diverse and commonly known, for they include almost all commercial species as well as whales, seals, sea-otters, sea snakes and large squids. Fishes are numerous and include several shark species as well as herring-like species (sardine, herring) cods and their relatives (haddock and pollack), sea trout and salmon, flat fish (sole, halibut) and mackerals including tuna and bonito.

The benthic part of the neritic zone is called the sublittoral zone which has a wide variety of animals among which are clams, shrimps, snails, lobsters, crabs, sea cucumber, starfish, brittle stars, anemones, sponges, bryozoa, annelids and foraminifera. These animals exhibit more diversity than those of the deeper waters, since the physical factors here are more variable. The bottom may be rocky, sandy or muddy and the temperature difference in the sublittoral zone of this region is greater as compared to the deeper ecosystems. The difference in the physical environment is reflected in the benthic community occurring here.

iii) **Biota of Pelagic Zone :** Pelagic region constitutes 90 per cent of the total ocean surface and is less rich in species and numbers of organisms than the two regions discussed before (Fig.8.17). The species of this zone are characteristic. The environment due to the continuity of the sea waters is uniform and stable for the organisms occurring here.

The most abundant pelagic phytoplanktons are still the dinoflagellates and diatoms which are the chief photosynthetic feeders, other are carnivores. Detritus feeders such as sea lillies rise above the sea floor while clams and tubeworms remain burrowed in mud. Sea cucumbers and sea urchins crawl on the floor eating detritus and bacteria and serve as food for the carnivorous brittle stars and crabs.

SAQ 4

i) State whether the following statements are true or false :

a) The total biomass in the marine ecosystems far exceeds that of all the fresh water ecosystems put together.

b) The fresh water ecosystems have salt content less than 5 ppt, the marine waters more than 35 ppt and brackish water ecosystems between 5 to 35 ppt.

c) Nutrients other than sodium chloride are found in very low concentrations in the marine ecosystems.

d) Oceans are the main reservoir of air and are solely responsible for the composition of air on this planet.

ii) Fill in the blank spaces using appropriate words :

a) The benthic zone which looks like an inverted hat consists of six horizontal divisions, (i) the .... zone, (ii) the .... zone, (iii) the .... zone, or the continental shelf, (iv) the .... and (v) the .... zone. (iv) and (v) together are classified as .... zone which starts from a depth of 200 m and descends rapidly to depth of .... m. This is followed by a flat broad zone called as the (vi) .... where temperature is always .... 4°C or below.

b) The oceanic one is vertically divided into four zones, namely, (i) the .... or the euphotic one, (ii) the .... (iii) the .... and (iv) the .... zone. Zone (ii), (iii) and (iv) together are classified as aphotic zone.

iii) Match the zones of ocean given in column A with their characteristics given in column B

Column A	Column B
1) Littoral zone	a) are dark zones. There exist occasional flash of light from lumniscent fish which are regular inhabitants of this zone.
2) Nekton of the neritic zone	b) there are no phytoplankton; animals below this are either carnivores or detritus feeders.
3) Nekton of the pelagic zone	c) is the region of high productivity with a simple community, many of whose members may be exceedingly abundant.
4) Below the epipelagic zone	d) consists of largest animals in the open sea, bony fishes, sharks and whales.
5) Bathypelagic as well as abyssopelagic zone	e) include almost all commercial species of fish.

8.6 ESTUARIES

All the rivers and lakes ultimately drain into the sea. However, many rivers develop a highly specialised zone before joining the proper sea. This zone is called estuary. An estuary is a transitional zone between rivers and sea representing an ecotone possessing unique ecological features and biotic communities. Estuaries are the most productive ecosystems of the world. An estuary is semi-enclosed part of the coastal ocean containing brackish water that has free connection with the sea on one side and on the other side it is connected with a river mouth and receives fresh water. In India, estuaries can be seen in plenty along the coast of Kerala.

8.6.1 Features of Estuaries

The physico-chemical properties of the estuaries have large variation in several parameters and this often creates stressful environment for organisms. This is the one cause that large organisms are less in number in this area than smaller organisms.

The most dominant feature of the estuarine environment is the fluctuation in salinity. Though salinity gradient exists sometime in an estuary but the pattern of gradient varies seasonally, with the topography, with the tides and with the amount of fresh water.

The estuaries are dominated by muddy substrates, which are often very soft. The deposition of particles is also controlled by currents and size of particle. If the strong currents prevail, the substrate will be coarse (sand) whereas where waters are calm and the currents are weak only fine silt will settle out. These particle in the estuary are of many organic origin derived from both the terrestrial and marine movements. As a result, the accumulated substrate is very rich.

Another important variable is temperature. The temperature of estuary keeps on fluctuating, it heats up and cools down more rapidly under prevailing atmospheric conditions. Another reason for this variation is fresh water input. Temperature also varies vertically. The surface waters have the greatest temperature range and the deeper waters the smallest.

All the variation i.e. the salinity, the texture of substrate, temperature, organic matter content and available oxygen are controlled by wave action and currents. The wave action in the estuaries is small. As a result there is deposition of fine sediments and development of rooted plants.

Currents in estuaries are caused primarily by tidal action and river flow. Currents are generally confined to channels, but velocities upto several knots can occur. The highest velocities occur in the middle whereas in the bottom and side bank the velocity is lowest. The erosion and deposition in the estuaries are due to currents which is a natural cycle. However, in estuaries deposition exceeds erosion so there is a net accumulation of silt. During dry part of the year, water movement is severely reduced, leading to stagnation, reduced oxygen content, formation of algal blooms and incidence of fish kills.

The water of estuaries is turbid because of the great number of particulates in suspension in the water. The turbidity is minimum near the mouth and increases with distance inland. The major ecological effect of turbidity is a marked decrease in the penetration of light. This, in turn, decreases photosynthesis by phytoplankton and benthic plants, thereby reducing productivity. One of the most important factors in estuary water is oxygen. Since the solubility of oxygen in water decreases with increased temperature and salinity, the precise amount of oxygen in water varies with these parameters. Oxygen is severely depleted in the substrate. The high organic content and high bacterial population of the sediments exert a large oxygen demand on water. Estuarine sediments are, therefore, anoxic below the first few centimetres unless they have large particle size and/or large number of burrowing animals such as ghost shrimp **Callianassa** and the hemichordate worm **Balanoglossus** which by their activities oxygenate lower sediment layers.

8.6.2 Biota of Estuaries

The estuarine community is a mixture of three components : Marine, Fresh water and Brackish water, but overall estuarine diversity is still lower than that of the river or marine community. This is because of tremendous variation in the estuary's physical environment. Thus, the great productivity of estuaries is built on a narrow base.

The plants of the estuary are of four basic types : i) Phytoplankton, ii) marginal marsh vegetation, iii) mud-flat algae and iv) epiphytic plants growing on the marginal marsh vegetation. Because of the turbidity in water, phytoplankton are normally uncommon. However, great blooms of certain algae are well known which include *Spartina* and *Salicornia*. Most of the estuarine algae are of marine origin common genera include *Ulva, Enteromorpha, Chaetomorpha* and *Cladophora*. These are often seasonally abundant, disappearing during certain seasons.

The obvious estuarine plants are the marginal and marsh vegetation. These include mangroves and marsh grasses and marsh submerged filamentous colonial green algae. A few animal-feed on them directly but a large proportion is consumed as detritus. The mud-flats which are uncovered at low tide may be sites of intense photosynthesis by diatoms and filamentous blue-green algae. The brown colour of a mud-flat may be due as much to number of diatoms as to the presence of organic material in the mud.

The animals of estuaries and related wetlands such as marshes and swamps are tremendously important not only as denizens of their environment but also for their role in marine communities and in human economies. The best known estuarine animals are detritus feeders such as oysters, clams, lobsters and crabs. Several insect larvae, annelid worms and mollusks enter the estuary from fresh water, most nearshore marine zooplankton can also be found partway into the estuary along with several types of larger animals. Most important of all this is that estuaries are the nursery ground for a vast number of marine animals ranging from shrimps and crabs to fishes.

The presence of high nutrient level in the estuaries results in a very high level of production within the detritus food chain. Nutrient matter is broken down by bacteria at a very high rate, and recycled into soluble form. Plants adapted to the difficult conditions of salinity found in the estuary can maintain a high level of productivity The amount of nutrient rich organic detritus also allow a high level of productivity for detritus eating animals.

The estuarine ecosystem is complex and significant. It is also vulnerable since estuaries have served as conduits for shipping and as sites for cities throughout human history. Estuaries are inhabited by animals that are adapted to a changeable environment, to be sure, but their strategic location has led to a substantially greater degree of human alterations than in any other ecosystem. Many people look upon estuaries as area whose greatest value is to be filled and built upon, or to serve as dumping grounds for garbage, sewage and industrial wastes. This is not true and their tremendous productivity can be made to serve as a food source for people — indeed, it is already a very important food source in the far East — and almost all the major marine fisheries of the world are totally dependent on the estuaries for their continuance, because the adult fishes often resort to estuaries for laying eggs, i.e., spawning.

SAQ 5

i) State whether the following statements are true or false :

a) The estuaries are characterised by high salt content in their substratum.

b) The estuaries do not support large organisms.

c) The estuaries are the most productive ecosystem of the biosphere.

d) Estuaries are a nursery ground for a large number of fishes.

ii) Fill in the blank spaces using appropriate words :

a) There are four categories of plants that are found in estuaries : (i) the .... (ii) the .... (iii) the .... and (iv) .... plants.

b) Estuaries are a .... and complex ecosystem as their ecology is likely to get easily imbalanced by human activities.

8.7 SUMMARY

- Ecosystems consisting of water as the main habitat are known as aquatic ecosystems. There are three kinds of aquatic ecosystems — fresh water, saline and brackish water ecosystems.
- Fresh waters are again of two types. The static water ecosystems are called as lentic systems and are exemplified by various lakes impoundments and wetlands. The lotic systems are characterised by flowing water and are exemplified by rivers.
- Eutrophic lakes are age old lakes with, rich nutrient content, low dissolved oxygen, shallow margines and high productivity. Oligotrophic lakes are deep, less warm, low in oxygen content and low in productivity.
- Rivers are main channels which supply surplus rainwater from land to sea. Each river has a slow moving and a fast moving zone. In slow moving one main factor limiting the growth of organisms is the availability of dissolved oxygen. In the fast moving waters the speed of water current is the main factor limiting the growth.

- Saline ecosystems comprise all the oceans of the world and contain a major portion of the total biomass of the earth. Oceans are also the main reservoir of air and water vapour in the atmosphere.
- Estuaries are examples of brackish water ecosystems. Their salt content varies between 5 to 35 ppt. They are the most productive ecosystems of the world. They are also the most delicately balanced ecological systems, because the factors governing the functions of estuarine ecosystems are intricately dependent upon each other. One should be careful before deciding to dump garbage, sewage or industrial wastes into such ecosystems.

8.8 TERMINAL QUESTIONS

1) Why tropical lakes do not show a pronounced thermal stratification during summers
2) How are impoundments different from lake? What are their similarities?
3) What is the difference between lentic and lotic ecosystems?
4) How is a river different from a lake?
5) What are the six features based on which oligotrophic lakes can be compared with eutrophic lakes?
6) Name the important physico-chemical factors affecting marine ecosystems.

8.9 ANSWERS

Answers to Self-assessment Questions

SAQ 1

i) a) T b) T c) T d) T

ii) a e
b d
c a
d c
e b

SAQ 2

i) a) epilimnion, metalimnion, hypolimnion
b) compensation point
c) littoral, open-water and benthic
d) six
e) limnetic, profoundal

ii) a) T b) T c) T d) T

SAQ 3

i) a) √ b) √ c) √ d) √

ii) a) four, three
b) current
c) wide
d) land

SAQ 4

i) a) T b) T c) T d) T

ii) a) i) supra littoral, ii) littoral, iii) sublittoral, iv) continental slope, v) continental rise, bathyal, 6,000 m vi) abyssal plain

b) i) epipelagic, ii) mesopelagic, iii) bathypelagic, iv) abyssopelagic

iii) 1 c
2 e
3 d
4 b
5 a

SAQ 5

i) a) T b) T c) T d) T

ii) a) i) phytoplankton, ii) marginal marsh vegetation
iii) mud-flat algae, iv) epiphytic.

b) vulnerable

Answers to Terminal Questions

1) Thermal stratification means distribution of water layers with respect to temperature gradient. If, however, the layers having different temperatures get mixed up, the lake will be left with no gradient. In case of tropical lakes the rate of mixing of layers is very fast, except in very deep lakes.

2) Impoundments are small or large reservoirs of water artificially created by man. Lakes are water bodies arising from natural causes such as warps or folds in rocks.

3) Both lotic and lentic systems are aquatic ecosystems. Stationary water systems are called as lentic ecosystems, such as a lake, whereas running water systems are called lotic ecosystems, such as a river.

4) Rivers are open heterotrophic systems, whereas lakes are closed, self contained systems. Nutrients in a lake may be reused several times, whereas, in a river plants and animals must avail of temporarily available nutrients, which are most likely to be used only once.

5) The six features based on which oligotrophic lakes are compared with eutrophic lakes are : depth/surface-area ratio, nutrient status, primary poduction, species diversity, oxygen content and transparency of water body.

6) The twelve physico-chemical factors effecting marine ecosystems are : salinity, light, temperature, concentration of nutrients, dissolved gases, alkalinity, pressure, continuity of oceans, depth of the sea, sea currents, tidal waves and circulation nutrients in the coastal zone.

GLOSSARY

abiotic : nonliving organisms

abyssal : deep water, i.e., approximately below 1,000 metres

alluvium : deposits of finely divided material (such as grit, silt and shingle) left by flood

benthic : on or near the bottom of an ocean or lake

biomass : weight of living material

biota : the organisms of an area

biotic : pertaining to life

calorie : the quantity of heat required to raise the temperature of 1 gram of water through 1° celsius

carnivore : animals which feed on other animals

climbers : climbing plants

consumer : organism that ingest organic food or other organisms as a food source

decomposer : organisms such as bacteria, fungi and maggots, etc. that obtain energy from breakdown of dead organic matter and convert them into more simple substances

deforestation : removal of forest

detritus : fresh or decaying organic matter of plant and animal origin

dunes : low stretch of loess, dryland formed by wind

ecological pyramid : a triangular graphic form showing number of individuals, biomass, or available energy at successive trophic levels in the ecosystem

ecosystem : the biotic community and its non-living environment as an interacting system. A functional unit of nature

ecotone : a zone of integration between ecological communities

estuary : a coastal ecosystem where fresh water meets salt water specially the wide mouth of a river, where the tide meets the current

faulting : discontinuity in a solid material such as a rock

food chain : a sequence of organisms each of which feeds on the preceding one

food web : the complex interlocking pattern of food chains in a biotic community

grit : particles of coarse sand

gross primary production (GPP) : the total amount of solar energy fixed by plants through photosynthesis over a unit area (or volume) and time. It is also called gross production

habitat : place where a plant or animal lives

herbivore : organism that feeds on plants

heterotroph : an organism which depends on organic matter for food or as a source of energy

homeostasis : the capacity of ecosystem to resist changes due to disturbances or to return to balance state

humus : dark amorphous colloidal material derived from partial decay of organic debris

mangrove vegetation : common name for species of inshore tropical trees or shrubs that dominate estuarine association

nutrient : a chemical substance that contributes to the growth of an organism

prairie : wide area of level land with grass but no trees

primary production : the energy accumulated and stored by plants through photosynthesis

producer : organisms that convert light energy from the sun into chemical bond energy. Green plants are the producers

productivity : the rate of production of organic matter per unit area in a community

riffle : to make special grooves in water course

savanna : grassy plain with few or no trees in tropical and sub-tropical regions

shingle : pebbles

silt : a type of soil with particle size and properties intermediate between sand and clay

solar radiation : any radiation from sun, for example high energy, ultraviolet, visible or long wavelength radiation

standing crop : biomass present at a given time in a specified area

steppes : level grassy plain devoid of forest

trophic level : functional classification of organisms in an ecosystem according to feeding relationship from first trophic level through succeeding levels of herbivores, carnivores, etc.

warp : a gentle fold in rock

Suggested Reading

1) *A Textbook of Plant Ecology,* R.S. Ambasht, Dev Jyoti Press, Varanasi, 1976.
2) *Basic Ecology,* E.P. Odum. Holt-Sauders, Japan, 1983.
3) *Communities and Ecosystem,* R.H. Whittaker, Macmillan, New York, 1975
4) *Concepts of Ecology* (third edition); E.J. Kormondy, Prentice-Hall of India Pvt. Ltd., New Delhi, 1986.
5) *Ecology* (Modern Biology Series—Holt, Rinehart and Winston Inc.), E.P. Odum, 2nd Indian Edition, Mohan Pirmlani, Oxford and IBM Publishing Company, New Delhi, 1975.
6) *Ecology and Field Biology* (Fourth edition), R.L. Smith, Harper and Row, New York, 1990.
7) *Principles of Environmental Biology,* P.K.G. Nair, Himalaya Publishing House, New Delhi, 1990.

Dear Student,

While studying the units of this block, you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions, in order to improve the course. Therefore, we request you to fill and send us the following questionnaire, which pertains to this block. If you find the space provided insufficient, kindly use a separate sheet.

QUESTIONNAIRE

LSE-02
Block-2

Enrolment No. | | | | | | | | | |

1) How many hours did you need for studying the units?

Unit No	5	6	7	8
No. of hours				

2) How many hours (approximately) did you take to do the assignments pertaining to this block?

Assignment Number		
No. of hours		

3) In the following table we have listed 4 kinds of difficulties that we thought you might have come across. Kindly tick (√) the type of difficulty and give the relevant page number in the appropriate columns.

Page Number and line Number	Types of difficulties			
	Presentation is not clear	Language is difficult	Diagram is not clear	Words/Terms are not explained

4) It is possible that you could not attempt some SAQs and TQs. In the following table are listed the possible difficulties. Kindly tick (√) the type of difficulty and the relevant unit and question numbers in the appropriate columns.

Unit No.	SAQ No.	TQ No.	Type of difficulty			
			Not-clearly posed	Cannot answer on basis of information given	Answer given (at end of Unit) not clear	Answer given is not sufficient

5) Were all the difficult terms included in the glossary. If not please list the words in the space given below.

6) Any Other Suggestion(s)

To,

The Course Coordinator (LSE-02; Ecology)
School of Sciences
Indira Gandhi National Open University
Maidan Garhi
New Delhi - 110 068

Uttar Pradesh
Rajarshi Tandon Open University

UGBY/ZY – 06
ECOLOGY

Block

3

COMMUNITY ECOLOGY

BLOCK 3 COMMUNITY ECOLOGY

As we have seen, the science of ecology encompasses the study of all the relationships among living things and between each of them and the non-living environment. These relationships can be considered mainly from two viewpoints. First, one may study the ecology of individual species in response to environmental conditions. This approach is known as autecology. Secondly, one may view these relationships as a whole — as they exist within a biological community. In such an approach we study the groups of organisms or community in relation to their environment. This is known as synecology. The approach of this block would be synecological, focussing primarily on the relationships organisms have with one another and examining the communities of organisms established by the intricate network of these relationships.

In this block of four units we will present an overview of some major aspects of community ecology. As with the previous blocks, we would emphasise on the ecological concepts and information. The study of this block would prepare you to understand and apply these concepts in your day to day life.

Unit 9, explains that all the populations inhabiting a given place at same time constitute a biological community. The nature and structure of community is determined by both the physical conditions present and the interactions among members of the community. Communities can be analysed and compared on the basis of certain characters such as diversity, life forms, biomass and many such parameters. In this unit we have discussed some important parameters that are used in the study of a community.

In Unit 10, you will study that communities exhibit several small scale and large scale changes. The large scale changes, also known as ecological succession are discussed here in detail. The basic processes, mechanisms and the various kinds of succession are described. The characteristic changes and the trends of succession are also highlighted.

Unit 11, discusses how a community is organised and the kinds of interaction that develop between the organisms that make up the community. Two important concepts in community ecology — habitat and niche have been explained. The general categories of interactions and the eventual outcome of the participants have been explained briefly while interactions like competition, predation and herbivory (a special type of predation) have been discussed at length as these are important in organising the community as a whole.

In Unit 12, you will study about the population parameters and its regulation. Density, natality, mortality, age distribution, biotic potential, dispersion and growth are characteristic features of the populations. These are unique possessions of the group and not of the individual in the group. Growth of population is limited by carrying capacity of the environment. The inherent tendency of all populations to increase with size is regulated by various density dependent and density independent factors. Genetic diversity and evolutionary trends in a population are also dealt with in the same unit.

After reading this block you would be able to :

- define a biotic community, and apply the various characters for assessing the nature and structure of community;
- recognise and describe the stages of succession and its trends in a community;
- describe community organisation and the various interactions among the organisms;
- discuss population parameters and various factors which limit and regulate population size;
- appreciate the importance of genetic diversity and evolutionary trends of a population.

Study Guide

For a meaningful study of the ecological concepts dealt with in this block, you must actually try to use them in your life by relating them to your surroundings. It would be useful to jot down your observations in a small booklet. You can also record the data, and make some pictorial manifestations. This way you would have a clear picture of what you have learnt so far.

While reading the block if you are stuck up with any fundamental concept, we advise you to consult the NCERT textbooks. And if you wish to explore the topices further, you may consult the books as mentioned in the last page of the block.

Like the previous two blocks there is a feedback form at the end of this block too. We expect that you would fill it up and mail it to us, to enable us to know your opinion and suggestions about this block.

Hope you would enjoy reading this block

UNIT 9 NATURE AND STRUCTURE OF COMMUNITY

Structure

9.1 INTRODUCTION

Every place on earth — grasslands, forests, ponds, edge of the river or sea is shared by many coexisting organisms. Plants, animals and microorganisms which occur together are related to one another by their feeding relationships and many other interactions, forming a complex whole, generally referred to as a biological community. Interrelationships between the organisms in a community determine several functional attributes of the ecosystem such as : flow of energy and cycling of elements. Therefore, to have a better understanding of an ecosystem, we should have a clear idea about the nature and structure of community. Thus, in this unit, we shall discuss with you some main features of the community level of organisation, with emphasis on some important community characters. After studying the section 9.2, you should be able to develop a clear understanding of the terms individuals, populations, community and stands and the distinction between a community and an ecosystem. Having understood the above terms, it would be easier for you to follow the remaining sections. After studying this unit you should be able to understand the various terms and concepts pertaining to the study of biotic communities. Go slowly, and try to relate each of it to your surroundings. This will help you to build a clear picture of a biotic community in your mind.

Objectives

After studying this unit you would be able to :

- explain the concept of a biological community
- describe the main features of a biotic community
- define and describe the various analytical characters used to study a biotic community
- define and describe the different synthetic characters used to study a biotic community

9.2 WHAT IS COMMUNITY?

In nature different kinds of organisms occur in association with each other, sharing the same habitat. Let us consider the example of a field to illustrate this point further. In a field different kinds of grasses, insects, worms, birds and mammals interact in various ways. Grasses provide food for certain insects and mammals; insects provide food for birds; and birds prey on small mammals and worms. The various kinds of organisms in this field thus constitute a community, which is also known as field community. Similarly a forest, desert, pond, marsh and stream — are examples of natural communities. After discussing briefly what a community is, we would now discuss six main features of a community.

nonliving part of environment + COMMUNITY } = ECOSYSTEM

First, a community represents the biotic or living component of the ecosystem. If the non-living (abiotic) factors, together with the living (biotic) entities are considered, then we would be dealing with an ecosystem rather than a community.

Secondly, considering the functional aspect, communities are made up of organisms with interlocking food chains and each species depends on many other species in a community which are taxonomically unrelated. Try to recall a food web, this will help you to understand this concept more effectively. Food web is a representation of the food relationships between various types of species found in an ecosystem, and as you know these biotic components constitute a community. While a species may not relate to every other species directly in a community, nevertheless, they all are indirectly interrelated. This situation can be compared with an engine in which various components are interrelated and they together make the working of an engine possible.

Fig. 9.1 : A deodara *(Cedrus deodara)* tree

Thirdly, a community may be of any size. A temperate forest of deodar trees is an example of a large community. (Fig. 9.1 shows a deodar tree). In contrast to this, a rotting log of wood harbouring many insects and worms represents a small community. So the size of a community may vary widely.

Fourthly, just like the concept of ecosystem, that it can be applied to any scale, that is, the earth as a whole can be considered as a large ecosystem, on the other hand, a bowl of water with various living organisms in it is an example of a small ecosystem. Similarly, a forest is a community, so is a rotting log in that forest containing fungus, insects like termites, and even mice. Similarly, a large number of microorganisms within the gut of termite, that occurs in the rotting log of wood, also constitute a community. This suggests that there is a community within a community, and the situation is just like the toys shown in Fig. 9.2.

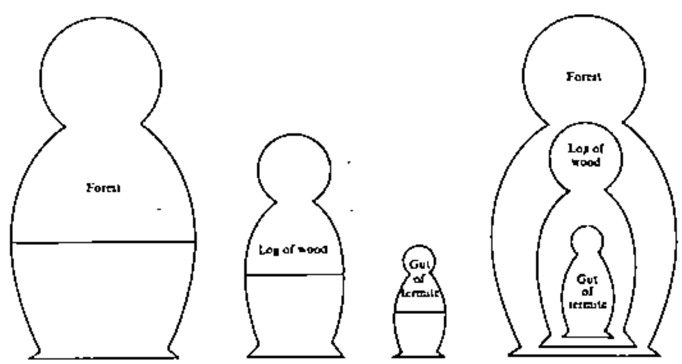


Fig. 9.2 : Wooden toys used as an example of community within a community

Fifthly, some communities may be autotrophic, in the sense that they include photosynthetic plants and obtain their energy from the sun. Other communities such as those found in springs and caves are heterotrophic, as they depend upon organic material such as detritus as a source of energy.

Sixthly, interrelated with the idea of community is that of the *stand*. In some situations these two terms mean *different* things; and in some other situations these two terms mean the *same* thing, and are used interchangeably. In order to avoid any confusion in the usage of these two terms, we shall illustrate these two situations with the help of two examples, that are discussed below.

The first example is of a temperate forest consisting of deodars, pines and rhododendrons (see Fig. 9.3). Have you noticed in the figure, that at places, the plants of a particular species are forming groups. These groups are indicated in the figure by the areas enclosed by the dotted lines. So each of this area containing plants of same species and almost of the same age is called a *stand*. You can also observe

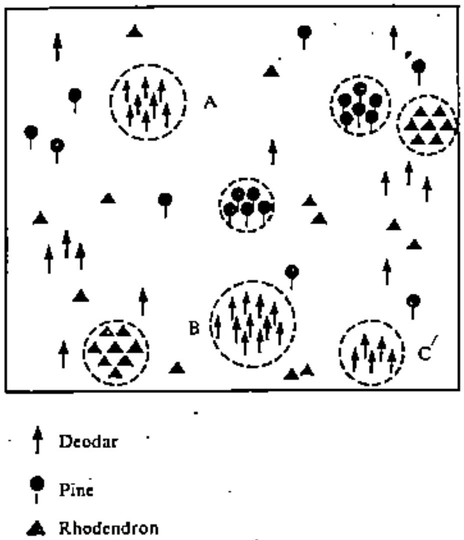


Fig. 9.3 : Diagrammatic representation of a temperate forest

from the figure that stands A, B and C of deodar trees are different from each other as far as their number is concerned. The term stand is applied to a more or less uniform area of vegetation. *While studying a community, when we talk of a stand, it means we are talking about a group of plants of a species in that community.* After going through this example, you would have seen that, here community and stand refer to different things.

The second example is of a cultivated wheat field. The wheat plants in this field constitute the wheat field community. Since, this field has a uniform vegetation, and plants are of the same age, this can also be called as a *stand of wheat*. This example shows one of the situations where the term stand and community mean the same thing and can be used interchangeably.

SAQ 1

i) A biotic community is an assemblage of :

a) food webs

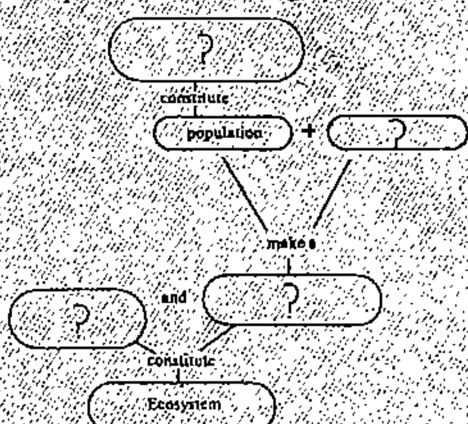
b) interacting populations

c) closely related species

d) ecosystems

(Tick the correct one)

ii) Fill in the spaces with question mark, using a[illegible]te word(s).



iii) What are the salient features of a Community?

....

....

....

....

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9.3 COMMUNITY GRADIENTS AND BOUNDARIES

It is often difficult or impossible to determine where one community ends and the next begins. Many communities, in fact, grade continuously into each other with no sharp boundaries. For example, if two forests, pine forest and spruce forest are nearby, one cannot see the boundaries between them. But if one moves from one end of the pine forest to the other end of spruce forest, one can observe difference in species composition between the two; yet one cannot demarcate a sharp boundary between these two forest communities. There are, however, instances where sharp boundaries between the communities are seen, especially where the physical environment changes abruptly — for example, at the transition between aquatic and terrestrial habitats between distinct soil types, or between north-facing and south-facing slopes of a mountain.

Ecotone — The zone of vegetation separating two different types of communities is called ecotone. It is also known as a transition zone. The border between forest and grassland, the bank of a stream running through a meadow are examples of ecotones.

Ecotone is a region where the influence of two different patterns of environment work together and hence the vegetation of ecotones are highly specialised. An ecotone may be narrow or wide. For instance, the ecotones between adjacent plots—one fenced and protected from grazing, and other without fence and openly exposed to grazing; or between a pond and an adjacent upland are quite sharp and narrow whereas among many other types of communities ecotones are very wide and community boundary differentiation is not easy.

A general characteristic of ecotone is that it has sufficiently greater number of species and the diversity of most of the species at times is higher than that in the neighbouring communities (also see Fig. 9.4). The phenomenon of increased variety of plants at the boundary is called the *edge effect* and is essentially due to wider range of suitable environmental conditions. The ecotone area contains organisms from both of the adjoining communities and besides there are organisms which are confined to the ecotone and can exploit the special conditions there.

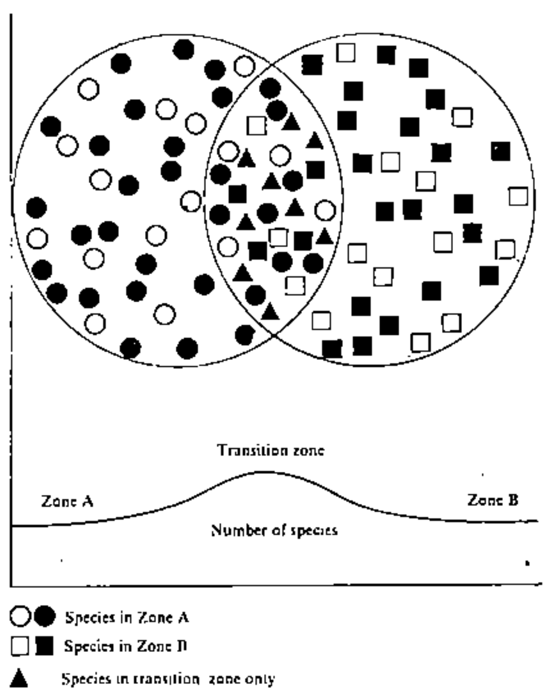


Fig. 9.4 : Ecotone — where two community types come together, such as a forest and field, species in the zone between them include both forest and field species and some additional species that do not exist in either forest or field

Some ecologists have introduced the *continuum concept* that means that there are no distinct communities with well defined boundaries but there is a gradual change in space and time along a gradient which may be of moisture, temperature, soil type, altitude or any combination thereof. There are no sharp borders or changes in species composition in areas, according to the continuum concept.

9.4 ANALYTIC CHARACTERS

As you know, a community has its own characteristics, which are not shown by its individual component species. These characteristics have meaning only with reference to community level of organisation and are discussed in this and the subsequent sections.

The community characters, mainly are of two types: analytic and synthetic. In this section we shall discuss the analytic characters. These are categorised as : *qualitative* and *quantitative*. Qualitative characters are difficult to measure, whereas the quantitative characters can be measured readily. We shall now take up these characters one by one.

9.4.1 Qualitative Characters

Given below is a discussion on six important qualitative characters of a community. Let us take them up one by one.

i) **Floristic Composition** — One of the important qualitative characteristics of a community is its floristic composition. This broadly refers to the kind of species occurring in a community. Here, we would like to make a point. Most communities are named after the dominant plant species that occur there.

In each community there are diverse species. All these species are not equally important, but there are only a few overtopping species which by their bulk and growth modify the habitat and control the growth of other species in the community, thus forming a sort of characteristic nucleus in the community. These species are called dominants. Generally, in most of the communities, only a single species due to being particularly conspicuous, is dominant, and in such case the community is called by the name of dominant species as for example, Spruce forest community. In other communities, there may be more that one dominants as in Oak-Hickory forest communities.

You may be thinking that why plants and not animals? The reason is that the plants are stationary, they remain at a particular place throughout their life. In contrast, the animals are mobile and they do not stay at a place for long, so they are not taken as representatives for naming a community.

The next aspect that we will take up for discussion is how to study the floristic composition of a community. The first thing done is to prepare a list of species comprising that particular community. In practice, it is nearly impossible to name each and every organism, as some of them are very minute. Amongst plants, usually the *vascular* plants are counted. In order to make a complete list, species appearing in different seasons are also considered. Although all the species in a community are significant, but only a single species or a few species are often used in naming a community, because of its (their) abundance or dominance.

Vascular Plants — plants having a well developed conducting system, having xylem and phloem elements.

The next point is what does one know or learn from these floristic lists? It gives the idea about the following : *One,* the relationship of a particular species to the environment and to other species; *two,* the habitat of different species, *three,* the ecological amplitude of species, and *four,* the present conditions and future trends of the community.

Ecological Amplitude — it is the range of the environmental factors that a particular species can tolerate.

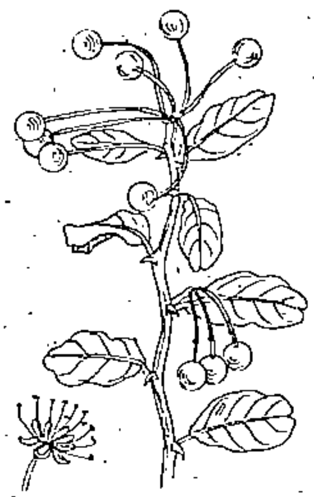
Now we shall take up these four points one by one. Let us now take the first point. We shall elaborate this with the help of an example, that is of *Adhatoda vasica* (Fig. 9.5a) it is a winter annual. It normally occurs with a co-dominant shrub *Capparis sepiaria* (Fig. 9.5b). So, as far as the relationship of *Adhatoda* species to environment is concerned, it grows when temperature is low and it grows in association with *C. sepiaria*. So this shows its relationship to the environment and to another species. Sometimes, the association between two species is so strong that a certain species may indicate the presence of other species, so prediction is possible to some extent, i.e., if species A is found in a certain area, then species B can also be expected there.

Second point is, *A. vasica* occurs on hilly tracts and similar rocky areas. This indicates its habitat.

Third point, each species has its own range of tolerance to certain environmental conditions. The abundance or sparseness of certain species indicates the prevailing favourable or adverse conditions in relation to their ecological amplitudes. Association of species may be brought about by the similarity in the ecological amplitudes of two or more species.

Fourth point, such floristic lists not only tell us about the absence or presence of species in a particular community, but also indicate the present conditions and future trends. For instance, a decline in the number of species from one area as compared to other, may indicate increasingly adverse conditions.

a



b

Fig. 9.5 : a *Adhatoda vasica*, and b. *Capparis sepiaria*.

ii) **Stratification of Vegetation** — Stratification of vegetation is another important feature of plant communities. There are different vertical strata in different communities. You have already some idea about this from the Course FST-1, Unit 15, Section 15.4, wherein we have discussed the example of a forest in this context. You might recall that in forests, we find several storeys or layers of plant species. Stratification usually occurs because of life forms such as trees, shrubs, herbs and mosses differ in their requirements and ecological amplitudes with regard to light intensity, temperature, moisture conditions, soil and biotic factors.

Now let us have a closer look at the vegetation of a forest. A well developed forest may have four to five layers of vegetation. (See Fig. 9.6). From top to bottom, they are : the canopy, the understory, the shrub, the herb or ground layer and the forest floor.

Fig 9.6 : Segment of Forest depicting vertical stratification diagrammatically

In a tropical rain forest, vertical stratification is very clearly seen. In addition to the different layers described above, there are lianas and climbers that twine around the trees. A forest with four or five strata can support a greater diversity of life forms as compared to a grassland with only two strata. Stratification is also seen in the underground plant parts, that is, the root and the rhizome systems. Root systems of different plant species tap moisture and nutrients from different soil depths. This enables them to avoid competition and too much exploitation of a particular soil layer.

Coming back to the above-ground parts of vegetation, the canopy which is the primary site of energy fixation, it has a major influence on the rest of the forest community.

A canopy is said to be *open* when considerable sunlight reaches the lower layers. In such cases the shrubs and understory tree strata are well-developed. In a *closed* forest, most of the sunlight is intercepted by tree canopies. The understory plants remain deprived of direct sunlight consequently the lower strata is comprised of shade tolerant species with poor growth of herbaceous layer. In such situations species requiring intense sunlight are absent or flourish only in the gaps created by the death of top canopy trees.

Aquatic ecosystems also exhibit marked stratification. In lake and ocean ecosystems light penetration, temperature and availability of oxygen varies with depth, (also see Unit 8, of this course). In summer, a well stratified lake has a layer of freely circulating surface water with uniform temperature known as the *epilimnion*. A second layer called *metalimnion* which is characterised by a thermocline (a very steep and rapid decline in temperature). The third layer — the *hypolimnion*, is a deep, cold layer of dense water, often low in oxygen; and a layer of bottom mud. In terms of availability of light, a water body is divided into two layers: an upper lighted zone which is dominated by phytoplanktons and where photosynthesis occurs vigorously, and a lower layer in which decomposition is most active. The lower layer roughly corresponds to the hypolimnion and the bottom mud.

Let us now see what is common between a terrestrial and an aquatic ecosystem. Both have similar type of trophic structure. They possess an autotrophic layer concentrated where light is most available, which fixes energy of the sun and manufactures food from inorganic substances. In forests this layer is represented by tree canopies; in grasslands by herbaceous vegetation; and in lakes and seas by the upper layer of water.

Ecosystems also possess a heterotrophic layer that utilises food stored by autotrophs, transfers energy and circulates matter by means of herbivory, predation and decomposition.

We shall now discuss the vertical stratification in relation to animal life. The degree of vertical stratification has a pronounced influence on the diversity of animal life in the community. A strong correlation exists between foliage height diversity and bird species diversity. Increased vertical stratification increases the availability of resources and living space, which favours a certain degree of specialisation. Grassland with their two strata, hold about 6 to 7 species of birds, all ground nesters. A deciduous forest may support 30 or more species occupying different strata. Like birds, insects too show similar stratification.

iii) **Periodicity** (Phenology, Aspection) — It refers to the study of seasonal changes in the community, that is, the periodic phenomena of organisms in relation to their climate. Periodicity is a strongly fixed characters in plants. Different species of plants have different periods of seed germination, vegetative growth, flowering and fruiting, leaf fall, seed and fruit dispersal, and dissemination of seeds. Such data for each species in a community is recorded. A study of the data and time of these events is termed as *phenology*. In other words, phenology is the calendar of events in the life history of a plant. Diagrammatic representation of such events is known as *phenograms*. In Fig. 9.7 phenograms of some Indian grasses and sedges are shown.

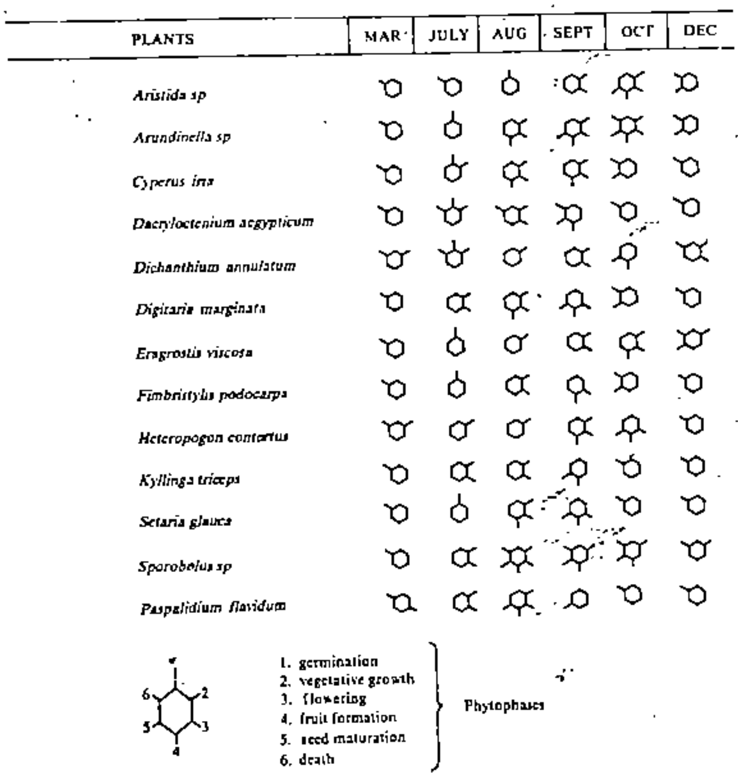


Fig. 9.7 : Phenograms of some Indian grasses and sedges

The phenology of different species present in a community may differ from each other significantly. It is these phenological changes which give a definite look to a community. *Aspection* is the appearance or aspect of the community as a whole at different seasons. We shall further elaborate this point by an example. There is a community having four different plant species. And these four component species flower in the months of January, April, July and August successively. So the community has a characteristic appearance during the different months of the year. And in the subsequent year too, the same pattern can be seen. But now if somehow another species, i.e., the fifth species comes in this community, and it flowers in June, the whole appearance of the community would be markedly different now. After going through the above example it may be clear to you now that the appearance of two different communities may be different.

So, what does one learn or know by studying such seasonal shifts in a community? Firstly, we come to have a calendar of different events in the life of the component species. From this calendar we can deduce as well as predict the appearance of the community during different periods of the year. We can also know about favourable and unfavourable seasons for the different phases of plant life.

So far we have talked about plants only. The animals in the community are directly or indirectly dependent on the plants also time their activities in such a manner that it coincides with the maximum activity of plants. For example, associated with the tree *Terminalia arjuna* is a psyllid (an insect) *Trioza fletcheri minor*. This insect forms galls on the leaves and flowers of this plant. During the season, when the plant puts on new leaves, this psyllid too grows actively. If forms new galls on the young, tender plant parts. The young ones of the insects develop in the galls thus formed. This example shows how the insect has timed its reproductive phase with that of the plant. It also shows the association of an insect with a plant. But in nature there are instances, where more than one species of insects and other organisms are associated with a species of plant.

iv) **Vitality and Vigour** — Vitality is related to the condition of a plant and its capacity to complete its life cycle, while vigor refers more specifically to the health or development within a certain stage. We can say that a seedling or a mature plant may be vigorous or it may be feeble or poorly developed. A number of criteria may be used in determining the vigour of plants such as the rate and total amount of growth especially in height; rapidity of growth renewal in spring or following mowing or grazing; area of foliage, colour and turgidity of leaves and stems; degree of damage caused by diseases or insects; time of appearance and number and height of flower stalks; rate of growth and extent of root system, appearance and development of new stems and leaves. For classification of vitality the following groups as given by Daubenmire (1968) are used :

V_1 — Plants whose seedlings die

V_2 — Seedlings grow, but unable to reproduce

V_3 — Reproduce only vegetatively

V_4 — Reproduce sexually, but are uncommon

V_5 — Reproduce sexually and grow regularly.

v) **Life Forms** — The form and structure of terrestrial communities are determined by the nature of vegetation. Vegetation may be classified according to growth form. The plants may be tall or short, herbaceous or woody, evergreen or deciduous. We might speak of trees, shrubs, and herbs, and then further sub-divide these categories into needle-leaved evergreens, broad-leaved evergreens, broad-leaved deciduous, shrubs, ferns, grasses and so on and so forth.

A more useful system was proposed by a Danish botanist, Christen Raunkiaer in the year 1903. In this system, instead of considering plants' growth form, he classified plants by life form, the relation of their height above ground to their perennating organ. A perennating organ is one that survives from one growth season to the next, remaining inactive over winter or dry periods. Perennating tissue is the embryonic or meristeimatic tissue of buds, bulbs, tubers, roots and seeds. Raunkiaer recognised five principal life forms that we shall discuss below :

The five life form classes (see Fig. 9.8) are : a) Phanerophytes, b) Chamaephytes, c) Hemicryptophytes, d) Cryptophytes, and e) Therophytes. We shall take up these five classes one by one:

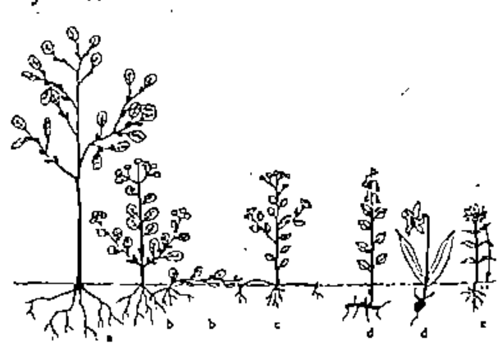


Fig. 9.8 : Raunkiaer's Life Forms : a) Phanerophytes, b) Chamaephytes, c) Hemicryptophytes, d) Cryptophytes, and e) Therophytes.

a) **Phanerophytes** (Greek word, Phaneros — 'visible') : The perennating buds in this case are present on erect, negatively geotropic shoots, much above the ground (see Fig. 9.8a). These buds are naked or least protected and are exposed to varying climatic conditions. These life forms include trees, shrubs and climbers. These are generally common in tropical climates, and their number progressively decreases when we move from tropics to polar regions.

b) **Chamaephytes** (Greek word, Chamai — on the ground) : The perennating buds and organs are borne on shoots close to but just above the ground (see Fig. 9.8b). The buds receive protection from fallen leaves and snow cover. These life forms include creepy, woody plants and herbs. These plants are typical of cool dry climate, that is the arctic and alpine regions.

c) **Hemicryptophytes** (Greek word, hemi — partly; kryptos — hidden) : In this case the perennating buds or organs are situated at the soil surface (see Fig. 9.8c) where they are protected by soil and fallen leaves. These include herbs growing in rosettes and tussocks. These plants are found in cold, temperate zones, where aerial parts die at the onset of unfavourable conditions. Most of the biennial and perennial herbs come under this category.

d) **Cryptophytes** (Greek word, kryptos — hidden) : Perennating buds or shoot apices are buried in the ground at a distance from the soil surface (see Fig. 9.8d) that varies in different species. The buds are buried where they are protected from freezing or drying. Examples are tuberous and bulbous herbs. Many of these are found in arid zones. Hydrophytes are the cryptophytes whose buds are found below the water surface.

e) **Therophytes** (Greek word, theros-summer) : These are annual plants of the summer season or of the favourable season. They complete their life cycles in a single favourable season and overwinter as seeds (see Fig. 9.8e), which remain dormant during the unfavourable period of the year. Therophytes complete their life cycle within a few months only and occur commonly in deserts and grasslands.

The relative proportion of different life forms in a vegetation, tells us about the geo-climatic conditions. For example phanerophytes comprise about 60-90% of the flora of humid tropics. Chameophytes are characteristic of arctic and alpine regions and in cool temperate regions about 50% species are hemicryptophytes.

vi) **Sociability** (Gregariousness) : Sociability refers to the nature of grouping of individual plants, that is, whether they grow singly, in patches, in colonies or evenly intermixed. This is dependent upon the life form and vigor of the plants, habitat conditions, and competitive and other relations between the individuals. Sociability expresses the degree of association between species. The five sociability groups given below are used for rating the sociability of species.

S_1 — Plant (stems) found quite separately from each other, thus growing singly

S_2 — A groups of 4-6 plants at one place

S_3 — Many smaller groups at one place

S_4 — Several bigger groups of many plants at one place

S_5 — A large group occupying larger area

9.4.2 Quantitative Characters

i) Population Density — Density denotes the average number of individuals of a particular species in a unit area. In other words, it represents the numerical strength of a species in a community. A study of density makes it possible to have accurate and direct comparisons of the **abundance** of species between different areas. Density also gives an idea of the degree of competition between the members of the same species as well as of one species with the other. It is calculated as follows :

$$\text{Density} = \frac{\text{Total number of individuals of a species in all the sampling units}}{\text{Total number of sampling units studied}}$$

The value thus obtained is expressed as number of individuals per unit area.

Crude density — is the density of individuals of a species throughout the habitat and is determined by random sampling.

Ecological density — refers to the density of individuals of a species, determined at the place where they actually occur in a community.

We shall elaborate it with an example, consider a small patch of land where there are a few water-filled ditches, and rest is dry land. Now, if we want to determine the density of frogs in that area, we would select a few sampling units distributed throughout the area and determine the density. In areas that are dry, the number of frogs would be very less, or they may be absent. This is crude density. And if we determine the density of frogs in areas that are moist and near water, then it is called as ecological density.

ii) **Cover** (area occupied) : Cover or specifically **herbage cover** refers primarily to the area of ground occupied by the leaves, stems and inflorescence i.e. the above-ground parts of the plants, as viewed from above (see Fig. 9.9). Each layer of vegetation is considered separately, since overlapping usually occurs, so that a tall plant is rated apart from one growing under it. *Basal area,* refers to the ground actually penetrated by the stems (see Fig. 9.9). This can be readily seen when the leaves and stems are clipped at the ground surface. (see Fig. 9.9).

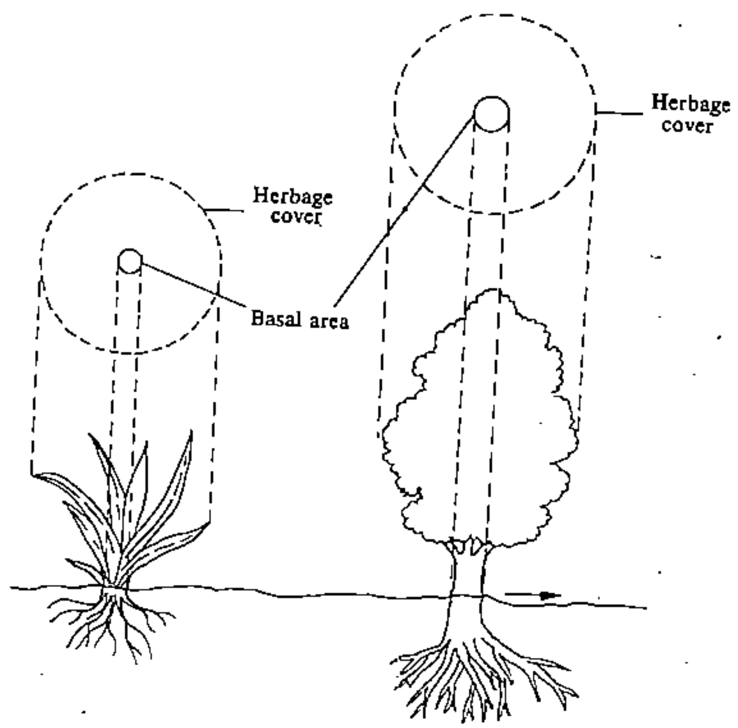


Fig. 9.9. : Diagrammatic sketch showing herbage cover and basal area in different plants

Herbage area or vegetation cover is an important aspect of vegetation study in understanding the nature of a community particularly in evaluating quantitative relationship between species. When the herbage covers of individual plants are in lateral contact and form a continuous cover, the vegetation is said to be closed. When the vegetation cover has gaps, which could be colonised by other individuals, it is said to be open, and if the amount of space is much greater than that occupied by plants the term sparse is used. Periodic record of herbage cover provides extremely valuable information in determining the nature and trend of changes in a community. This is illustrated very clearly in Fig. 9.10. It shows the basal area over a considerable period of time changes.

iii) **Height of Plants** — The height of a plant is a very good indicator of their general performance and therefore, can be employed as a criterion of the success of a species in various habitats. It can also be used as a measure of the favourableness of the environment and is much used by foresters as an index of site quality for various species of trees.

iv) **Weight of Plants** — Weight is one of the most important quantitative characteristics of plants. Quantitatively growth is best measured on the basis of dry weight, since it expresses the total mass of the vegetation or the biomass.

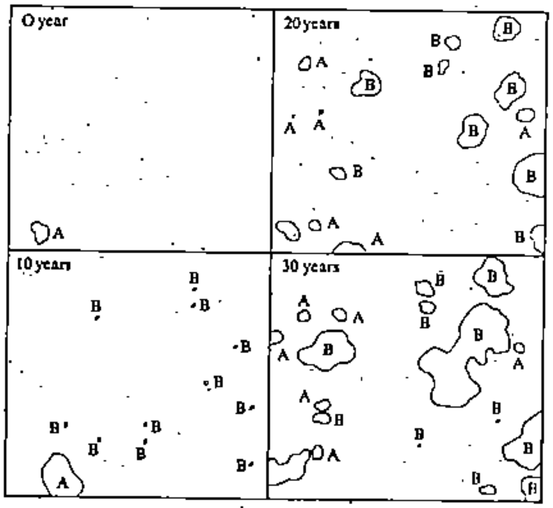


Fig. 9.10 : Changes in species composition and basal area in a sampling unit, over a period of 30 years

Biomass or the weight of plants can be measured separately for the above ground plant parts and for underground parts, i.e., by drying them at 80°C in an oven. The data from such studies provide us valuable information about the yield of that species. For example evaluation of the above ground plant parts that are useful provide an accurate idea about the availability of forage in a community.

SAQ 2

Given below are some analytic characters. Write in brief, what information does each one give.

i) **Floristic composition**

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ii) **Stratification**

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iii) **Periodicity**

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iv) **Vitality and vigour**

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v) **Life forms**

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vi) **Sociability**

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vii) **Population density**

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viii) Cover

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ix) Height

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x) Weight

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9.5 SYNTHETIC CHARACTERS

To make comparisons between different communities, one needs to make a study of their synthetic characters. What are these synthetic characters? We shall discuss them now.

9.5.1 Presence and Constancy

Presence and constancy refer to how uniformly a species occurs in different stands in a community. For example, when a species is found in 15 out of the 20 stands in a community the presence or constancy is 75 per cent.

$15/20 \times 100 = 75\%$

The terms presence and constancy are used in more or less in the same sense but they are however not synonyms. The term constancy is used when equal, measured sample areas are used for study, and presence is used when the area of sampling unit varies from stand to stand and especially when it is not measured. Many times, the sampling units do not have the same area, because of the nature of vegetation, as for example, small irregular stands in rock crevices or on sand deposits along a stream.

Species in a community can be classified into five classes of constancy, according to the percentage of occurrence in sampling units or stands. These classes are:

Class I — 1-20% of the sampling units of a community

Class II — 21-40% of the sampling units of a community

Class III — 41-60% of the sampling units of a community

Class IV — 61-80% of the sampling units of a community

Class V — 81-100% of the sampling units of a community

You might have noticed that Classes IV and V include those species that occur in a large number of stands. The species that occur in over 80-90% or in more sampling units are called *constant species*. These species are important as they characterise and help to distinguish a community type. The species belonging to class IV and V indicate two possibilities : i) the species have a wide ecological amplitude and are therefore capable of growing in various micro-habitats, and ii) the various sampling units are very similar in environmental conditions, so that species of narrow amplitude can grow in all of them.

9.5.2 Fidelity

Fidelity refers to the degree to which a species is restricted in its occurrence to a particular kind of community. The species with low fidelity occur in a number of different communities, and species with high fidelity are restricted to few or only one community. The following five fidelity classes can be recognised:

A) Characteristic species (Character, faithful species)

Fidelity 5 — *Exclusive*, completely or almost completely restricted to one kind of community

Fidelity 4 — *Selective*, occurring most frequently in one kind of community, but also, though rarely, in other kinds

Fidelity 3 — *Preferential*, occurring more or less abundantly in several kinds of communities but with optimum conditions for abundance and vitality in one kind of community.

B) Companion Species

Fidelity 2 — *Indifferent*, occurring without pronounced affinity or preference for any particular kind of community

C) Accidental Species

Fidelity 1 — *Strange, rare and accidental intruders* from another community or relicts from an earlier stage of succession

You have seen that some species cannot grow or are not found in other communities, because species differ in their ecological amplitude or in their capacity to tolerate a wide range of ecological conditions. Some species are able to associate with others, whereas others are not.

Fidelity and constancy are independent characteristics. Fidelity being concerned with the occurrence of a species in different kinds of community types, constancy with various stands in the same community. Fidelity is primarily a sociological quality. A species which has high fidelity or belonging to class 5 is known as *indicator species.*

9.5.3 Dominance

It is a characteristic of vegetation which expresses the predominating influences of one or more species in a stand so that the population of other species is more or less repressed, or is reduced in number and vitality. Dominants are those species which are highly successful in a particular habitat. Cover and population density are the chief qualities determining dominance, but parameters like frequency, height, life form and vitality are also important. The dominants exercise a controlling influence in the habitat while modifying the microhabitat which permits the growth of many different species which otherwise cannot survive in the absence of dominants.

Let us consider an example, a dominant species occurring in pastures, say *Cynodon dactylon*. It owes its success to excellent vitality, rapid multiplication and growth, possessing deep penetrating root system. All these features make it a dominant species in many grasslands.

9.5.4 Physiognomy and Pattern

Physiognomy is the general appearance of vegetation as determined by the growth form of dominant species. It may be considered a synthetic character because the appearance is based on a number of qualitative characteristics such as the kind of dominant species, life form, population density, cover, height, sociability, stratification, and association of species. For example, if we look at a community where large trees are dominant and some shrubs are also present we would immediately say that it is a forest. Similarly on the basis of appearance one can identify a community as grassland or desert community.

Pattern refers to whether the vegetation occurs in the form of groups or clumps of individuals or in any other non-random arrangement.

9.5.5 Frequency

This term refers to the degree of dispersion of individual species in an area, and is usually expressed in terms of percentage. Frequency can be studied by sampling the study area at several places at random or in a desired pattern, so that the site is covered adequately and the names of the species that occur in each sampling unit are recorded. Let us now see how frequency of a species is determined. Consider a species that occurs in five sampling units out of a total of 20 sampling units, then its frequency (F) is 25%. It is calculated by the following formula :

$$F = \frac{\text{Number of sampling units in which that species occurred}}{\text{Total number of sampling units studied}} \times 100$$

A species most abundantly spread all over the area will have chance of occurring in all the sampling units, and therefore, its frequency will be 100%. A poorly dispersed species, with large number of individuals aggregated in one place will have a chance of occurrence in only a few sampling units and its frequency value will be low. Thus a high frequency value shows a greater uniformity of its dispersion. Have you noticed that for determining the frequency, the presence or absence of a species in the sampling units is recorded and not the number of individuals of each species, and thus, you should be able to differentiate it from density for which the number of individuals per unit area is recorded.

Frequency of a species relative to other species in a community is called relative frequency, and is calculated as :

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total frequencies of all species}} \times 100$$

9.5.6 Importance Value Index (IVI)

In any study of community, the quantitative value of each of the frequency, density, and cover has its own importance. But the total picture of ecological importance cannot be obtained by any one of these alone. For instance, frequency gives an idea as to how a species is dispersed in an area but we do not get any idea about its number or the area covered. Density gives an idea about the numerical strength and so on. To have an overall picture of ecological importance of a species with respect to the community structure, the percentage values of the relative frequency, relative density and dominance are added together and this value out of 300 is called the Importance Value Index or IVI of the species.

IVI can also be ascertained by using diagrammatic representation in the following manner. Draw a circle and divide it into four equal segments by drawing two lines at right angles to each other passing through the centre. (See Fig. 9.11).

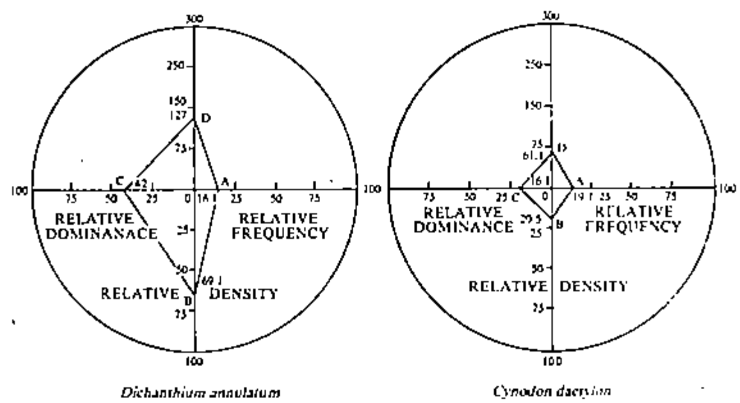


Fig. 9.11 : Polygraphic method of showing sociological characters of individual species (after Ambashth, R.S., 1986).

Each of the three radii is divided into 100 parts from the centre to the circumference and the fourth into 300. On the 0-100 scales are marked the values of relative frequency on A, relative density on B, relative dominance on C, and the IVI value as the 0-300 scale on D. All these points are joined as shown in the figure. Such illustrations help to appreciate sociological features and IVI of a species at a glance.

The IVI as such, gives the composite picture of sociological status of a species in a community but it does not provide an idea of relative values of frequency, density and dominance.

9.5.7 Species Diversity

It is one of the most important and basic characteristics of a community. There are various ways of measuring species diversity, the simplest is to enumerate the number of species present in a given area. This is relatively easy to achieve for plants, and large or sedentary animals but it is generally difficult to enumerate the various insect species accurately. For large areas such as forests, islands etc., it may take many years to prepare a reasonable estimate of species numbers. Assessment of species diversity on the basis of species list is not fully satisfactory because drawing of an exhaustive and accurate species list is often an involved exercise. And, unless an elaborate exercise is undertaken there is a good possibility that a number of species may be left out. Since so many species in a sample are likely to be rare, we should not ignore this fact while measuring diversity. For example, compare two imaginary samples of

100 individuals each with two species A and B. The details of number of species of each sample are given in Table 9.1.

Table 9.1 : Number of Species In Two Sampling Units

Sample	Number of Species	
	A	B
I	50	50
II	99	1

In sample I there are 50 individuals of A and 50 individuals of B, but in sample II there are 99 A and 1 B. Is the diversity of these two samples really same? If we choose to measure diversity as the numbers of species present in each sample then the answer is yes, but most ecologists would consider the community with 50A and 50B to be more diverse than the one with 99A and 1B. Let us see how.

To determine species diversity, the most widely used index is Shannon's Index of Diversity (H′) and it is calculate as below :

$$H' = -\sum_{i=1}^{i=S} p_i \log_e pi$$

H′ = Index of species diversity

S = Number of species

p = Proportion of the total sample belonging to the *i*th species (in rank), which is calculated by dividing the number of individuals in species *i* by the total number of individuals in the sample.

e = base of natural logarithms ($\log_e p_i = 2.302 \times \log_{10} p_i$)

(Remember that $\sum_{i=1}^{i=S}$ means that — add up the following expression, for values of i from $i = 1$ to $i = S$).

The larger the value of H′, the greater the uncertainity about predicting the next species to be encountered and so the greater the diversity. Let us now compare the two samples I and II, each of 100 individuals, and see whether sample I has higher index of diversity H′ or sample II?

Sample I :

$$\begin{aligned} H' &= -[(0.50 \times \log_e 0.50) + (0.50 \times \log_e 0.50)] \\ &= -[2\,(0.50 \times -0.69)] \\ &= 0.69 \end{aligned}$$

Sample II :

$$\begin{aligned} H' &= -[(0.99 \times \log_e 0.99) + (0.01 - \log_e 0.01)] \\ &= -[(0.99 \times -0.01) + (0.01 \times -4.61)] \\ &= -[(-0.01) + (-0.05)] \\ &= 0.06 \end{aligned}$$

Sample I has the higher index of diversity.

SAQ 3

What information does each of the following synthetic character give?

i) Presence and constancy

....

....

ii) Fidelity

....

....

iii) Dominance

....

....

iv) Physiognomy and pattern

....

....

v) Frequency

....

....

vi) Importance Value Index

....

....

vii) Species diversity

....

....

9.6 SUMMARY

In this unit you have learnt some aspects of nature and structure of community. So far you have learnt that :

- Communities are made up of populations of organisms, occupying and interacting in a given area. They constitute the biotic component of ecosystems.
- Communities have several group characteristics which are not exhibited by either its individuals or populations.
- The size of community may vary. Just like an ecosystem, a bigger community too may be sub-divided into smaller communities.
- Based on the source of energy, a community may be autotrophic or heterotrophic.
- Rarely, can different communities be sharply delimited, because they blend together to form a continuum along some environmental gradient. Sometimes, because of severe environmental disturbance(s), sharp boundaries between the communities can be seen.
- The area where two communities blend is an ecotone. This zone has a high species richness. It not only supports the species of the adjoining two communities, but also a few species found exclusively in this zone.
- To get a complete picture of a community, a study of its analytic and synthetic characters is necessary.
- Qualitative analytic characters include : floristic composition — kinds of species occurring in a community; stratification — layering of vegetation, that influences the nature and distribution of animal life; periodicity — periodic changes in a community in a year; vitality and vigour — the rate and amount of growth; life form — the location of perennating tissue in plants; sociability — nature of grouping of plants.
- Quantitative analytic characters include : Population density — the number of individuals of a species within a unit area; Cover-area of ground covered by the above-ground plant parts (herbage cover), and the area of ground actually covered by stem (basal area); height of plants; weight of plants — measured as biomass.
- The synthetic characters are : presence and constancy — the uniformity with which a species occurs in different stands in a community; fidelity — egree to which a species is restricted in a particular community; dominance — the .cological success of species in a community, and influencing the occurrence of other species in the

community; physiognomy and pattern — the general appearance of vegetation based on a number of qualitative and quantitative characters; frequency — the degree of dispersion of species in an area; Inportance Value Index — complete picture of sociological structure of a species in a community; species diversity — number and kind of species in a community.

9.7 TERMINAL QUESTIONS

1) Comment on the following statement :
"Community is an association of interacting populations."

....

....

....

....

....

....

2) Fill in the blank spaces with appropriate words :

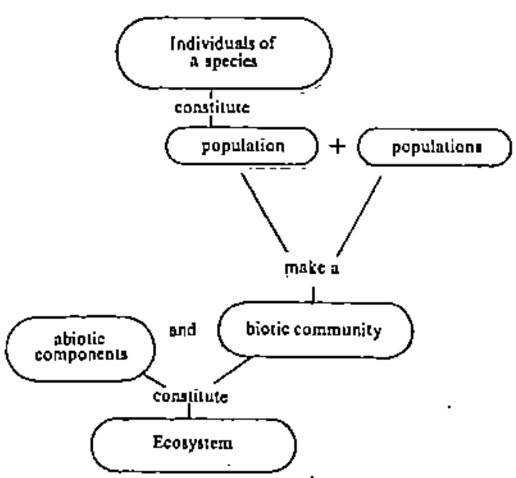
   a) The area where two adjacent communities blend is an ....
   b) A .... refers to an area of vegetation having species of same kind and age.
   c) In situations where there is a wide range of environmental conditions at the junction of two communities .... is seen.
   d) The .... concept implies that there is no distinct community with well defined boundaries, but there is a gradual change in space and time, along some environmental gradient.
   e) .... have four or five layers of vegetation and .... have two layers.
   f) .... of plant species in a community can be made only after we have the complete calendar of events of their life history.
   g) .... plants have high fidelity and occur in a particular type of community only.
   h) For determining the Importance Value Index of species, data of relative ...., ..., and .... is required.

9.8 ANSWERS

SAQ I

1) i) b

   ii)



iii) a) represents biotic components of an ecosystem
b) consists of organisms with interlocking food chains
c) may vary in size
d) concept can be applied to any scale
e) may be autotrophic or heterotrophic
f) may consist of stand(s)

2) i) species of a community
ii) different layers of vegetations, and dependent animal life
iii) changes in vegetation in a year
iv) rate and amount of growth
v) kind of vegetation based on the position of perennating bud
vi) nature of grouping of plants
vii) the numerical strength of species in an area
viii) area of ground, and above ground regions covered by plants
ix) tells about the suitability of plants to its environment
x) total biomass of vegetation.

3) i) how uniformly a species occurs in a community
ii) to what degree a species is restricted to a community
iii) the predominant influence of one or more species in a community
iv) the general appearance and kind of distribution of organisms in a community
v) the degree of dispersion of individual species in an area
vi) total picture of the ecological importance of a species
vii) the number and kinds of species in a community.

Terminal Questions

1) **Hint :** Community is an assemblage of populations of various kinds of organisms in a prescribed area. Community is the biotic component of an ecosystem. And in an ecosystem, the various kinds of organisms are related in terms of food and they form a food web. So the populations interact with each other directly or indirectly not any for food, but also influence the existence of other populations.

2) a) ecotone
b) stand
c) edge effect
d) continuum
e) forests, grasslanos
f) phenograms
g) indicator
h) density, frequency, dominance

UNIT 10 COMMUNITY CHANGE

Structure

10.1 INTRODUCTION

You know ecosystems are dynamic entities in which a number of events take place. Associated with the biotic communities of the ecosystem are some changes, which may be either small-scale changes or large-scale changes. Small-scale changes may be brought about by natural causes or by the activities of man. One of the examples of small-scale changes is a stream, in which some sewage is accidentally dumped. In such a case there would be an increase in the organic and inorganic chemicals in the water. The organic molecules are consumed by bacteria. With the increased availability of organic matter, the number of bacteria would increase. Bacteria use up oxygen as they consume organic materials, thus the level of oxygen in the stream usually drops. This can kill the fish and other organisms or cause them to migrate to new areas. In due course of time, the stream will return to normal. The bacteria will die if the level of organic matter falls off, and dissolved oxygen will return to normal, thus allowing fish to return. This example, clearly shows that the biotic community of an ecosystem may be temporarily affected by the small scale changes.

On the other hand, there are certain long-term changes in the ecosystem which can permanently change the organisation and composition of biotic communities. These long-term changes may be caused by factors like volcanic eruptions, landslides, earthquakes, floods, hurricanes, and of course human interventions such as mining and deforestation. All these disturbances, change the habitat considerably. A variety of species invade the changed or disturbed site, and eventually over a period of time, a new community develops there. This process continues — one community replacing another community, until a stable, mature community develops.

In this unit, we shall focus our attention, primarily on the large-scale changes in a community. Such large-scale changes are collectively known as ecological succession. We shall discuss the basic processes involved in succession. Then we shall take up two specific examples to explain how succession takes place in nature. Subsequently you would study, models of succession. We shall also talk about the characteristics and trends in succession.

Objectives

After studying this unit, you would be able to :

- define succession
- recognise differences between primary and secondary succession
- contrast autogenic and allogenic succession
- compare autotrophic and heterotrophic succession
- describe the basic processes involved in succession
- describe the process and various stages of succession in aquatic and terrestrial habitats, and explain why animal life changes with seral stages
- discribe the facilitation, inhibition and cyclic models of succession
- discribes the characteristics and trends in succession.

Study Guide

While studying this unit, if you are not able to fully understand subsection 10.2.2 and 10.2.3, at the first instance, do not be disheartened. We advise you to continue your study of the subsequent sections, and after you have completed section 10.4, come back to these two subsections.

10.2 WHAT IS SUCCESSION?

As we have discussed in the previous section that factors like fire, floods and human interventions affect an ecosystem considerably. They often lead to the depletion or stripping off of original vegetation of an area. The eventual result is the formation of bare ground or area. But this bare area does not remain devoid of life for long. It is rapidly colonised by a variety of species that subsequently modify one or more environmental factors. This modification of the environment may in turn allow additional species to become established. So, a biotic community destroyed by natural or human causes is gradually replaced in a series of changes, until a mature or *climax community* is reached. The process of community development, through a series of intermediate successional stages leading to climax community is known as seral stage and all such intermediate stages from bare area to climax community are collectively referred as 'seres'.

Succession is a universal process of directional change in vegetation, on an ecological time scale. If said in another way, succession is a progressive series of changes which leads to the establishment of a relatively stable climax community.

Having discussed as to what succession is we shall now take up for discussion various kinds of succession in the following three subsections:

10.2.1 Primary and Secondary Succession

Succession occurring in bare areas where no community existed before is called Primary Succession. For instance, primary succession would take place on new volcanic flows, islands, deltas, dunes, bare rocks and in newly formed lakes. Secondary Succession occurs at a site from where an already developed community has been destroyed by some natural catastrophe such as fire or flooding; or by human activity (such as deforestation, ploughing, grazing etc. and a series of communities subsequently develop at the site. Secondary succession also occurs on abondoned farmlands, in overgrazed areas and construction projects.

In primary succession on a terrestrial site (see Fig. 10.1) the new site is first colonised by a few hardy pioneer species, that are often microbes, lichens and mosses. The pioneers over a few generations alter the habitat conditions by their growth and development.

These new conditions may be conducive to the establishment of additional organisms that may subsequently arrive at the site. The pioneers through their death any decay leave patches of organic matter in which protists and small animals can live. 'The organic matter produced by these pioneer species produce organic acids during decomposition that dissolve and etch the substratum releasing nutrients to the substratum. Organic debris accumulates in pockets and crevices, providing soil in

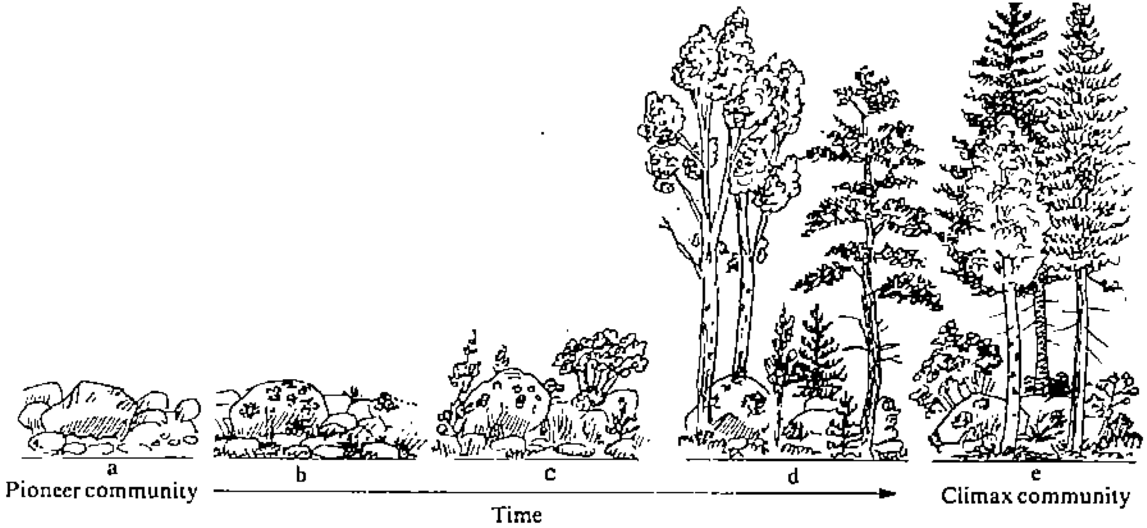


Fig. 10.1 : Primary succession on a terrestrial site developed through five seral stages (a-e), from left to right, beginning with bare rocks, colonised by lichens and mosses, and developing a relatively stable climax forest community.

which seeds can become lodged and grow. As the community of organisms continues to develop, it becomes more diverse and competition increases, but at the same time new niche opportunities develop. The pioneer species disappear as the habitat conditions change and invasion of new species progresses, leading to the replacement of the preceding community. Similarly, primary succession in aquatic habitat also develops through a number of seral communities. We shall discuss this with an example in the Subsection 10.4.1.

Secondary succession is the sequential development of biotic communities after the complete or partial destruction of the existing community. A mature or intermediate community may be destroyed by natural events such as floods, droughts, fires, or storms or by human interventions such as deforestation, agriculture, overgrazing, etc. Let us look briefly at an example of secondary succession occurring on an abandoned agricultural farm where soil has been already formed before cultivation started (see Fig. 10.2).

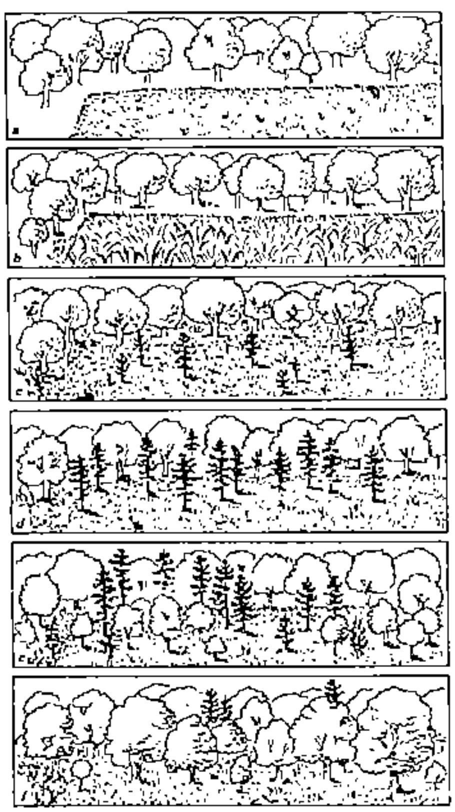


Fig. 10.2 : Secondary succession in an abandoned farmland shown in six stages (a-f). First grasses appear (a, b), and through the intermediate stages (b-e), finally a woodland ecosystem develops(f)

This abandoned farmland is first invaded by hardy species of grasses that can survive in bare, sun-baked soil. These grasses may be soon joined by tall grasses and herbaceous plants. These dominate the ecosystem for some years along with mice, rabbits, insects and seed-eating birds. Eventually, some trees may come up in this area, seeds of which may be brought by wind or animals. And over the years, a forest community develops. Thus an abandoned farmland over a period say 30 to 40 years becomes dominated by trees and is transformed into a forest.

When talk of the differences between primary and secondary succession, one obvious difference between the two is that the secondary succession starts on a well developed soil already formed at the site. Thus secondary succession is relatively faster as compared to primary succession which may often require hundreds of years.

10.2.2 Autogenic and Allogenic Succession

Autogenic = self-generated
Allogenic = externally generated

In many cases the living beings of an ecosystem, modify their environment considerably by their growth, death and decay. The changed conditions lead to the establishment of new kinds of species in that area. The whole process goes on and on, that is, there is replacement of one kind of community with another. Such a succession process is called autogenic succession. To sum up, autogenic succession results because of the changes brought about in the habitat by the members of the community themselves.

In some cases, the changes brought about in the habitat are caused by external agencies and not by the existing vegetation itself. This is called as allogenic succession. Such a succession may occur in a highly disturbed or eroded area or in ponds where nutrients and pollutants enter from outside and modify the environment and in turn the communities.

10.2.3 Autotrophic and Heterotrophic Succession

The succession where initially the green plants are much greater in quantity than the animals, is known as autotrophic succession. Such a succession takes place in a medium rich in inorganic substances. Since there are green plants, there is gradual increase in the organic matter content and energy flow in the ecosystem. On the other hand, in heterotrophic succession, the populations of heterotrophic organisms, like bacteria, actinomycetes, and fungi are present in greater quantity in the initial stages. Such a succession begins in a medium rich in organic matter such as the rivers and streams which are polluted heavily with sewage, or in small pools receiving leaf litter in large quantities. As indicated earlier, it begins, prominently in organic environment, and there is a progressive decline in the energy content.

SAQ 1

Put a tick (√) mark against the correct choice :

1) Succession involves the turnover of species ing :
   a) the seasons of the year
   b) ecological time
   c) micro-evolutionary time
   d) macro-evolutionary time

2) Primary succession takes much longer than secondary succession because it involves :
   a) development of the soil
   b) accumulation of a wide variety of seeds
   c) colonisation by organisms that are farther away
   d) destruction of a habitat by some natural catastrophe

3) Most agriculture makes use of plants from :
   a) early primary succession
   b) early secondary succession
   c) late primary succession
   d) late secondary succession

4) Autogenic succession is brought about by :
   a) human activities
   b) physical conditions of the environment
   c) living inhabitants of that area
   d) natural disasters

5) The kind of succession, in which the green plants constitute the initial stages are known as :
   a) heterotrophic
   b) allogenic
   c) autotrophic
   d) both (a) and (b).

10.3 PROCESSES IN SUCCESSION

Whether succession is primary or secondary, in terrestrial or aquatic ecosystems, the basic processes involved in succession are similar. There are a number of sequential steps in succession. In this section we shall discuss them in detail. These steps or processes are : *nudation; invasion* or *migration; ecesis; aggregation; competition, reaction;* and *stabilisation – climax.*

10.3.1 Nudation

The first step or requirement is the availability of the right kind of habitat, primary succession takes place in a bare area, that is, without any life form; and secondary succession occurs in area where soil is already formed, but the vegetation is destroyed. The bare area may develop due to several causes, some of them are :

i) *Topographic* — factors like soil erosion by gravity, water or wind, may destroy the existing vegetation thus creating a bare area. Other topographic causes include deposition of sand, landslide and volcanic activity.

ii) *Climatic* — glaciation, long dry periods, hails and storm, frost and fire are the agents that destroy vegetation.

iii) *Biotic* — One important agent is man that causes destruction of forests, grasslands and other stretches of vegetation for agriculture, industry, housing and several other purposes. Overgrazing by animals, diseases caused by organisms like bacteria, fungi and insects too destroy vegetation of an area to produce bare areas.

10.3.2 Invasion or Migration

When a habitat is changed it can be a potential site for the establishment of many organisms. Many species actually invade or reach this new site from any other area. The seeds, spores or other propagules of the plant species reach this area. This process is known as *migration*, and is generally brought about by air, water and various other agents.

10.3.3 Ecesis

After reaching the new area, the process of successful establishment of the species as a result of adjustment with the conditions prevailing there is known as ecesis. In plants, after migration, seeds or propagules germinate and grow if the conditions are favourable. Ecesis is considered to be complete, if the plant is able to sexually reproduce in that particular area. As a result of reproduction, the number of individuals multiply rapidly and the species becomes established in that area.

10.3.4 Aggregation

After successful establishment of a species as a result of reproduction, the individuals of the species increase in number. So, as compared to earlier stages, there are a larger number of individuals of a species that have aggregated in the given area.

10.3.5 Competition

Interspecific competition : competition between two different species A and B.
Interaspecific competition: competition amongst the individuals of the same species.

The aggregation of individuals in an area leads to interspecific and intraspecific competition. The competition is usually for i) *water,* particularly when there is shortage of water; ii) *nutrients,* particularly when they are in short supply; iii) *radiant energy,* if one plant grows in the shade of another plant; iv) *carbon dioxide;* v) *oxygen,* and vi) *space.* Success of a species during competition depends on several features, e.g., strong and efficient root system, capability to trap nutrients, endurance to drought and poor soil aeration, and efficiency of reproduction of the plant.

10.3.6 Reaction

This is the most important stage in succession. The mechanism of modification of environment, through the influence of living organisms on it is known as reaction. As a result of reaction, changes take place in soil, water, light conditions, temperature and many other factors of the environment. The environment thus gets modified, and becomes unsuitable for the existing community, and is eventually replaced by another community. The old occupants are ousted and fresh migrants establish themselves. Thus, through a series of invasions, a sequence of plant communities marked by changes from lower to higher forms establish themselves in the course of time. Each stage of succession plays some part in reducing the extreme conditions in which the sere began. Thus, gradually the conditions of the area are modified by the seral communities to suit the growth of a wider range of species.

10.3.7 Stabilisation — Climax

The whole process of succession results in stabilisation of the vegetation which is now in complete harmony with the environmental complex of that place. And it is likely to persist as long as the climatic and physiographic conditions remain unchanged. The soil is fully occupied by plants and the community is closed. Only those species, which are capable of completing their life cycles, despite the intense competition, establish themselves, the homeostasis is thus attained. This final community is not replaced, and is known as climax community and the stage as climax stage.

The kind of succession that takes place from simple, few forms to complex, several kinds of forms are known as **progressive succession.** In some cases, reverse situation is seen, that is, the process of succession, instead of being progressive becomes retrogressive. This may be due to the destructive effects of organisms. For example, a forest changing into a grassland community is an example of **retrogressive succession.**

10.4 KINDS OF SUCCESSION

The ecological succession can be broadly classified into two kinds, on the basis of the nature of the habitat.

Succession
- A. Hydrarch
  - i) Hydrosere
  - ii) Halosere
- B. Xerarch
  - i) Lithosere
  - ii) Psammosere

A. Hydrarch — When succession takes place in a wet area, that is, succession progresses from hydric to mesic conditions. This can be further subdivided as: i) hydrosere — when succession starts in fresh water ecosystems like ponds, pools, lakes and marshes; ii) halosere — when succession starts in saline water ecosystems, e.g., mangroves, coral reefs, estuaries.

B. Xerarch — When the succession takes place in drier area, i.e., the succession progresses from xeric to mesic conditions. It is further subdivided as : i) lithosere — when it takes place on bare rocks; ii) psammosere — when succession takes place in a sandy area, like sand dunes. In this section, we shall discuss in detail, an example each of Hydrarch and Xerarch.

10.4.1 Hydrarch

Its various stage are well studied in ecosystem like ponds, pools and lakes. In this subsection, we shall discuss, succession in a pond. Since pond is a fresh water ecosystem, the succession in it is also referred to as hydrosere. Succession in pond, begins by colonisation by the pioneers like the phytoplanktons, and finally terminates into a forest which is a climax community. As succession progresses, changes take place in the kind of vegetation as well the associated animal life (see Fig. 10.3). The whole process of succession or the hydrosere is further subdivided into a number of stages depending on the kind of organism(s) dominating a stage. We shall now discuss these stages one by one, in detail.

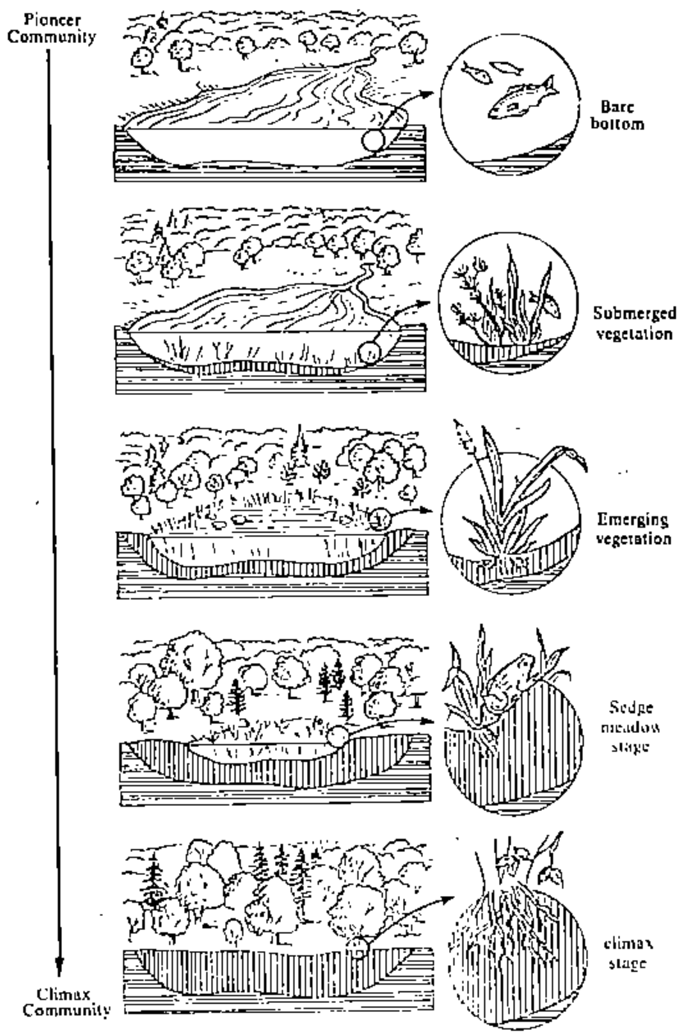


Fig. 10.3 : Hydrosere in a pond ecosystem. The pond is gradually converted into a forest ecosystem. Sediments begin to accumulate, and a series of biotic communities develop until the mature ecosystem is reached

i) **Phytoplankton Stage :** In this initial stage, the pond water is poor in nutrients and is devoid of much life. At this stage, the water is incapable of supporting larger life forms. So, in such situations, phytoplanktons consisting of microscopic algae, begin to multiply and they quickly become the pioneer colonisers. As the phytoplanktons and the dependent animal population dies, decomposer organisms like bacteria and fungi increase in number and bring about decomposition of the organic material. Decomposition results in the release of minerals and enrichment of aquatic habitats. Besides this, some silt may be brought to the pond, by the rain water from the surrounding land. By now the pond becomes shallower, and the mud at its bottom is rich in nutrients. Now it can support some rooted hydrophytes, thus initiating the next stage.

ii) **Submerged Stage :** This habitat which is now shallower and is richer in nutrients, and where light is available upto a certain depth, becomes suitable for the growth of rooted, submerged hydrophytes like *Myriophyllum, Elodea, Hydrilla, Potamogeton*

Vallisneria, Utricularia and *Ceratophyllum*. These grow at various depths, mostly rooted in the muddy or sandy bottom depending on the species, and also on the clearness or turbidity of water. Year after year, this vegetation expands and covers large areas, and brings about marked changes in the habitat. Materials eroded by streams, rainwater or surface runoff are brought to the pond, and some of it are deposited on the plants because they form a direct obstacle in its advance, and especially because they slow down the currents, when the plants and the associated animals die, they sink to the bottom, where because of the insufficient oxidation, this organic matter is partially decomposed. Thus humus is formed which cements the mucky soil together making it firmer. The result of these reactions is the building up of substratum and shallowing of lake. Obviously, this process is disadvantageous to the present occupants and these are eventually replaced by another type of plants, which are of floating type.

iii) Floating Stage : The pond is now colonised by plant species which are rooted in mud but their leaves reach water surface and float. These are species of *Nelumbo, Nymphaea, Trapa, Monochoria.* Some free-floating species that are not fixed in the mud, also make their appearance. Examples are *Lemna, Wolffia, Pistia, Salvinia, Azolla* and *Eichhornia*. Due to the growth, and death and decay of these organisms, the water level by now becomes very much decreased, making the pond much more shallower. Evaporation of water, along with the addition of silt from the adjacent area also contribute in making the pond shallower. The pond, now does not remain suitable for this kind of plants and the next stage appears.

iv) Reed-Swamp Stage : This stage is also known as amphibious stage, as the plants of the community are rooted but most parts of their shoots remain exposed to air. Species of *Typha, Sagittaria* and *Phragmites* are some examples of this stage. These plants have well developed root system and they form dense patches of vegetation. The reaction of the reed-swamp plants is not only to shade the surface of the water but also to build up the pond margins by retaining the sedimentary materials washed into the lake and by the very rapid accumulation of plant remains. Not only is the plant population much denser than before but also mechanical tissues, which resist decay, are much more highly developed in plants with aerial organs. After the invasion and activities of these plants, the water level is very much reduced, and finally it becomes unsuitable for these plants also.

v) Sedge-Meadow Stage : Favoured by an increasing amount of light, as the former occupants disappear, they gradually change the reed swamp into a sedge meadow. And now species of Cyperaceae and Gramineae such as *Carex, Juncus, Cyperus* and *Eleocharis* colonise the area. They form a mat-like vegetation with the help of their much branched rhizomatous systems. All these react upon the habitat by binding water-carried and wind-borne soil, accumulating plant debris and transpiring enormous quantities of water. There is much rapid loss of water, and sooner or later the mud is exposed to air. As a result nutrients like ammonia, sulphides become oxidised to nitrates and sulphates. Thus the conditions in the area gradually change from marshy to mesic, and the marshy vegetation shows a decline. Upto the end of sedge-meadow stage, the climate of the region has no control over the succession because the water content of soil is high, irrespective of rainfall and climate of the region. At the end of this stage, the soil becomes dry and its water content will henceforth be dependent upon rainfall and climate of the region. The plants which succeed the sedge-meadow stage are therefore controlled by the climate to a very large extent. In dry climates the next stage may be grassland or some other xeric climax but in more moist climates it is woodland.

vi) Woodland Stage : When the lowland has been built upto an extent where the soil is saturated perhaps only in spring and early summer, certain species of shrubs and trees may appear. Those that can tolerate waterlogged soil around their roots will be the pioneers. Various species of *Salix, Cornus, Cephalanthus, Alnus* and *Populus* may form dense thickets. Some shade-tolerant herbs may also grow among the trees an shrubs. These woody plants react upon the habitat by producing shade and by lowering the water table both by further building up the soil and by vigorous transpiration. By this time of succession there is much accumulation of humus wit rich flora of microorganisms like bacteria, fungi and others. Thus mineralisation o the soil favours the arrival of new tree species in the area leading to climax stage.

vii) Climax Stage : A variety of trees invade the woodland community which soon develop into the climax community. The nature of the climax is dependent upon the climate of the region. In tropical region, where rainfall is high, dense rain forests develop, and in temperate regions, mixed forests of trees like *Quercus, Ulmus, Acer* may develop. In regions of moderate rainfall the climax stage consists of deciduous forests or monsoon forests.

Thus in the hydrosere you have just studied, stage i) is the pioneer community stage, vii) the climax community, and stages ii) to vi) as the seral communities or seral stage.

Successive Changes in Animal Life During Hydrosere

So far, we have discussed the successive changes in plant communities in the different seral communities of a hydrosere. The question arises, is there any change in the animal life along with the different seres. There are certainly changes in the animal life also, but these may not be as obvious as in case of plant community. In an aquatic ecosystem like this, protozoans like *Paramecium, Amoeba, Euglena* and many others are the pioneers. When the planktonic growth forms are very rich, then animals like blue gill fish, sun fish, large mouth bass etc. start appearing. Some caddisflies are also found. In the second stage, that is, the submerged stage, the caddisflies are replaced by other animals that may creep over the submerged vegetation. Thus dragonflies, mayflies and some crustaceans as *Asellas, Gammarus, Daphnia, Cypris, Cyclops* inhabit the pond at this stage. At the floating stage, the animals life is chiefly represented by *Hydra* spp., gill breathing snails, frogs, salamanders, diving beetles, and other insects. There also appear some turtles and snakes.

At the reed-swamp stage, the pond becomes shallower, and the bottom starts becoming exposed. The floating animals are replaced by different species of mayflies and dragonflies, whose nymphs remain attached to submerged parts of the vegetation, and adults present on the surfaces of exposed parts of vegetation. Gill-breathing animals like snails are replaced by lung breathers as *Lymnea, Physa* and *Gyraulus.* Among insects, water scorpion, giant water bug, scavenger beetles etc. are present at this stage. The bottom of the pond is now inhabited by some annelids, mud pickrel and bull-heads. Red-winged black birds, kingfisher, great blue heron, swamp sparrow, ducks, musk rats, and beavers become common in the area.

At the sedge-meadow stage, the animals like snails as *Anodonta, Psidium* become common. Finally, at the woodland stage, under terrestrial conditions, most of the terrestrial forms of animal life appear in the area.

10.4.2 Xerarch

Successions initiated on bare rock, wind-blown sand, rocky talus slopes, or other situations where there is an extreme deficiency of water are termed xerarch. Here, we shall discuss the example of a bare rock. It is not only deficient in water but also lacks any organic matter, having only minerals in disintegrated, unweathered state. The pioneers to colonise this primitive substratum are crustose type of lichens, and through a series of successive seral stages, the succession finally terminates into a forest which constitutes the climax community (also see Fig. 10.1). As in the hydrarch, successive changes take place in both plants as well as animals, but changes in plants are more obvious than animals. Now, we shall take up the various stages of xerosere for discussion.

i) Crustose Lichen Stage : On bare rocks, conditions are inhospitable for life, as there is extreme deficiency of water and nutrients, great exposure to sun, and extremes of temperature. Crustose lichens alone are usually able to grow in such situations. Some examples of these pioneering species are, *Rhizocarpon, Rhinodina, Lecidea* and *Lecanora*. These plants flourish during periods of wet weather and remain in a state of desiccation for very long periods during drought. During the wet weather they rapidly absorb moisture by their sponge-like action. Mineral nutrients are obtained by the secretion of carbondioxide which, with water forms a weak acid that slowly eats into the rock into which the rhizoids sometimes penetrate for a distance of several millimetres. Nitrogen is brought by rain or by wind-blown dust. Thus all the life requirements of this simple, crust-like species is met with. Thus, lichens help corrode and decompose the rock, supplementing the other forces of weathering. And by mixing the rock particles with their own remains, make conditions favourable for

Lichen — an alga and a fungus that live in symbiosis, forming a distinctive structure or thallus that may be crusty or leafy; Lichens are pioneers on rock or other surfaces.

growth of other organisms. Thus, a thin layer of soil is formed. The rapidity with which a small amount of soil is formed is controlled largely by the nature of the rock and by the climate. On quartzite or basalt rocks in a dry climate, the crustose-lichen stage might persist for hundreds of years. But on limestone or sandstone in a moist climate, sufficient changes permit the invasion of foliose lichens, and all this may occur within a life time.

ii) **Foliose Lichen Stage :** As mentioned earlier, the weathering of the rocks and the decaying of the crustose lichens results in the formation of soil on the otherwise bare rocks. The foliose lichens make their appearance on such spots on the rocks which have accumulated some soil. These lichens include *Dermatocarpon, Parmelia* and *Umbilicaria.* These lichens have large, leaf-like thalli, which overlap the crustose lichens. The latter are thus cut-off from direct light. This results in death and decay of the crustose lichens. The mass of foliaceous lichens can absorb and retain more water to some extent. Wind and water-borne dust particles are trapped by these lichens. This helps in the further building up of substratum. All these processes result in the accumulation of more and more humus. The rocks are weathered by the acids secreted by the living and the decaying plants. The weathering of the rocks and the rapid addition of humus to it result in the increase in thickness of soil layer. Thus, a considerable change in habitat is brought about.

iii) **Moss Stage :** The accumulation of soil, particularly in the crevices and depressions of rock favours the growth of certain xerophytic mosses., e.g., species of *Polytrichum, Tortula* and *Grimmia.* The spores of these mosses are brought by the blowing wind. They have more or less the same power of withstanding desiccation as that of foliose lichens. The lichens and mosses grow together and compete with one another. The rhizoids of mosses and foliose lichens compete for water and nutrients, and the stems of the former attain greater height than the latter. The plants in the lower strata, i.e., the lichens die, and the mosses grow. The mosses form cushion-like structure, that may be a few centimeters in thickness. The substratum is thus gradually built up and is widened. The foliose lichens gradually give way to mosses that overtop the lichens. Many times, all three stages may be found on a single rock surface, the pioneers occupying the most exposed places.

iv) **Herb Stage :** The Soil-forming and soil-holding reactions of the mosses are so pronounced that the seeds of various xerophytic herbs, especially short-lived annuals, are soon able to germinate and grow. The plants mature, although the first generations, because of the drought and sterility of the soil, may make only a stunted growth. Their roots continue the process of corroding the rock, and each year the humus from their decaying remains enriches the soil. Gradually, biennials and perennials begin to invade the area and with the habitat becoming more and more favourable, their numbers also increase.

The processes of rock disintegration and humus and nutrient accumulations are greatly increased, as the tangled network of roots increases and the soil becomes shaded. Evaporation and temperature extremes are decreased, humidity is slightly increased, and drought periods are shortened. The bacterial, fungal and animal populations of the soil increase and conditions gradually become less xeric. Upto now, some xerophilous, shallow rooted grasses like *Aristida, Festuca* and *Poa* were growing. As the conditions improve, then some drought-enduring species like *Potentilla, Solidago and many others invade the area. As a result of growth of the herbs, the smaller plants like mosses and lichens do not get enough light. So these conditions are detrimental for their growth, they gradually start perishing.*

v) **Shrub Stage :** Sufficient soil is formed in the herbs stage, for supporting the woody plants or the shrubs. They migrate with the help of seeds or rhizomes from the adjacent areas. Examples are : species of *Rhus* and *Phytocarpus.* The shrubs soon develop into dense vegetation. The habitat is considerably modified. The herbs are shaded by the overgrowing shrubs. They no longer find it possible to thrive in such a situation and are, therefore, completely replaced by the shrubs. The shrubby vegetation adds a lot of organic matter to the soil, through leaves and other plant parts. The soil is thus enriched with considerable amount of humus. The huge mass of roots of the shrubs corrode the rocks. The enriched soil attains greater capacity for holding water. The soil is shaded, and, therefore, evaporation of water is considerably reduced. The humidity is increased over such areas. All these favour the growth of seedlings of trees which start invading the area.

vi) **Climax Forest :** First, some xerophytic species of trees, establish in this area. They are sparsely distributed and are stunted because the conditions are still not very congenial for them. With passage of time, the rocks are further weathered and a deep layer of soil is formed. This favours vigorous growth of a much larger number of trees. The moisture in the soil is conserved because of the shading of soil. The climax forest is thus developed. The vegetation becomes more and more mesophytic with the accumulation of humus.

Thus, in the xerosere, as in the hydrosere the habitat has changed from one extreme condition to a medium situation which permits the development of a mesophytic type of vegetation.

Changes in Animal Life During Xerosere

Just like the hydrosere, there occur successive changes in animal life during the xerosere. A few mites are usually found associated with the lichens. Initially, the fauna is sparse in terms of species composition. There are a few ants or a few spiders present in the cracks and crevices of rock. These pioneer animals are exposed to harsh environment particularly the thermal extremes. As succession progresses, the mites become more varied in terms of species and small spiders, springtails as well as tradigrades become associated with the mosses. At later stage of succession, when grasses start appearing, the fauna increases markedly, both in qualitative and quantitative terms. Nematodes, larvel insects, collembola, ants, spiders and mites appear in this new environment. With the development of forest climax community, there develops a rich fauna consisting of invertebrates as well as vertebrates. These include springtails, mices, squirrels, shrews, mammals like fox, chipmunk, mouse and mole, birds, reptiles like turtles, snakes, and amphibians like salamenders and frogs.

SAQ 2

1) Which of the following organisms will be the first to colonise a bare rock?
   a) annual plant
   b) biennial plant
   c) perennial plant
   d) lichen

2) The kind of climax community in an area depends most on the area's:
   a) pool of available colonists
   b) soil organisms
   c) climate
   d) bed rock

3) This is a thought puzzle — put it together. Here are the pieces:
   (Write the correct sequence of the numbers of the pieces arranged by you in the space provided.)
   a) inter, and intra-specific competition
   b) aggregation of species in a given area
   c) development of bare area
   d) stabilised vegetation, likely to persist long
   e) reaching to the new site
   f) sexual reproduction, increase in number and establishment of organisms
   g) modification of the environment through the influence of living organisms.

10.5 MODELS OF SUCCESSION

After studying the processes and kinds of succession, there remains a question as to why succession happens; what mechanisms operate so that a bare rock is colonised by lichens and mosses; why does shrub stage succeed grassland; and some type of woodland (that is often predictable) succeeds shrub stage? This is an area of long-standing controversy in ecology, its resolution is hampered because of lack of sufficient field data and experimentation. Currently, it is believed that different mechanisms operate at different stages during primary succession and for different types of secondary succession, but there is disagreement about the relative importance of these different mechanisms.

There are two main points of debate in successional mechanism; one, whether the effects of early species on the environment is the critical factor determining succession of species; or whether what matters most are life history characteristics of species, such as longevity. Below, we describe three mechanisms, (see Fig. 10.4) the first one emphasises on environmental modification, while the other two emphasise on the life-history characteristics.

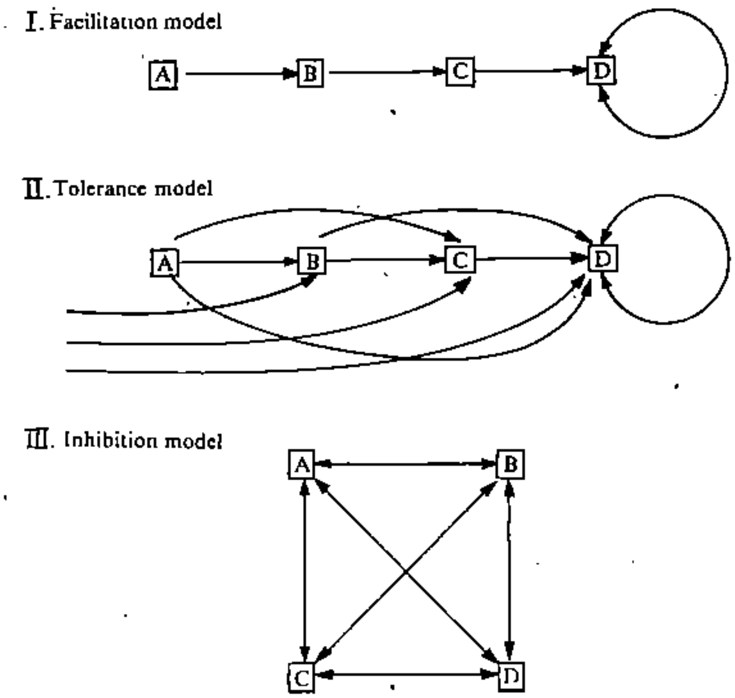


Fig. 10.4 : Three Models of Succession. The four species are represented by A,B,C and D. The arrows indicate 'is replaced by'. (After Krebs, C.J., 1985).

10.5.1 The Facilitation Model

This is considered as the classical model of succession. It is based on the assumption that species of a previous stage are replaced by the succeeding stage. And at each stage the species modify their own environment to make it progressively less suitable for themselves and increasingly more suitable for succeeding colonisers. Based on these characteristics Connell and Slayter (1977) proposed the facilitation model (see Fig. 10.4, I). To explain it better let us consider the example of succession in a pond. You may have noticed that due to the death and decay of different species of plants, siltation takes place and bottom of ponds is raised and the conditions become less suitable for their own survival and more suitable for the establishment of succeeding species. The essence of the facilitation model is that species of early stages of succession modify their own environment in a way that inhibits their own regeneration but facilitates the entry and survival of species of next higher stage of succession.

For many years this model was considered to be the only one. For the early stages of primary succession, it still seems to provide the best explanation of what is actually observed. But for later stages of primary succession and for secondary succession in forests or grasslands this model is not fully tenable.

10.5.2 The Tolerance Model

In this model, the presence of early successional species is not essential, that is, any species can start succession (see Fig. 10.4, II). Some species are competitively superior and they eventually predominate in the climax community. Species that are more tolerant of limited resources, replace the other species. Succession proceeds either by the invasion of later species or by a thinning out of the initial colonists, depending on the starting conditions. The crux of the whole thing is that there is a competitive hierarchy in which later species can outcompete earlier species (see Fig. 10.4, II) and can also invade in their absence.

10.5.3 The Inhibition Model

According to this model, succession is very heterogenous because the development at any one site depends on who gets there first. Species replacement is not necessarily orderly (see Fig. 10.4, III) because each species tries to exclude or suppress any new colonists. Thus succession becomes more individualistic and less predictable because communities are not always converging at climatic climax. In this model, no species is competitively superior than another. Whoever colonises the site first holds it against all new comers. Succession in this model proceeds from short-lived species to long-lived species and is not an orderly replacement. The essence of this model is that during succession, all replacements are possible, and much depends on who gets there first.

The three models of succession agree that the pioneer species will appear first because these species have evolved certain colonising characteristic such as rapid growth, abundant seed production, and means of efficient dispersal. Early colonising species are not well adapted to establish in occupied sites, on account of root competition with the established species and the reduced availability of light. In the different models of succession, the early colonisers, are fugitive species that create conditions which makes the habitat progressively unsuitable for themselves.

The main distinction between the three models is in the mechanisms that determine subsequent establishment. In the facilitation model, species replacement is facilitated by the species of the preceding stage. In the inhibition model, species replacement is inhibited by the present residents until they are damaged or killed. In the third model, species replacement is not affected by the present residents.

10.6 TRENDS IN SUCCESSION

Succession is an important aspect of change in ecosystems and a simple description of successional communities (as in Section 10.3 and 10.4) is only the beginning of the story. We need to know at a more fundamental level *what is happening* during succession because this might give some *clue* as *to why it happens.*

During primary succession, for example, from an aquatic habitat or a bare rock to climax woodland, there are certain obvious changes in the vegetation and soil. For example, increase in community biomass, and development of soil containing dead organic matter mainly from a largely mineral substrate. These changes are linked with many other ecosystem features. For instance, energy flow and nutrient cycling.

Succession may begin with a bare area colonised by small plants and may culminate in a community of large plants whose growth form results in increased vertical stratification and a marked influence on the environmental conditions within the community. Many such changes, enumerated in Table 10.1, are quite characteristic of ecological succession.

You have learnt from your study of Section 10.4 that the early successional stages are characterised by a few species, low biomass, and dependence on abiotic sources for nutrients. In the early stages, the net primary production is greater than respiration, resulting in increased biomass over time. Energy is channelled through relatively few pathways to many individuals of a few species, and production per unit biomass is high. Food chains are short, linear and largely grazing.

The mature stages in succession are characterised by a greater species diversity, greater biomass, gross production that almost equals total community respiration

Table 10.1 : Changes in Ecosystems During Succession (Modified from Odum, 1969)

Characteristics	Immature (early) ecosystem	Mature (late) ecosystem
Gross production/Respiration (P/R ratio)	High, > 1, (P>R)	Approaches 1, balance (P=R)
Net community production	High	Low
Food Chains	Linear, mainly grazing	Web-like, mainly detritus
Total organic matter (biomass)	Small	Large
Species diversity	Low	High
Structure of community	Simple	Complex (stratification with many microhabitats)
Total organic matter	Small	Large
Inorganic nutrients	Mostly found in physical environment	Large amounts, locked in organic matter
Mineral cycles	Open	Closed
Stability	Low	High
Size of Organisms	Small	Large
Gross Production/standing crop biomass (P/B ratio)	High	Low

(P=R), substratum rich in organic matter. Food chains are complex and largely detrital. Large amounts of inorganic nutrients locked in organic matter in the soil, and the vegetation.

The trend of most successions is towards a more complex and longer-lasting ecosystem, in which less energy is wasted and hence, a greater biomass can be supported without further increase in the supply of energy. Actually, succession may be very complicated because stages may be skipped, telescoped or extended. Human activities retard or reverse this succession back — due to agriculture, farming, lumbering, urbanisation and environmental pollution. If any habitat is left undisturbed, then eventually a stable climax community will be formed.

SAQ 3

I) Fill in the blank spaces with appropriate words:

1) Three mechanisms may influence the path of succession, ... in which early species alter the environment in ways that improve the area for later species; .... in which early species make it more difficult for later species to colonise; and ...., in which early species have no influence over colonisation by later species.

2) During a succession, the number of species ...., the community biomass ...., and the community's ratio of respiration to production .... At climax, the rate of production is .... the rate of respiration.

10.7 SUMMARY

- Succession occurs when a series of communities replace one another, as each community changes the environment to make conditions favourable for a subsequent community, and unfavourable for itself. The first plants to colonise an area make up the pioneer community. The final stage of succession is called the climax community. The stage leading to the climax community are called successional stages or seres.
- Primary succession occurs when plants colonise bare rocks or other areas where there is no soil. Secondary succession occurs when plants recolonise an area in which the climax community has been disturbed.
- When succession is brought about by living inhabitants, the process is called autogenic succession, while change brought about by outside forces is known as allogenic succession.

- Succession in which, initially the green plants are much greater is quantity is known as autotrophic succession; and the ones in which the heterotrophs are greater in quantity is known as heterotrophic succession.
- The basic processes of succession are more or less the same for any kind of succession. These processes are; nudation; invasion or migration; ecesis; aggregation; competition: reaction: and stabilisation — climax.
- Succession in aquatic ecosystems like pond begins with increased nutrient sediments, encroachment by shore plants, and a general increase in both numbers and kinds of organisms. The continued trend results in the pond filling in and later blending in with the surrounding terrestrial community.
- Succession in xeric habitat like a bare rock begins by pioneer plants. These establish on the substratum with hostile conditions, like deficiency of water, too much exposure to sun. By the activity of the pioneers, some soil is formed on the bare area. This area is subsequently colonised by various kinds of plants, and a considerable amount of soil builds. The overall xeric conditions change to mesic conditions.
- There are three popular models to explain the mechanism of succession. The facilitation model suggests that the species in the early stages of succession modify the habitat in a way that inhibits their own regeneration, but is suitable for the growth of species of the subsequent stages of succession. The toleranace model says that there is a competitive hierarchy in which the later species can outcompete earlier species and can also invade in their absence. The inhibition model suggests that during succession, all replacements are possible and much depends on who gets there first.
- Succession is characterised by the following: increased productivity, the shift of nutrients from the reservoirs, increased diversity of organisms with increased niche development, and a gradual increase in the complexity of food webs.

10.8 TERMINAL QUESTIONS

1) Give an example that illustrates each of the following: (Do not use examples given in the text).

   a) Primary succession

   ....

   ....

   b) Secondary succession

   ....

   ....

   c) Progressive succession

   ....

   ....

   d) Retrogressive succession

   ....

   ....

2) Explain how primary succession on land differs from succession in a lake or pond.

   ....

   ....

   ....

   ....

   ....

3) Where would one expect to look for signs of secondary succession? What does secondary succession end?

....

....

....

....

....

4) Essentially what determines the rate of succession in fresh water bodies?

....

....

....

5) Imagine two volcanic areas, both the same size. In both areas, a fresh lava flow has spread newly formed rock over the land. One area is an island, far from land, and the entire island has been covered with lava. The second area exists in the middle of a large continent. Would succession occur faster on island or on the continent; or would the two be the same? Defend your answer.

....

....

....

10.9 ANSWERS

Self-Assessment Questions

1) 1) b 2) a 3) b 4) c 5) c

2) 1) d 2) c 3) c, e, f, b, a, g, d

3) 1) facilitation, inhibition, tolerance
   2) increases, increases, increases, equal

Terminal Questions

1) Write the examples from your experiences.

2) Primary succession on land occurs in areas, where there is deficiency of water, and the soil is not formed. Succession in this case proceeds from xeric to mesic conditions. On the other hand, succession in lake or pond proceeds from a situation where there is plenty of water and very less soil to the mesic conditions.

3) Secondary succession occurs in disturbed areas, where soil is often in place, eliminating the long soil building stages as seen in primary succession. Some plants like weeds grow profusely and their growth is not checked. As secondary succession progresses, the initial invaders are eventually replaced by plants from the surrounding community. Larger, fast growing trees block the sunlight and a new generation of shade-tolerant shrubs emerges below the conopy, eventually the lines between the area in succession and the surrounding community begins to fade. At this stage the last stage of secondary succession is reached.

4) The availability of nutrients determine the rate of succession in fresh water bodies. By the growth and development of different seres, the nutrient content in the ecosystem increases. The rate of succession is also enhanced if the nutrient supply is increased; such as in the case of eutrophication in ponds and lakes.

5) Succession would occur faster in area existing in the middle of the large continent. This is because, here all propagules or seeds of plants belonging to the different seres would reach much faster, establish and ultimately result in climax community.

UNIT 11 COMMUNITY ORGANISATION AND INTERACTION AMONG ORGANISMS

Structure

11.1 INTRODUCTION

In Units 9 and 10 you have learnt about the structure of a community. You learnt that communities change over time and uninterrupted succession ends with a relatively stable group of organisms — the climax community.

Although seemingly calm and quiet an ecosystem can be as busy as any large city during rush hours — minus the noise. Let us consider a forest as an example. The soil teems with bacteria, fungi, insects, mites, slugs, worms, spiders and scores of other organisms that dig up the ground as they move and reproduce. Delicate seedlings errupt through the surface, absorb nutrients recycled by the decomposers and eventually grow into shrubs, trees etc., that manufacture food for herbivores. Carnivores devour the herbivores as well as other carnivores.

The organisms will vary from one ecosystem to another and the example here of the forest illustrates how some organisms interact with each other. Some interactions benefit one or both participants whereas, some harm one or both participants. In this unit we will first discuss the various approaches used to explain community organisation. The following sections would deal with the interaction among organisms that make up the community.

In the next unit we will explore the various parameters that affect the populations in a community.

Objectives

After reading this unit you should be able to:

- describe the processes that affect community organisation and define niche, guild, keystone and dominant species
- define the various interspecific and intraspecific interactions giving examples of each

- explain competitive exclusion principle and how potentially competing species may coexist
- define various forms of predation and explain the predator-prey system
- describe the relationship of plants and herbivores alongwith some examples of plant defence systems

11.2 COMMUNITY ORGANISATION

You have learnt in Unit 9 that a community contains populations of many species. We shall now see how a community is organised in the ecosystem. Three processes — competition, predation and symbiosis help to organise communities. For instance competition among plants, herbivores and carnivores could control the diversity and abundance of species in a community. Predation could organise the community along feeding lines while symbiosis which includes important interactions like mutualism that link species could help to increase community organisation in a positive way. This would be made clear as you study these interactions in later sections.

Before we examine the various factors that influence the organisation of a community we should first review the important concepts of habitat and niche.

11.2.1 Habitat and Niche

The difference between habitat and niche can be made clear if we take a simple example. To become aquainted with a person we need to know his address, i.e., where he would be found, i.e. habitat. To really know the person well we would want to know about his occupation, interests, associations and his role in community, this would be his niche.

The **habitat** of an organism is where it lives, you could say its mailing address. When we describe an organism's habitat it is best to be specific and describe in as much detail as possible the exact location.

Although the word **niche** recalls to mind a small space, in ecology it means much more. The niche of an organism refers to the role it plays in the ecosystem. It includes tolerence of physical factors such as temperature, light, soil, moisture, pH and nutrient requirements. It also includes biological aspects such as — how it acquires its food, what season of the year it reproduces and how it interacts with other organisms in the community. In short the niche defines a particular species role in the community, and is unique for each species. Table 11.1 lists some of the factors that should be taken into account when describing the niche of a species.

Table 11.1 : Aspects of Niche

Plants	Animals
Season of year for growth and reproduction	Time of day for feeding and season for reproduction
Sunlight, water, soil, pH, temperature requirements	Habitat and food requirements
Relationship with other organisms	Relationships with other organisms
Effect on abiotic environment	Effect on abiotic environment

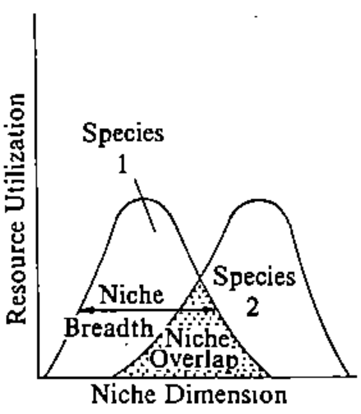


Fig. 11.1 : Niche parameter in a community.

In a community two niche dimensions usually taken into consideration are — **niche width** and **niche overlap** (Fig. 11.1). Niche width or niche size is the sum total of the different resources exploited by the organism. Measurement of niche usually involve the measure of some ecological variable such as food size or habitat space. Niche width may be described as narrow or broad. A narrow width indicates a specialised species while a broad width would indicate that the species is a generalist and can use a wide range of resources. Niche overlap indicates that two or more species use a portion of the available resources, such as food, or space, simultaneously. You can see in the figure that some niche space is shared and some is exclusive.

The concept of niche suggests that related species that differ with respect to niche are able to coexist in a habitat or community because their niche difference partitions the resources and thus competition is avoided. This is true for both plants and animals and we shall discuss this in more detail in section 11.4.

11.2.2 Functional Roles and Guilds

To find out how a community is organised we can use several approaches. The simplest approach would be to group the species present in the community according to feeding habits. In this way we can get information about the food web and then subdivide each trophic level into **guilds.** These guilds are groups of species exploiting a common resource base in a similar fashion. For instance all organisms like monkeys, parrots or other birds that eat fruit in a forest can form a guild; or ants, rodents, and birds that eat seeds in a desert habitat can form a single guild. Guilds may serve to pinpoint the basic functional roles of the species and different guilds interact amongst themselves and provide the organisation that we see in a community. The guild is a convenient unit for studies of interactions between species in a community and should help us to study its organisation better by making it unnecessary to study each and every species as a separate entity.

11.2.3 Keystone Species

When the activities of a species determines community structure that species is called **keystone species.** For example, consider the case of the starfish, *Pisaster ochraceous*. When this starfish was removed from the rocky intertidal areas of western north America, the mussel *Mytilus californianus* was able to occupy the space and excluded other invertebrates and algae which require attachment sites. However, under natural conditions, predation of mussels by starfish keeps their population under control and does not allow it to become dominant. This permits other species requiring attachment sites to survive in such habitats.

Another example of a keystone species could be of the African elephant. By their feeding habits elephants destory shrubs and small trees and push woodland habitats towards open grassland. Large mature trees can be destroyed by elephants feeding on their bark. As more grasses invade the woodland habitats, the frequency of fires increases, which accelerates the conversion of woods to grassland. This works to the disadvantage of the elephant, because grass is not a sufficient diet for elephants, and they begin to starve as woody species are eliminated. However, other ungulates that graze the grasses are favoured by the elephants' activities. Thus in this community elephants play an important role in shaping the community organisation.

Kestone species may be relatively rare in natural communities or may not be easily recognised. At present, few terrestrial communities are believed to be organised by keystone species, but in aquatic communities keystone species may be common.

11.2.4 Dominant Species

These are recognised by their greater number or more biomass and in general, are described separately for each trophic level. Dominance is related to the concept of species diversity. This means that some of the measures of species diversity could be considered as measures of dominance. We may thus define simple *community dominance index* as follows:

Community dominance index = percentage of abundance contributed by the two most abundant species.

$$= \frac{y_1 + y_2}{y}$$

Where y_1 = abundance of most abundant species

y_2 = abundance of second most abundant species

y = total abundance for all species

Abundance may be measured by density, biomass or productivity.
Dominance, however, is not always closely related to diversity. Dominant species are usually assumed to be competitive dominants. However, dominant species in some communities may be a matter of chance. For example, of the many invertebrates species present in a rotting log community, many species may be dominant at least once but none would be dominant in every log. Thus a species could be dominant in one log while very rare in the adjacent log. It seems that the determining factor is very much a question of who gets there first.

Available data suggests that dominance can be achieved in three ways; i) the first species to reach a new resource like in a rotting log, may become dominant, ii) a species may become dominant by specialising on one part of a resource set that is widely distributed, and iii) a species may generalise so that it could use a wide variety of resources.

Dominance is an important component of community organization, although it is still poorly understood. Dominant species may affect not only the organisation of a community but also its stability. Therefore, let us now investigate community stability.

11.2.5 Stability

It is a dynamic concept that refers to the ability of a system to absorb change and return back from disturbance. Let us look at figure 11.2. It explains the concept of stability in an ecosystem. The black ball represents the community on a surface which represents environmental conditions. In (a) the community is stable as the system will return back to point I after disturbance. In (b) the community is locally stable but if perturbed beyond a limit it will move to other positions of relative stability (II and III). In (c) large disturbances will cause extinction of some species and recolonisation by newer species.

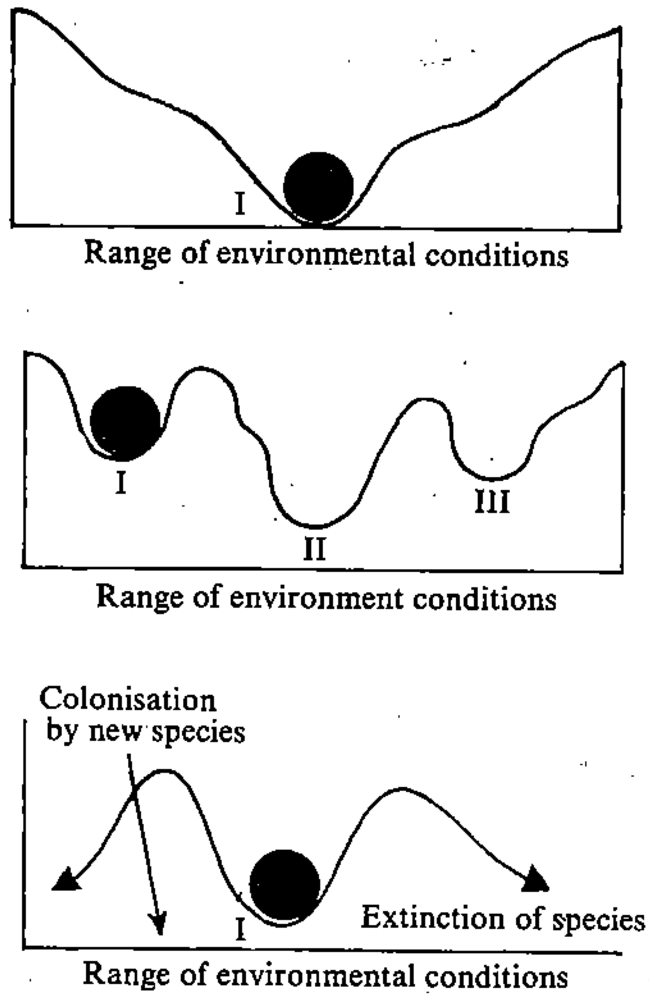


Fig. 11.2 : Stability concept in an ecosystem

Thus stability is a dynamic concept but is equilibrium centered. There must be one or more equilibrium limits or points at which the system remains when faced with a disturbing force. Stability may be local or global. *Local stability* is the tendency of the system to return to its original position from a small disturbance; gaps in forests filling in with similar species of trees are examples of local stability. *Global stability* is the tendency of a community to return to its original condition from all possible disturbances. Eucalyptus forest's return to its original condition after an outbreak of fire represents global stability. Communities show resistance and resilience. *Resistance* is a measure of the degree to which a system is changed from an equilibrium state after disturbance. *Resilience* is the speed with which a perturbed system returns to equilibrium. A rapid return is an evidence of high resilience.

The simple and appealing notion that diversity of species causes stability is incorrect. Infact increasing complexity reduces stability in mathematical models and therefore, if diversity causes stability as is often said for tropical communities, it is not an automatic consequence of species interactions. Natural communities are products of evolution where nonrandom combination of interacting species are produced in which diversity and stability are related. The stability of whole communities has rarely been studied in detail inspite of the great number of perturbations caused by man.

Aquatic communities have been disturbed by pollution of human origin and the stability of aquatic systems under pollution strees is a critical focus of applied ecology today. We have seen an example of how nutrient additions affect lakes in Unit 6. It is imporant that we acquire information on how much we can perturb the community before it changes to a less desirable configuration. At present, it is done by trial and error method only.

Let us now take a look at the two opposing views about community organisation.

11.2.6 Views of Community Organisation

The conventional (older) view is the *equilibrium hypothesis* where local populations are controlled by competition, predation, and mutualistic interactions. Global stability is the rule, and disturbances are suppressed. Species diversity is determined by diversification of niche, therefore, each species is competitively superior in exploiting a particular habitat. The newer and less accepted view is the ***nonequilibrium hypotheis.*** This one states that the species composition of a community is always changing and no balance remains. There is no global stability for communities in the world and persistence or resilience is a more relevant measure.

Nonequilibrium hypothesis can be explained if we assume that high species richness is maintained in communities which suffer from medium to moderate levels of disturbances. If disturbances like fires, frost, landslides, windstorms etc., are very frequent, only those organisms will occupy a site, that mature quickly. At the other extreme if no disturbances will occur then the competitor which is more aggressive will eliminate the other species.

Tropical rain forests and coral reefs are two communities that have always been considered to represent the equilibrium hypothesis. But in a rain forest, canopy trees do not replace themselves locally and small trees at the site are rarely the same species as the canopy trees. Therefore, the community at a site is seemingly not in equilibrium in the rain forest. Coral reefs also seem to retain high diversity only in areas of frequent hurricanes.

More experimental work will have to be done before we know better which of the two views given above is more appropriate for natural communities.

SAQ 1

State whether the given statements are true or false. Justify your answer where you think the statement is false.

i) A guild consists of taxonomically similar organisms sharing the same food resource.

....

ii) Basically a niche is the functional role of an organism in a community.

....

iii) Habitat is synonymous with the niche of an organism.

....

iv) Keystone species commonly determine the structure of aquatic communities.

....

v) Stability in a community means that the community faces no changes.

....

11.3 SPECIES INTERACTION

Now that we have learnt how communities are organised. Let us see how populations of plants and animals interrelate within the community. Individuals in a species population interact amongst themselves — **intraspecific interactions** as well as with individuals of other species population — **interspecific interactions.** Some have minimal influence on one another while some such as parasites and their hosts, predators and their prey, have very distinct and immediate relationships. At an individual level these relationships can be harmful or beneficial; at a population level they can reduce, stabilise or enhance the rate of population growth

The effects of these interactions can be positive, negative or neutral (see Table 11.2). **Neutral interactions** (OO) have no affect on the growth of population. **Positive interactions** (+ +) benefit both populations and if the relationship is mutually detrimental then the **interaction is negative** (– –). When one species maintains or provides a condition necessary for the welfare of the other but does not affect its own well being by doing so, the interactions is called **commensalism** (O+). An example is an epiphytic plant growing on the trunk of a tree. The tree provides support and the epiphyte gets its nourishment through its aerial roots. The interaction (O–), in which one species reduces or adversely affects the population of another but remains unaffected itself is called **amensalism.** An example may be the release of toxic substances by one organism that inhibits the growth and survival of another. This is known as allelopathy. An example is juglone a chemical substance released into the soil by black walnut tree which suppresses the growth of other plants near it. Amensalism may be considered a form of competition.

Table 11.2 : Interspecific Relationships

Type of Interaction	Species 1	Species 2	Nature of Interaction
Neutralism	o	o	Neither population affects the other
Competition	–	–	Direct inhibition of each species by the other
Predation (including hervibory)	+	–	Population 1 predator kills prey species 2
Parasitism	+	–	Population 1 parasite lives on population 2 prey without killing it
Commensalism	+	o	Population 1 commensal benefits population 2 is unaffected
Mutualism	+	+	Interaction favourable to both
Amensalism	o	–	Population 1 unaffected population 2 harmed

Ecologically more important than both amensalism and commensalism is the relationship which benefits both population (++). Such interactions are termed **mutualism.** For example, bacteria present in termites and stomachs of ruminent animals help in the digestion of cellulose. The bacteria get a warm environment and help their host to extract nutrients. The nitrogen fixing bacteria *Rizobium* found in the root nodules of leguminous plants are another common example of mutualism.

Negative interactions are **competition** (– –), which is detrimental to populations or both species and **predation and parasitism** (–+), in which the population of one species benefits at the expense of another. Parasitism involves one organism's feeding on another and the prey or 'host' is seldom killed outright. The host survives, though its fitness is reduced and when it dies it is due to reduced resistance to other infections. Familiar parasites are tapeworm, fleas, *Plasmodium* and numerous other disease causing microorganisms.

Ecologists have studied negative interactions involving competition and predation much more than positive ones, because impacts of positive interactions are not easily demonstrated. In this unit we will study interactions between two species involving competition and predation.

11.4 COMPETITION

Competition occurs over **resources.** For plants light, nutrients, and water may be important resources. Plants may compete for pollinators or for attachment sites. Water, food and mates are possible resources for animals, and they may compete for space such as nesting sites, wintering sites or places that are safe from predators. Thus we see that resources can be complex and diverse.

- There are two types of competitive interactions: *Exploitative* or *scramble competition* occurs when a number of organisms of same or different species utilise common resources that are *in short supply.*
- *Interference* or *contest competition* occurs when organisms seeking a resource will harm one another in the process even if the *resource is not in short supply.*

When a shared resource is sufficient like oxygen in terrestrial environment or in the aquatic habitat there is no competition for it amongst organisms. But most resources are generally in short supply, therefore, organisms with niche overlap enter competition. The greater the niche overlap, the more intense the competition (Fig. 11.3). Because members of the same species require many of the same resources *intraspecific* competition is more intense than *interspecific competition* between members of different species.

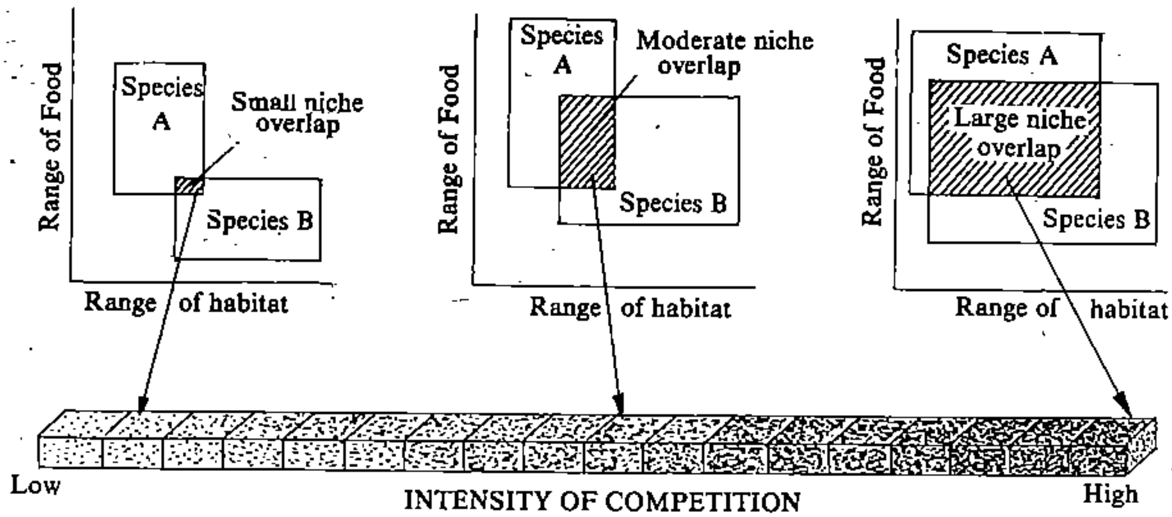


Fig. 11.3 : Niche overlap and intensity of competition. Each graph compares food and habitat requirements for two species A and B.

Simplified communities and laboratory experiments allow ecologists to single out and study qualitatively the various interactions. Mathematical models have been used extensively to build up hypothesis about what happens when two species live together either sharing the same food or occupying the same space or preying on one another. The best known models were developed independently by two mathematicians Lotka (1925) in U.S. and Volterra (1926) in Italy. Lotka-Volterra equations apply to predator-prey situations and non-predatory situations involving competition for food and space.

The Lotka-Volterra equations for competition between organisms based on the logistic growth equation, one for each species, can be written in the following form.

$$\frac{dN_1}{dt} = r_1N_1 \frac{K_1 - N_1 - \alpha N_2}{K_1}$$

$$\frac{dN_2}{dt} = r_2N_2 \frac{K_2 - N_2 - \beta N_1}{K_2}$$

where N_1, N_2 = population of species 1 and 2
K_1, K_2 = Equilibrium population size for each species in the absence of the other
t = time
r_1, r_2 = per capita rate of increase of species 1 and 2 respectively.

α is a constant representing the inhibitory effect of species 2 on species 1 and β is the constant signifying the inhibition of species 2 by species 1. Lotka-Volterra models assume that: 1) the environment does not change, 2) migrations are unimportant, 3) coexistence requires stable equilibrium points, 4) competition is the only important biological interaction. Now if we put these two species N_1 and N_2 together what might be the outcome of this competition?

1) both species coexist

2) species 1 becomes extinct or

3) species 2 becomes extinct

The theoretical Lotka-Volterra equations stimulated studies on competitions in the laboratory where under controlled situations the outcome is easily determined.

11.4.1 Competition in Laboratory Populations

Although species with small niche differences are able to co-exist in a community, those with identical niches cannot, even if only one shared resource is in short supply. Competition becomes so intense that one species is finally eliminated. Greater number of offsprings of the 'winner' species with better suited traits gradually displace members of the less efficient species. This is known as the **competitive exclusion principle.** It was first demonstrated in the laboratory by G.F. Gause (1934) in mixed cultures of closely related paramecium species. Although each population survived when grown individually, only one survived when grown together with a fixed amount of food (Fig. 11.4).

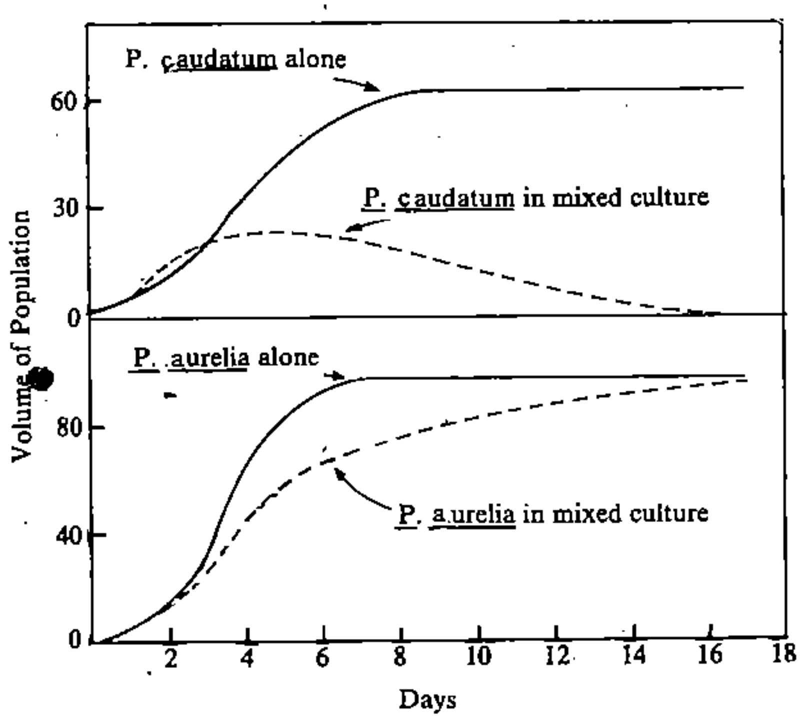


Fig. 11.4 : Competition between two species of paramecium. When grown in pure culture, *P aurelia* and *P caudatum* exhibit rapid growth. When grown in mixed cultures *P aurelia* is the better competitor and *P caudatum* dies out. (After Gause 1934).

Competition between species does not always lead to expansion of one population and restriction of another. Gause showed in another experiment that when two different species of paramecia *P. aurelia* and *P. bursaria* occupy the same tube, both survived because *P. aurelia* could feed on the yeast suspension in the upper layers of the fluid whereas *P. bursaria* could feed on the yeast in the bottom layers. This difference in the feeding behaviour between these species allowed them to coexist. It was thus demonstrated *that two or more similar species can live together only if their niches differ.*

11.4.2 Competition in Natural Populations

Now let us see if these laboratory results apply to populations in nature. There is a wide range of opinion on the importance of the competitive exclusion principle. Although this principle has been repeatedly demonstrated in laboratory experiments, it is not the rule in nature or rather it is not easy to see in natural communities.

Let us first examine situations where competitive exclusion would not be expected to occur. These situations are:

1) When the critical resource is in abundance. For example, six species of the leafhopper *Erythoneura* can live on the same tree and feed on the same leaves. Not only are their habitats and food source same but their life cycle phases are similar. Apparently competitive exclusion is avoided because of an abundance of resources.

2) When environmental conditions are unstable and change frequently. There is just not enough time for one species to replace the other during the short period when resources become limited. For example, in oceans and temperate lakes, changes sometimes occur so suddenly that there is no time for one species of phytoplankton to increase so much in numbers so as to exclude the other, despite intense competitions for limited nutrients. Because steady changes take place during primary and secondary succession, competitive exclusion has not been seen in communities undergoing succession.

Another reason why the process of competitive exclusion may go unnoticed in nature is that is takes time for one species to exclude another. If researchers are unable to observe the community continuously then they may miss the process entirely. There is an interesting example to illustrate this. Goats were introduced on the island of Abingdon in the Galapagos Archipelago in 1957. The goats browsed on the same low-growing grass as the native tortoise, as well as other leaves and higher stems. In the absence of any predators, the goats multiplied rapidly and the low growing food that the tortoise required got exhausted. By the time the research team revisited in 1962 all the tortoise were gone. Here competitive exclusion had caused the extinction of the Abingdon tortoise.

11.4.3 The Results of Competition

Competitive exclusion is not the only outcome of competition. Sometimes a shared resource can be partitioned in such a way that potential competitors use different portions of the resource. Let us take a hypothetical case of 4 species of birds that live in a similar habitat. They would feed on different positions in the canopy and thus avoid competition. In addition to partitioning of space, a shared resource may be exploited at different times.

These are example of *resource partitioning*. A study involving closely related species of birds to test Gauses' hypothesis was done on the cormorant *(Phalacrocorax carbo)* and the shag *(P. aristotelis)*, see Fig. 11.5. These species occur in similar habitats and

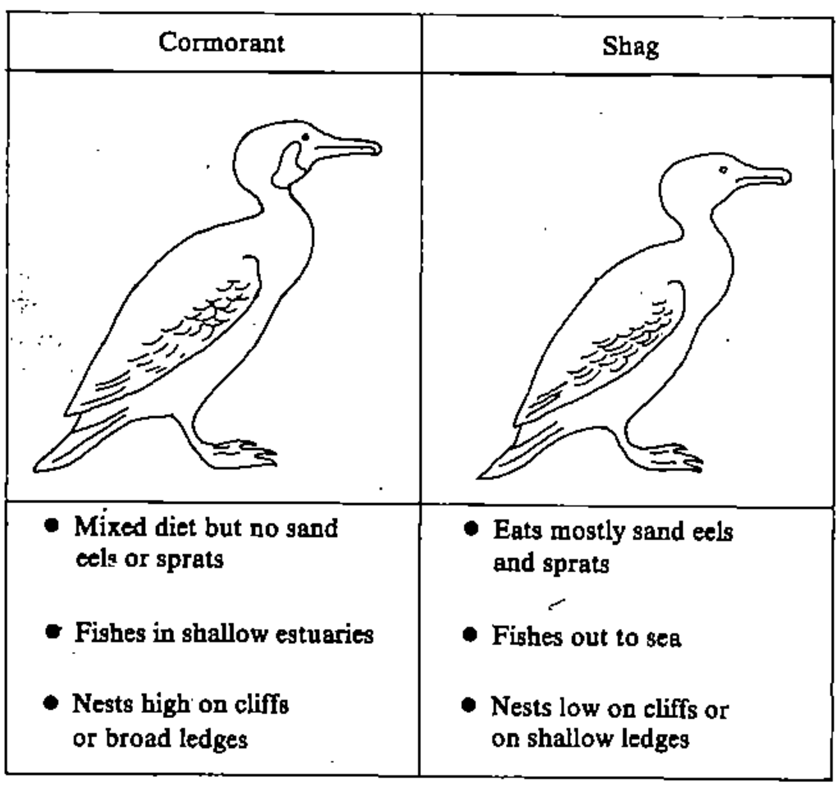


Fig. 11.5 : Closely related *Phalacrocorax* species get their living in different ways and so do not compete.

appear to have a wide niche overlap. They are both cliff nesters and eat fish. It was shown that coromorant nests chiefly on flat broad cliff edges and feeds chiefly in shallow estuaries and harbours; the shag nests on narrow cliff edges and feeds mainly out at sea. Thus because of these differences competition is minimised.

A similar partitioning of resources exists among plants. Species of plants cultivated together exploit different soil depths (Fig. 11.6). Some have shallow fibrous roots that draw water from the soil top. Another species may have sparsely branched taproot that extends to an intermediate depth. Yet another may have a taproot that is moderately branched in the upper layers but develops primarily below the rooting zone of the other species.

In addition to spatial partitioning a shared resource may be exploited at different times. This is known as *temporal partitioning*. An example can be seen in grasslands where a species of buttercup *Ranunculus* grows only in early spring before competing perenial grasses begin to grow.

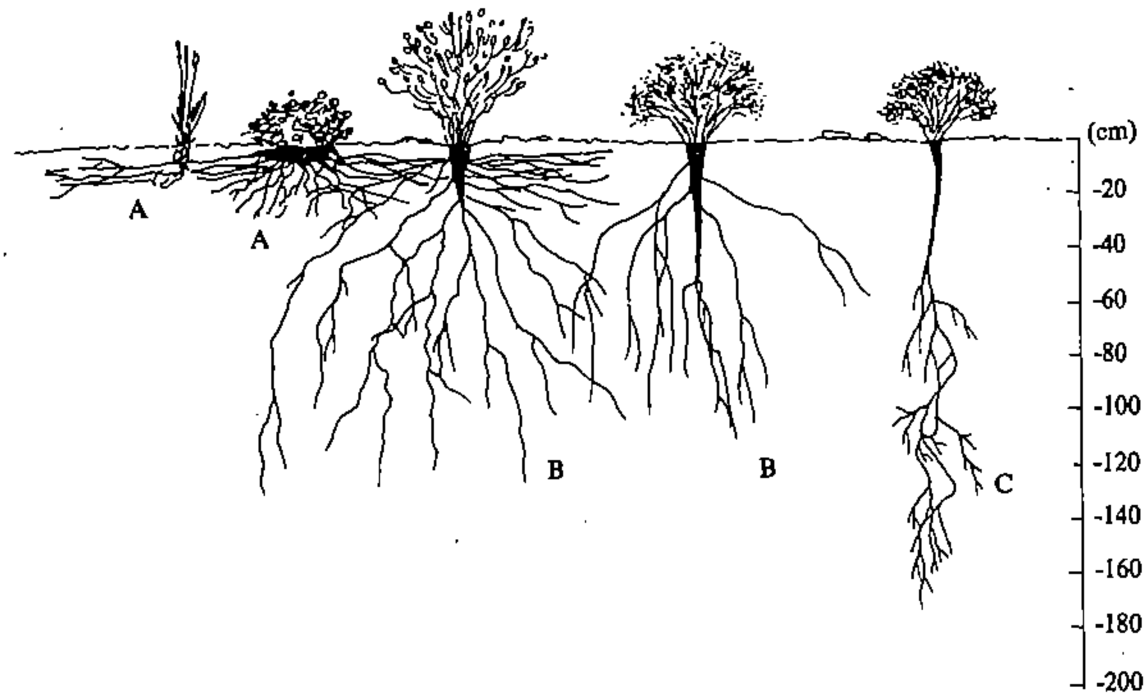


Fig. 11.6 : Resource partitioning of the soil by a group of desert plants. Root system morphology is species specific. Species (A) are shallow surface rooters, able to take up moisture quickly during occasional rains. (B) have more spreading roots at intermediate depths. Plants such as (C) have deep tap roots.

Another alternative to competitive exclusion is character displacement where intense competition affects evolution, leading to displacement or change in a characteristic rather than extinction of a species. An example is seen in the forests of Europe, where six species of a small bird called titmice (*Parus*) coexist because each species has a slightly different beak size. These differences in beak size prevent any two species from seeking the same food in the same feeding area. For example, titmice with longer beak catches larger insects. Biologists have found out that all the six species evolved from an identical ancestor and that variations in beak size are the result of character displacement.

11.4.5 Evolution of Competitive Ability

It would be obvious from the examples discussed in earlier subsections that if two species are competing for a resource that is not abundant, then it would be advantageous to both species to evolve differences — structural, physiological and behavioural — that would reduce competition. However, it is not always possible to evolve such mutually beneficial changes because the species may have other possible competitors.

So the only way to survive is to evolve competitive ability or 'stay and fight'. This concept is not very easy to define. But in short it means that any mechanism that prevents a competitor from gaining access to a limited resource will improve competitive ability. Territorial behaviour in birds is a good example. In animals, the evolution of a broad array of aggressive behaviour has been critical in substituting ability in combat for ability in utilising resource in competition. On the basis of this we can recognise an idealised evolutionary gradient.

In animals aggressive behaviour leads to establishment of dominance hierarchies or rank order. The dominance is determined by actual fighting or a ritual contest in which one frightens the other away. The dominant animal eats and mates first, and drives the other away from his territory.

Low density —leads to→ Colonisation and growth
↓
High density —leads to→ Resource competition
↓
High density —leads to→ Interference mechanisms that prevent resource competition.

Populations may exist at all points along this evolutionary gradient.

SAQ 2

i) According to the principle of competitive exclusion, species cannot remain in the same community if they have the same a) taxonomy, b) habitat, c) food requirement, d) niche.

ii) a) When members of the same or different species exploit common resources that are in short supply, ... competition occurs.

b) .... competition occurs when both individuals have access to resources but one individual uses more of it or more efficiently than the other.

iii) Species can avoid competition in the community if they .... resources. Whereas, intense competition often leads to .... rather than extinction of the species.

11.5 PREDATION

In addition to competing for food or space, species in a community may interact by *predation* which literally means plundering. Most of us would associate predation with a hawk swooping on a mouse or a tiger killing a deer. That is a narrow view of predation while it implies much more. A fly laying its egg on a caterpillar to develop there at the expense of the victim is also an example of predation called **parasitoidism.** A deer feeding on shrubs and grass or a mouse or bird feeding on seeds and fruit is a form of predation called **herbivory.** A special form of predation is **cannibalism** in which the predator and prey belong to the same species.

The effect of predation on population has been studied theoretically and practically because it has economic implication for our own species. Predation may affect populations mainly in three ways:

- restricts distribution or reduces abundance
- affects structure of community
- is a major selective force, and many adaptations that we see in organisms such as mimicry or warning colouration have their explanation in predator — prey coevolutions.

We begin our analysis of the predation process by considering theoretical models. The underlying assumptions of these models are that prey populations grow exponentially and that reproduction in the predator population is a function of the number of prey consumed. As a single predator population increases, the prey decreases to a point at which the trend is reversed. The rise and fall of the two populations results in *oscillations* in each (Fig. 11.7).

The cycle or oscillations may continue indefinitely. The prey is never destroyed by the predator; the predator never completely dies out.

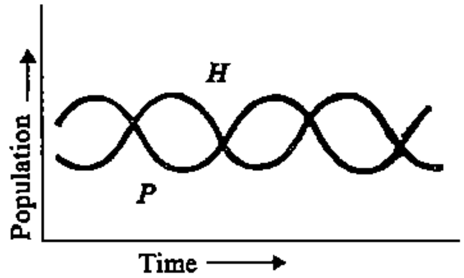


Fig. 11.7 : The abundance of predator (H) and prey (P) population is plotted against time. An increased abundance of prey is followed by increased predators

11.5.1 Predation in Laboratory

In general laboratory experiments for the study of theoretical predator — prey systems result in the extermination of the prey. G.F. Gause (1934) reared *Paramecium caudatum* (prey) and *Didnium nasutum* (predator) together in a closed system. *Didinium* always ate the *Paramecium* and then died of starvation. The result was same even if the culture vessel was very large or number of predators introduced was small and so on (see Fig. 11.8a).

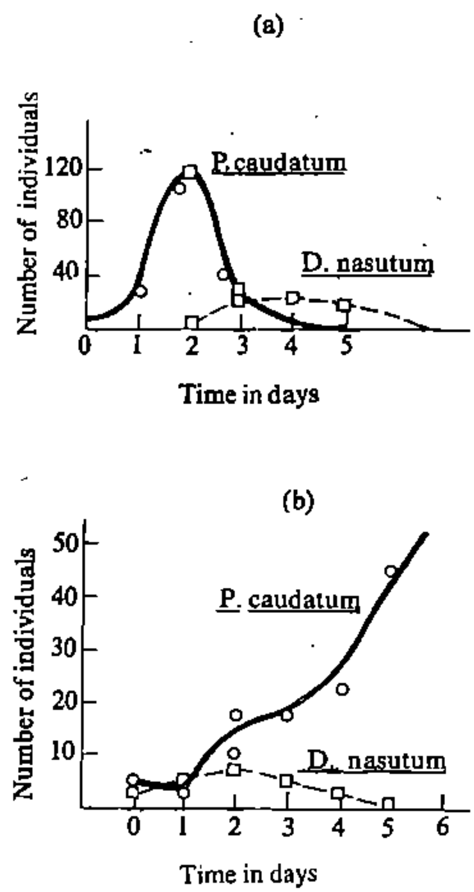


Fig. 11.8 : Predator — prey interaction between *Paramecium caudatum* and *Didinium nasutum* in two situations
a) oat medium without sediment b) oat medium with sediment

However, if Gause provided a *refuge* for the prey, in this case sediment on the bottom of the culture vessel, part of the prey population survived (Fig. 11.8b). This suggests that predator — prey relationship can stabilise when predator pressure eases when the prey population decreases in size. However, predator-prey interactions may show cyclic fluctuations of both populations when the predator depends exclusively on a single type of prey species. In another experiment, a system of azuki bean weevil as a host (prey) and a wasp (predator) parasitic on the larvae of weevil was maintained in the laboratory. Figure 11.9 shows the oscillations. The wasp lays its eggs on the larvae of a large prey population ensuring the survival of the wasp offspring thus increasing the predator population. But as the predator population increased the weevil population crashed, reducing the survival of the next generation of wasp population. The reduced wasp population again allowed the prey species to increase, and so on. It was noted that over 12 generations a long-term trend was seen, the host population gradually increased in density and the parasite population gradually declined.

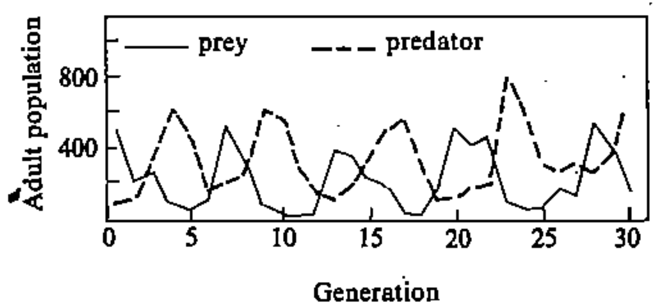


Fig. 11.9 : Cyclic fluctuations in laboratory populations of the azuki bean weevil and its wasp predator

You would now naturally like to know whether short term predator-prey experiments can lead to evolutionary changes in the two organisms. Lotka-Volterra models, however, assume that prey and predator species are constant and unchanging.

Experiments using housefly and a parasitic wasp maintained for 20 generations showed distinct changes to reduce the intensity of predation. In short, we can assume that predators determine the abundance of their prey and vice versa and that as a result of evolutionary changes fluctuations of the predator-prey numbers occur. Now let us consider whether this generalisation is true for situations in nature.

11.5.2 Predation in Field Studies

How can we find out whether predators determine the abundance of their prey? The logical suggestion would be to remove predators from the system and observe the response. In Australia, when the dingo, a wild dog was killed off because it attacked sheep, the rabbit and red-kangaroo populations increased. It was then concluded that dingo predation limits the density of rabbits red kangaroos. Let us examine another case, of moose population on an island in Lake Superior of USA.

It was supposed that a small group of moose arrived on the island in 1908. In the absence of a predator the moose population grew rapidly and in 1935 was 30,000. This proved too many for the vegetation, resulting in starvation and death of about 90% of the moose. With the numbers reduced, the vegetation recovered and so the number of moose also started increasing reaching a peak of 30,000 in 1948 and then crashed again. In 1949, a group of wolves reached the island and started to prey on the moose mostly attacking the old, infirm and the young. Soon a stable balance of two dozen wolves, 800 moose and a healthy crop of grass was reached.

Some farmers now recognise the benefits of maintaining owl populations, because they capture rodents. In other instances predators have been used to control pest population. The colony cushion scale, a small sap sucking insect named for the large white egg mass deposited by the female on tree limbs threatened the California citrus industry. It was brought under control by importing its natural predator, a lady-bird beetle called *Vedalia*.

This example shows that predator-prey relationship can lead towards a dynamic balance. However, such clear cut evidence of predators controlling the population of prey is not widely available.

11.5.3 Co-evolution of Predator-Prey System

The above example illustrates that to survive the predator must feed and the prey must avoid becoming food. Because if the prey becomes exterminated then the predator will naturally starve. How is this stable predator-prey relationship

The coevolutionary adaptations of predators and prey are beautifully illustrated by the relationship of an insect-assassin bug and the desert camphor weed. The camphor weed exudes a sticky harmful resin from its leaves that discourages herbivoreous predators. The assassian bug is not discouraged by the sticky glue. The female bug scrapes off the substance and smears it on her abdomen where it coats her eggs as they come out. This makes them undesirable to predators. This, however, does not complete the story, the young bugs soon after hatching, scrape the glue from the discarded egg shells and transfer it to their forelegs where it l elps to catch their own prey. In this complex association, defences evolved by the plant are used by the bug against its predators as well as prey.

maintained? One may suggest that natural selection changes the characteristic of both so that their interactions produce populations stability.

Prudent predators would kill and eat individuals that have crossed the reproductive age, the weak and the young. Young individuals in nature have a high death rate due to one cause or another. In the wolf-moose example many moose in the breeding age group are 'tested' by the wolves and quickly ignored because they are difficult to catch and kill.

Evolutionary change in two or more interacting species or *coevolution* occurs most tightly when predators regulate the prey population. In some predator-prey systems where the predator does not regulate the size of the prey population evolutionary pressures are reduced. Much of the stability we see in nature probably results from continued coevolution of predator and prey. Foolish predators that kill all their prey. exist for a short time in evolution, with the result that we are left today with highly selected predator-prey systems.

SAQ 3

Predation affects population in a community by:

a) restricting distribution of prey populations

b) affecting structure of community

c) causes the evolution of many adaptation in prey and predator populations

d) all of the above

e) Only (a) and (c).

11.6 HERBIVORY

Herbivory is just a special kind of predation and in this section we will cover some very specific relationships that herbivores have with plants. Predation on plants by herbivores involves defoliation and consumption of fruits and seeds. Defoliation is the destruction of plant tissue like leaves, bark, stem, roots etc. Even though plants may persist and regenerate, defoliation has an adverse effect. Plant biomass is decreased, removal of leaves and subsequent death of some roots reduce the vigor of the plant; its competitive ability and its fitness. In case of seed predation, even if only a few seedlings survive then seed predation has no real impact; only if seeds are removed from an expanding population, then seed predation reduces the rate of increase. On the other hand if consumption of seeds is a mechanism for dispersal of seeds then predation works to the advantage of the herbivore. We all realise that plants cannot move so to 'escape' from herbivores they must evolve some clever adaptation. Thus herbivores can be important selective agents on plants. Let us now examine some of these adaptations.

In many game ranges in South Africa, hundreds of kudu a kind of antelope, died during each dry season. The killers were *Acacia* leaves. *Acacia* is normally a prime source of food for kudu and it produces tannins for its defence against herbivores. Under normal conditions the tannin levels do not harm kudu. But under drought or extensive foraging the leaves increase the production of tannin, enough to inactivate liver enzymes of kudu. When antelopes forage on an *Acacia* tree its leaves emit ethylene which appears to signal other trees to step up their production of tannin. The short term increase in tannin production acts as a natural population regulatory mechanism.

11.6.1 Defence Mechanisms in Plants

Some plants use mechanical means to discourages predation. The sharp spines of cacti, the thorns in the rose bush, leathery leaves of oak trees are some examples. Plants may use a variety of chemical weapons that we are only just starting to appreciate. These chemicals are known as *secondary plant substances*. These substances are by-products of the primary metabolic pathways in plants.

Secondary plant substances are not waste or excretory products but have an ecological role as anti-herbivore components, and have rapid turnover rates in the metabolic pool. Some of these chemicals are familiar to us, species like cinnamon and cloves are phenylpropanes; peppermint oil, and catnip are terpenoids; nicotine, opium, marijuana and caffine are alkaloid secondary plant substance.

It is believed that antagonistic plant-herbivore interactions just like the predator-prey interactions, co-evolve. Based on this a general defence theory has been formulated from the observations that *defences are costly in terms of fitness to organisms*. The cost is due to the diversion of energy and nutrients from other needs and we can expect that when enemies are absent less well defended individuals will have better fitness. The following points emerge from the above observations.

- More predators result in more defences.
- More defences are allotted within an organism to valuable tissues that are at risk. For example, young growing leaves and shoots, seeds etc.
- Defence mechanisms are absent when enemies are absent.
- Defence mechanisms cannot be maintained if plants are severely stressed by environmental factors.

Acacia trees and shrubs have thorns in the tropical and subtropical regions to protect them from browsers. In Australia, where there are no browsers, most species of *Acacia* lack thorns.

Defence mechanisms in plants may be of two types:

1) *Quantitative* : that are most expensive and not easily mobilised. They are most effective against the specialist herbivores. Tannins and resins concentrated near the surface of the leaves, in barks and in seeds are examples. They form indigestible complexes with leaf proteins, reduce the rate of assimilation of dietary nitrogens, and the ability of gut microorganism to break down leaf protein and lower the palatibility.
2) *Qualitative* : present in low concentration (less than 2% of dry weight). Examples are alkaloid and cynogenic compounds that interfere with metabolism. These compounds can be synthesised quickly at low cost, are effective at low concentrations and are readily transported to the site of attack. They can be shuttled about in the plant from growing tips to leaves, stems, roots and seeds and they can be transferred from seed to seedling. They protect the plants from generalist herbivores.

11.6.2 Herbivore Countermeasures

Herbivores of course do not sit idle while plants evolve defence systems. Animals try to overcome plant defences by evolving mechanisms to render them harmless. The coevolution of plants and animals can thus occur. Let us examine some examples. A milkweed (*Asclepias curassavica*) containing a chemical that affects vertebrate heartbeat is not eaten by cattle. But certain insects for example, the larvae of the familiar monarch butterfly, eat it without any harmful effect. In fact they set apart the poison in their bodies as a chemical deterrent to predation! These milkweed eating butterflies are avoided by birds because they find them distasteful. This is because of the heartbeat affecting chemical stored in the tissue of the butterflies. Obviously the butterflies have evolved a mechanism to remain unaffected by the chemical and to be able to store it, giving themselves chemical protection against the birds.

11.6.3 Hervibore Interactions

As we have said earlier, the plant-herbivore interaction is thought to be of the predator-prey type, in which the predator (animal) gains and the prey (plant) looses. But it may not always be so. It can be mutualistic in which both benefit. A very interesting example is seen in the ant-acacia system. The swollen thorn acacia provides ants a place to live and food to eat (Fig. 11.10) and the ants in turn provide

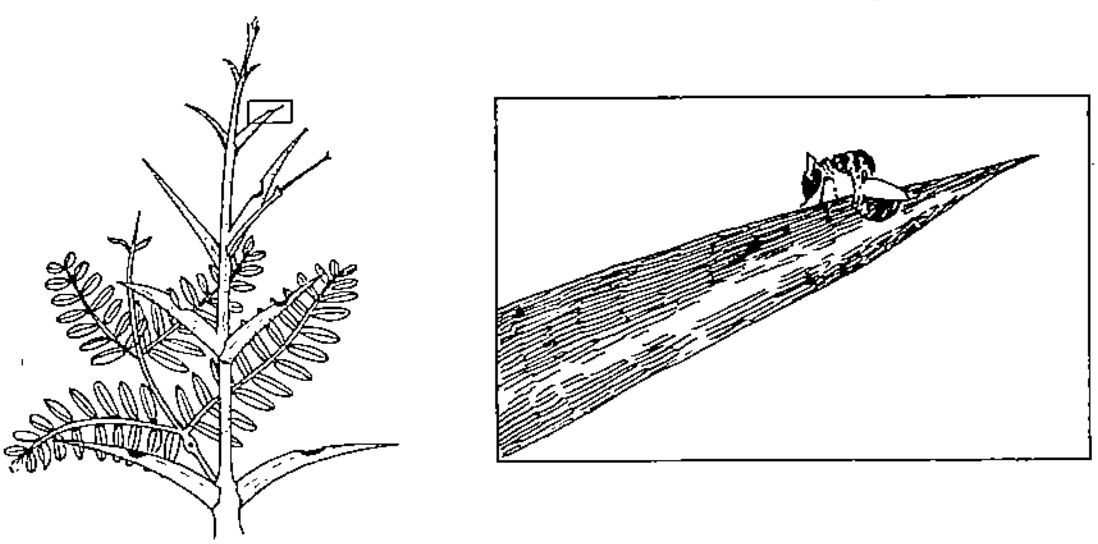


Fig. 11.10 : Swollen thorns of *Acacia cornigera* on a lateral branch. Each thron is occupied by 20-40 immature ants and 10-15 worker ants. An ant entrance hole is visible in the figure.

protection to the plant by attacking any herbivore that attempts to eat the plant. The ants thus reduce herbivore destruction and serve as a living defence mechanism.

The best worked out example is of the grazing system in the plains of East Africa. First, the migratory zebras come and eat away long grasses. Then come large hordes of migratory wildebeest which graze the grasses to short heights. These in turn are followed by gazelles which feed on short grasses during the dry season. Gazelles eat grass sheaths and herbs, wildebeest eat sheaths and leaves and zebras eat grass stems and sheaths leaving the grass alone. Obviously, a beautiful example of feeding differences. There is no competition between the three herbivores, in fact the feeding activity of one herbivore species improves the food supply available to the second species. This is what is known as *grazing facilitation*. However, competition for grass in the above region occurs between very different types of herbivores, apart from the large ungulates there are grasshoppers, rodents, etc. Obviously in showing such a system we should always be aware of the presence of many different types of herbivores and their contribution to the working of the whole herbivore-plant system.

SAQ 4

i) Secondary compounds are molecules synthesised by .... and deleterious to .... An herbivore becomes tolerant of secondary compound by either .... or .... the compound.

ii) Why are defences costly for the plants?

....

....

....

11.7 SUMMARY

- Communities can be organised by competition, predation and symbiosis among organism working within the physical environment. Two important concepts in community ecology are habitat and niche. Habitat is where the organism lives and niche is its functional role in the community.
- Species in a community are organised into food webs and further into groups or guilds that exploit a common resource base. Keystone species are those species that can determine the community structure and can be recognised by removal experiments. Dominent species are those that have maximum abundance or biomass in a community and may affect the stability of the community.
- Stability is the ability of a system to come back to the original condition after a disturbance. The ecological generalisation that diversity causes stability is not supported by field or laboratory studies.
- There are two opposing views on community organisation. The equilibrium hypothesis suggests that natural communities are stable and the nonequilibrium hypothesis suggests communities are never stable and always recovering from disturbances. High species richness is maintained in communities that face moderate disturbances.
- The organisms of a community interact in a variety of ways that may be classified as negative, positive or neutral interactions. Competition occurs over resources. Theoretical models indicate that in case of competition between similar species, one species may be displaced or both may reach a stable equilibrium. Possibility of displacement gave rise to the competitive exclusion principle which states that complete competitors cannot coexist. Species can coexist in the same community only if they have slightly different niches. Intensity of competition increases with niche overlap.
- The results of competition are resource partitioning and character displacement. Organisms evolve competitive ability by becoming more efficient resource users and by developing interference mechanisms that keep competing species from using the same resources.

- Species may interact by predation. Mathematical models suggest regular oscillation of predator and prey numbers. This is supported by laboratory experiments and laboratory systems may show gradual evolutionary changes towards greater stability over a short number of generations. In nature, evidence suggests that predation tends to control prey numbers but there are other environmental factors involved too. Predators-prey systems always involve a coevolutionary race. Just as predators are adapted to catch prey so are the prey adapted to escape the predators. These systems stabilise when prey have a safe refuge from predators or when predators are prudent and hunt old or juvenile animals of little reproductive value.

- Herbivory is a special type of predation involving plants and herbivores. Plants have evolved special types of structural and chemical defences that discourage herbivores from eating them. Secondary plant substances are chemical defences against the herbivores. Herbivores have responded to these by evolving detoxifying enzymes or by timing their life cycles in such a way so as to avoid the chemical threats. Herbivores may compete for plants but they may also facilitate each other so that in some cases grazing may increase plant production.

11.8 TERMINAL QUESTIONS

1) Fill in the blanks with suitable community interactions.

ORGANISM INTERACTIONS		
	both unaffected	.... (a)
	both harmed	.... (b)
	one harmed	.... (c)
		.... (d)
	one benefits	.... (e)
	one benefits – one unaffected	.... (f)
	both benefit	.... (g)

2) A certain inland has two closely species of birds, one of which has a slightly larger beak than the other. Interpret this finding with respect to competitive exclusion principle and ecological niche, defining both terms.

....

....

....

....

3) Why would you recommend that animals such as wild dogs be not killed even though they sometimes prey on farm animals?

....

....

....

....

....

4) How does predation of animals on seeds and fruit differ from predation of animals on leaves and stems of plants?

....

....

....

....

11.9 ANSWERS

Self-assessment Questions

1) i) False, a guild consists of groups of species that may not be taxonomically related but have similar or comparable feeding roles in a community.

   ii) True

   iii) False. Habitat describes the place where an organism is to be found. Niche, however, includes the physical space the organism occupies as well as its functional role in the community.

   iv) True

   v) Stability in a community means its ability to return to the original condition after disturbances. It does not mean that stable communities never face any fluctuations.

2) i) d, ii) (a) scramble, (b) contest, iii) partition, character displacement

3) d)

4) i) plants; animals; detoxifying; storing.
   ii) Defences are costly as precious nutrients are diverted from growth and reproduction.

Terminal Questions

1) a) neutralism; b) competition; c) predation
   d) parasitism; e) herbivory; f) commensalism
   g) mutualism

2) Competitive exclusion principle states that no two species can occupy the same niche. If closely related species are to survive, they must show some difference, however, small in their niches. Ecological niche refers to the role that the organism plays in the ecosystem. It defines the physical and biological requirements of the organism. The related species of birds coexist because a part of their niches i.e. beak size, differ so they cannot exploit the same food resource.

3) In nature predator-prey populations often show oscillations. Predators help control prey population. If all the wild dogs are removed then their natural prey species like rodents, rabbits etc. will increase tremendously and cause damage to the food crops.

4) Predation of animals on fruit and seed does not eliminate the plant because even if a few seeds survive then new plants can appear. Consumption of seed and fruit is often the means for dispersal and infact beneficial for the plant. On the other hand predation on leaves and shoots results in defoliation, loss of competitive ability and vigour and reduction in fitness of the plant.

UNIT 12 POPULATION PARAMETERS AND REGULATION

Structure

12.1 INTRODUCTION

In Unit 11 you have studied how communities are organised through interactions among organisms that constitute the community. Interspecific interactions like predation, competition and symbiosis have also been dealt with. In the present unit you will study the population as a collective group of organisms of the same species which occupy a particular space at a particular time. The population is attributed with various characteristics that are unique possessions of the group and are not characteristics of the individuals in the group. We will discuss here some of these properties like density, natality, mortality, age distribution, biotic potential, dispersion, and growth form. It is also known that populations possesses genetic characteristics which are directly related to their ecology, such as adaptiveness, reproductive fitness, persistence. The persistence means the probability of leaving descendents over long periods of time. Also, you will study the parameters of population estimation, demographic techniques, various approaches employed for population regulation and evolutionary implications of natural regulation.

In the next block you will have an overview of human evolution and human population in relation to environment. Pollution, degradation of ecosystem and its impact on wildlife and its conservation and ethics for a better environment shall also be dealt with in the foregoing block.

Objectives

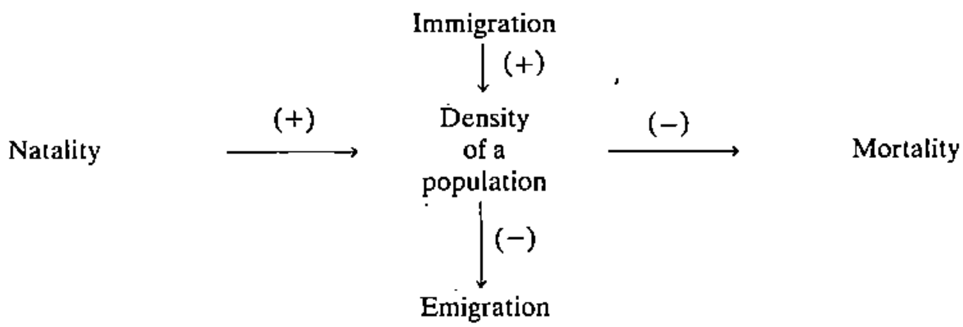
After reading this unit you will be able to:

- define population and understand the concepts of density, natality, mortality, dispersal, population distribution, age distribution,
- explain that growth is the fundamental feature of the population which is limited by the carrying capacity of our environment and population size is regulated by various density dependent and independent factors,
- appreciate the importance of genetic diversity for the future survival of mankind and nature and how systems of natural regulations are affected by evolutionary changes.

12.2 DEFINITION

Population, as you have already read in Unit 1, can be defined as a *group of organisms* of same species occupying a specific area at a particular time, such as all the deer or all the pine trees in a certain wood land. We may even speak of human population of the world, of India or of Delhi, simply by shifting the borders that enclose the group. Individual organisms that interbreed are the ultimate constituent of the population and share a common gene pool. *Gene pool* is the sum total of the genes of all the individuals in a population. Populations may be further subdivided into *demes* or local population, which are the smallest collective group or unit of interbreeding individuals. You have already read about demes in Unit 1 of Block 1 of this course.

A population has a number of group characteristics, that are *statistical measures* unique to the population group and are not the characteristics of the individual. These group characteristics are density, natality, mortality, immigration and emigration, age distribution, disperson, growth, regulation and genetic composition. Density or size of population, however, is its basic characteristic and is affected, by other group characteristics such as natality, mortality, immigration and emigration. Any change in the density of the population implies a change in one or more of these four characteristics. The relationship between these factors is expressed as follows:



The study of the group characteristics or parameters of the population, their changes over time and prediction of future changes is known as *demography*. Techniques used for quantitative analysis of these statistics are known as *demographic techniques*. In the following subsections we will discuss various statistical parameters of population.

12.2.1 Density

Density is defined as number of individuals or population biomass per unit of area or volume at any given time. Biomass refers to the total weight of all the organism or of a specific group of organisms in a given area. Density is generally expressed in terms of biomass when the size of individuals in a population is quite variable. This measure of number or biomass of individuals per unit total area is called *crude density*. However populations do not occupy all the space within the unit area because whole of it is not a suitable habitat. Each organism occupies only areas that can adequately meet its requirements, resulting in patchy distribution. No matter how uniform a habitat may appear, it is not uniformly habitable, sometimes because of even micro differences in light, moisture, temperature etc.. Density, thus measured in terms of the amount of area as habitat or living space is *ecological density*.

To cite an example we may talk of density of a goat population in a given area as 500 individuals per hectare, but goats might not utilise the entire area because of various factors such as human habitation, lack of vegetation cover or lack of food. Other examples can be of mango trees as 50 trees per acre, of diatoms as 5 million diatoms per cubic metre of water, of fishes as 200 pounds of fishes per acre of water surface, of human population as hundreds of individuals per square kilometres as it is in modern cities, etc. These examples indicate the range of figures we have to study. Techniques to study density that work nicely with goats cannot be applied to diatoms. The choice of technique is influenced by the *size* and *mobility* of organism with respect to man. We will briefly discuss some of these methods here.

1) *Total Counts* : The most direct way to find out how many organisms are living in an area is to count them. It is possible with large or conspicuous organisms or

with those which aggregate into colonies. The best example of this is human population census. Periodic head counts are made as we have recently done it in India. India's population stood at 843.93 million on March 1, 1991, with territorial birds, one can count all the singing males in the area. Some animals, such as northern fur seal, may be counted when they are all gathered in breeding colonies. Large plants on small areas can sometimes be counted in total.

2) *Sampling Method* : In this method a small proportion of the population is counted and this sample is used to estimate the total. There are two ways of sampling which are given as follows:

A quadrat is a sampling area of any shape. Although the word literally indicates a four-sided figure, in ecology it has been used for all shapes of areas, including circles.

Use of quadrats involves counting or weighing organisms in several quadrats, i.e. plots or transects of known size and number to estimate the average density. This average density is then extrapolated to the whole area. For example, if you count 9 individuals of beetle species in a soil sample of 0.01 m^2, you could extrapolate it to 900 beetles per square meter of soil surface. In another example, as shown in Fig. 12.1 there are 30 individuals (centipede) in 37 hexagonal quadrat. The mean density is

$$\frac{30 \text{ individuals}}{37 \text{ quadrats}} \doteq 0.811 \text{ individual per quadrat}$$

Since each quadrat is 0.08 m^2, estimated density is 10.1 individuals per square metre. This sampling of centipedes was done by Lloyd in 1967 in central England.

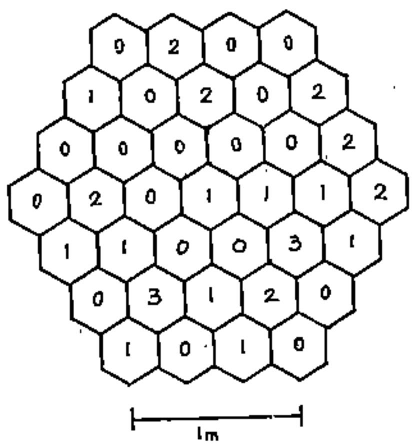


Fig. 12.1 : Sampling of centipedes in 37 hexagonal quadrats. The estimated population came out to be 10.1 individuals per square metre

Quadrats have been extensively used in plant ecology and are most common method for sampling plants. By doing the quadrat sampling for old trees and then for seedlings in the same quadrat, one can determine if the populations were likely to change with time. Foresters have deviced various ingenious quadrat sampling techniques for estimating the forest trees.

Capture-recapture Method involves capture, marking, release and recapturing of samples of a population. The proportion of marked individuals in the recaptured samples helps in determining the population as follows:

$$\frac{\text{Marked individuals in total population}}{\text{Total population size}} = \frac{\text{Marked individuals in the sample caught}}{\text{Total caught in the sample}}$$

For example, if 100 individuals of a population were marked and released and 10 out of recaptured sample of 100 were found to be marked, then the population would be as follows:

$$\frac{100}{P} = \frac{10}{100}$$

Therefore, total population (P) is of 1000 individuals. Capture-recapture method does not work well when population is open, i.e. the density is undergoing a rapid change due to death and emigration. This method is used in animal ecology for the estimation of the population of mobile and conspicuous animals like butterflies, snails, lizards, birds etc.

A population is closed if it is not changing in size during the period of capture, marking and recapturing. A population is open if it is changing in size during this period of study. Real populations are clearly open, unless we sample them for a very brief period.

Before proceeding further try the following SAQ to see whether you have understood the concept of density.

SAQ 1

Match the items in column I with those given in column II. Write your answer in the space provided.

Column I		Column II
a) Ecological density	[ ]	i) Does not work with populations whose density change rapidly.
b) Sampling method	[ ]	ii) Density per unit area as habitat or living space.
c) Capture-recapture method	[ ]	iii) A small proportion of population is counted and used to estimate the total
d) Quadrats	[ ]	iv) Average density is measured with the help of plots of same size.

So far you have read about one important parameter of population, i.e. density which would be first one to get the attention while studying population. The affect of population in any ecosystem depends both on type and number of individuals. For example one crow in a 10 acres crop field might not affect the yield, but 100 crows per 10 acres would certainly affect the yield. We will now discuss briefly the other attribute of population which also affects density, i.e. natality.

12.2.2 Natality

Natality is the ecological concept which means number of offsprings produced during a period of time. Fertility is a physiological notion that indicates that the organism is capable of breeding.

Natality is the ability of a population to increase. Natality rate is equivalent to birth rate which means the production of new individuals by birth, hatching, germination, or fission. Maximum production of new individuals under ideal conditions of ecological and physiological factors is always theoretical and is called *maximum natality*. It is constant for a population. However, the actual increase in a population under a specific environmental conditions is referred to as *realised or ecological natality*. This is not constant for a population and may vary with the size and composition of the population, i.e. the number of females in reproductive age at a particular time. It also varies with the physical environmental conditions of the habitat a population is acquiring. For examaple, the realised natality rate for the human population may be only one birth per five years per female in the child bearing ages, whereas the maximum natality rate for humans is one birth per nine to eleven months per female in child bearing ages.

Symbol △ (delta) represents "the change in" something, and by writing it in front of the letter indicates that the thing is changing.

Natality rate or birth rate is determined by dividing the number of individuals born by unit time and is expressed as follows:

$$\text{Natality rate} = \frac{\Delta Nn}{\Delta t}$$

ΔNn = production of new individuals in a population
Δt = unit time

Natality rate can also be determined as the number of new individuals per unit of time per unit of population. This is called specific natality rate and can be expressed as:

$$\text{Natality rate per unit of population} = \frac{\Delta Nn}{N \Delta t}$$

N may represent the total population or only the reproductive part of the population, i.e. females, for example, in higher organisms natality rate is per female. Natality rate is zero or positive but never negative.

The measurement of natality or birth rate is highly dependent on the type of organism being studied. Some species breed once a year, some breed several times a year and others breed continuously. Some produce many seeds or eggs, and others few. For example, a single oyster can produce 55 to 114 million eggs, whereas birds usually lay between 1 and 20 eggs. Also the specific natality rate differs for individuals of different age groups in the population. For example in a rabbit population for 1 to 2 year old females the specific natality rate is average 4 young ones per year per female, while for females of less than 1 year the rate is 1.5 on an average. Since natality is the concept referring to the population and not to the isolated individuals, the average reproductive capacity should be taken as the measure of natality, and not the capacity of the most productive or least productive individuals.

12.2.3 Mortality

The death of an individual in a population is known as mortality. Mortality rate like natality rate can be expressed as the number of individuals dying per unit time. Specific mortality rate is expressed in terms of units of total population. Again like natality, mortality can also be potential or ecological. *Potential mortality* also called *minimum mortality* represents the death of an individual living under an ideal or non limiting environmental and physiological conditions. It is constant for a population. *Ecological mortality* also called *realised mortality* is the loss of individuals in a population under a given environmental and physiological conditions. It varies with populations and environmental conditions. This means that under the best environmental conditions individuals will die of old age determined by their physiological longevity. In most populations in nature the average longevity is far less than the physiological inherent longevity and so the realised mortality rate is much greater than the potential rate.

Only few organisms in nature attain their potential longevity. In most of them the life span is shortened by predators, diseases and other hazards long before they reach their old age. Measurement of mortality may be done directly or indirectly. Capture-recapture method is a direct method about which we have discussed earlier in this unit. One of the methods of indirect measure is that if one knows the abundance of successive age groups in a population, one can estimate the mortality between these age groups.

What is really vital for the population is not which members die, but which member survive? Consequently specific mortality rate of a population is expressed by survivorship curve. To construct a survivorship curve, we start with a cohort of many individuals newly added to the population and follow them to determine the age of death of each member of cohort. The study is completed when the last individual dies. We then plot number of survivors against ages. As shown in Fig. 12.2 survivorship curves may be of three types.

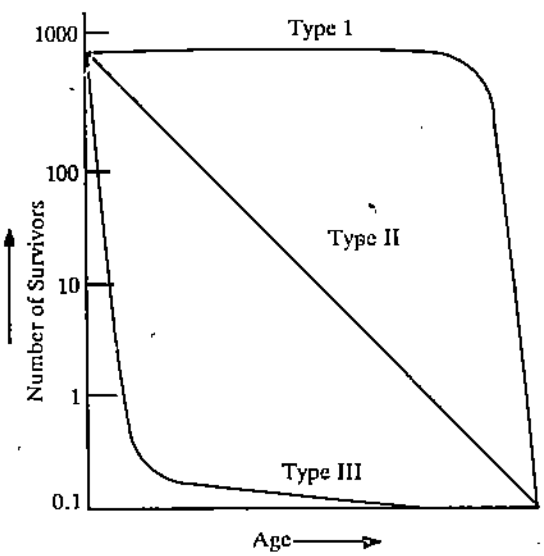


Fig. 12.2 : Three main types of survivorship curves. In type I curve most of the mortality occurs towards the end of the life. In type II curve age specific survival remains constant. In type III curve mortality is very high during the young stages.

In type I survivorship curve, most individuals of the cohort find environmental conditions ideal and live out full physiological life and die as a result of old age. However, a perfect type I curve never occurs because there is always some early mortality. Most of the modern industrialised men approach a type I curve after their first year of life. In first year the high infant mortality is from genetic or developmental defects or birth accidents.

In type II curve which falls between types I and II the rate of mortality is constant at all age groups, so that an individual's chance of living another year is just as good at one age as another. This curve is typical of several birds and of human beings exposed to poor nutrition and hygiene.

In type III survivorship curve, most individuals die at an early age as eggs or larvae, for example in many invertibrates, bony fishes plants and fungi. But those few individuals that survive have a high life expectancy. Most survivorship curve observed under natural conditions are intermediate between these types.

Life tables for human populations are used by National and regional planners and Life Insurance companies to predict how much longer people of a given age are likely to live. This is helpful in determining the price of insurance for people of various ages.

Survivorship within a population can also be represented in the form of a life table. A life table is an age-specific distribution of a population that gives picture of mortality and survival. An example of life table is given in Table 12.1.

Table 12.1 : Life Table for the Total Population in a Developed Country

Age Interval	Of 100,000 Borne Alive		Average Remainaing life span	
Life span Between two exact ages (in Years) (x)	Number of living at the start of age interval (lx)	Number Dying During age Interval (dx)	Mortality rate $\frac{dx}{lx} = qx$	Average Number of Years of Life at the Beginning of Age Interval
0-1	100,000	1,107	0.0110	73.6
1-5	98,893	269	0.0027	73.7
5-10	98,624	175	0.0017	71.7
10-15	98,449	181	0.0018	64.6
15-20	98,268	497	0.0050	59.7
20-25	98,771	673	0.0068	55.0
25-30	97,098	663	0.0068	50.4
30-35	96,435	725	0.0075	45.7
35-40	95,710	986	0.0103	41.0
40-45	94,724	1,483	0.0156	36.5
45-50	93,241	2,352	0.0252	32.1
50-55	90,889	3,483	0.0383	27.9
55-60	87,406	5,063	0.0579	23.9
60-65	82,343	7,281	0.0884	20.3
65-70	75,062	9,005	0.1196	17.9
70-75	66,057	12,214	0.1849	13.8
75-80	53,843	14,455	0.2684	10.4
80-85	39,388	14,467	0.3672	10.1
85 and over	24,921	24,921	1	9.2

To set up a life table, we must decide on age intervals to classify the population data into groups. For example age interval for humans is generally 5 years, for deer 1 year and for field mice 1 month.

SAQ 2

Tick mark (√) for the correct statements and (×) for wrong statements.

i) Ecological natality is always constant for a population. [ ]

ii) Natality rate measurement is dependent on the type of organism being studied. [ ]

iii) Potential mortality is the death of an individual under a given environmental condition. [ ]

iv) Very few organisms in natural populations attain their potential longevity. [ ]

12.2.4 Population Dispersal

Population dispersal is the movement of individuals into or out of the population or the population area. It occurs in three following ways in a population:

- emigration — one way outward movement of individuals from an area.
- immigration — one way inward movement of individuals into an area.
- migration — periodic departure and return of individuals to same area.

A population is inherently dynamic in nature since individuals are always leaving or entering the populations. But such changes normally do not affect the size of a population. It is because emigrations balance immigrations or because gains and losses in terms of entry and exit of individuals are compensated by changes in natality and mortality. However, mass dispersal may bring out rapid changes in the population e.g., immigration may speed up population growth or in case of extreme reduction may prevent extinction. Mass dispersal affects the balanced population in other ways also e.g., the immigration of large number of blue gill fishes into a pond already full of blue gill population may result in reduced growth of the fish population and also result in smaller average size of fishes due to environmental limitations. So even though the biomass density remains unchanged, the size of fishes may be much reduced affecting the fishing process.

Dispersal is affected by the presence or absence of the barrier and vagility which means inherent power of movement also called dispersal powers. Many plants and lesser form of animals have greater dispersal power, although we all know that birds and insects are much known for their ability to move around.

Migration is a special type of population dispersal process often involving the mass movement of entire population. It occurs only in motile organisms and is best developed in arthropods and vertebrates like certain fishes, birds and mammals. Due to seasonal and diurnal migrations the organisms are able to occupy the regions which would be otherwise inhabitable during unfavourable conditions. In most cases migration of population may occur for food, shelter or reproduction and various ecological hazards such as temperature fluctuation, predation etc. Non-migratory populations in such unfavourable periods assume some form of dormancy or undergo considerable reduction in number, for example, frogs hibernate during winter season

Apart from its influence on the size and density of a population, dispersal has few advantages. It is the means by which new or depopulated areas are colonised. It also contributes in gene flow and brings about gene exchange between populations and hence the process of speciation.

12.2.5 Age Distribution

It is obvious that individuals in a population will be of different age groups. Relative numbers of young and old individuals in a population will significantly influence the behaviour of a population such as natality and mortality. The age structure of any population can be classified into three categories, i.e. pre-reproductive, reproductive and post-reproductive ages.

Mortality usually varies with age as chances of death are more in early pre-reproductive and late post-reproductive periods. Likewise, natality is restricted to the reproductive age of individuals in a population. The relative duration of these ages in proportion to life span is different in different organisms. For example, in modern man the three 'ages' are relatively equal in length, about one third of the life span. In comparison, the primitive man had much shorter post reproductive period. Many animals and plants have quite long pre-reproductive period. For example, a locust in its seventeen years of life has an extremely long development history with adult life lasting only less than a year.

Functional age breakdowns can be useful to understand the importance of specific environmental factors on the population as a whole. If we know both the time spent by an organism in specific functional age groups and environmental factors that have greatest effect on each age, we can gain a considerable insight into the characteristics of that particular species. For example, this knowledge is essential if we are trying to control an economically important crop and it is necessary to know which stage in life cycle of the pest is most vulnerable to attack and by which means.

The easiest and convenient way to picture age distribution in a population is to arrange the data in the form of age pyramid. An age pyramid is vertical bar graph in which the number or proportion of individuals in various age groups at any given time is shown from youngest at the bottom of the graph to oldest at the top. Fig. 12.3 shows the three types of hypothetical age pyramids which are as follows:

1) A pyramid with a broad base, indicating a high percentage of young individuals in a population. This shows that population is expanding exponentially.
2) A triangular or bell shaped pyramid indicating moderate proportion of young to old individuals. This is the characteristic of a stable population where natality equals mortality.
3) An urn shaped figure indicating a low number of young individuals. This pyramid is the characteristic of aging or declining population.

Also shown in the figure is the example of age pyramids of laboratory populations of the vole *(Microtus agrestis)*. Pyramid *a* shows the expanding population with an exponential expansion by increased number of young ones produced in unlimited environment. Pyramid *b* shows the stable population where birth rates and death rates are equal. Stable populations maintain the same age structure and may be steadily increasing, decreasing or remain stationary. A stationary population is the one in which number of individuals remain same over a period of time and birth rate equals the death rate during the same period.

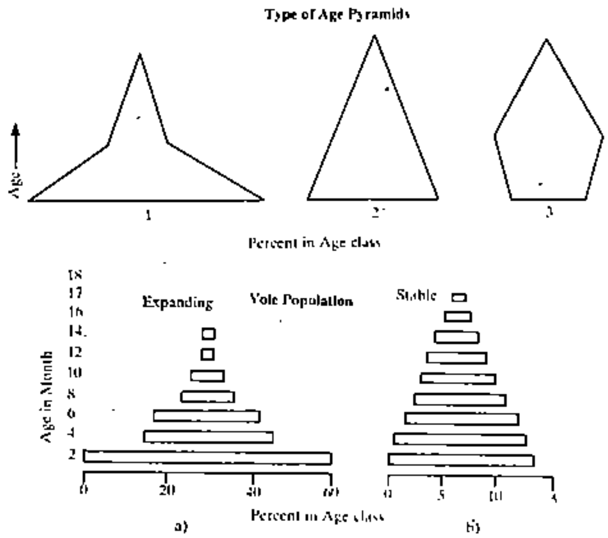


Fig. 12.3 : Three types of age pyramid showing large (1) moderate (2) and small (3) number of young individuals in a population. Vole population under laboratory conditions is shown expanding (a), and stable (b) age pyramids.

12.2.6 Population Distribution

Dispersion or distribution refers to the pattern of distribution of individuals of a population. As shown in Fig. 12.4 , individuals in a population may be distributed in three broad patterns; a) uniform, b) random, and c) clumped. *Uniform* distribution is more regular than random and may occur where competition between individuals is severe or where there is antagonism which promotes even spacing. *Random* distribution occurs where environment is very uniform and there is no tendency to aggregate. This type of distribution is relatively rare in nature. *Clumping* of individuals in groups is the most common pattern. In this case the groups could be of same or of varying size.

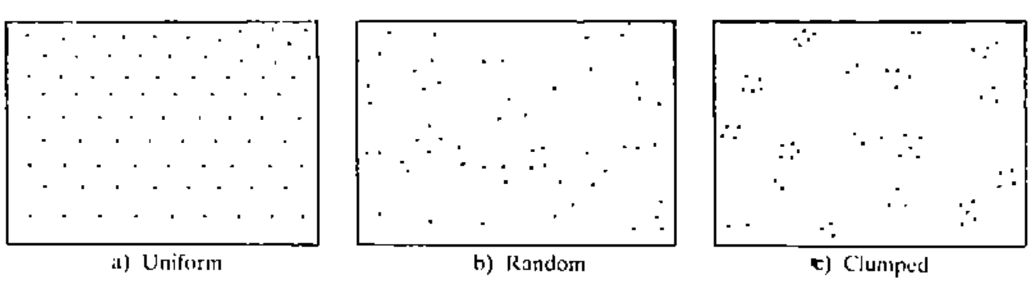


Fig 12.4 : Distribution patterns of individuals in a population. Note that each rectangle contains approximately the same number of individuals.

Again these groups could be randomly distributed, uniformly distributed or further clumped with each other. All these ways of dispersions are found in nature. It is obvious from the figure that if we examine small samples of dispersion from each population, the results will be very different. For example, a sample from a population with clumped distribution will give either too low or too high a density, when the number in the sample is multiplied to obtain the total population. So we can say that clumped populations require larger and more careful techniques for study of populations than non-clumped ones.

SAQ 3

i) State the ways of population dispersal.

....

....

....

....

ii) Differentiate between stationary and stable populations.

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....

iii) List the three patterns of population distribution.

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....

12.3 POPULATION GROWTH

By now you are aware that size of a population depends upon the balance between natality and immigration through which individuals are added to a population and mortality and emigration which remove them. If natality and immigration exceed mortality and emigration, population will grow, if these are equal population will remain same size, i.e. static and if death and emigration exceed population will decrease.

Let us discuss the growth of population by taking few examples. The size of a population of mice in a field seems to vary little from year to year despite the fact that these organisms produce so many offsprings that their population could increase greatly from one year to the next. The size of such type of natural populations is limited by environmental factors. Now consider another example of *Paramecium caudatum* population studied by Russian ecologist G.F. Gause to see how rapidly population could increase if nothing stopped their growth. Every few hours a well nourished Paramecium divides to form two new individuals. Gause set up tubes containing sufficient bacteria for food and introduced one paramecium into each. If nothing checked the growth of paramecium, population showed exponential growth, that is as time went on the number of individuals added in each time period kept on increasing. When this type of increase in population size is graphed on a linear axis, the exponential growth is plotted as a curve that shows steep growth. When the population size is plotted on a logarithmic axis, the exponential growth plots as a straight line (see Fig. 12.5 a,b).

Linear scale on the axis of a graph is taken when change in variables is not large and can be accommodated on the axis. But if the change in variables is very large viz. upto 100 or more, it is advisable to plot it on a logarithmic scale by taking the log of the variables.

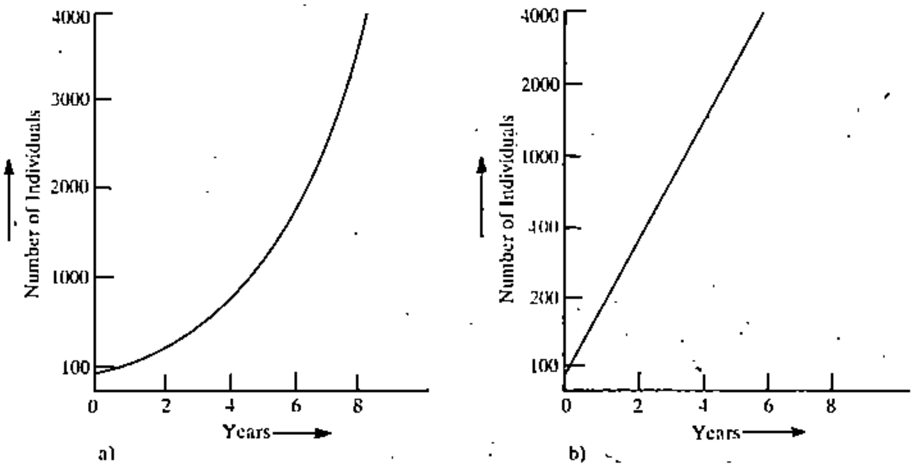

Fig. 12.5 : Exponential growth of a population expressed on a linear scale (a) and logarithmic scale (b).

This type of exponential growth can be expressed in the form of following equation

$$\frac{dN}{dt} = \Upsilon m\, N$$

Where N is the number of individuals in a population, $\frac{dN}{dt}$ is increase (or change) in number of individuals per unit time and Υm is the maximum rate of population growth per individual and is known as *innate capacity for increase* or *biotic potential* of the population. This is achieved when environment does not impose any limitations, i.e. food and space are superabundant and there is no interference from the members of other species.

Biotic potential also called reproductive potential is difficult to measure because optimum conditions for growth almost never occur except under artificial laboratory conditions. What we see in nature is the outcome of interactions between a population's biotic potential and various environmental factors that restrict the actual growth. The *actual rate of population* increase is represented by r which is the difference between birth rate and death rate per individual per unit of time. In most natural populations Υ varies in response to interactions between a population and its environment. Exponential growth occurs in nature when a population has abundant supply of resources e.g., population explosion occurs when bacteria invade the intestinal tract of an animal or when decomposers invade a freshly dead animal or plant. However, exponential growth does not necessarily mean that the population is growing at its biotic potential.

12.3.1 Factors Affecting Biotic Potential

Biotic potential differs from one species to another e.g., bacterial populations can grow faster than population of oak trees. The rate of reproduction of any individual can be increased in any or all of three following ways:

- by producing a large number of offsprings each time it reproduces,
- by having a long reproductive life, and
- by reproducing as early in life as possible.

Of these three factors, the last one is most important. Let us take an example to understand this. A bacterium neither lives for a long time nor produces many offsprings each time it reproduces. Its reproductive potential is higher than that of a dog because most bacteria can reproduce within an hour after being formed by cell division, whereas a dog is not able to reproduce until it is at least 6 months old. So we can say that shorter the generation time of a species, the higher its reproductive potential. In case of organisms with equal generation time, the number of offsprings produced determines which has higher potential for population growth.

Thus the population of a plant that produces 100 seeds a year can potentially grow faster than the population of a plant that produces 10 seeds a year. However, with longer pre-reproductive period, number of offsprings produced does not affect much the biotic potential of a population.

12.3.2 Carrying Capacity

No population can grow exponentially for long. Gause found that his Paramecium populations eventually stopped growing after reaching a certain level. So the level beyond which no major increase can occur represents the saturation level or *carrying capacity* which is represented by letter K. It is the number of individuals of a particular species that a particular environment can support indefinitely.

Accordingly such type of population growth can be explained by following logistic equation and the curve plotted is called logistic curve (see Fig. 12.6).

$$\frac{dN}{dt} = \gamma m\, N \left(\frac{K-N}{K}\right)$$

where N = population Number

$\frac{dN}{dt}$ = change in Number per unit time

γm = innate capacity for increase

K = Carrying Capacity

The term $\left(\frac{K-N}{K}\right)$ indicates how much of the resources are still available to populations. When N is much less than K, the term $\left(\frac{K-N}{K}\right)$ becomes approximately 1 and the equation becomes $\frac{dN}{dt} = \gamma m\, N$ (equation for exponential growth). As N almost becomes equal to K, the term $\left(\frac{K-N}{K}\right)$ is almost zero and $\frac{dN}{dt}$, i.e. the growth rate also becomes zero.

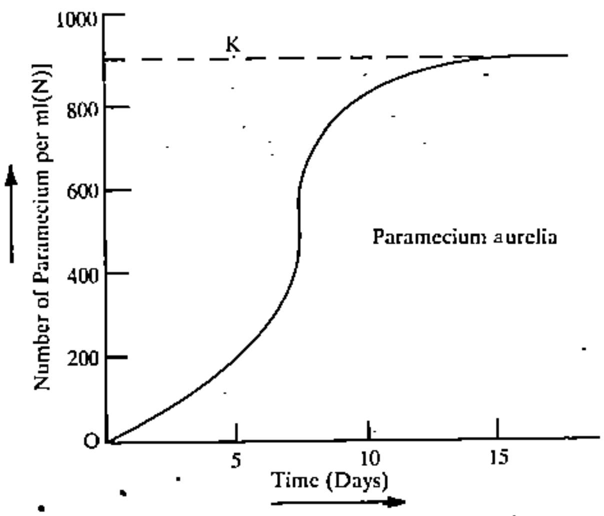

Fig. 12.6 : S-shaped curve obtained as a result of growth of Paramecium population in a c... e medium with constant supply of bacteria as food each day. Population grew exponentially at first ...entually reached zero as its numbers (N) approached the carrying capacity (K).

Another type of population growth curve called J-shaped curve is obtained when the density of organisms increases rapidly and then stops abruptly as environmental resistance or other limits become effective more or less suddenly. Carrying capacity is determined by various factors including predation, competition and climatic conditions. All factors which limit a population growth are collectively known as the *environmental resistance* to population growth. Since such factors are many and varied, it is clear that the carrying capacity of any area for a population may vary over a period of time. In the next section we will discuss regulation of population size, but before that try the following SAQ.

SAQ 4

Strike off the incorrect word in the following statements.

i) The size of natural populations is/is not limited by environmental factors.

ii) Biotic potential is the innate capacity for decrease/increase of a population.

iii) The length of the reproductive life of an individual affects/does not affect the biotic potential of a population.

iv) Carrying capacity is/is not the saturation level beyond which a population does not grow.

12.4 POPULATION REGULATION

The number of individuals in a natural population varies with time. If the size of a population declines too drastically due to some reason, it may become extinct, but may later be re-established by immigration from other populations. On the other hand, increase in size of a population is not infinite since the carrying capacity of the environment always imposes a restriction upon it. In spite of such fluctuations, however, an outstanding feature of most large populations is that their average size changes relatively little over the years and certainly less than is expected from their biotic potentials. This indicates that population sizes are regulated in such a way that small population grow fast, larger populations grow more slowly and still larger populations decline. Let us see what brings about such ecological homeostasis. In low-diversity, physically stressed ecosystems or in those subjected to irregular or unpredictable external perturbations, populations tend to be regulated by physical components such as weather, water, chemical limiting factors, pollution etc. In high diversity ecosystems, or in those which are not physically stressed, populations tend to be biologically controlled. In all ecosystems there is a strong tendency for all populations to evolve through natural selection towards self-regulation such as failure of reproduction and self-inflicted mortality. Even though this is difficult to achieve under external stress. It is because over-population is not in best interests of any population. Thus it can be said that limitation of number in any population is brought about by the action and interaction of two basic regulatory processes namely density dependent and density independent factors. We will discuss these processes in the following subsections.

12.4.1 Density Dependent Factors

The density dependent factors are intrinsic or biotic factors and they depend on interactions between individuals within same population or populations of different species. Density dependent factors may stabilise the population at the level determined by carrying capacity of the environment. The important density dependent factors are reproductivity, emmigration, competition for resources, predation, parasites, and diseases. The contribution of these factors may vary from species to species. You have already read how in large populations the number of offsprings produced are less, thus self-regulating the population size. You have also read how emmigration of individuals from a population reduces its density. Competition can be between individuals of same species called *intraspecific competition* and between individuals of different species called *interspecific competition*. Generally, members of the same species need same resources and are bound to compete for them. In some bird species males and females have different beak lengths enabling them to feed on different insect prey.

Let us take an example, where seeds of white clover, *Trifolium repens*, were planted at three different densities. Half of the plants at each density were watered throughout the experiment but other half were watered only for first 18 days. After seven weeks, the densities of the surviving seedlings were measured. As shown in Fig. 12.7 among the seedlings that were watered regularly, mortality was low

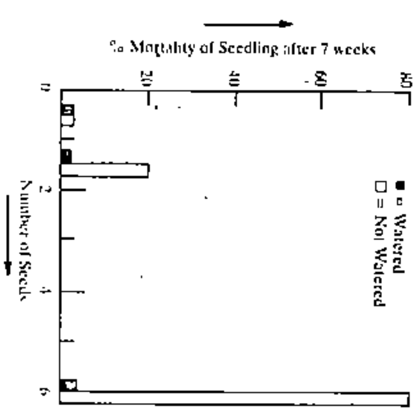

Fig. 12.7 : Effect of seed density on survival of white clover seedlings subjected to water shortage. Solid bars show that mortality was same at all population densities when water was available. Unshaded bar represent the mortality of seedlings not watered after 18 days.

regardless of density. However, the proportion of seedlings killed among the deprived ones was three times greater in the high density plots than in the intermediate density plots.

Interspecific competition occurs when ecological niches of the species overlap. Predation and diseases are a part of this type of competition and are partly density dependent factors. It is because a disease causing organism is more likely to encounter a host, or a predator a prey, when there are more hosts or prey per unit area. In dense animal populations individuals have decreased health and vigour which make them more susceptible for predators and diseases. You have already read about interspecific competition in Unit 11.

12.4.2 Density Independent Factors

Density independent factors are the extrinisic factors which tend to regulate the density of a population in ways that are not correlated with its density. Environmental factors such as bad weather and scarcity of space, pollution etc. are some factors. A hurricane, a severe winter, or a drought may kill most of the individuals in a population irrespective of its density. In a bad weather only some individuals may be able to shelter from it; if the number of shelters is limited. Thus only a fraction of a large population will be protected. However, we cannot pinpoint one or two factors and say that they determine the size of a particular population. Often the sizes of natural populations are affected by many different factors whose interactions can be complex.

SAQ 5

Fill in the blanks in the following sentences with appropriate words from the text.

i) Ecological homeostasis is .... of population sizes.

ii) Density dependent factors are .... factors which affect the .... of population.

iii) Competition for resources between individuals of different species is called ....

iv) Environmental factors .... which affect the size of population.

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12.5 GENETIC DIVERSITY OF THE POPULATION

You will be aware that reduction in species and genetic diversity in historical times has produced short-time benefits in agriculture and forestry. This can be evidenced by the propagation of specialised, high yielding varieties over large areas of the world's crop and forest land. To call attention to the overall threat posed by loss of diversity, biologists are organising gene resources conservation programmes.

The biological diversity of animals, plants, and microorganisms is of fundamental importance to human survival. The term "gene resources" may be defined as the genetic diversity that is very essential for meeting the society's needs in perpetuity. This diversity is expressed in the differences between species as well as in the variation among individuals that comprise a species. Gene resources include wild and domestic species having many species of no commercial value. Every year gene resources are utilised to provide crores of rupees worth of new and familiar products e.g., food, clothing, shelter, pharmaceuticals, energy and hundreds of industrial products. You will be aware that a wide range of species and their products are required for medical and other research. Agricultural, forestry and related industries are dependent, whenever needed on appropriate diversity as for example resistance to plant diseases. It is this diversity that sets the limits to which both wild and domestic species can successfully adopt to changes involving: 1) weather, insects and disease, 2) technology, 3) demand and, 4) human preferences. Most of the biological diversity is still found in natural ecosystems whose survival is dependent, in large part, on the diversity within them.

Good area and regional planning can compensate to some extent for the reduction in local diversity which tends to accompany intensive agricultural, forestry and urban development. If crop and forest monocultures as well as tract housing (rows and rows of similar houses on small, un-covered plots), are intersporsed with more diverse natural or seminatural ecosystems, the ecosystem can be preserved in perpetuity as park, nature centres and so on. If floodplains and other wetlands together with steep slopes and ravines are left underdeveloped, not only will there be a pleasing landscape full of recreation possibilities, but also a high level of diversity will have been safeguarded.

Landscapes can be planned to preserve diversity and yet accommodate urban and industrial development. Thus the diversity is necessary for the future survival of humans and nature.

12 6 EVOLUTIONARY IMPLICATIONS OF NATURAL REGULATION

You would like-to know that how systems of natural regulation are affected by evolutionary changes. You will be aware of the interaction involved in co-evolution of predator-prey systems and herbivore-plant systems. In many of these interactions, evolutionary changes operate very slowly and are difficult to be detected. But recent studies have shown that evolutionary changes may occur very rapidly, so that the evolutionary time scale approaches the ecological time scale. Thus natural selection may impinge upon natural regulation.

Many changes in abundance can be attributed to changes in extrinsic factors such as weather, disease or predation. But some changes in abundance are the result of changes in the genetic properties of the organisms in a population. Such evolutionary changes are produced by the genetic feedback mechanism. It is believed by the biologists that natural population regulation has its foundation in the process of evolution.

We will illustrate the type of systematic changes by a simple model which could be involved in the genetic feedback mechanism. Consider a two-species system of one plant and one herbivore, and to make the model simple, let us focus on only one gene on one chromosome in the plant. The hypothetical gene has a major effect on 1) the ability of the plant to survive in its environment and 2) the palatability of the plant to the herbivore. Two different alleles (A and a) occur at the hypothetical gene locus, and the properties of the genotypes are as shown in Table 19.2.

Table 19.2 : Genotype of Plants

	AA	Aa	aa
Ability of plant to survive	Good	Poor	Very poor
Palatability to herbivores	High	Low	Very low

Thus plants of genotype AA are to survive very well but attract many herbivores because they are desirable foods. Each plant genotype can support only a limited number of herbivores before it is killed by overgrazing. Finally we assume that the reproductive rate of the herbivore will be affected by the genotype of plant on which it lives, so that highly palatable plants are best for herbivore reproduction.

We can give here some examples of genetic changes of this type playing a role in population regulation. For example, the Hessian fly population was reduced drastically in Kansas after 1942 when resistant varieties of wheat were introduced. The herbivore population of Hessian flies was significantly reduced by changing the genetic makeup of the wheat plant. Another example is the myxomatosis-rabbit interaction in Australia. The European rabbit was introduced into Australia in 1859 and increased to very high densities within 20 years. After World War II, an attempt was made to reduce rabbit numbers by releasing a viral disease from south America, myxomatosis. The myxoma virus was highly lethal to European rabbits, killing over 99 per cent of infected individuals. Since myxomatosis was introduced into Australia in 1951 evolution has been going on in both the virus and the rabbit. The virus has become attenuated so that it kills fewer and fewer rabbits and takes longer to cause death. Since mosquitoes are a major vector of the disease, the exposure time before death is critical to viral spread.

Rabbits have also become more resistant to the virus. By challenging wild rabbits with a constant laboratory virus source, we can detect that natural selection has produced a growing resistance of rabbits to this introduced disease. Evolution in the rabbit myxoma system has thus been towards an intermediate rate of increase. This is explained by selection operating at the individual level for the rabbit but at the level of the group for the myxoma virus. Group selection occurred because less virulent viral colonies are favoured over more virulent viral colonies because they take longer to kill the host rabbit.

Self-regulatory populations present yet another problem not covered by the genetic feedback mechanism. How does a population evolve the machinery to be self-regulatory? Self-regulation is clearly a desirable adaptation for any population that has the potentiality of destroying its resources.

SAQ 6

Which features listed in Column II below, correspond to statements given in Column I. List them under suitable headings.

Column I	Column II
a) Genetic Diversity	i) The myxoma virus was highly lethal to European rabbits, killing over 99 per cent of individuals infected.
b) Evolutionary implications of natural selection	ii) European rabbit was introduced into Australia in 1859 and increased very high densities within 20 years.
	iii) Landscapes can be planned to preserve diversity and yet to accommodate urban and industrial development

12.7 SUMMARY

In this unit you have studied that:

- Population is a group of interbreeding individuals occupying a particular space a particular time. Density, natality, mortality are some characteristics which are attributed to the whole group and not to any individual.
- Density of any population is influenced by natality rate, mortality rate, immigration, emigration and dispersal of individuals in the population. Life table tabulates the statistics of mortality for various age groups in a population. Plotting of these data gives a survivorship curves for various species.
- Populations have relative numbers of young and old individuals with different distribution of pre-reproductive, reproductive and post-reproductive stages. Age pyramids are the vertical graph of horizontal bars showing the number or proportion of individuals in various age ranges with youngest at the bottom and oldest at the top.
- Individuals in any population may be distributed in uniform, random or clumped pattern. These three patterns of distribution are much dependent upon the various resources such as food and space.
- Growth is the most fundamental feature that a population displays. Populations have innate capacity to increase and can attain exponential growth. However, there is a level beyond which no major increase occurs due to environmental limitations representing the saturation level or carrying capacity.
- There is inherent tendency of all populations to increase their size. However, this increase is not infinite and is regulated by various density dependent and density independent factors.
- Genetic diversity of a population can be evidenced by the propagation of specialised, high yielding varieties over large areas of world's crop and forest land. Landscapes can be planned to preserve diversity and yet to accommodate urban and industrial development. Genetic diversity is necessary for the future survival of human race and nature as well.

- Recent studies have indicated that evolutionary changes may occur very rapidly, so that the evolutionary time scale approaches the ecological time scale and thereby natural selection may affect the natural regulation.

12.8 TERMINAL QUESTIONS

1) Discuss very briefly in the space given below the role of quadrats in measuring the density of a population.

2) Explain briefly what is survivorship curve.

3) Enlist in the space given below the three types of hypothetical age pyramids.

4) Explain briefly what do you understand by carrying capacity.

12.9 ANSWERS

Self-assessment Questions

1) a) ii, b) iii, c) i, d) iv
2) i) ×, ii) √, iii) ×, iv) √
3) i) a) Emigration — One way outward movement of individuals.
   b) Immigration — One way inward movement of individuals.
   c) Migration — Periodic departure and return of individuals.
   ii) Stationary population remains the same size over the period of time. Stable population may be steadily increasing decreasing or remain stationary.
   iii) Random distribution — occurs in very uniform environment.
   Uniform distribution — occurs where competition between individuals is severe.
   Clumped distribution — individuals are distributed in group forms.
4) i) is, ii) increase, iii) affects, iv) is
5) i) regulation, ii) intrinsic, size, iii) interspecific competition,
   iv) density independent
6) i), ii) : b) Evolutionary implications
   iii) : a) Genetic Diversity

Terminal Questions

1) Quadrat is the sampling area of any shape in ecology. To measure the density of a population the individuals are counted or weighed in various plots of known size and number to estimate the average density. This average density is then extrapolated to whole area.
2) Survivorship curves describe mortality in relation to age by plotting number of survivors against the age groups. These curves are of three main types. In type I most individuals live for a long time. In type III most individuals die at an early stage. Type II is in between these two.
3) Age pyramids are of three types:
   i) Pyramid with a broad base indicating a high percentage of young individuals.
   ii) Triangular shaped pyramid showing the moderate proportion of young to old individuals.
   iii) Urn shaped pyramids indicate a low number of young ones.
4) Carrying capacity is the saturation level in the density of a population, beyond which no substantial increase occurs in size and is represented by letter K. The relationship of the number of individuals per unit time in a population and its carrying capacity is shown by the following equation.

$$\frac{dN}{dt} = \gamma m\, N \left(\frac{K-N}{K}\right)$$

GLOSSARY

Allogenic succession—ecological change or development of species structure and community composition brought about by some externally generated force such as fire or storm

Autogenic succession—ecological change or development of species structure and community composition brought about by the existing vegetation itself

Carrying capacity—maximum number of organisms of a population the resources of a given area can support indefinitely

Chamaephyte—perennial shoots or buds on the surface of the ground to about 25 cm above the surface

Character displacement—divergence of characteristics in two otherwise similar species occupying overlapping niches; brought about by selective forces of competition

Climax—stable, and community of succession that is capable of self-perpetuation under prevailing environmental conditions

Community—also called a biological community. The population of plants animals, and microorganisms living and interacting in a given area

Coevolution—joint evolution of two or more non-interbreeding species having a close ecological relationships. The interacting species act as agents of natural selection on one another over evolutionary time

Cohort—group of individuals of same age

Crytophyte—buds buried in the ground in a bulb or rhizome

Deme—local population or interbreeding group within a larger population

Density dependent—varying in relation to population density

Density independent—unaffected by population density

Diversity—a measure of the number of different species in a biotic community. Diversity is high when there are many different species, and low when there are few

Dominant species—population possessing ecological dominance in a community present in largest numbers or greatest biomass

Ecesis—establishment of a species

Ecotone—transition zone between adjacent ecosystems

Facilitation model—model of succession in which previous community prepares or "facilitates" the way for succeeding community

Fugitive species—species characteristic of temporary habitats

Gene pool—sum of all the genes of all individuals in a population

Guild—group of populations which utilises a gradient of resources in a similar way

Hemicryptophyte—perennial shoots or buds close to the surface of the ground, often covered with litter

Hydrarch—succession on wetlands

Importance Valve Index—sum of relative density, relative dominance and relative frequency of a species in a community

Inhibition model—model of succession proposing that the dominant vegetation occupying a site prevents colonisation of the site by other plants of the next successional community

Keystone species—particular species whose presence is necessary for the organisation of a community

Life table—tabulation of mortality and survivorship schedule of a population

Logistic curve—s-shaped curve of population growth which slows at first, steepens and then flattens out

Logistic equation—mathematical expression for the population growth curve in which rate of increase decreases linearly as population size increases

Microhabitat—that part of the general habitat utilised by an organism

Model—in theoretical and systems ecology, an abstraction or simplification of a natural phenomenon developed to predict a new phenomenon or to provide insights into existing ones

Mortality—death of individuals in a population

Natality—production of new individuals in a population

Niche—functional role of a species in the community including all its activities and relationships

Niche breadth—range of a single niche dimension occupied by a population

Oscillation—regular fluctuation in a fixed cycle above or below some set point

Pioneer species—plants that are initial invaders of disturbed sites or early seral stages of succession

Population—group of related individuals capable of interbreeding

Primary succession—Vegetational development starting from a new site never before colonised by life

Resilience—ability of a system to absorb changes and return to its original condition

Secondary plant—organic compounds

Secondary succession—plant succession taking place on sites that have already supported life

Sere—A series of stages of community change in a particular area leading toward a stable state

Stability—ability of a system to resist change or recover rapidly after disturbance

Succession—the natural replacement of one biotic community by another

Tolerance model—of succession that proposes that succession leads to a community composed of species, most efficient in exploiting resources; colonists neither increase or decrease the rate of growth of new colonists

Xerarch—succession in dry or desert habitats

Suggested Reading

A textbook of Plant Ecology, R.S. Ambasht, Dev Jyoti Press, Varanasi, 1976.

Basic Ecology, E.P. Odum, Holt-Sauders, Japan, 1983.

Communities and Ecosystem, R.H. Whittaker, Macmillan, New York, 1975.

Concept of Ecology (third edition), E.J. Kormondy, Prentice-Hall of India Pvt. Ltd., New Delhi, 1986.

Ecology (Modern Biology Series-Holt, Rinehart and Winston Inc.), 2nd Indian Edition, E.P. Odum, Mohan Primlani, Oxford and IBM Publishing Company, New Delhi, 1975.

Dear Student,

While studying these units you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions in order to improve the course. Therefore, we request you to fill and send us the following questionnaire which pertains to this block.

QUESTIONNAIRE

LSE-02
Block-1

Enrolment No. | | | | | | | | | | |

1) How many hours did you need for studying the units?

Unit Number					
No. of hours					

2) How many hours (approximately) did you take to do the assignments pertaining to this block?

Assignment Number		
No. of hours		

3) In the following table we have listed 4 kinds of difficulties that we thought you might have come across. Kindly tick (√) the type of difficulty and give the relevant page number in the appropriate columns.

Page Number	Types of difficulties			
	Presentation is not clear	Language is difficult	Diagram is not clear	Terms are not explained

4) It is possible that you could not attempt some SAQs and TQs. In the following table are listed the possible difficulties. Kindly tick (√) the type of difficulty and the relevant unit and question numbers in the appropriate columns.

Unit No.	SAQ No.	TQ No.	Type of difficulty			
			Not clearly posed	Cannot answer on basis of information given	Answer given (at end of Unit) not clear	Answer given is not sufficient

5) Were all the difficult terms included in the glossary. If not, please list in the space given below.

6) **Any Other Suggestion(s)**

To,

The Course Coordinator (LSE-02; Ecology)
School of Sciences
Indira Gandhi National Open University
Maidan Garhi
New Delhi - 110 068

NOTES

NOTES

Uttar Pradesh
Rajarshi Tandon Open University

UGBY/ZY – 06
Ecology

Block

4

HUMANS AND ECOLOGY

BLOCK 4 HUMANS AND ECOLOGY

This is the last block of the course. Here you would study three important aspects of humans and ecology. In the three units of this block you would be mainly using and applying the ecological principles and concepts developed in the earlier units of the course.

The block starts with an overview of human evolution and population. The changing environment has literally formed humankind in a process spanning nearly 4 million years. But only since the onset of industrial revolution has the human population expanded at a rapid rate. We have examined this explosive growth and its associated problems in the light of various concepts of population ecology. The differences between the developed and developing nations and the possible future scenarios of world population have been highlighted.

The second unit deals with two broad issues—ecosystem degradation and the wildlife. The first issue deals with the degradation of ecosystems caused by various activities of man. And the second issue is about the effect of ecosystem degradation on the wildlife. The safety and well-being of wildlife species is the cause of concern today, as many of them are at the brink of extinction, and several others are likely to reach the same state if proper measures are not taken at the right time. In this unit you would study about the various categories of threatened species and the conservation measures taken or needed to save them. You would also learn about the advantages of wildlife to us.

In the last unit of this block we discuss the causes and consequences of the rapidly growing pollution which has deteriorated the quality of our air, water and food. In the last two centuries our environment has been severely damaged due to growth in population, industrialisation, technological advancements and expanding human activities. We would discuss the damages caused by different pollutants to atmosphere, aquatic bodies, forests and material with special stress on living organisms including human beings.

After studying this block you would be able to:

- discuss human evolution in relation to changing environment and give reasons for the rapid growth in human population in the present times
- give reasons for the variations seen in population growth in different regions and relate population growth to resource use and environmental degradation
- identify and describe the various causes of degradation of ecosystems
- describe the factors that have endangered certain wildlife species, and the conservation measures needed/taken for their protection
- explain the advantages of wildlife to us
- discuss the generation of excessive gaseous, liquid and solid wastes and how they result in pollution of air, water and land
- describe the effects of various pollutants on human health, plants, ecosystem, materials and climate.

Study Guide

Unit 14 is a long unit requiring a study time equivalent to two units but it is not formally divided into two units. As you know, the relationship of the abiotic components of the ecosystem and the life therein is very intricate one. Therefore, we thought it would be appropriate to cover the degradation of ecosystem and its effect on the wildlife in a single unit. Similarly, Unit 15 is also a long unit and would require more study hours. We have dealt with pollution of air, water and land together as the pollution in all three is closely related.

We would like to remind you to go through the figures and tables critically and also read the margin remarks carefully though, you are not expected to memorise the statistical figures and data given in the units. Like the previous blocks of this course, you would find a feedback form at the end of this block too. It would be very helpful if you would fill it up and send it to us. This will enable the course team to know about your opinions and suggestions for the improvement of this course.

The following remarks pertain to maps shown in Figure 14.11 and 14.12.

1 Based upon Survey of India Map with the permission of the Surveyor General of India.

2 The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from appropriate base line.

3 The boundary of Meghalaya shown in this map is as interpreted from North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.

UNIT 13 AN OVERVIEW OF HUMAN EVOLUTION AND HUMAN POPULATION

Structure

13.1 INTRODUCTION

In Unit 12 you studied population parameters and became familiar with some of the terms and indices used to gauge population trends in general. In this unit you will learn about the evolution and population ecology of human beings. It is important for you to appreciate how the stage was set for humans by prehuman evolution and how our species was literally shaped by the environment existing throughout the history of evolution.

Man's evolutionary history extends back in time to about 4 million years. We will trace this evolutionary history briefly to the present times. During this period several adaptive radiations like stereoscopic vision, upright posture, bipedal locomotion, dexterity of limbs and most of all development of the brain, all led to the evolution of the first *Homo sapiens*. The *Homo sapiens* flourished and reproduced slowly in the early period and later assumed a rapid rate of growth.

The later part of the unit gives an overview of the world population and the associated problems of rapid population growth. Various concepts in population ecology that have been developed in the earlier block will be elaborated with the example of human population.

In this unit we will also explore some of the causes of the recent population explosion, we examine the differences in population characteristics of developed and less developed nations with a discussion on the methods for projecting the future world population.

Objectives

After reading this unit you will be able to:

- discuss human evolution in relation to the changing environment, explaining the importance of bipedal locomotion, erect posture, flexible hands and opposable thumb, stereoscopic vision and large brain size
- explain the cause of rapid growth of human population following agricultural and industrial revolutions
- explain and use the basic measures of population growth like, birth rate, death rate, annual rate of increase, total fertility rate and age-sex structure to predict the growth of a population
- give reasons for the variation in population growth in different regions and explain the role of demographic transition and
- discuss the relationship between human population size, resource use and environmental degradation.

13.2 TRENDS IN HUMAN EVOLUTION IN RELATION TO ENVIRONMENT

You have already got an idea how human beings evolved in FST-1 Block 3, Unit-13. Let us recapitulate briefly.

Homo sapiens belong to the mammalian order Primates, which also includes tree shrews, tarsiers, lemurs, lorises, monkeys and apes (see Table 13.1).

Table 13.1 : Classification of the order Primates

A. Suborder—Prosimii : (before apes)
Tree shrews, lemurs, lorises, bush baby, tarsiers

B. Suborder Anthropoidea : Monkeys, apes, humans

1. Superfamily Ceboidea : New world monkeys.
2. Superfamily Cercopithecoidea : Old World monkeys
3. Superfamily Hominoidea
   Family Anthropoidii : Anthropoid apes:
   Gibbon, orang-utan, gorilla, chimpanzee

   Family Hominidae :
   Australopithecus (extinct prehumans)
   Homo habilis, H. erectus, H. sapiens

The most distinct primate adaptations are found in the development of the nervous system and parts of the brain which are responsible for greater muscular dexterity and intelligence.

The adoption of a hand over hand locomotion in early primates required many muscular changes and changes in the placement of internal organs. These adaptations led to the upright posture, and bipedal locomotion characteristic of human beings today. Primates have 5 digits (fingures and toes) on each limb with at least one digit opposable to the rest, to help in grasping the tree limbs or food. The digits end in sensitive pads with nails rather than claws. Figure 13.1 shows the gradation in the grasping ability in primates. Note that humans have a completely opposable thumb.

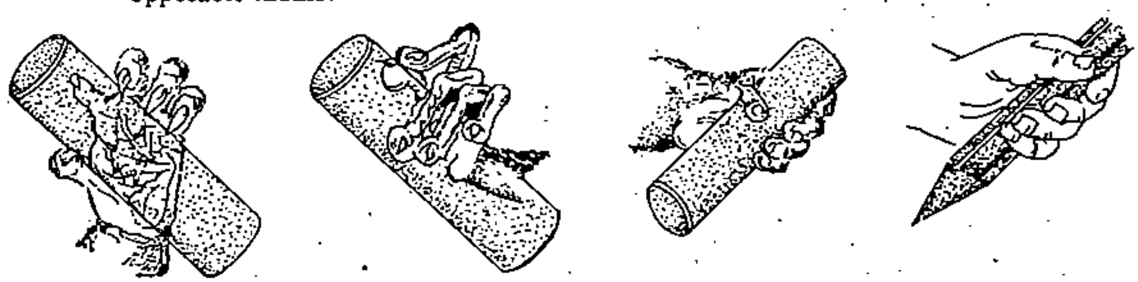


Fig. 13.1 : Primate hands from the relatively immobile fingers of a tree shrew to the completely opposable thumb in humans.

At one point in the history of primates it was necessary for some of them to come down from the trees. This move is believed to be related to the then existing environment, a prolonged dry spell which lasted from 60 million to about 4 million years ago. This period favoured low forms of vegetation, such as those seen in prairies or savanna. As the trees receded the arboreal habitat must have become overcrowded and less desirable. Perhaps the climatic changes produced a decline in fruit yields. What happened really, was that as the niche of dense forests receded, another one that of savanna expanded. Thus adaptive features that began in tree dwelling primates underwent further changes in the expanded niche of the savanna. The environment was giving birth to *Homo sapiens*. The adaptations that enabled primates to graps tree branches eventually led to the ability to make and handle tools and to perform delicate manipulations requiring hand-eye coordination. This evolution of the nervous system is linked to the arboreal or tree-dwelling life style of early primates. An animal living on trees requires muscle dexterity to jump from branch to branch and a keen and sharp vision. In most primates both eyes face forward and therefore, see the same thing; the two superimposed images provide **stereoscopic vision** or ability to perceive depth. During evolution the snout of primates became progressively shorter. This was probably an adaptation which gave the forward looking eyes a better view. The jaws got shortened with a change in dentation.

The fossil record of evolution of humans is quite incomplete and we have much to learn yet. A tentative scheme of how primates emerged during the Cenozoic era and the relationship of modern human beings to various fossil forms is given in Fig. 13.2.

You could compare your depth perception by using one eye with that using both eyes to thread a needle.

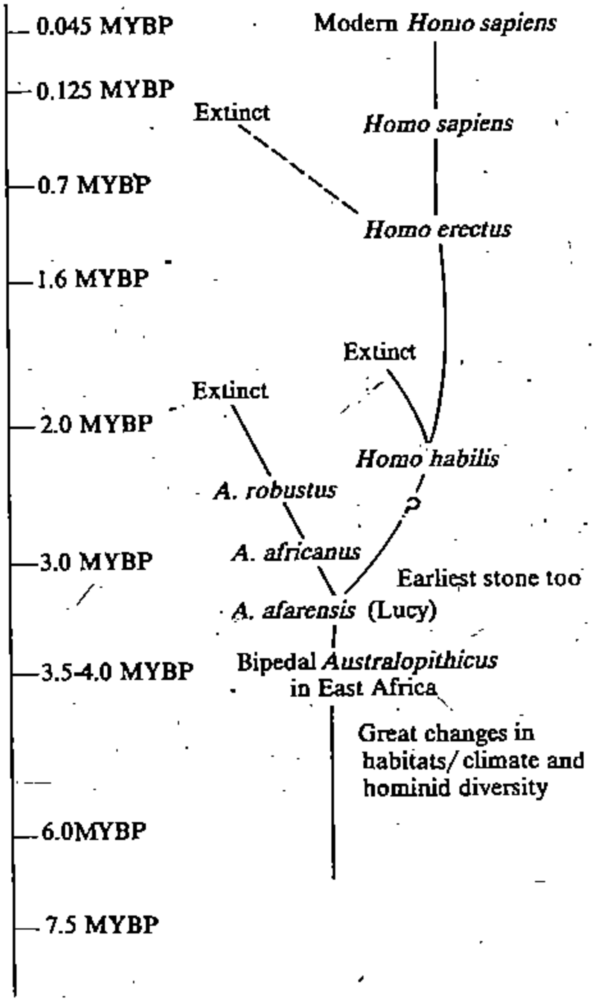


Fig. 13.2 : Plausible pattern of human evolution and some famous ancestors of modern man in time (MYBP is million years before present).

Some time after *Australopithecus afarensis* about 500,000 to 1000,000 years ago *Homo erectus* appeared as the first species in fossil records to live a human type of existence. *Homo sapiens* appeared sometime as recently as 100,000 to 40,000 years ago. *Homo sapiens* survived as a result of the competitive advantage it gained due to better developed brains and tools (Fig. 13.3).

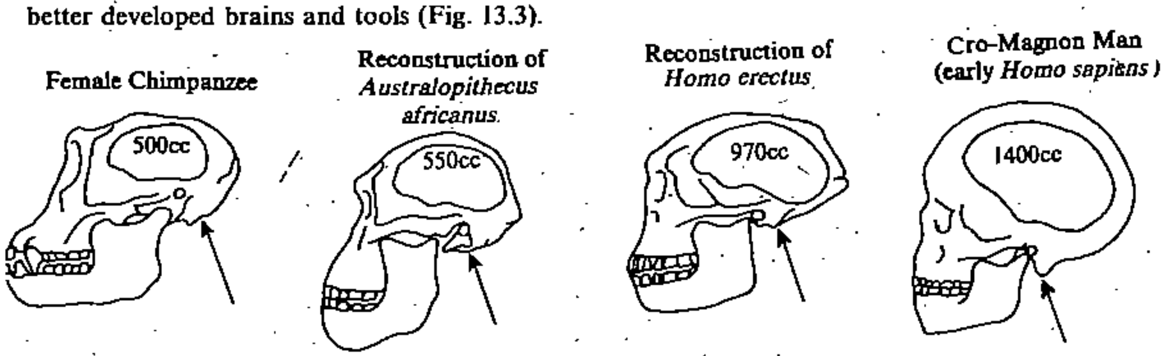


Fig. 13.3 : Changes in the skull from chimpanzee to human. Size of the brain increased progressively (cc=cubic centimetre); the place where the neck joins the head (shown by arrow) moved as hominids became more upright; and the size of the teeth and jaws was reduced with the change from a herbivorous to an omnivorous diet.

Changes in the outward appearance of our human ancestors were slow and subtle. The further evolution of the species was favoured by intraspecific cooperation and culture leading to a gradual increase in reproductive success.

The success of the human species can also be attributed to ecological adaptability. We have no special physical abilities but a little of every ability present in other animal species. Humans can swim, run, climb, but there are other organisms that can do it much better. However, no other species can do all we can. Because of the cooperative-interactive way of life only one of us had to invent the wheel for all of us to use it.

Archeological records of human campsites indicate that early humans started out as small bands of hunters who supplemented kills with foraged and gathered edible items. The hunter-gatherer cultures allowed humans to exploit agriculture, once it was discovered about 10,000 years ago. Humans began to farm seriously around 8000 BC in parts of the Middle East and South Western Asia and there was full-scale agriculture in many places just after 4000 BC.

Turning to agriculture for food was extremely important for the human species, since plants are the primary producers and form the base of the food chain as you have learned in Block 2 . As food energy moves from one trophic level to another about 90% of the available energy is lost with each transfer. It remains true to this day that a vegetarian diet can support many more people than if the crop was fed to sheep and these sheep were eater by humans. Apart from this, grain and beans are more easily stored than meat for unfavourable periods when hunting may not be possible.

For these and many more reasons agriculture permitted the establishment of stable populations with more free time from the process of providing a subsistence. This gave humans greater opportunities for inventiveness and development of technologies which have greatly influenced the survival and growth of human population.

SAQ 1

Choose the correct answer from those given below.

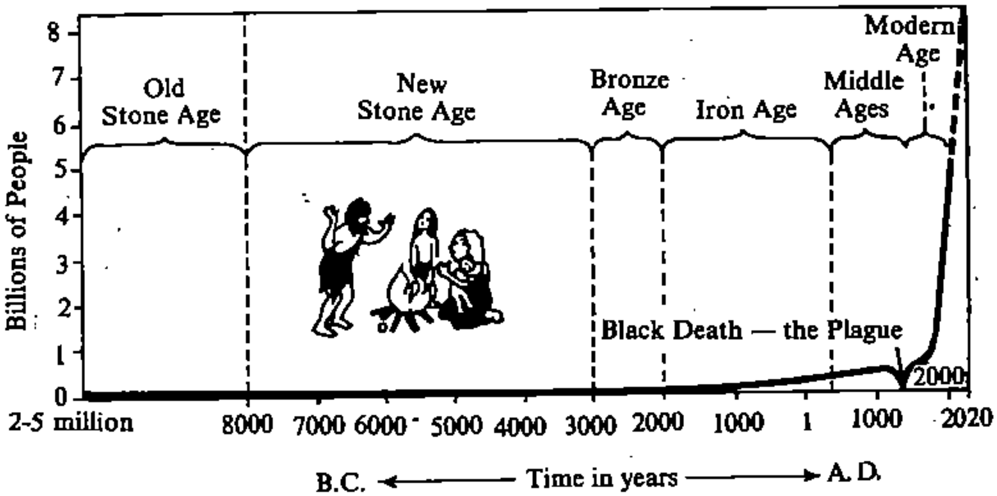
a) The ability to tie a knot in a string is the result of adaptations like
   i) muscle power
   ii) grasping ability
   iii) stereoscopic vision
   iv) all of the above
   v) ii) and iii)

b) The first hominid species to live a definately human type of existence was
   i) *Australopithecus afarensis*
   ii) *Homo erectus*
   iii) *Homo sapiens*
   iv) *Homo habilis*

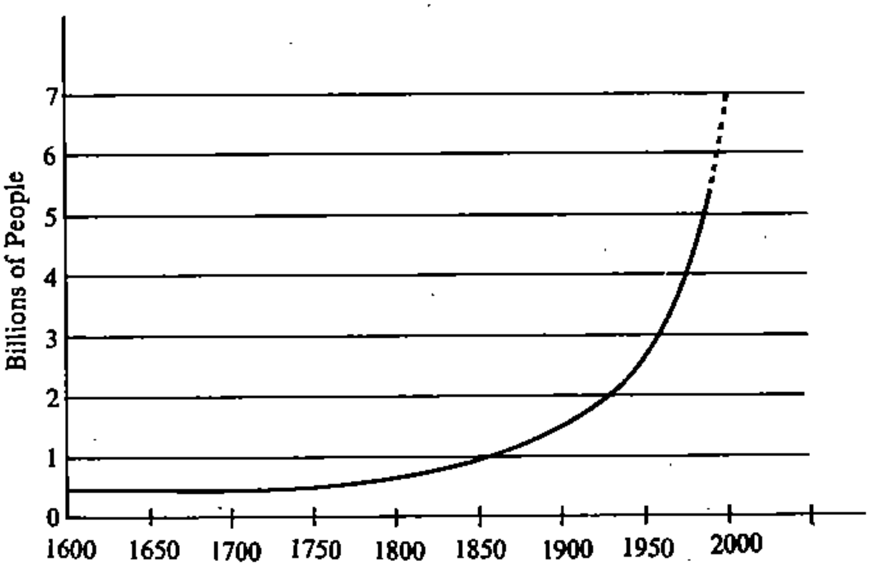
c) Human beings survived the harsh climatic changes in the past because of their
   i) specialist ability to live on the ground
   ii) generalist heritage
   iii) ability to make tools
   iv) herbivorous diet.

13.3 HUMAN POPULATION—HISTORICAL OVERVIEW

Throughout history, the human population has been quite small. It has grown relatively slowly and even experienced occasional declines. Fig. 13.4 shows the general trend of population growth in the last half million years. As said earlier, the dawn of agriculture, triggered a series of major global environmental changes. As agriculture became more efficient, women began to bear more children and the human population increased. It was possible to grow more food in a given area of land. Hunter-gatherers were mostly nomadic and in their way of life, infants were a liability as children could not become very good hunters. Whereas, in a stationary agricultural society, babies are not much trouble and children can help in the farm. Therefore, the population increase between 10,000 BC and about 1800 AD was largely the result of increasing birth rates that coincided with the growth of agriculture.



(a)



(b)

Fig. 13.4 : Growth of human population. (a) In the last half million years, note the rapid upturn in the world population in the last 2000 years. (b) During the past 400 years.

But our early ancestor were vulnerable to hostile environments, food was often scarce and famine and outbreak of diseases often took heavy tolls. Thus population growth remained low due to high death rates. For example, it is believed that during the 14th century the bubonic plague killed more than half the population of Europe and Asia. This is shown in figure 13.4(a) as a depression.

After 1800, a second and more dramatic increase in the rate of population growth occurred. This coincided with the industrial revolution. Cities grew rapidly, goods and services became more readily available. Progress in medical sciences and improved sanitation brought down the death rates drastically resulting in exponential increase in human population. From Fig. 13.4(b) we can also see that it took several thousand years for the human population to grow to 1 billion which occurred sometimes around 1850. In marked contrast, the population doubled to 2 billion persons in only 80 years and redoubled to 4 billion in hardly 45 years. Therefore, we are living in an era of population growth that is unequaled during the span of human existence.

Now let us study the principles of human population growth and then we shall examine the implications of this population explosion for the future.

SAQ 2

Choose the correct answer.

The human population explosion has resulted mainly from:
a) an increased birth rate
b) industrial revolution
c) improved nutrition and hygine leading to decreased death rate
d) education of woman.

13.4 CHARACTERISTICS OF HUMAN POPULATION GROWTH

Human populations grow in much the same way as the population of any other organism. Thus the principles of population growth that you have studied in Unit 12 also apply to humans.

For example, the simplest way to measure the growth is by subtracting the population at an earlier date from that at a later date. Let us take the example of populations of India and the United States of America during a 36 years period from 1950-1986.

Population in Millions

	India	USA
1986	785	241
1950	360	152
Increase	425	86

What do these differences indicate? They show that even though USA has many times the wealth of India and three times the land area yet it's population increase was one fourth that of India. However, population growth is not usually measured in absolute numbers but the annual average growth rate is calculated as:

$$\text{Average annual growth rate (per cent)} = \frac{\text{Population in final year} - \text{Population in initial year}}{\text{Population in initial year} \times \text{number of years}} \times 100$$

The average annual growth rate for Indian population from 1950-1986 was

$$\text{Average annual growth rate (1950-1986)} = \frac{(785\times10^6 - 360\times10^6)\times 100}{360\times10^6\times36}$$
$$= 3.3\% \text{ per year}$$

You can calculate the average annual growth rate for USA during the same period. (It was 1.6%/year). While a growth rate of 1, 2 or even 4 per cent does not sound enormous, these small numbers make a big difference. The significance of a per cent annual growth rate is easier to visualise when we consider the corresponding **doubling time** that is, the time needed for a population to double in size if the present annual growth rate continues unchanged. For example if a population is growing at 1% a year then it will double in 70 years, if at 2% a year then it will double in 35 years and so on. A convenient method to calculate doubling time is to divide the number 70 by the per cent growth rate i.e.

$$\text{Doubling time} = \frac{70}{X} \text{ where}$$

$X =$ per cent growth rate.

To compute doubling time from rate of growth, let us take an analogy from the compound interest in the bank. If the rate of growth (interest rate in the bank) is applied once a year to a population of size Po (capital in the bank). The population (capital) at the end of the year is

$P_1 = P_0 + P_0r = P_0(1+r)$

If the population growth is compounded n times a year the the population in year t is

$P_t = P_0(1+r/n)^{nt}$

It is reasonable to assume that population grows continuously i.e. $n = \alpha$

From elementary calculus

$\lim_{n \to \alpha} (n+r/n)^{nt} = e^{rt}$

The doubling time td is then the solution of the equation

$2P_0 = P_0 e^{rtd}$

or taking logrithms on both sides of the equation

$td = 0.693/r$ or $\frac{.70}{r}$

or 70/ per cent growth rate.

For example : in 1987 the doubling time for the world population was 41 years (70/1.7 = 41).

Average rates of growth and doubling time tell us how fast the population has been growing but this information is not enough for predicting the future of populations. A demographer is interested in the number of vital events that occur in a given population i.e. births, deaths, marriages, migrations—that occur in a given period of time.

As you already know from Unit 12, two basic measures of population growth are birth rate and death rate. For human populations, demographers use **crude birth rates** and **crude death rates** rather than total live births and deaths to describe population changes. The crude rates give the number of live births and deaths **per 1000 persons** at the mid point of a given year (July 7) since that should represent the average population of the year. The differences between these is the **rate of natural increase.**

Rate of natural increase = birth rate — death rate.

Suppose in year x there are about 225,000 people in a country. There were 2600 births and 1600 deaths.

$$\text{The birth rate was} = \frac{\text{number of live births}}{\text{mid year population}} \times 1000.$$

$$\text{Or} \quad \frac{2600}{225{,}000} \times 1000 = 11.1 \text{ births per 1000 people.}$$

$$\text{The death rate was} = \frac{\text{number of deaths}}{\text{mid year population}} \times 1000.$$

$$\text{Or} \quad \frac{1600}{225{,}000} \times 1000 = 7.1 \text{ deaths per 1000 people.}$$

and rate of natural increase = 11.1 — 7.1 = 4 per thousand or 0.4%. Fig. 13.5 shows the crude birth rates and death rates for the world and various groups of countries in 1987.

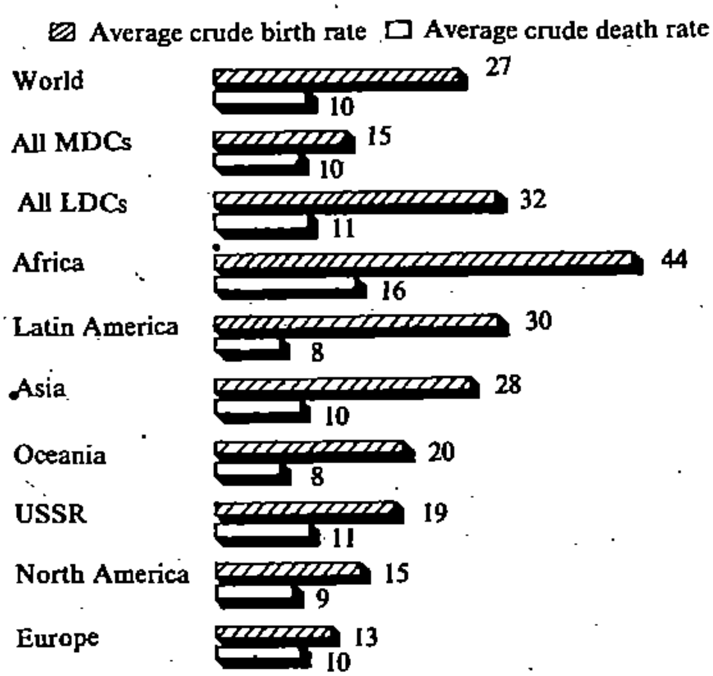


Fig. 13.5 : Average crude birth rates and crude death rates per 1000 of various countries in 1987. MCD is more developed countries. LDC is less developed countries. Oceania comprises islands of pacific and adjacent seas. (Data from Population Reference Bureau).

SAQ 3

Calculate the per cent rate of natural increase for Africa, Asia and Europe from the data given in Fig. 13.5.

13.4.1 Exponential Growth

To understand how populations grow, it will be helpful first to recall the concept of **exponential growth** from Unit 12. You must remember that exponential growth can generate enormous numbers in a short time. For example, if the doubling time for the world's population is 40 years then at this rate by 2090 the population will be 32 billion persons.

Exponentially growing animal populations can overshoot the carrying capacity of their habitat, so can human population in terms of certain resources. It would be useful to understand that as the population grows exponentially with it, the demands for resources such as water, food, fertilisers, housing and medical care, minerals, etc., also grow exponentially and so do the wastes, organic and inorganic, released into the air, soil and water, with consequent pollution of the environment. Thus even small reductions in exponential growth rates are important contributions towards efforts to maintain the human population within the earth's carrying capacity.

13.4.2 Age-Sex Distribution

While studying exponential growth we need to know more than just the birth and death rates because these rates vary with age and sex.

Age structure in a population is important because individuals vary in their age and many functional aspects are linked with age. For example, women can bear children only between ages of 15-44 years, also infants (children under 1 year of age) and older people have higher rates of mortality as compared to individuals of intermediate ages. Accordingly a population can be subdivided into three sub groups.

- prereproductive (0—14 years)
- reproductive (15 — 44 years)
- post reproductive (45 years and above)

For a more detailed understanding of the age-structure individuals of a population are divided into age groups with 5 or 10 year interval.

Further, males and females can be shown separately in a diagram. Alternately **age-sex distributions** are also drawn by plotting the percentage of the population of each sex in each group.

Fig. 13.6 shows the age-sex distribution of three nations India, France and West Germany in 1984. Now let us see what kind of information can be obtained from these.

The age-structure diagram that has a very broad base, like the one for India (Fig. 13.6 a) tells that :

a) birth rates have been very high in the recent past, that the population has many young children and these young children will reach the reproductive age in the near future. Such a population can be expected to expand rapidly.

b) the narrow upper part of the diagram indicates that a small percentage of the population is at, or approaching old age. Hence, the total number of deaths over a short period will be relatively small. Thus when the number of births increase and number of deaths remain stable, the population can be expected to grow rapidly.

In France (Fig. 13.6 b) birth rates have declined so that there are equal number of people in each age group between zero and 35 years of age. Ten years later there will be about the same number of men and women in the reproductive age group. The population will be fairly constant in the near future.

In West Germany in 1984 (Fig. 13.6 c) births rates have been quite low in the past few decades so there are fewer infants and children than young adults. Ten years later there will be fewer people in the reproductive group than before. If this trend continues the population of this region will eventually decline.

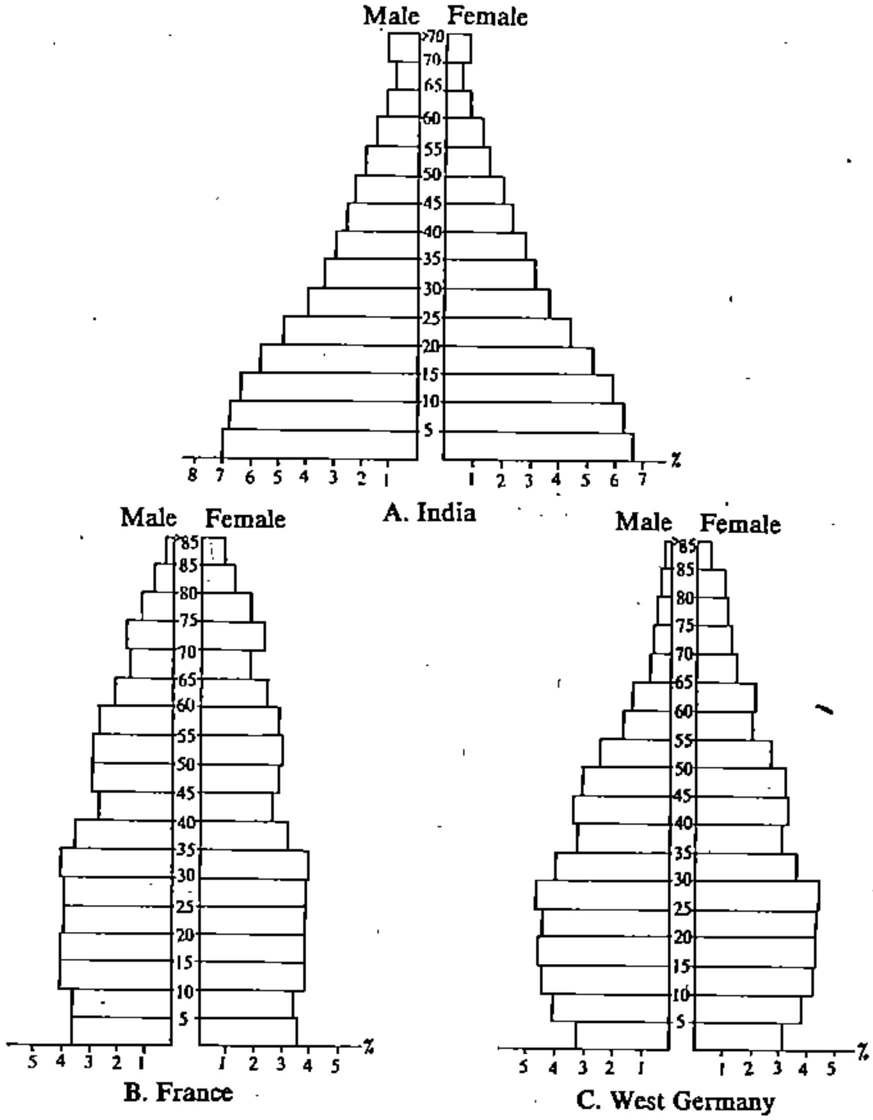


Fig. 13.6 : Age-sex distribution for three nations, India (a) an expanding population; France (b) a stable population; West Germany (c) a declining population. (Source : UN Demographic Year Book 1984)

Estimation of the size of child bearing age groups provides useful clues but not any definate information. For example, the age distribution of women in Sweden had a broad base in 1910. One could expect a similar age distribution pattern of women in Sweden for 1930 also. However, in 1930 the base was pinched (Fig. 13.7). Because of World War I there were fewer eligible males and thus fewer marriages and fewer births. Therefore, additional indicators are needed to foresee future change.

Death rates give only the overall idea in a population. However, deaths of individuals in prereproductive or reproductive age group will have a very different impact on the growth of population. The rate of **infant mortality** alongwith death rate provides much greater information. Infant mortality is expressed as:

$$\text{Infant mortality (\%)} = \frac{\text{Number of infant deaths}}{\text{Number of live births}} \times 100$$

Similarly birth rates tell us the number of births in the population as a whole but not the current fertility patterns. Therefore, **total fertility rate (TFR)** and **replacement level** are important factors affecting the future growth of a population.

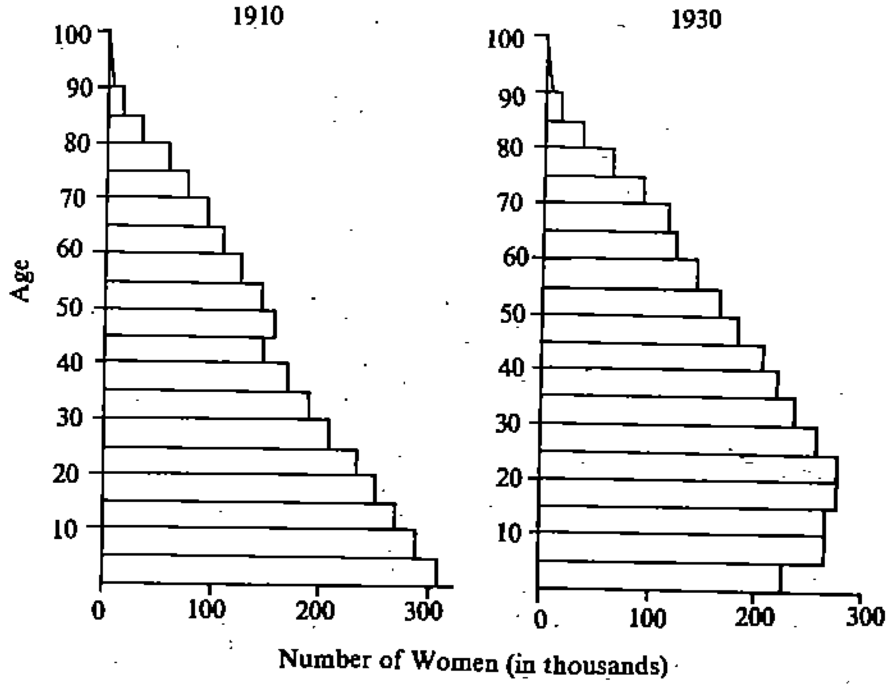


Fig. 13.7 : Female age distribution in Sweden 1910, 1930.

Total fertility rate (**TFR**) is the total number of children a women can be expected to bear in a given population if birth rates are constant for at least one generation. Replacement level, is a value of TFR and is the number of children a couple must have to replace themselves. You might think that two parents would have to have only two children to replace themselves. The actual average replacement level is, however, slightly higher, primarily because some children die before reaching their reproductive years. In developed countries the replacement level is fixed at 2.1. In developing countries where infant mortality rates are high and life expectancies are short, replacement level is about 2.7. If replacement level is low—below 2 i.e. each couple has children less than those required to replace themselves, then the population will actually decline as in the case of Sweden and Germany.

If a demographer knows the number of females of reproductive age in a population from the age-sex distribution and the average number of births per female from TFR and if **birth rates do not change** for a generation then it is relatively easy to predict the future behaviour of the population. But in reality vital rates do change. They are influenced by war, famine, migration, medical care, natural disasters and diseases. If TFR changes unpredictably then demographic predictions will be wrong.

SAQ 4

a) The total fertility rate of Sweden is 1.55 and that of Kenya is 8.1. Which of the two population is stationary and which is expanding? Explain.

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b) What is meant by death rate and infant mortality rate? Why is infant mortality rate an important demographic indicator?

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13.4.3 Trends in Growth of Human Population

In the beginning of Section 13.3 we looked at the size of human population through out history in Fig. 13.4 but that does not provide enough information to extrapolate for the future. Look at Fig. 13.8 and compare it with Fig. 13.4. Figure 13.8 shows the global rate of growth of human population. The growth rate reached a peak value of 2.06% in 1970 and then declined to 1.7% in 1986.

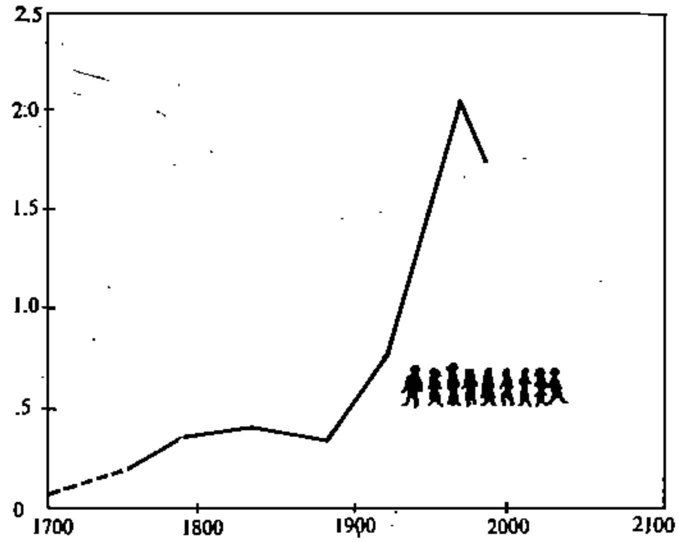

Figure 13.8 : The rate of growth of the world population from 1700 to 1986.

The decline in the rate of population growth was due to the reduction in birth rate in many regions in the world. You could ask, if the rate of growth declined why has the population continued to increase? There are two reasons for this.

a) Any positive growth rate will lead to an increase in population. If the growth rate declines but is still positive the increase in population will be less than what it would have been otherwise, but it will continue to grow.

b) In recent years even though growth rate has declined the number of new born infants has increased steadily every year. This is because the base population is increasing. For example when the population was 3.8 billion, the growth rate was 2% therefore $3,800,000,000 \times 0.02 = 76$ million new individuals were added. In 1986 the growth rate had decreased to 1.7% but the population was already 5 billion leading to $5,000,000,000 \times 0.017 = 85$ million new individuals. Look again at Fig. 13.6. The age-sex distribution for India, a less developed nation is different from France and Germany that are developed nations. Because this is a general observation demographers study developed and developing nations separately.

13.5 POPULATION GROWTH BY REGION

The overall pattern of population growth shown in Fig. 13.8 is not representative of all the regions of the world. In general, the wealthier industrialised developed nations are experiencing a low growth rate of 0.6% while the rate of growth in most less developed countries is still high, 2% or more, which means that their populations double every 35 years or less. Many African nations (such as Kenya, Ghana, Uganda) and Middle East nations (such as Jordan, Syria and Kuwait) have growth rates higher than 3%. Thus their population will double every 24 years. Table 13.2 reflects the annual increment in population for slow growth and rapid growth regions at 1988 growth rate.

What are the reasons for these dramatic differences?

As we saw earlier, death rates and birth rates have been nearly equal throughout much of human history. However, in Western Europe, death rates began to fall in the 17th and 18th centuries but birth rates were still high therefore the population increased. However, birth rates also began to decline and today birth rates and death

Table 13.2 : World Population Growth of Selected Countries (1988)

Regions	Population (million)	Population Growth Rate (per cent)	Annual Increase (million)
SLOW GROWING REGIONS			
Western Europe	159	0.2	0.3
North America	272	0.7	1.9
Soviet Union	286	1.0	2.9
Australia	17	0.8	0.1
China	1,087	1.4	15.2
Japan	123	0.5	0.6
RAPID GROWING REGIONS			
South East Asia[1]	433	2.1	9.1
Latin America	429	2.2	9.4
India	817	2.0	16.3
Western Asia[2]	124	2.8	3.5
Africa	623	2.9	18.1

1. Mainly Burma, Thailand, Vietnam, Indonesia, Philippines.

2. Mainly Iraq, Syria, Turkey Saudi Arabia.

rates are nearly equal in Europe. This decline in death rate followed by decline in birth rate leading to low population growth is called **demographic transition.** These declines in birth and death rates were generally concurrent with economic development in European nations. Thus this transition also refers to changes in economics from primarily agrarian to a more urban, commercial and eventually industrial system. An understanding of demographic transition is useful to see clearly what has brought about the rapid growth of world population especially in the last 50 years. Demographic transition takes place in four distinct phases.

1. **Pre-industrial stage** in which harsh living conditions lead to high birth rates to compensate for high infant mortality and high death rates. This leads to little population growth.

2. **Transitional stage** which starts shortly after industrialisation begins. At this stage death rates drop as a result of increased food production and better sanitation and health care. Birth rates remain high, population grows at a high rate (2.5-3% per year) for a long period but begins to level off later as living conditions improve.

3. **Industrial** stage in which industrialisation is widespread. Birth rates fall and eventually approach death rates, as people after moving to cities realise that it is more to their advantage to raise small families in an expanding economy. Population growth continues but at a lower rate. U.S.A., Japan, Soviet Union, Canada, Australia and most industrialised western nations are in this stage.

4. **Post-industrial stage** in which birth rate equals death rate thus leading to **zero population growth (ZPG)** Birth rate continues to fall so that the population size begins to decline slowly. Population of some countries, namely, Australia, Denmark, Hungary started declining by 1987 and many other European nations are approaching ZPG.

As a result of demographic transition the more developed nations are now growing at the rate of 0.6% per year with a doubling time 118 years. In less developed countries better health care and improved sanitation led to a steady decline in death rate without bringing down the birth rates sufficiently. Consequently populations have continued to increase rapidly.

Almost 90% of current world population growth can be attributed to the developing nations. It is predicted that of the 6 billion people expected to occupy this planet by the year 2000, 5 billion would belong to the developing countries.

According to a US government study, developing nations had 66% of the world's population in 1950, had 72% in 1955 and are likely to have 79% in the year 2000. In 1986, the world's population was 5 billion persons with an annual growth rate of 1.7% resulting in the addition of 85 million during that year. The contribution of India alone amounts to 16 million persons every year. Figure 13.9 shows the growth of the population of India from 1911 to 1991.

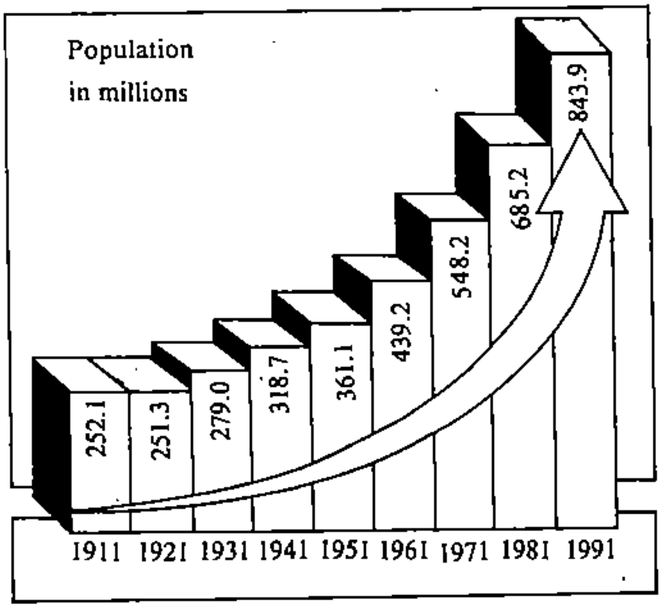

Fig. 13.9 : Population of India from 1911 to 1991

If economic growth leads to zero population growth, then economic development should reduce population growth in the developing countries. Many demographers disagree with this view and give several reasons for their argument. The economic resources of many developing countries are too small to build industries that ushered in demographic transition in USA and Europe. The demographic transition in developed nations took more than 200 years in spite of all the other developments and favourable conditions. The developing nations simply do not have the time. The rapid growth of population in these countries far exceeds their ability to raise their standard of living. Even to maintain the prevailing low standard the developing nations must double each and every resource and facility by the year 2000 which may be difficult in the wake of rapid population growth. Demographic transition, therefore, must come about in other ways, especially through population control.

SAQ 5

State at which stage of demographic transition are the countries listed below from the data given along side.

Country	Birth rate	Death rate
A	46	15
B	19	8
C	10	11
D	55	53

13.6 PROBLEMS OF RESOURCE USE RELATED TO POPULATION GROWTH

What would the state of our planet be if there were two or three times as many people as there are today? Famine, crowding, inflation, unemployment, pollution and decreasing resources are all tied up to the fact that there are too many people competing for limited resources and opportunities.

Because the world population is growing, the demand for goods is also rising and it is becoming increasingly difficult to enhance the supply of available resources (such as water, food, wood, minerals, fuels) to meet the demands.

Fig. 13.10 indicates that almost all future population growth will occur in the less developed countries yet many of them do not have the resources to meet the demands of their current population leave alone the additional millions that will be added. In India we will have to double every facility and resource within the doubling time of 33 years to even maintain the present unsatisfactory standard of living.

A related concern is the growing disparity between the developed and developing nations. In 1960 the difference in per capita income between them was $1240, in 1980 it was $5700 and in the year 2000 it is expected to be $8000.

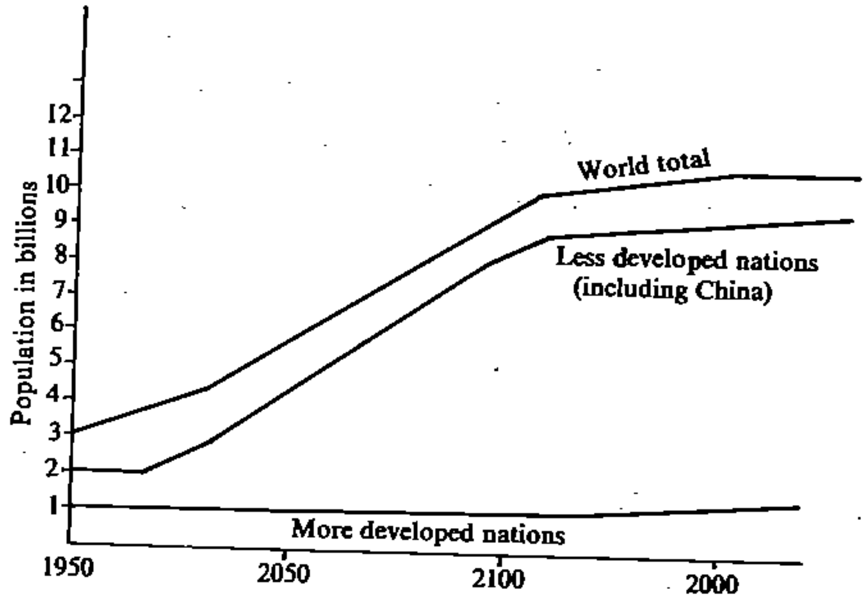

Fig. 13.10 : Projected population growth till the year 2100. Note that almost all future population growth will occur in the less developed nations (based on UN data 1981).

The environmental impact of population in a given area depends on three factors (1) number of people; (2) the average amount of resource each person uses; and (3) the environmental degradation and pollution resulting from each unit of resource used.(Fig. 13.11).

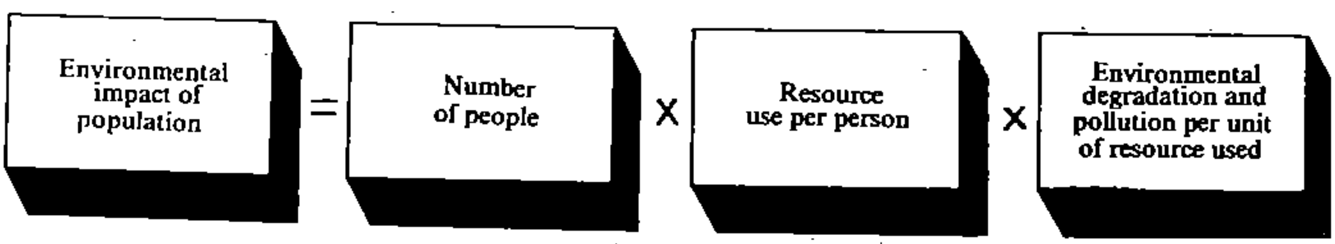

Fig. 13.11 : Simplified model of three factors that affect the overall environmental impact of population.

We can say that **over population** occurs when people in a country or a region or the world as a whole are using non-renewable and renewable resources to such an extent that the resources are degraded or depleted and pollution of air, water and soil begin to harm the life supporting systems of the biosphere.

Differences in the relative importance of each factor shown in Fig. 13.11 have been used to distinguish between two types of overpopulation.

1. **People overpopulation** refers to a situation where there are more people than the supplies of food, water and other vital resources i.e. population growth exceeds the rate of economic growth and people are too poor to grow sufficient food or buy essential commodities. In this type of overpopulation the size of population and the resulting degradation of potentially renewable resources such as soil, grassland, forests, fisheries tend to be more important in determining the total environmental impact. In the world's poorest less developed countries people

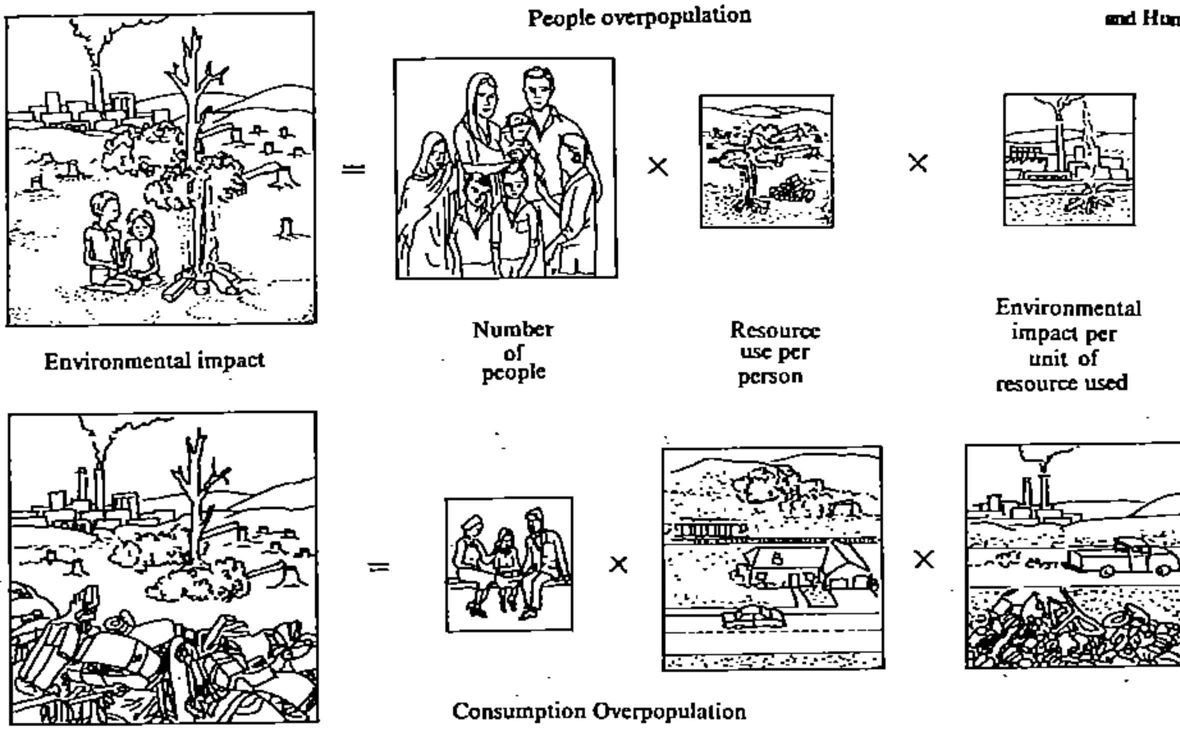

Fig. 13.12 : Two types of overpopulation based on relative importance of factors shown in Fig. 13.11.

overpopulation results in the premature death of 12-20 million human beings per year due to hunger and nutrition stress and famine induced diseases. Some regions, stressed by overpopulation, overgrazing, severe soil erosion—are reducing the land's productivity. Thus many subsistance farmers and nomads are loosing their means of livelihood and source of food.

2. **Consumption overpopulation** is a phenomenon seen in technologically advanced and affluent countries such as U.S.A., Japan, West European nations etc. A small number of people are using disproportionately large amounts of resources. This results in resource depletion and environmental degradation at a much higher rate than if more people were using the resources at a lower rate of consumption. In this type of overpopulation resource use per person and resulting high level of pollution per person are the important factors that determine the environmental impact of population.

The three factor model shown in Fig. 13.12 is rather simple. The actual situation is much more complex with many different interrelated factors. Another cause for concern regarding population growth is, where will all these people go? The average density of population in India now is 267 persons per square kilometer with urban population growing from one-seventh of the total population in 1950 to one-third in 1990. Apart from pollution of air and water, overcrowding creates mental, physical and social stress. The entire ecosystem is under stress. Not only are soil, water and air polluted as you will learn in Unit 15 but all other living beings, plants and animals are affected. The price of unchecked human population growth is the near elimination of nature with all its wealth and diversity produced and finely balanced over millions of years of evolution.

SAQ 6

Complete the following paragraph by using suitable words from the text.
Consumption overpopulation results when..of people use resources at a..rate producing pollution and..
..While ....overpopulation occurs when there are more people than available..
In this type..size and resulting environmental degradation are more important in determining the total impact of population on the..and characteristic of..
.. ....

13.7 PREDICTING THE FUTURE POPULATION OF EARTH

By 1987 the size of human population had increased to 5.03 billion and was still growing at the rate of 1.7% annually. More than 85 million people are being added each year. If the earth was infinitely large, the human population might continue to increase indefinitely. Our planet and the resources are finite hence continued population growth cannot be sustained. Therefore, population growth must be contained and determined effort must be made to achieve zero population growth at the earliest. The important question is when will this zero population growth be realised? What will be the population size when ZPG is attained.

Imagine for a moment that birth rates were reduced to the replacement level today. Even if this were to occur by some miracle, population would still continue to increase because 35% of the human population is under 15 years of age while only 6% is older than 64 years of age hence many more persons will be entering the reproductive age as compared to the number of people dying in the same period. In most countries, especially in the less developed ones, a large number of women are in the reproductive and prereproductive ages. For example, in India in 1985 nearly 40% of the females were in prereproductive age and even larger number were between 15-39. Even if these women began to bear children at the replacement level immediately, the population would rise until it is 1.6 times greater than the 1985 level.

Table 13.3 : Total fertility rate by region (Population Reference Bureau 1986 Washington D.C.)

Africa	6.3
Latin America	4.1
Asia	3.7
Oceania*	2.7
USSR	2.4
North America	1.8
Europe	1.8

* Islands of pacific and adjacent seas.

See Table 13.3. There are marked differences in the TFR among the developing and developed nations. Fig. 13.13 shows the TFR rates of some countries from the developed and less developed regions. Note that the TFR rate for China is falling faster than any other nation. Significant though less dramatic changes are seen in India and Indonesia also.

China has a population of 1 billion individuals which is one-fifth of world population. In mid 1980s the Chinese Government started an austere birth control program of one child per couple. The rate of growth reduced drastically and TFR reached replacement level in 1985. Still the population will continue to grow and will level off to 1.5 billion only by the year 2075.

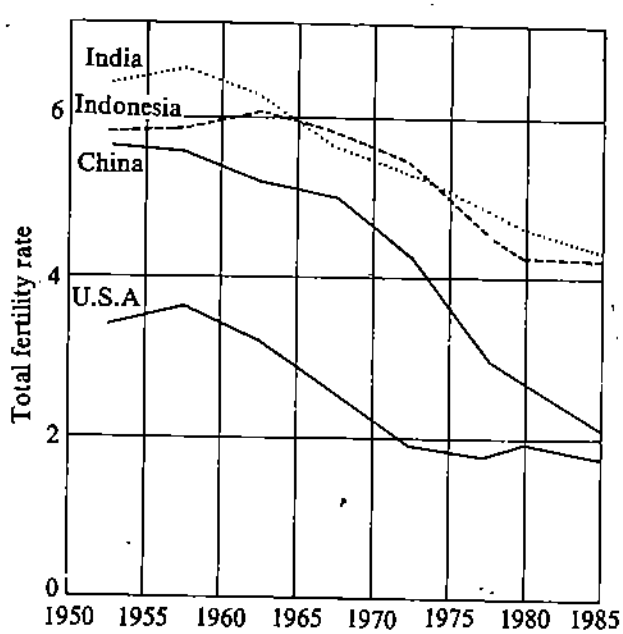

Fig. 13.13 : The TFR for some developed and less developed countries. TFR in China is dropping significantly.

In contrast TFR is constant or even rising throughout Africa, South West Asia and parts of Latin America. Therefore, the actual population of the World will continue to increase. Fig. 13.14 shows UN projections for the world population and eventual stabilisation based on different assumptions about when the TFR will drop to replacement level of 2.1

In the figure when population growth is :

high—	replacement level reached in year 2065; estimated population in year 2100 is 14.2 billion.
medium—	replacement level reached is year 2035; estimated population in year 2100 is 10.2 billion.
low—	replacement level reached in year 2100; estimated population in year 2100 is 7.5 billion.

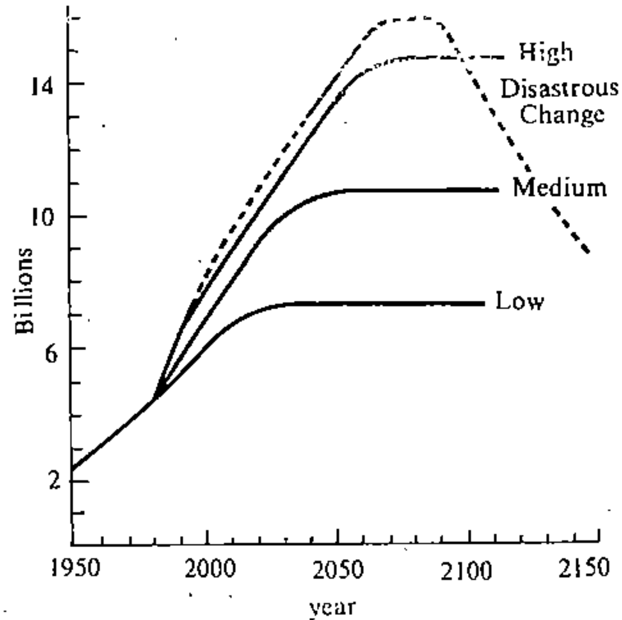

Fig. 13.14 : Four different predictions for the world population growth (Data from United Nations).

You should, however, remember that such a transition is not guaranteed. There is always the possibility of disaster. In such a scenario, the population will continue to grow rapidly until the carrying capacity of the earth is greatly exceeded and the combined effects of starvation, strife, pollution and resource depletion will bring a population crash. Such a pessimistic and catastrophic outcome is shown by the dotted line in Fig. 13.14.

No one knows whether these predictions will prove to be accurate. The only thing that all would agree upon is that the world population cannot grow indefinitely. Some countries will make the transition smoothly while others may experience periodic crashes due to war, famine, or epidemics of diseases in crowded urban areas. It remains to be seen whether we will achieve population stabilisation by deliberate reduction in birth rate or through chaos resulting in famine and natural disasters.

13.8 SUMMARY

- Human beings probably evolved from tree-dwelling ape like ancestors. The change from arboreal habitat to the ground caused distinct adaptations like stereoscopic vision, bipedal posture, opposable thumb and enlarged and more developed brain.
- The advent of agriculture led to stable populations and triggered a series of environmental changes.
- Throughout history, the human population has been quite small but since the onset of industrial revolution it has been increasing steadily and now in an explosive manner.
- A study of human population or demography involves the measurement of the growth of population or annual average growth rate; its doubling time; vital events like birth and death rates, infant mortality rate and rate of natural increase which is the birth rate minus death rate.

- Human population grows exponentially and the shape of age-sex distribution diagram reflects past history and provides insight into the future growth. The total fertility rate (TFR) is the total number of children a woman is expected to bear during her life time if birth rates remain constant for one generation. Replacement level is a value of TFR which corresponds to a population exactly replacing itself. It is 2.1.
- The growth rate of global population is declining but is still positive which means that the population will continue to grow. Growth rates of developing countries are much higher than those of developed countries.
- Earlier in history, birth rates were high and in the absence of adequate health care and sanitation, death rates were also high resulting in very little population growth. Modern medicines and improved sanitation leads to rapid decrease in death rates but with little effect on birth rate hence population increases rapidly. Slowly with improved economic situations birth rate also declines and population stabilises. This pattern of change in death and birth rates leading to Zero Population Growth is called demographic transition. Most developed countries have arrived at or are past the demographic transition stage.
- The increasing human population strains the world's resources. The environmental impact of population in a given area depends on three factors, number of people, resource use per person and environmental degradation per unit of resource used. This leads to people overpopulation seen in less developed nations and consumption overpopulation seen in developed nations.
- Birth rates are falling in most developed nations but an increase in world population is definite. In 1986 the population was 5 billion. Demographers predict the world population to stabilise somewhere between 7.5 to 14 billion with most of the population increase coming from less developed countries.

13.9 TERMINAL QUESTIONS

1. List the major adaptations in primates that ultimately led to the first *Homo* species.

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2. According to the 1991 population census, India's population had increased by 160 million people since the 1981 figure of 683 million. Calculate the average annual growth rate and the doubling time for the population.

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What is replacement level? If women in India were to bear children at the replacement level, will zero population growth be realised immediately? Why or why not. Explain.

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4. What is meant by demographic transition? Compare birth rates and death rates, before, during and after demographic transition.

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5. Draw a graph showing the hypothetical population if the rate of growth is

   a) high, then decreases but remains positive.

   b) negative then becomes positive.

   c) positive then becomes negative.

13.10 ANSWERS

Self-Assessment Questions

1. a) v; b) iv; c) ii

2. c)

3. Rate of natural increase.
   for Africa = 44-16 = 28 per 1000.
   or 2.8%
   for Asia = 28-10 = 18 per 1000
   or 1.8%.
   for Europe = 13-10 = 3 per thousand
   or .3%.

4. a) The TFR of Sweden is well below the replacement level of 2.1 i.e. not even enough children to replace their parents. Hence the population will decline eventually. On the other hand the population of Kenya will continue to expand as the TFR is much above the replacement level.

   b) Death rate is the number of deaths occurring per thousand people in a population, it includes people of all ages. Infant mortality rate is number of deaths among individuals below one year divided by number of live births. Infant mortality is an important consideration because high infant mortality means less people reaching reproductive stage also it indicates the health status of the population.

5. A — transitional stage
   B — industrial stage
   C — post industrial stage
   D — pre-industrial stage.

6. Small number; high; environmental degradation; people; resources; population; environment; less developed nations.

Terminal Questions

1. Stereoscopic vision; change in musculature and placement and orientation of internal organs which made upright posture possible; bipedal locomotion; opposable thumb; enlargement and development of brain.

2. average annual growth rate = 2.3%
   doubling time = approx 30 years.

3. a) Replacement level is the value of total fertility rate which if continued unchanged for a generation would result in zero population growth.

   b) No, because there is a very large population in the pre-reproductive and reproductive ages. (see the age-sex diagram in Figure 13.6 a)

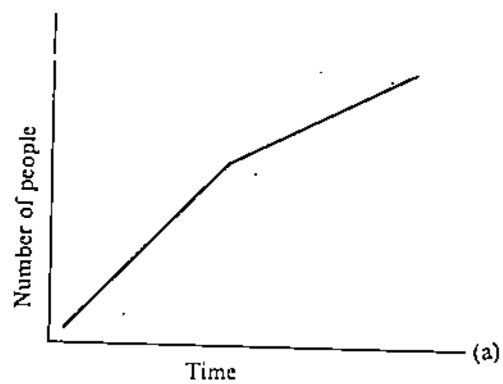
4. When death rates decline and birth rates also decline in response to economic trends the population stabilises. This pattern of changing vital rates is demographic transition.

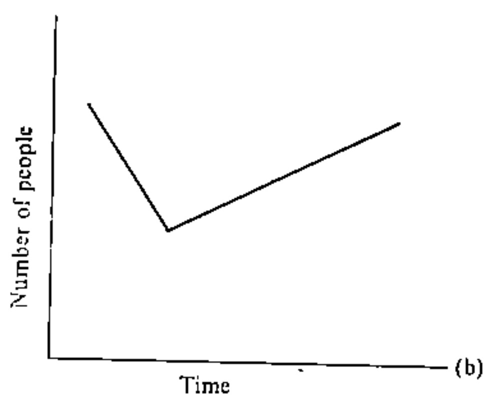
   a) before transition — death rate and birth rate both high.

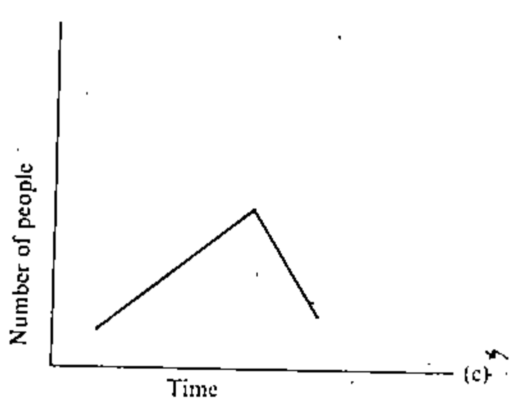
   b) during transition – death rate declines, birth rate high and then stabilises.

   c) after transition -- death rates and birth rates both decline leading to ZPG.

5.







UNIT 14 ECOSYSTEM DEGRADATION AND WILDLIFE

Structure

14.1 INTRODUCTION

Man is an animal with ecological requirements just like any other animal. It constantly needs a source of energy and mineral nutrients for its survival. It also needs optimum levels of, and a limited range of certain environmental factors, for its survival.

Human beings are peculiar, in the sense that they have the capacity to modify the global ecosystems on a considerable scale. This is in order to redirect the products of the various ecosystems to fulfil the needs of human society. No other organism has produced such an impact on the physical, chemical and biological constitution of the earth. For this reason, it is necessary to look carefully at the relationship between man and nature from an ecological viewpoint. Such a study would help to locate those areas in which the stresses created by human beings are becoming intolerable and are threatening the future of certain species and habitats. This would also help in predicting the outcome of some of these harmful activities, and it may supply answers to a number of issues which are creating environmental dilemma.

In this last but one unit of the course, we shall discuss with you the role man has played in degrading the ecosystems and some of the resultant effects, particularly on the biological components. How the wildlife has been affected and the measures taken to contain or minimise the damage are also discussed. This unit is a bit lengthy, as several examples, figures and tables are included to concretise the learning tasks. You are not expected to memorise the mathematical data presented in the tables but you should go through it critically. We hope you would enjoy reading this unit, as you might have experienced several situations or you may be familiar with several instances mentioned here.

Objectives

After studying this unit you would be able to:

- describe the main causes and consequences of ecosystem degradation
- define wildlife
- list and explain the main threats to wildlife
- explain the concept of extinct, threatened, endangered, rare, depleted, indeterminate, and out of danger species
- list and explain the measures required for wildlife conservation
- explain the importance of wildlife to human beings.

14.2 DEGRADATION OF ECOSYSTEM

Ancient man was simple-minded food gatherer and hunter. He looked upon nature with awe and respect and in fact he worshipped it. But from the time he began to use his superior intelligence and began to understand nature, he became progressively self-centred and in the process started disrespecting and destroying/degrading the natural environment. Today, he is attempting to dominate nature, shape the environment to suit himself and use everything around him for his benefit. And he has not thought much about the fragile balance of the nature. Only in the past two or three decades, as some of the ominous signs of environmental degradation have started showing up, has man realised the gravity of the situation. It has now become very clear to him that the humans should not put the planet earth, which is the ecosystem that he lives in, in an impossible position, so that a point of no return is reached.

In this section we shall list and discuss the various activities of man that have led to degradation of the ecosystem. This section is a bit long, but it would form a base for the subsequent sections of this unit.

We list and explain below the important causes that have lead to the degradation of the ecosystem.

14.2.1 Deforestation
14.2.2 Overgrazing
14.2.3 Agriculture
14.2.4 Mining
14.2.5 Urbanisation

Let us discuss each cause in detail with the help of relevant illustrations.

14.2.1 Deforestation

We shall discuss three aspects under this heading. One, what is meant by this term? Second, what are the causes of deforestation? And third, how does deforestation degrade or affect the ecosystem.

Taking up the first point, deforestation is a broad term. It means the removal/destruction of the forest cover or the vegetation of an area. It includes repeated lopping, felling, removal of forest litter, browsing, grazing and trampling of seedlings.

Now the second point, that is, what causes deforestation? The following are the mair causes of deforestation:

i) Shifting cultivation
ii) Development project
iii) Fuel requirements
iv) Raw materials for industry
v) Other causes

l) **Shifting cultivation:** This method of cultivation is practised all over the globe, but is more prevalent in the tropical countries. In this practice a patch of land is cleared, vegetation is burned and the ash is mixed with the soil thus adding nutrients to the soil. This patch of land is used for raising crops for two to three years, and the yield is modest. Then this area is abandoned and is left to recover its fertility, and the same practice is repeated elsewhere on a fresh piece of land. All that is required for this method of cultivation is a set of simple tools, not high level of mechanisation. In India it is widely practised in the North-Eastern region comprising the states of Assam, Meghalaya, Nagaland, Manipur, Tripura and the Union Territories of Arunachal Pradesh, Mizoram, and Andaman & Nicobar islands. The practice is also prevalent in Andhra Pradesh and Orissa and to a lesser extent in Bihar, Madhya Pradesh, Kerala, Karnataka, Maharashtra and Sikkim. This is locally known as Jhum in North-Eastern region, Podu in Andhra Pradesh, Bewar or Dahza in Madhya Pradesh. In Orissa it is known as Dahi (firing), Gudia, and Chas. On the whole about 5 lakh hectares of forest is cleared annually for this kind of cultivation in the country.

Now the question arises as to how it degrades or affects the ecosystem. As the land is cleared for agriculture, and biomass is burned, and the resultant ash enriches the soil. After burning the vegetation in the area, although the rain continues to fall but the addition of leaves and other organic debris that enriches the soil, is stopped (see Fig. 14.1.). Without the protecting layer of tree cover, the heavy downpours pelt the bare soil. Because of this, not only there is soil erosion, but the existing nutrients are also flushed away into rivers and out to the sea. Besides that, the decreasing amount of organic matter in the soil and the loss of vegetation cover binding the soil also reduce the moisture-retention capacity of the soil considerably. Moreover, the cultivation and harvest of two or three crops also takes away many nutrients from the soil.

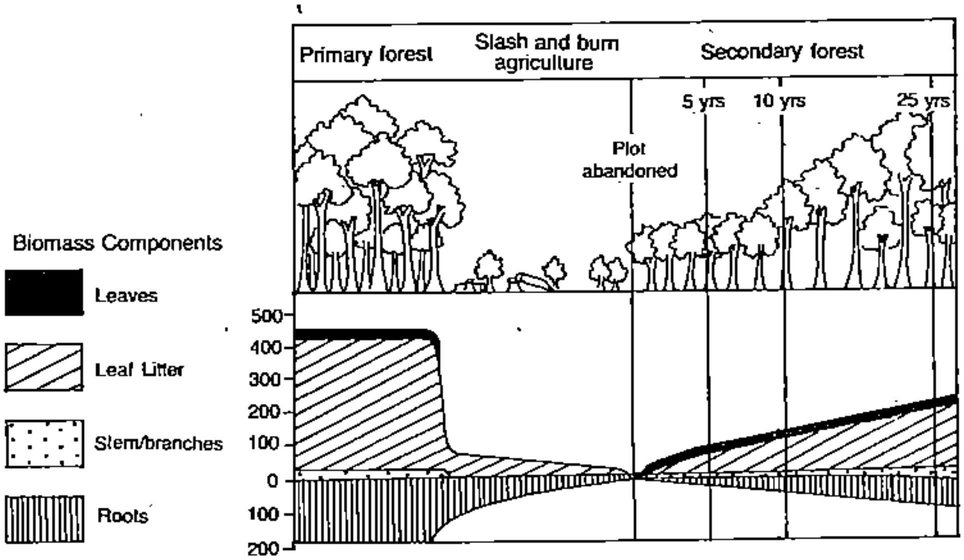


Fig. 14.1 : Status of biomass before, at the time of, and after slash and burn method of cultivation. Crucial changes take place in the biomass when primary forest is cut down, used for agriculture, and then abandoned. Nutrients are stored in the living biomass and forest floor litter. When the forest is cut and burned its mass is reduced to almost nothing and its nutrients exploited briefly before the plot is finally abandoned. Even 30 years later, the secondary forest that takes its place bears little resemblance to the original. It is poor in total biomass and also in species diversity. (After Arnold Newman, Tropical Rainforest, 1990).

Many a time the area may be used too soon, thus there is a permanent degradation. Another very important effect is seen in the vegetation pattern that develops in the abondoned land. It is seen that jhummed sites encourage more of annuals (therophytes) at the expense of perennials and trees (phanerophytes) as removal of forest cover makes soil open and changes the microclimate of the site. Many such sites which were initially phanero-therophytic after shifting cultivation turned to the thero-phanerophytic. It is seen that the effect of short *jhum* cycles is the rapid growth of various weeds such as *Parthenium*, *Eupatorium* and *Eichhornia*. This results in the depletion of germplasm because of the drastic changes in the microclimate and other elements of the habitat.

In our country the present forest cover is about 67.2 million hectares constituting around 22% of the total area. In the recent years vast areas have undergone deforestation. A statewise breakup of the area deforested between 1972-75 to 1980-82 is given below (Source: National Remote Sensing Agency).

State Union Territory	Forest Area (million hect.) 1972-75	1980-82
Andhra Pradesh	4.90	4.04
Assam	2.11	1.93
Bihar	2.27	2.01
Gujarat	0.95	0.51
Haryana	0.08	0.04
Himachal Pradesh	1.51	0.91
Jammu & Kashmir	2.23	1.44
Karnataka	2.95	2.59
Kerala	0.86	0.74
Madhya Pradesh	10.86	9.02
Maharashtra	4.07	3.04
Manipur	1.51	1.38
Meghalaya	1.44	1.25
Nagaland	0.82	0.81
Orissa	4.84	3.94
Punjab	0.11	0.05
Rajasthan	1.13	0.60
Sikkim	0.18	0.29
Tamil Nadu	1.67	1.32
Tripura	0.63	0.51
Uttar Pradesh	2.59	2.10
West Bengal	0.83	0.65
Andaman&Nicobar	0.33	0.64
Arunachal Pradesh	5.14	5.21
Dadra & Nagar Haveli	0.02	0.01
Goa Daman-Diu	0.12	0.11
Mizoram	1.39	1.20

ii) **Development Projects :** The use of science and technology to support the ever-increasing needs of man is termed as development. In the recent years, the human populations have increased considerably, so have their requirements. Any country, especially the developing countries like ours would have to undergo the process of development at a much rapid rate to fulfil the requirements of its people. Likewise, in the recent years we have witnessed a number of development projects completed and several others coming up.

Development projects like the hydroelectric projects, large dams and reservoirs, laying down of railway lines and roads are not only extremely beneficial, but they also are linked with several environmental problems. Many of these projects require immense deforestation. For the various development projects, infrastructural facilities like buildings, townships, electric supply etc. require clearing the land. And also for the various development projects, the forest products like wood etc. are used in the project itself. Deforestation begins much before the actual commissioning of the project and continues even after the completion of the project. Deforestation affects not only the biota and neighbouring ecosystems, but the soil is eroded, land is degraded, ground water channels are altered, and water becomes polluted and scarce.

All that we have mentioned above are not merely the theoretical possibilities but such events have been seen in actual. We shall mention a few examples to concretise the points mentioned above.

During recent years, a number of new roads have been constructed and some old roads have been widened for two-way traffic. This activity has promoted deforestation, landslides and erosion. It is well known that, a few years earlier there was almost no landslide between Rishikesh and Byasi on Badrinath highway. During the 1985 rainy season, more than 15 landslides were observed in this short distance of about 30 km only. Roads have no doubt provided facilities for transport and modern tourism and nobody would speak against road construction, but the manner in which mountain roads have been made has been defective and objectionable. During road construction, huge portions of fragile mountainous regions are cut or destroyed by dynamite and thrown into adjacent valleys and streams. These down-falling land masses not only weaken the already weak mountain slopes but also increase the turbidity of the streams.

The construction of dams which are necessary for hydroelectric power generation, has also affected the mountain ecosystems. Tehri dam across the river Bhagirathi at about 1.5 km down stream of Tehri has been a subject of controversy in the recent years. It has a reservoir of 42 sq km area. The total capacity of the power house is 1000 MW and it is to be doubled in the second stage of the project. As a result of dam construction activities the geomorphology of the Bhilganga and Bhagirathi is altered to a great extent. During tunnelling activities, the rocky materials, ranging in size from dust particles to one cubic metre rock pieces, were thrown into the rivers. The total material thrown into the river by the end of July 1981 was 38.42 lakh cubic metres. In the process of tunnelling, 18.95 tonnes of explosives have been used for blasting. The tunnelling material and the by-products of explosives are disturbing the natural set-up of the Bhagirathi near the dam site in a stretch of about 2 km. The most drastically changed physio-chemical parameters of water downstream the dam site are flow speed, transparency, temperature and dissolved oxygen (see Table 14.1).

Table 14.1 : Physio-chemical parameters of the Bhagirathi water at Tehri (After Singh, H.R., 1987).

S.No.	Place	Water Temp. (°C)	Turbidity (NTU)	Velocity (m/sec)	DO. (ppm)	BOD (ppm)
1.	Tehri (before dam)					
	Winter	11.25+287	10.5+7.51	1.44+0.48	10.26+0.69	2.15+0.32
	Summer	15.75+0.96	50.17+76.07	1.7+0.1	9.75+1.55	2.87+0.64
	Monsoon	16.75+2.06	188.75+154.38	1.81+0.17	9.55+1.11	3.45+1.11
2.	Tehri (after dam)					
	Winter	12.33+2.31	17.17+15.69	0.86+0.19	10.07+0.85	2.45+0.21
	Summer	16.25+1.26	115.00+141.03	0.93+0.27	9.48+0.53	3.85+1.51
	Monsoon	16.88+2.02	241.75+136.06	0.99+0.07	8.4+0.97	3.58+1.66

Along with these parameters, the planktonic and benthic life and fisheries of the river are also depleting in the areas affected by dam construction.

The above examples of degradation of environment as a result of the development projects is not the only one. We discuss below another example that is of Sarda Sahayak Canal Irrigation Project. This was commissioned in eastern U.P. in 1974. The irrigation potential of this project is about 16 lakh hectares and is vital for the rabi and kharif crops of the area. The operation of this canal has created serious problems of environmental degradation in the command area. The problem of seepage started from the beginning and at present it has created a serious situation. As a result of seepage from this canal about 385 villages, 13,677 houses, and 2,200 cattle have been damaged upto the year 1984. And about 1,42,000 hectares of land has gone out of cultivation (data from Singh, P.P. & Afroz, A., 1987). Besides this, vast tracts of natural forests containing about a million mature sal *(Shorea robusta)* trees have been killed by canal seepage. Such massive destruction of trees in a natural forest also affects the dependent animal and plant life.

Seepage is defined as slow, lateral movement of water through the soil. Seepage, invariably leads to irreversible change of the soil and creates anaerobic conditions in the crop root zone.

All these result in loss of germplasm which is of immense value to the mankind. The canal seepage and high water table rendered vast tracts water-logged. Due to continuous water-logging in the command area, incidence of diseases like malaria, filaria, skin and several other diseases has increased in the recent years. This example clearly shows that the introduction of irrigation does not always have positive effects but sometimes produces adverse effects on soil and ground water table. During most of the development projects only the beneficial effects are taken into account and their adverse impacts on the environment are not considered. Therefore, development without concern for environment can be development for short-term, and in the long-term it will become anti-development.

iii) **Fuel Requirements :** The increasing demand for fuelwood is one of the major factors leading to the degradation of the forest ecosystem. Fuelwood is of such major importance as a forest produce that about one-half of all the wood cut in the world is used for lighting, cooking or heating purposes. Even today more than one third of humanity still relies on wood for fuel. In the recent years, the oil crisis and the sharp increase in the prices of oil have further escalated the demand for wood as fuel.

In India about 135-170 million tonnes of firewood is consumed annually and about 10-15 million hectares of forest cover is being stripped off every year to meet these needs. The fuelwood consumption has gone up from 86.3 million tonnes in 1953 to about 135 million tonnes in 1980, and it is believed that by the year 2000 A.D., the demand for firewood would be in the range of 300 to 330 million tonnes. The increasing demand for firewood with every passing year means greater pressures on the forests, which also means increased intensity of deforestation.

iv) **Raw Materials for Industry :** Wood is not only used as fuel, but it also has a variety of other uses. It is used for making boxes, crates, packing cases, match boxes, furniture, paper and plywood. About 1.24 lakh hectares of forests have been cut for various industrial uses during the period 1951-1971. The industrial requirement for wood in 1970 was about 16 million cubic metres, which has risen to 25 million cubic metres by 1980. Paper industry consumes about 2 per cent of the country's annual consumption of wood. In 1983, there were about 175 paper mills requiring 3.1 million tonnes of wood as raw material. Fifty one per cent of this requirement was being met by the use of bamboo. This exerted tremendous pressure on the bamboo plantations of the country. Besides this the apple industry in Himachal Pradesh requires a vast number of packing cases for the transportation of apples and their products. For this purpose wood of *Abies sp.* and other species are used for making packing cases.

Packing cases made of plywood are also used extensively in the tea industry. Presently, there are about 52 plywood factories in Assam. Today the state is such that the forests of Assam can provide only 22 per cent of the raw material for the plywood industry. The rest of the raw material comes from Arunachal Pradesh, Meghalaya and Nagaland.

Industries that manufacture drugs, scents and perfumes, resin, gums, waxes, turpentine, latex and rubber, tannis, alkaloids, bees' wax—all obtain their raw materials from plants, exerting tremendous pressure on plants, ultimately leading to their destruction.

From the discussion so far, you have seen that a large number of industries are dependent on forests. The *thoughtless* and *unrestricted* exploitation of forests for various raw materials is the main cause of degradation of the forest ecosystem.

v) **Other Causes :** Natural enemies like termites, pests and several kinds of diseases affect the forests adversely. There is also massive destruction of forests because of floods and fires. Some forest fires are not natural, but they are due to deliberate burning of trees by smugglers. Defence activities like preparing ditches and bunkers, movement of heavy armoury and their testing and use, also affects the ecosystem considerably.

In addition to the above causes, **deforestation also results from overgrazing, agriculture, mining and urbanisation.** All these topics are dealt with under separate subsections because of their complex impact on the ecosystem.

14.2.2 Overgrazing

It refers to the condition when the grazing pressure on the vegetation is so intense that it does not recover. Ultimately, there is a loss of the soil binding cover (**deforestation**), and it leads to soil erosion and desertification. Deforestation and overgrazing combined make desertification intense. As vegetation retrogresses, with continued overgrazing, the crucial soil and water relationships fail, ultimately reducing the area's carrying capacity of the animals. Rate of water infiltration is proportionally related to the grazing intensity. Water infiltration is low in heavily-grazed areas and high in lightly-grazed areas. Heavily-grazed areas also have high rates of runoffs. In the overgrazed areas, the amount of water storing capacity of the soil declines. The moisture available at a particular time is so less that it is not enough to meet with the regeneration needs of the plants that are left. All the events described above degrade the quality of soil and eventually the ecosystem.

In India, livestock wealth plays a crucial role in rural Indian life. Over the years, the livestock population has continuously increased. A total increase of 42 per cent was registered in a span of thirty years, that is, from 1951 to 1981. The number of cattle heads increased from 292.02 million to 415.95 million in the above said period. On the other hand, in the same period, the land resources available in the form of grazing lands for producing fodder declined from 14545 million ha to 129.26 million ha. This accounts for the shrinkage of habitat by 11.03 per cent. Thus, the land available per animal declined from 0.51 to 0.32 ha i.e., a reduction of 37 per cent. These figures clearly show that the livestock resources have increased and the available land resources have decreased. So there is tremendous pressure on the grazing lands. You can have a better idea of the situation from the following data.

Under normal grazing conditions one ha of grazing land can support an average 3 livestock heads in rainfed areas and 6 livestock heads in extensively irrigated areas. Actually, the number of animals which depend on each ha of such lands is much higher—any thing from 2.4 to 4.5 times their carrying capacity. In Jammu and Kashmir, for example, 16.8 animals are supported by each ha of grazing and forging land. The grazing and foraging lands are thus being overgrazed.

14.2.3 Agriculture

Agriculture whether traditional or modern involves intervention and modification of the natural ecological systems. Ever since man has started practising agriculture, his main aim has been to modify the agro-ecosystem in such a way as to remove or diminish natural limitations upon productivity and to provide a more favourable environment for crop growth. These modifications include the introduction of new species or varieties of crop plants and livestocks, the elimination of competing plants (weeds etc.) and other organisms by the use of pesticides and removal of habitats, the use of high level of fertilisers, manipulation of soil conditions by tillage, and control of soil moisture by irrigation and drainage. Though the achievements in this field have been astonishing, the other side of the picture has often been ignored, that is, its impact on the environment. The various agricultural practices adopted by man have considerably degraded the environment over the years.

Degradation of the ecosystem due to agriculture can be on the following accounts :

a) Removal of trees **(deforestation)** and clearing the land for agriculture destroy the habitats of many kinds of living organisms. Deforestation ultimately leads to problems like soil erosion, loss of nutrients and desertification.

b) Cultivating the land intensely without proper soil management, leads to problems like soil erosion, desertification, and depletion of plant nutrients.

c) Irrigation without sufficient drainage leads to excessive accumulation of water (water-logging) or salts (salinisation), rise in water table in the soil, ultimately leading to the degradation of the quality of soil.

d) Indiscriminate use of agrochemicals—fertilisers and pesticides. leads to their increased build up, often reaching harmful levels in the soil and the underground water resources. This causes their bioaccumulation in the food chain. Not only that, these chemicals often degrade the quality of soil and ultimately the ecosystem.

14.2.4 Mining

Mining may be defined as the removal of minerals and other materials from earth's crust for the welfare and prosperity of man. Modern industrial, economic and commercial activity depends a lot on the exploitation and consumption of minerals. The process of extraction of mineral resources and its use in various ways generates a wide range of environmental changes—often leading to degradation of ecosystem and other far-reaching consequences.

More than 80,000 hectares of land in the country (see Fig. 14.2) are presently under stresses of mining activities of various kinds

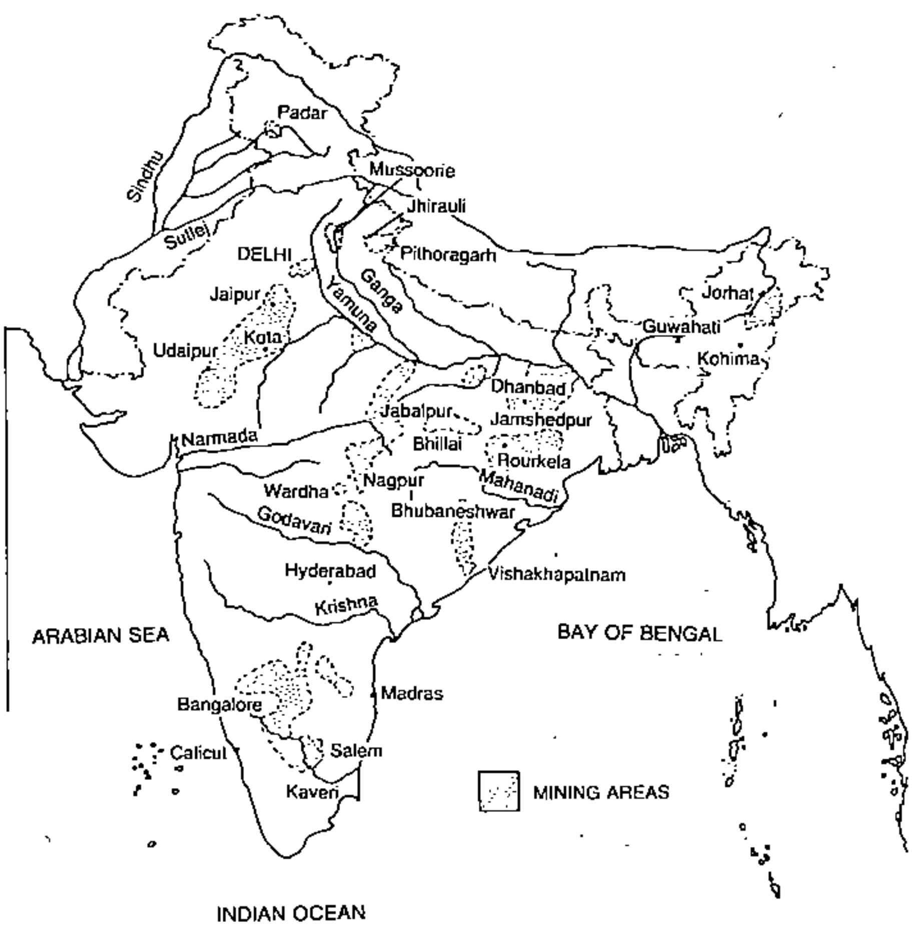


Fig. 14.2 : Areas affected by mining activities (From K.S. Valdiya, 1987).

The recovery of minerals and construction material requires removal of vegetable cover **(deforestation)** with underlying soil mantle and excavating overlying rock masses (known as overburden). The amount of overburden commonly exceeds the volume of materials or minerals sought. The result is reshaping of the topography, generation of great volumes of debris (waste) and disruption of surface and ground water circulations. These further lead to soil erosion, increased incidences of landslides and ultimately land degradation. The network of roads constructed, further aggravates the problem of land degradation.

Limestone mining at Mussourie, in Doon Valley provides good illustration of the devastation caused by mining activities. Here intense mining and its associated activities have greatly affected the area and the living beings there. Mussourie—the queen of hill stations is being stripped off the forest cover due to limestone quarrying. The hills which were once thickly wooded with shisham and sal near the river beds and with firs, birch and pines in the higher slopes are gradually being denuded, exposing large patches of white rock and dust-limestone which is abundant in this region. The once varied fauna which included foxes, deers, goats, pigs, jackals and monkeys as well as a wide variety of birds are steadily getting depleted.

Near the limestone quarrying area, animal husbandry was an important enterprise because there were vast expanses of grassland for the animals and most of the villagers were involved in production and trade of milk. Now, due to limestone quarrying, pastures have vanished and fodder has become a very scarce commodity, or this has reduced productio ı of milk in the area. The decrease in the number of domestic animals has also triggered off a shortage in organic manure and the felling of pine has affected the production of resin used in the manufacture of turpentine. The springs too have dried up as a result of the deforestation. The oak tree is said to store rain water which is released to the springs in the dry season. It is believed that one oak tree stores about 500 to 1,000 litres of water.

Another important factor leading to environmental degradation in this area, is the construction of extensive network of roads connecting the quarrying areas. These roads have not only scarred these hills and the beautiful landscape, but also have resulted in repeated landslides affecting the ecosystem there.

In addition to the above, extensive damage is caused by rock blasting too. In the hills of Mussoorie, explosives are being used in large quantities. On an average there are three blasts per day per quarry (in the 80-odd quarries). These blasts not only cause annoyance because of the noise, but the more important problems are: hazards from flyrocks and damages due to ground vibrations. These are contributed to the destabilisation of the hill tops. There is not only increased incidence of landslides, but also drying up of spring in places and increased discharge elsewhere. For instance, there is drying up of springs feeding the streams such as Kakbari, Derinala, Kempty and others. Till today the discharges of many springs in more than a dozen valleys have diminished and many streams which bear evidence of flow of water in recent years are now quite dry.

The above example clearly illustrates the environmental problems leading to the degradation of land in Mussorie, which is a terrestrial ecosystem. Similarly, mining activity in oceans which is having immense potential has increased considerably in the last few years. It is also causing concern because of its effect on the area and ultimately the life.

Ocean floor mining on an extensive scale to recover polymetallic nodules (containing sulphides of Zn, Ni and others) will have considerable effect on the benthic biotic community, owing to the stirring up of sediments and formation of flumes of suspended materials. Disposal of deep sea sediments brought out with the ores will be a big problem. As the harvest of a target 1,000 tonnes per day of dry nodules will entail disposal of 9,000 tonnes of sediments brought to the land every day. The sediments and the wastes remaining after processing the nodules, if allowed to be washed down back to the sea, would affect the life on the shallow sunlit coastal belts. Particularly the spawning of fishes and other fauna will be seriously affected.

14.2.5 Urbanisation

For more than 200 years, the world's population has tended to concentrate in a relatively small part of the earth's surface in towns and cities. But the pace of this process called urbanisation has accelerated sharply during the 20th century. In 1985, urban dwellers comprised an estimated 41.6 per cent of the world population compared to 33.6 per cent in 1960 and 13.6 per cent in 1900. During the past 25 years, virtually all countries have experienced an increase in the proportion of the population living in the urban centres.

Environmental degradation due to urbanisation has occurred in a number of ways such as :

i) Encroachment of fertile agricultural and forest land for housing, industries, construction of roads and dams. As towns grow, they invade the productive crop lands and rich forest land causing **deforestation**. Thus the biological diversity of that area is lost for ever. Since 1950, about 1.5 million hectares of fertile land has been lost to towns and cities. It is estimated that by 2000 A.D. an additional eight million hectares of such land would be diverted for the development of cities and towns. For example, Delhi city has expanded by 35% within the last 20 years, the cities which are about 30 years or older, have practically lost all wildlife from their suburbs because of the destruction of their habitats.

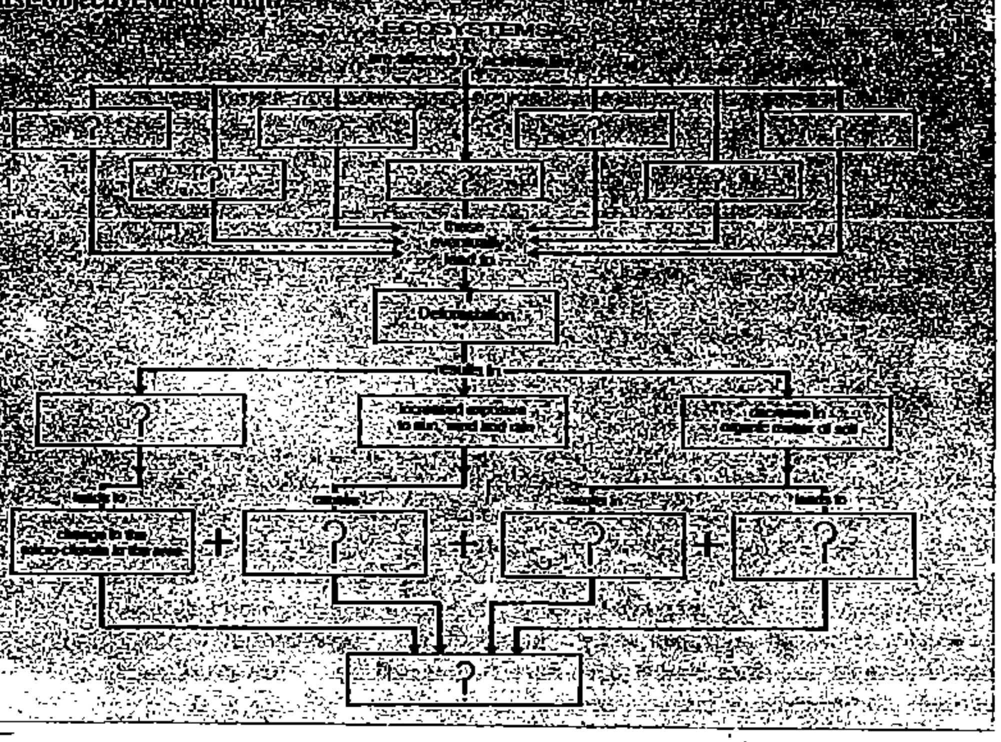
ii) For construction purposes large quantities of building materials are required. Kilns, where bricks are made, not only pollute the atmosphere, but also use a huge amount of nutrient rich soil for brick making. Thus, fertile land which would have been good for agriculture is degraded and is lost for good!

iii) Development of industry goes hand-in-hand with urbanisation. Cities like Bombay, Calcutta, Madras and Delhi are heavily industrialised. About 60% of the industry of Maharashtra is situated in Bombay alone. Some industries due to their by-products/emissions and excessive utilisation of natural resources, affect the ecosystem considerably. You would study more about the effect of industry and pollution on the ecosystem in Unit 15 of this block.

iv) Slums represent the worst type of environmental degradation. Development and proliferation of slums is concomitant with urbanisation and industrialisation. About 18.8% of India's urban population lives in slums. The slum dwellers have an environment with inadequate living space, water supply, sewerage facilities. This, not only causes deterioration of surrounding regions, but also of human health as well.

SAQ 1

Fill in the blank spaces using appropriate word(s). This SAQ corresponds to the first objective of the unit.



14.3 WHAT IS WILDLIFE?

The term wildlife probably originated in 1913 in a book, *Our Vanishing Wildlife* by William Hornaday, Director of the New York Zoological Park. The main focus of this book was on the over-exploitation of game birds, mammals and fishes; and also the harvesting of some birds that were not game, notably the song birds that the European immigrants often hunted. By 1937, the term wildlife had been contracted into one word.

Though the word wildlife was coined and contracted as one word by the nineteen thirty seven, it was not defined in the well known dictionaries. It was, however, included in the Webster's dictionary in 1986. Webster's dictionary defines wildlife as "living things that are neither human nor domesticated", and the Oxford dictionary says that the wildlife is "the native flora and fauna of a particular region".

If we are asked to prepare a list of wildlife species, the list would be dominated by examples of animals, birds and occasionally fishes. Generally, we all think that only large animals, carnivores, game animals and birds constitute the wildlife. In the present times, the term wildlife encompasses much more than the above mentioned life forms. Now plants, microorganisms and all other lesser known living beings too fall within the purview of wildlife. One essential characteristic feature of wildlife is that they grow and survive in a particular area, without the care of human beings. They are well adapted to the soil, light and temperature conditions of that particular area. All our garden flowers are descendants of the wild flowers. The wild flowers grow on their own in nature, complete their life cycles and grow again the next season.

14.4 THREATS TO WILDLIFE

As many as 500 million kinds of plants, animals and microorganisms have made earth their home since life began, over 3.5 billion years ago. Presently, it is believed that there are only 5 to 10 million species alive. We, however, do not have an exact figure because there are many areas on the earth that are biologically unexplored. Tropical rain forests are examples of such areas, about which we know little. About 90% of the organisms living there remain unclassified. Thus, since life began about 490 million species have become extinct.

In the present age of environmental awareness we often hear of or read about the threat of extinction of many wildlife species. Some such examples are the pitcher plant, several species of orchids, rhododendrons, rhinoceros, Indian pangolin, and flying fox. In the present section, we would discuss with you the causes that lead to such situations. We shall be discussing them under the following headings:

14.4.1 Hunting the export
14.4.2 Elimination or disturbance of wildlife habitats
14.4.3 Selective destruction
14.4.4 Domestication
14.4.5 Introduction of new species
14.4.6 Pesticides
14.4.7 Pests, medical research and zoos

14.4.1 Hunting and Export

The hunting and export of excessive numbers of certain animal species is another important factor leading to dangerous reductions in numbers. There are three main types of hunting : i) commercial hunting—in which the animals are killed for profit from sale of their furs or other parts; ii) subsistence hunting—the killing of animals to provide enough food for survival; and iii) sport hunting—the killing of animals for recreation. Although subsistence hunting was once a major cause of extinction of some species, it has now declined sharply in most areas. Sport hunting is now closely regulated in most countries; game species are endangered only when protective regulations do not exist or are not enforced.

On a worldwide basis, commercial hunting threatens a number of large animal species. The jaguar, tiger, snow leopard, and cheetah are hunted for their skins, elephants for their ivory tusks (accounting for the slaughter of about 90,000 elephants a year) and rhinoceros for their horns. Single rhino horn—which is a mass of compact hair—is worth as much as $ 24,000 in the black market. It is used to make handles for ornamental knives in North Yemen, and ground into a powder and used in parts of Asia for medicinal purposes, especially reducing fever. It is also thought to be an aphrodisiac or sexual stimulant even though it consists of a substance (Keratin) that can be obtained by eating hair trimmings and finger nails. Although 60 countries have agreed not to import or export rhino horns, illegal trafficking goes on because of its high market value. The number of black rhinos in Africa dropped from 65,000 to about 5,000 between the years 1970 and 1986. And about 100 white rhinos were left by 1986. If poaching continues at present rates, all species of rhino will be extinct within a decade.

Another highly publicised commercial hunt is that of the whale. The whaling industry has generally concentrated its efforts on the large, profitable baleen whales, which were slaughtered for their blubber and baleen, the bony sieves they filter sea water with. From the blubber, a high grade oil was made for lamps and for lubricating machines. The baleen or "Whalebone" was used to make corset stays, combs and similar products.

The history of whaling is one of over-exploitation followed by abandonment. Whalers harvested a species until it approached extinction and then moved on to another profitable one, repeating the patterns many times.

The blue whale, the largest animal that has ever lived, once numbered around 2,00,000 but by the mid 1950s it has been reduced to about 1,000. Many scientists believe that the blue whale population, although now protected, may not recover.

14.4.2 Elimination or Disturbance of Wildlife Habitats

Habitat refers to the area where species seek food, get shelter, and reproduce. The greatest threat to wild plant and animal species is due to destruction or alteration of their habitat. If an animal's habitat is destroyed or disrupted, it must either adapt to the new changes, move elsewhere or die. When it is forced out of its territory, and if it finds a suitable habitat there is a possibility that the habitat is already in use. Consequently, it must compete with the existing animals of the same species or animals in similar niches. The other option is that it must migrate into a marginal habitat where it may succumb to predation, starvation or disease. Some organisms such as pigeon, house sparrow, rodents (like rat and mice) and deer flourish in the modified habitats provided by human activities but many others do not.

Habitat is disturbed or destroyed due to various factors such as deforestation, drainage or filling of wetlands, overgrazing, expanding agriculture, urbanisation, various development projects, mining and several others. The Great Indian Bustard has been exterminated because of habitat destruction and hunting (for more details see Section 14.5.2., ii) Similarly, the Bengal tiger faces extinction as its jungles are torn down to supply timber and farm land.

Pollution also disturbs the natural habitat considerably. Industrial wastes cause severe impact, particularly on the aquatic habitats. For example, although the impact of acid rain is far from being understood, it may be a slow, subtle agent that is driving some species in the lakes and streams to extinction. Furthermore, during the 1950s and 1960s, insecticides particularly chlorinated hydrocarbons (such as DDT), reduced the population levels of several birds such as the bald eagle, brown pelican considerably.

We shall now take up the issue of habitat destruction due to deforestation, and elaborate on it further. More than three quarters of the species that are in danger of extinction today are due to the destruction of their forest habitats. A large number of these species are from the tropics, where human population growth has been most explosive and habitats have been destroyed most rapidly. Tropical rainforests cover a mere 7 per cent of the earth's surface, yet they house about three quarters of the total species. Today these forests are being destroyed at an alarming rate, and if the ecosystems are obliterated, hundreds of thousands of species will be lost forever, and some of these may be of great importance. We shall now tell you about a species of wild corn, which got accidently saved. Several years ago, a hillside in Mexico was being ploughed when a few alert scientists discovered a previously unknown species of wild corn—*Zea diploperennis,* that only grew on that hill and was found nowhere else. These corn plants are perennial whereas the domestic varieties of corn are annuals. Moreover, the wild corn is resistant to many diseases that infest domestic varieties. The species was thus saved and it is now being used to breed and improve new domestic varieties. So it is of utmost importance to save the living species from extinction from the face of the earth.

14.4.3 Selective Destruction

The selective destruction of one species of an existing fauna can produce equally unfortunate results. The perfect demonstration of unexpected consequences of such destruction occurred in the early years of this century in the USA. In a mistaken effort to increase the deer herds on the Kaibab Plateau, President Theodore Roosevelt, himself a very keen naturalist, authorised the destruction of the natural enemies of the deer, the puma and the wolf. The result was not as expected. Deprived of their natural enemies, which had served to keep their number in check, the deers multiplied so rapidly that there was soon insufficient grazing areas to support them. As a result what had been fertile grassland capable of supporting large herds of deer was soon reduced to unproductive desert virtually unable to support any wildlife. As their available food supplies diminished so the deers died of starvation in the thousands nd in a very short time the total deer population fell far below what it had been en they were subjected to the full effects of their natural enemies.

Fig. 14.3 : Passenger pigeon a lesson learnt but too late!

Extinction or near extinction can also occur because of attempts to exterminate pest and predator species that compete with people and livestock for food. The Carolina parakeet was exterminated in the United States around 1914 because it fed on fruit crops. Its disappearance was hastened by the fact that when one member of a flock was shot, the rest of the birds hovered over its body, making themselves easy targets.

When we talk of selective destruction we must narrate you the story of Passenger pigeon. (See Fig. 14.3). The Passenger pigeon (*Ectopistes migratorius*) probably was the most numerous bird on earth as recently as the middle of the nineteenth century. Passenger pigeons certainly were the most abundant birds in pristine North America. The records include very interesting details about these birds. They were in such immense numbers that their flocks darkened the sky during migration, and one such flock alone was 400 km long and had no less than two billion birds! So huge was their number that the branches of trees would break under the weight of the perching birds. It took hours for the flocks to pass through a place. There used to be as many as 90 nests per tree throughout a stretch of forest of about 5 km width and 67 km length. In 1871, an estimated 136 million passenger pigeons nested in a 2,200 sq. km area of central Wisconsin. An immense tonnage of droppings fertilised the forests where passenger pigeons roosted. One interesting feature about these organisms is that a passenger pigeon laid just a single egg. All the above information gives us a picture of immense abundance of the species. But as you will see in the following details, an immense abundance does not immunise a species from extinction. Despite their large numbers, today there is not even a single passenger pigeon on the earth. You must be wondering why this extinction occurred. We shall discuss that now. Millions of passenger pigeons were killed for food (See Fig. 14.4).

In a span of three months in 1878, more than 1.5 million pigeons were shipped to market from a nesting area in Michigan. It is believed that, as many as 10 million may have perished due to hunting in the above area. The birds were served in fashionable restaurants in Chicago, New York and Boston for two cents each. Not only that, their young ones were a particular delicacy; hence trees in nesting colonies sometimes were felled to obtain large numbers of young birds. Thus the outright killing of passenger pigeons often was accompanied by the destruction of irreplaceable nesting habitats. The lack of refrigeration meant that even more birds were killed to cover losses from spoilage during transportation to market. Another

Fig. 14.4 : Passenger pigeons being hunted (American Museum of Natural History).

interesting aspect that played a great role in their extinction was the two technological developments—rail roads and telegraph, in the nineteenth century. The extensive rail network helped the pigeon hunters in providing ready access to the major nesting colonies of passenger pigeons east of Mississipi river. One dealer in New York received 18,000 birds a day as a result of the new rail connections. Because these birds were nomadic, the telegraph kept hunters informed about the locations of nesting colonies. Because the rail roads benefited from their association with the market hunters, the train companies also provided up-to-date information concerning places where pigeons might be caught. Such relentless disturbances of colonies resulted in large-scale nesting failures year after year, and passenger pigeons steadily diminished. The last pigeon—Martha died in Cincinnati Zoo in 1914, and its body is preserved and kept in U.S. Natural Museum in Washington. The decline and eventual extinction of such an abundant species now seems beyond imagination—but is an event marking one of the darkest hours in environmental history.

14.4.4 Domestication

It means that man has taken under his direct care the living beings which are useful to him. Through extensive breeding programmes, he has modified them to derive maximum benefit of their products. During the process, the species have lost certain useful characteristics so much so that these forms cannot survive on their own in nature. A very good example is corn, which is pampered so much by man that if it is left on its own, it cannot survive.

We shall now take up the other aspect of how domesticated species create hostile conditions for the survival of wildlife.

Today man has large herds of domestic animals. These animals can also play a significant part in the reduction of animal populations by overgrazing the land, thus destroying the vegetation on which both they and the wild animals depend. The native wildlife of a particular area is capable of utilising the native plant life much more efficiently than introduced domestic cattle, and is thus much less likely to convert fertile areas into deserts. So, often domestic animals have little more than prestige value, providing little in the way of either meat or milk.

The other important parameter is that the domestic cattle are carriers of several diseases which they can transmit to wild animals. For example, the steady rehabilitation of the Great Indian Rhinoceros was seriously hampered by the rinderpest disease which they contracted from the local domestic cattle.

14.4.5 Introduction of New Species

As long as human beings have travelled around the world, they have carried with them (accidentally or intentionally) many species of plants and animals, which they have introduced to new geographical areas. In some instances, an opening has existed in the new environment and the foreign or alien species has been able to establish itself without seriously affecting the population size of the native species. But in other instances, the alien has been a superior predater, parasite or competitor, and has brought about extinction or near extinction of native species. It can also cause a population explosion of the existing species by killing off their natural predators. Island species are particularly vulnerable because many have evolved in ecosystems with few if any natural herbivores, or carnivore predators.

In 1859 a farmer in southern Australia imported a dozen pairs of wild European rabbits as a game animal. Within six years these 24 rabbits had mushroomed to 22 million so that by 1907 they had reached every corner of the country. By the 1930s, their population had reached an estimated 750 million. They competed with sheep for grass and this cut the sheep population to half. They also devoured food crops, gnawed young trees, fouled water holes and accelerated soil erosion in many places. In the early 1950s, about 90% of the rabbit population was killed by the deliberate human introduction of a virus disease. There is a concern, however, that members of the remaining population may eventually develop immunity to this viral disease through natural selection and again become the scourge of Australian farmers.

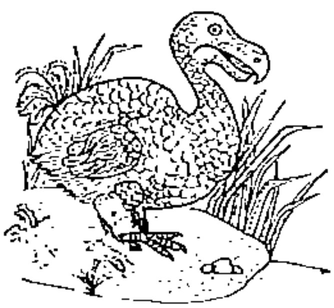


Fig. 14.5 : Dodo, the first animal species whose extermination could be fully documented.

We shall now take up another example that demonstrates the devastating effects of the introduction of alien species on islands. In islands, particularly the endemic species are often inadequately equipped to deal with invasions of humans and their domestic animals. For example, the bird dodo (see Fig. 14.5) lived only in Mauritius, which is a small island in the Indian Ocean. The dodo possessed two characteristics that were its eventual undoing; it had no fear of people and, therefore, could be easily clubbed to death, and it was flightless, so, it had to lay its eggs on the ground. The dodo became extinct by 1681, after the introduction of pigs to the island, who devoured its eggs.

On an island, both the variety of habitats, and the area that comprises each habitat are physically limited. As a result of such constraints, the native animals' ability to adapt to new predators and competitors is often reduced. For example, the habitat may not be large enough or diverse enough for a prey species to avoid new predators. And the diversity of resources may not be adequate to allow an existing species to coexist with a new competitive species. Hence, in some instances competitive exclusion leads to extinction of the native species.

Competition exclusion can be illustrated by the demise of tortoise on one of the Galapagos islands after fisherman released some goats on the island in 1957. When a research team from the Charles Darwin Station arrived in 1962 to investigate the tortoise population on the island, they found only empty tortoise shells, many of which were wedged among the rocks that covered the upland slopes. Investigations of the lowland indicated that all the vegetation that had previously been within reach of the tortoises had been consumed by the flourishing goat herd. As a result, the hungry tortoises apparently were forced to obtain food on rocky slopes, where they subsequently either became entrapped between rocks or fell over precipices and starved to death.

Island flora, too, has been devastated by the introduction of alien species. For example, in the Hawaiian islands, no large herbivorous animals existed until the 1700s, when Europeans introduced domestic livestock. Because no prior selection pressure had existed to favour them, thorns or poisons to ward off herbivores were not characteristic of native plants. Moreover, the limited size of habitats on the islands favoured overgrazing. Thus species that had not been threatened previously were devastated by grazing animals. As a result, nearly one half of the native vegetation in the Hawaiian islands is thought to be in danger of extinction.

An island, in the usual sense of the word, is a land mass that is surrounded by water. Ecologically, however, a *habitat island* is defined as any restricted area of habitat that is surrounded by dissimilar habitats. Hence, a lake without outflow is considered to be an aquatic island. Also, when natural habitats are bisected by highways and converted into farms and cities, natural and semi-natural areas become increasingly smaller and more isolated (see Fig. 14.6). To save what little remains, some of those isolated areas have been set aside as parks and conservancies. Forest preserves are usually widely scattered and the intervening highways, farms and cities serve as barriers that prevent the migration of many species of plants and animals into and out of them. Hence those natural and semi-natural habitats have become islands as well, and the animals and plants that live in them are subject to the same pressures as those living on islands that are surrounded by water. Furthermore, the smaller the habitat island, the greater is the pressure on its inhabitants. Thus we would consider these factors when we plan how to use land rather than indiscriminately invade and carve up natural habitats into increasingly smaller pieces.

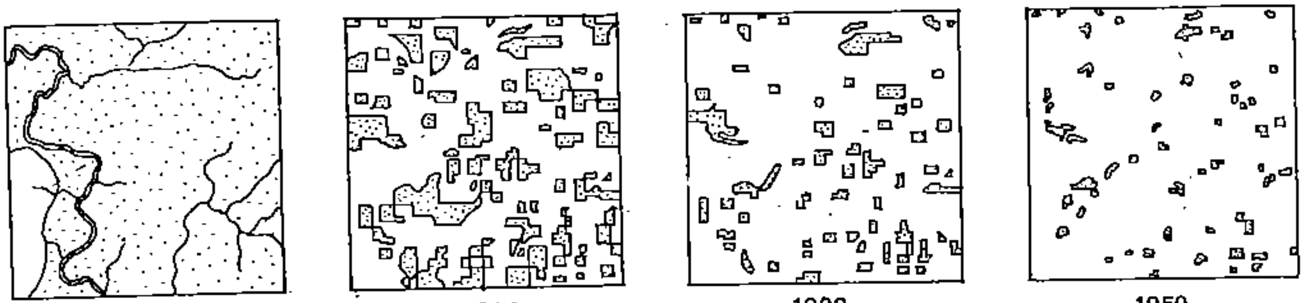


Fig. 14.6 : The reduction and fragmentation of woodland (shaded areas) in Cadiz township, Wisconsin between 1831 and 1950. The piecemeal destruction of habitat resulted in piecemeal extinction of many species (after J. Curtis, 1955).

14.4.6 Pesticides

Another recently realised danger to wildlife in many parts of the world has come from the development of more effective pesticides. As agriculture became more efficient so the need to control crop pests also became more urgent, and the agricultural chemists have devoted a great deal of their time and energy to synthesising compounds to meet this need. In the early 1960s it became clear that a certain group of chlorinated hydrocarbons, notably aldrin, dieldrin and heptachlor, which are undoubtedly extremely effective in controlling pests, are proving increasingly harmful to many wild animals. Their great disadvantage, it was discovered, was that whereas most other pesticides were fairly rapidly destroyed when they fell on the ground, the above three pesticides persisted in the soil for years, and tended to accumulate (bioaccumulation) since each year's spraying reinforced the persisting residues from previous years.

The first effect of these pesticides is a gradual accumulation in the bodies of worms, insects and some small animals. These in turn are eaten by birds, which thus acquire these accumulations, and the effects of which may be reproductive failure and egg shell thinning. These effects have been seen in birds like peregrine falcon, eastern and California brown pelicans, osprey, bald eagle.

In India, the threat to wildlife through the use of these compounds had taken rather a different turn. Here the farmers have been using them directly as poisons to kill tigers, leopards and other large animals either by adding a few grams to the animal's food or by scattering poisoned bait along their known tracks. In Kerala, elephants have also been killed by poisoned bananas.

14.4.7 Pets, Medical Research and Zoos

Animals and plants are gathered throughout the world for zoos, private collectors, pet shops and researchers in biology and medicine. Worldwide more than 6 million live birds are sold each year, most of them as pets, in countries like United States, Great Britain and West Germany. Large number of these animals die during shipment and after purchase, many are killed or abandoned by their owner. The ratio may be very high, for each bird that makes it into someone's home, 10 to 50 die along the way. As a direct result of this trade, at least nine bird species are now listed as threatened or endangered, but still these continue to be smuggled illegally into the US and Europe. For example, bird collectors may pay as much as $ 10,000 for a threatened hyacinth macaw illegally smuggled out of Brazil.

Animals are only one side of this story: plants such as cacti and orchids are also in high demand and support a growing industry. These may be used to decorate houses, offices and landscapes. A single, rare orchid may be sold for $ 5,000 to a collector.

Each year, about 7 million cacti are imported to United States from more than 50 countries. Also, cacti are shipped out of Texas annually. In one area of Texas near Big Bend National Park, 25,000 to 50,000 cacti were uprooted in a single month for sale elsewhere. In the late 1970s, about 10 million cacti were shipped out of Texas annually.

Researchers throughout the world use a variety of animals such as mice, rats, dogs, cats, primates, birds, frogs, guinea pigs and rabbits for their studies, many of which came from the wild. Demand is especially great for monkeys and the great apes such as chimpanzees. Taken from their homeland in Africa, as many as five chimpanzees die for every one that enters the laboratory. Some biologists believe that the species will be extinct in the wild by the end of the decade. Primates are desired because of their anatomical, genetic and physiological similarly to humans. Primates have played important part in biomedical research. The chimpanzee, for example, has been used in work on human reproduction and cancer detection. Although there has been a reduction in the import of these animals into the developed nations, still the figures of these animals cause concern. Since these research animals often do not breed in captivity and because they have a high mortality, continual replenishment from wild populations is likely to continue.

Today, 60 primate species are on the endangered list. Many of these have been exploited by researchers with little concern for their declining population or ultimate demise in the wild. Most people agree that research must continue under humane conditions but that it should not be carried out at the cost of existence of animal and plant species. Captive breeding programmes which supply zoos and researchers can be extended in countries where primates are used. This would stop the flow of these animals from their natural habitat. Prompt action now can prevent the extinction of many primates.

Public zoos, botanical gardens and aquariums are under constant pressure to exhibit rare and unusual animals such as orangutan. For each exotic animal or plant that reaches a zoo or botanical garden alive, many others die during capture or shipment.

No animal lives for ever even under the most favourable zoo conditions, and unless an animal is one of those which breeds readily in captivity, then when it dies it has to be replaced from the wild. Eventually this steady replacement demand can have a serious effect upon the wild stocks. At the present time the future of the monkey-eating eagle, *Pithecophaga jefferyi*, a magnificent eagle living on the islands of Hindanoa and Luzon in the Philippines is in jeopardy because the rate of capture for the zoos of the world exceeds the annual reproduction rate. Because of the serious position the members of the International Union of Directors of Zoological Gardens have agreed not to buy these rare birds until the wild population has had a chance to reestablish itself. Unfortunately a stuffed monkey-eating eagle on the sideboard is regarded as a status symbol by the inhabitants of the Philippines, and this adds to the perils facing the species at the present time.

SAQ 2 : Which of the following best defines wildlife? Write your answer in the space provided.

a) all birds and animals that are not domesticated by humans

b) all microorganisms occurring in a forest that are not useful to man

c) all forms of life that man has not been able to domesticate

d) all forms of life including microorganisms that grow and survive without human intervention.

☐

SAQ 3 : The following are some of the basic causes that threaten the existence of wildlife :

a) elimination or disturbance of habitat

b) domestication

c) introduction of new species

d) selective destruction
e) hunting and export
f) pesticides
g) pests, medical research and zoos

For each of the following explanations, indicate which of the above cause is involved. Write the correct choice in the space on the left side. Write N if none of the above are involved.

i) being superior competitors, some alien species pose danger to the originally occurring species. ☐
ii) disruption in reproduction and various other disorders are seen in instances of bioaccumulation. ☐
iii) non-availability of food, proper habitat and human care to the animals ☐
iv) destruction or nonavailability of the area where species seek food, get shelter and reproduce because of factors like deforestation, overgrazing, agriculture, urbanisation, pollution, development projects and mining ☐
v) picking, choosing, overexploiting and exterminating a particular species for various uses ☐
vi) bringing under human care, and modifying their characters through selective breeding to suit the human requirements ☐
vii) chasing, capturing or killing of wild animals for sport, subsistence or profit ☐
viii) natural enemies, and collection of animals for exhibition, breeding and as tool for study ☐

14.5 EXTINCT AND THREATENED SPECIES

Some of wildlife species are considered threatened and some are extinct. What is the difference between the two? You would study in this section. Also you would learn about the various classes of threatened species.

14.5.1 Extinct Species

These no longer exist outside museums and photographs. You have read about the passenger pigeon in the previous section. It is one of the most noted examples of extinct species. Other extinct species include the Carolina parakeet, heath hen, Labrador duck, Cheetah, Pink-headed duck, and Jerdon's Courser.

The above examples indicate that the species have become extinct because of human activities. Many conservation experts warn that if deforestation, desertification and destruction of wetlands and coral reefs continue at their present rate, at least 5,00,000 and perhaps 1 million species will become extinct as a result of human activities between 1975 and 2000. Using the lower estimates, this amounts to an average extinction rate by 2000 of 20,000 species a year (See Fig. 14.7), or 1 species every 30 minutes. There is thus a 200-fold increase (also see Fig. 14.7) in the extinction rate in only 25 years (that is between 1975 and 2000). Most of the species will be plant and insects that are yet to be classified and not much is known about their use to people and their role in the ecosystems.

Carolina parakeet—also see Sub section 14.4.4, their brightly coloured feathers caused their downfall. These feathers were prized for decorating women's hats and made the birds popular as pets. Their extinction came in 1914.

The heath hen was used as food. In the early 1900s people realised that the bird was becoming scarce and a bird sanctuary was set up. The flock soon grew, but a fire swept across the sanctuary, and only a few males survived. The last bird died in 1932.

The labrador duck became extinct before anyone realised it was gone. Most of the birds were killed for their feathers, which were used to stuff pillows.

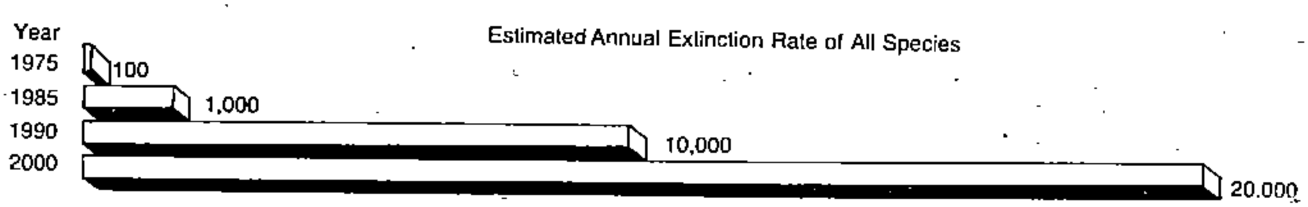


Fig. 14.7 : Estimated annual extinction rate of all species between 1975 and 2000. (From Miller).

Among all the countries, India has the greatest number of mammalian species on the threatened species (endangered, rare etc.) list, and in the Red Data Book, ranks first in the world. Following is a list of some threatened animals of our country.

Mammals :

1. Andaman Wild Pig
2. Bharal
3. Binturang
4. Black Buck
5. Blue Whale
6. Brow-antlered Deer
7. Capped Langur
8. Caracal
9. Catecean species
10. Cheetah
11. Chinese Pangolin
12. Chinkara or Indian Gazelle
13. Clouded Leopard
14. Crab-eating Macaque
15. Desert Cat
16. Dugong
17. Fishing Cat
18. Four-horned Antelope
19. Dolphin (Gangetic)
20. Flying Squirrel
21. Golden Cat
22. Golden Langur
23. Himalayan Ibex
24. Himalayan Thar
25. Hispid Hare
26. Hog Badger
27. Hoolock Gibbon
28. Hump-backed Whale
29. Indian Elephant
30. Indian Lion
31. Indian Wild Ass
32. Indian Wolf
33. Kashmir Stag
34. Leaf Monkey
35. Leopard
36. Leopard Cat
37. Lesser or Red Panda
38. Lion-tailed Macaque
39. Loris
40. Lynx
41. Malabar Civet
42. Malay or Sun Bear
43. Marbled Cat
44. Markhor
45. Mouse Deer
46. Musk Deer
47. Nilgiri Tahr
48. Ovis Ammon or Nyan
49. Palla's Cat
50. Pangolin
51. Pygmy Hog
52. Ratel
53. Rhinoceros
54. Rusty-spotted Cat
55. Serow
56. Sloth Bear
57. Slow Loris
58. Small Travancore Flying Squirrel
59. Snow-Leopard
60. Spotted Linsang
61. Swamp Deer
62. Takin or Mishmi Takin
63. Tibetan Antelope or Chiru
64. Tibetan Gazelle
65. Tibetan Wild Ass

Although animal extinctions receive the most publicity, plant extinctions are more important ecologically, because most animal species depend directly or indirectly on plants for food. An estimated 10 per cent of the world's plant species are already threatened with extinction and an estimated 15 to 25 per cent of all plant species will face extinction by 2000.

Some scientists, however believe that the projected extinction rate for 2000 is only a wild guess and it greatly overstates the situation. But even if the average extinction rate is only 1,000 a year then by the end of this century, this will rank as one of the great mass extinctions since the beginning of life on this planet.

14.5.2 Threatened Species

Many plant and animal species are threatened by the possibility of extinction. However, the seriousness of the threat varies. For example, a species with fewer than 50 known survivors living in one small area is in much more critical condition than another with 5,000 individuals living in several areas.

The Survival Service Commission (now called Species Survival Commission) of International Union of Conservation of Nature (IUCN) has established four categories of threatened species. These describe the degree to which a species is threatened with extinction. These categories are:

i) Endangered
ii) Rare
iii) Depleted, and
iv Indeterminate

i) Endangered Species : A species is considered endangered when its numbers are so few or/and its homeland is so small, that it may become extinct if not given special protection.

The lion-tailed macque which inhabits the rain forests and "Sholas" of South India, is among the world's most endangered primates. It is believed that there are not more than 195 of this beautiful animal left in the wild, as its forest home has diminished rapidly over the last 30 years to a small fraction of its former extent. The habitat of these rainforest dwellers had dominant *Dipterocarpus* trees, which have been ruthlessly axed down. To worsen the situation, the indigenous vegetation has been cleared indiscriminately for establishment of coffee and tea estates. Poaching is also responsible for reducing their number considerably. The animal is also hunted for its flesh. Their capturing for pet and zoo trade also flourishes.

ii) Rare Species : These are those species whose numbers are few or they live in such small areas or in such unusual environments (endemics), that they could quickly disappear.

The Hawaiian monk seal *(Monachus schauinslandi)* is an example of a rare species. It is found only on six small islands extending north west from the Hawaiian islands. There are probably no more than 1,500 of these seals. They were killed for their fat in the late 1800s and they almost became extinct. Since 1909 they have been protected and have slowly increased in number. Unfortunately, even stopping the killing may not be enough to save these seals. If they are disturbed on the beaches where they give birth, the mothers rush away into the water. Many of the pups left behind die. With all the Hawaiian monk seals located on just these few islands there is a great possibility of these being wiped off, by some natural catastrophe, such as an oil slick. There are a few in captivity, but they have never bred.

The second example is of the Great Indian Bustard *(Ardeotis nigriceps)* one of the world's rare birds, belonging to India. (See Fig. 14.8) Its earlier distribution ranged from Pakistan east to West Bengal and Southwards through the Peninsular region of southern Madras. It occurs in small groups, in large grassland tracts, cultivated fields in arid and semi-arid lands of Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Haryana and Uttar Pradesh. It is believed that, presently only 750 birds are left, Gujarat being the main surviving habitat for the species today. This, rare and apparently declining species has been annihilated in the recent past by poachers and its natural habitat has been destroyed. The indiscriminate use of insecticides and pesticides around its natural habitat has also affected them. They have also been slaughtered for food. In all, the situation is pretty bad, and we can say that locating a bustard at the moment is often as hard as "finding a needle in a haystack"!

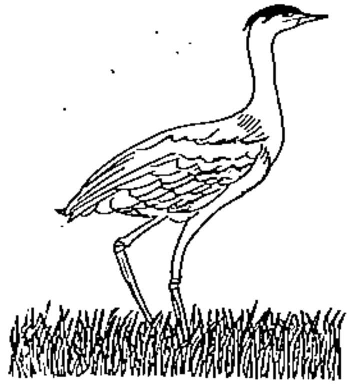


Fig. 14.8 : The Great Indian Bustard

iii) Depleted (Vulnerable) Species : These are the species whose numbers are greatly reduced from those of the recent past, and they are continuing to decrease. It is the continued decrease, that is the main cause of concern. Animals in this category can quickly change to a rare or endangered status.

The addax *(Addax nasomaculatus)* of northern Africa is a member of the antelope family. It originally lived in deserts from Egypt to Mauritina. This animal has been so heavily hunted that presently, fewer than 5,000 survive all across their former range. Since 1900, they are no more in Egypt, and they have also been wiped out in Tunisia. It is doubtful whether they exist in Libya and Spanish Sahara, Algeria or Sudan. Their last stronghold seems to be in Mauritania and Mali, where they are still hunted by nomadic natives, who dry the meat for food. The number of the addax antelope continues to decline. If the population continues to decrease much longer, the species will become extinct. However, if the hunting were stopped today, there would still be enough animals and a habitat extensive enough for the species to survive.

In the past few years, the fur of the clouded leopard *(Neofelis nebulosa)* was sold illegally in Kashmir markets. In Himalayas, its number has decreased so much that it is rarely seen. The deteriorating state of the evergreen forests, accounts for its depleted status. Since the range of this beautiful animal extends from Nepal, Bhutan, Sikkim to Assam, proper steps for its conservation can save it from reaching a point of extinction.

iv) Indeterminate Species : The fourth category consists of those species that seem to be in danger, but there is not enough information about them to make a reliable estimate of their true status.

Examples of species in this category are many. One is the three-banded armadillo *(Tolypeutes trincinctus)* of north eastern Brazil, which is hunted for its flesh.

Second, the short-eared rabbit *(Nesolagus netscheri)* of Sumatra which is disappearing as the forests are cleared for agriculture. Third is the Mexican prairie dog *(Cynomys mexianus)* which is killed for food and whose habitat is taken over for agriculture.

Usually, when detailed information is collected about an indeterminate species, its changes and depending upon its status it may be placed in any of the above three categories, or may be declared a safe species. For example, the status of the Amazon manatee *(Trichecus inunguis)* a fresh water sea cow, was considered indeterminate in 1966. Within two years, its condition was determined and changed to endangered. Since it is hunted for its flesh, it is now amongst the most endangered species. The snow leopard *(Leo uncia)* was classified as indeterminate species in 1968, and was declared endangered in 1970. You probably know that the snow leopard is hunted for its thick beautiful fur.

In this, and the previous subsection you have studied about the extinct and various categories of threatened species. The examples discussed therein might have given you some idea that a multitude of factors (environmental and human) are involved in making them reach their present state. We would like to draw your attention to another facet of the picture, that is, what features/characteristics predispose certain animal species to become threatened (See Table 14.2). While you study these

66. Tiger
67. Urial or Shapu
68. Wild Buffalo
69. Wild Yak

Amphibians and Reptiles

1. Agra Monitor Lizard
2. Atlantic Ridley Turtle
3. Barred, Oval or Yellow Monitor Lizard
4. Crocodiles
5. Gharial
6. Ganges soft-shelled Turtle
7. Green Sea Turtle
8. Hawksbill Turtle
9. Himalayan Newt or Salamander
10. Indian egg-eating Snake
11. Indian Soft-shelled Turtle
12. Indian Tent Turtle
13. Large Bengal Monitor Lizard
14. Leathery Turtle
15. Logger-head Turtle
16. Oliver-back Logger-head Turtle
17. Peacock-marked soft-shelled Turtle
18. Pythons
19. Three-keeled Turtle
20. Tortoise
21. Viviparous Toad
22. Water Lizard

Birds

1. Andaman Teal
2. Assam Bamboo Partridge
3. Bazas
4. Bengal Florican
5. Black-necked Crane
6. Blood Pheasants
7. Brown headed Gull
8. Cheer Pheasant
9. Eastern White Stork
10. Forest Spotted Owlet
11. Great Indian Bustard
12. Great Indian Hornbill
13. Hawks
14. Hooded Crane
15. Hornbills
16. Houbara Bustard
17. Humes bar-backed Pheasant
18. Indian Pied Hornbill
19. Jerdon's Courser
20. Lammergeier
21. Large Falcons
22. Large Whistling Teal
23. Monal Pheasants
24. Mountain Quail
25. Narcondom Hornbill
26. Nicobar Megapode
27. Nicobar Pigeon
28. Osprey or Fish-eating Eagle
29. Peacock Pheasant
30. Peafowl
31. Pinkheaded Duck
32. Scalater's Monal
33. Siberian White Crane
34. Spur Fowl
35. Tibetan Snow-Cock
36. Tragopan Pheasants
37. White-bellied Sea Eagle
38. White-eared Pheasant
39. White Spoonbill
40. White-winged Wood Duck

It is believed that out of the 15,000 flowering plants that exist in India, atleast 100 or possibly upto 200 plants are found to be threatened. Amongst the most threatened plant species in India are over-exploited medicinal plants, ornamental plants like orchids and botanical curiosities like pitcher plants. Some 1250 species of orchids occur in India, of which 300 are becoming scarce in Meghalaya alone. Today, about 20 Meghalayan orchid species are threatened. Given below are a few examples of threatened plants in our country.

1. Atis
2. Vacha
3. Khulanjan
4. Angurshaga
5. Guggal
6. Mishmee Teeta
7. Picotee Dendrobium
8. Kins
9. Snow Orchid
10. Kadu
11. Lotus
12. Indian Podophyllum
13. Sarpagandha
14. Sukad
15. Kuth roots
16. Brahm Kamal

characteristics which are discussed below you should keep in mind that *no single species possesses all of the following characteristics.* At the most, two or more of these characteristics may be seen in a species.

Table 14.2 : Characteristics of Extinction-prone Species

S.No	Characteristic	Details	Examples
1.	HABITAT	i) island species - -unable to compete with invasion from continental species	Pureto Rican parrot, Pahrump Killifish, Indiana Bat, Golden-Cheeked Warbler. Besides this, more than half of the 200 plant species of Hawaii are endangered
		ii) Species with limited habitats—some species are found only in a few ecosystems (endemics)	Woodland Caribou, Everglades Crocodile millions of species in the tropical rainforest, Elephant Seal, Cooke's Kokio
		iii) Species with specialised niches—the niche can be destroyed even if the ecosystem remains more or less intact	Ivory-billed Woodpecker, Whooping Crane, Orangutan
2.	FEEDING HABITS	i) Specialised feeding habits	Everglade Kite *(apple snail of southern Florida)*; Blue Whale *(Krill in polar upwelling areas)*; Black-footed Ferret *(prairie dogs and pocket gophers)*; Giant Panda (bamboo)
		ii) Feed on high trophic levels	Bengal Tiger, Bald Eagle, Andean Codor, Timber Wolf
3.	REPRO DUCTION	i) Species with low reproductive rates. Many species evolved low reproductive rates because predation was low, but in modern times, people have become very effective predators against some of these species	Blue Whale, California Condor, Polar Bear, Rhinoceros, Passenger Pigeon, Giant Panda, Whopping crane
		ii) Specialised nesting/breeding areas	Kirtland's Warbler *(Nests only in 6 to 15 years old Jack pine trees)*; Whooping Crane (*depends on marshes for nesting*); Green Sea turtle *(lays eggs on a few beaches)*; Eagle *(prefers forested shoreline)*; Nightingale wren *(nests and breeds only on an island in Panama)*
		iii) Species that have limited number of offsprings per breeding, long gestation/incubation periods, or require extensive parental care	Mountain Gorilla, Abbott's booby, Mississipi Sandhill Crane, California Condor
4.	PREDATORS	Often killed to reduce predation of domestic stock	Grizzly Bear, Timber Wolf, Bengal Tiger, some Crocodiles, Asiatic Lion Gray Wolf.
5.	BEHAVIOUR	i) Intolerant of the presence of humans	Grizzly bear
		ii) Peculiar behavioural pattern of the extinct species	Passenger Pigeon *(used to nest in large colonies)*
		iii) Behavioural indiosyncracies that are non-adaptive today	Red-headed woodpecker *(flies in front of cars)*; Carolina Parakeet *(when one bird is shot, rest of the flock hovers over the body of the dread bird)*; Key Deer (*forages for cigarette butts along highways—it is a "nicotine addict"*)
		iv) Migration -- live largely in (or migrate across) international boundaries.	Atlantic Green Sea Turtle, Ocelot, Atlantic Salmon, Blue Whale, Kirtland's Warbler, Whooping Crane
6.	ECONOMICALLY VALUABLE FOR SPORT	Hunting pressure by humans for various commercially important products	Snow Leopard, Blue Whale, Elephant, Rhinoceros
7.	POLLUTION	Some species are more susceptible to industrial pollution, insecticides and pesticides	Bald Eagle, Great Indian Bustard

The extinct animals are gone forever. We can never bring them back. Threatened species can be managed and it should be our goal to make sure that they do not go the way of extinct species.

14.5.3 Out of Danger Species

This includes species, that were formerly included in one of the above categories, but are now considered relatively secure because effective conservation measures have been taken or the previous threat to their survival has been removed.

14.5.4 The Red Data Book

Species judged as threatened are listed by various agencies as well as by some private organisations. The most cited of these lists is the Red Data Book. It is a loose-leaf volume of information on the status of many kinds of species. This volume is continually updated and is issued by the International Union for Conservation of Nature (IUCN) located in Morges, Switzerland. "Red" of course is symbolic of the danger that these species both plants and animals presently experience—throughout the globe. The Red Data Book was first issued in 1966 by the IUCN's Special Survival Commission as a guide for formulation, preservation and management of species listed. In this Book, information for endangered mammals and birds is more extensive than for other groups of animals and plants, coverage is also given to less prominent organisms facing extinction.

The pink pages in this publication include the critically endangered species. As the status of the animals changes, new pages are sent to the subscribers. Green pages are used for those species that were formerly endangered, but have now recovered to a point where they are no longer threatened. With passing time, the number of pink pages continue to increase. There are pitifully few green pages.

SAQ 4

In the line on the left of each phrase in column A write the letter of the word in column B that *best matches* the phrase. Each word in column B may be used once, more than once, or not at all.

A	B
——— I) Species which are thought to be in danger but their exact data is not available	a extinct species
——— II) Species whose numbers are few or they occur in unusual environments	b threatened species
——— III) Species whose all individuals have perished	c endangered species
——— IV) Species whose numbers have greatly reduced in the recent past and they continue to decrease	d rare species
	e depleted species
	f indeterminate species
	g out of danger species.

14.6 CONSERVATION OF WILDLIFE

From your study of the earlier sections you have learnt that species have been wiped off from the face of the globe, and many of them are in the process of being wiped off, if proper measures are not taken to save them.

14.6.1 What is Meant by Conservation of Wildlife?

Now a days, we frequently hear or read about conservation. People from diverse fields such as the environmentalists, scientists, architects, politicians, town planners and the common man—all talk of conservation. Actually conservation means different things to different people. In the present context, conservation refers to the preservation of wild plants, and animals in natural ecosystems or even in gardens or zoos, detached from their natural environment. Today, wildlife conservation is a total concept and it not only involves plants and animals, but also the microorganisms, soil and other physical elements of the environment in which they live or on which they depend. We shall now discuss with you the various kinds of measures required for species conservation.

14.6.2 Measures for Species Conservation

Several types of actions needed for species conservation are described below:

i) Habitat Conservation : Habitat destruction is the major factor in the extinction of plants and animals. If the ecological considerations are kept in mind during urban and other developments, the damage to the habitat can be prevented considerably.

ii) Providing Critical Resources : Another way to improve the habitat of a threatened species is to determine which resource is limiting the population size and to provide more of that resource. Construction of nest boxes for wood ducks has increased the wood duck population in parts of America. The white-naped crane winters in Japan, but the one area where these large, beautiful birds used to feed has now been built over. In 1985, about 45 birds only appeared in all of Japan. The Japanese, therefore, started feeding the birds at just one location in Kyusu, and more than 700 birds now winter in the area each year.

iii) Captive Breeding : Species which are reduced to dangerous levels need more intensive management, and one strategy is their captive breeding. It means, the eggs from the nests of endangered birds are taken and hatched in captivity. Such attempts have been successful with California condor and several species of cranes. Captive breeding in zoos, animal breeding parks, and research centres has also been attempted with some success. For example, the Arabian oryx became extinct in the wild by the mid-1960s, and captive breeding was attempted and a few animals produced were released in the reserves. Some species such as Cheetah, Pandas, Cranes, Bats and Penguins are not inclined to breed in captivity. So techniques like artificial insemination and many others are used.

A major goal of captive breeding programme is the eventual release of species back into the wild. It has been found that the individuals that are released are especial vulnerable. They must face all the dangers that occur in small populations; in addition, since they have been raised in captivity they frequently fail to develop vital behavioural patterns such as those necessary for finding food. So when left in wild many animals die on their release. Despite all this, if the natural habitats of species are destroyed, zoos and animals breeding parks may be the last refuge for some wildlife species.

iv) Development of Reserves : Establishment of Biological reserves, National parks, Forest reserves, Wildlife refuges and Biosphere reserves are effective means of preserving wildlife species. Such reserves are mostly established in the naturally functioning ecosystems, therefore, it is easy to manage them. Besides, the maintenance cost and requirement of resources is minimal. The main objectives of these reserves are illustrated in Fig. 14.9. An important aspect about these reserves is that more than one endangered species can be protected in the same area.

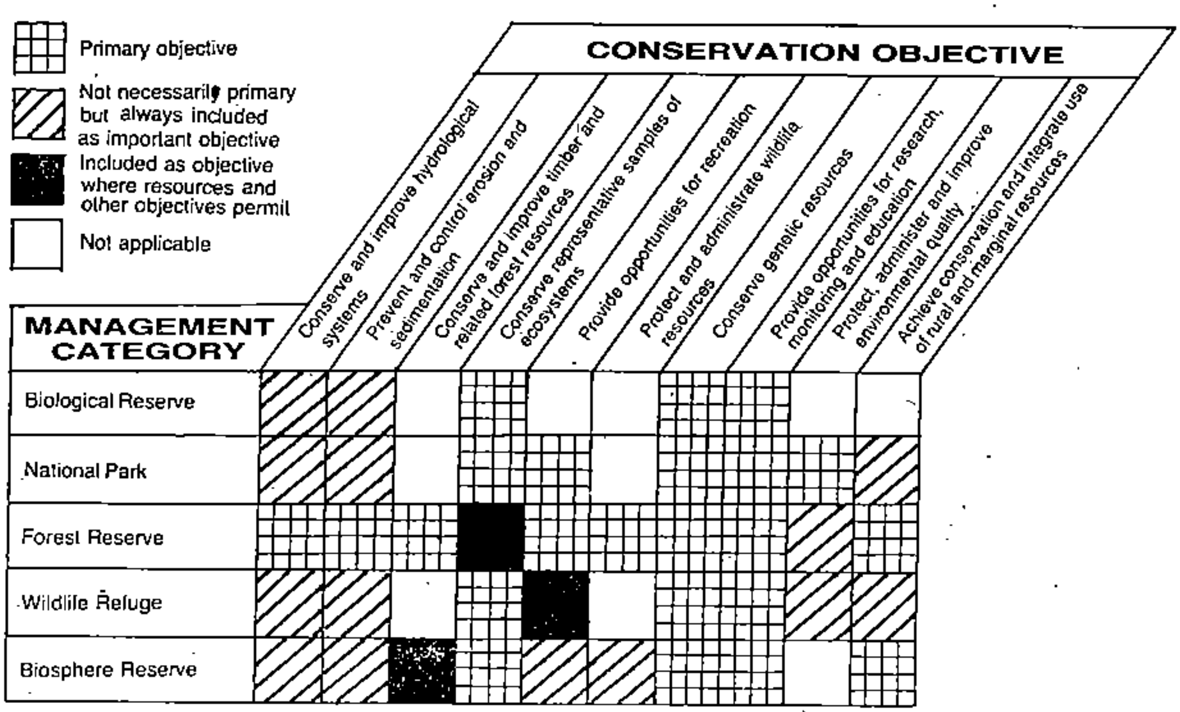


Fig. 14.9 : Conservation objectives of various reserves

Reserves (Fig. 14.10) are areas demarcated especially for the protection of wildlife. The various zones of a reserve and its use by humans for various activities is also shown in the figure.

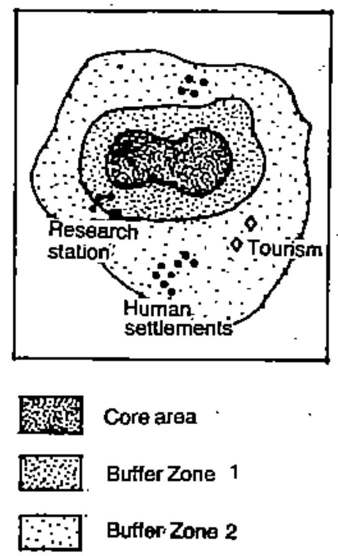


Fig. 14.10 : A popular and effective form of reserve consists of a totally protected core area surrounded by buffer zones in which scientific research and limited human activity is permitted.

v) Controlling Introduction of Alien Species : As you know the alien species can cause the existing population to decrease or even become extinct. The individuals of alien species, may affect the other species by preying on them, providing tough competition for food, or destroying their habitat. The alien species can also cause a population explosion of existing species by killing off their natural predators. Island species are particularly vulnerable to the alien species, because they have evolved in ecosystems with few if any natural herbivorous or carnivorous species. So before introducing the alien species, all these aspects should be kept in mind.

vi) Reducing Pollution : As you already know, pollution of various kinds has affected the survival of living beings, particularly the wildlife in various ways. Pollution is the product of modern civilisation and this problem continues to grow. Then, what should be done? Today, our life styles have become such that it is not easy to revert back to the old stage. So, development of effective methods to curb pollution, change in practices to avoid the generation of pollutants is called for.

vii) Research and Documentation : First, list of endangered species are established by various national and international agencies. Another important action used to save an endangered species is the compilation of information about it. What is the current size of the population, and what is critical minimum size of the species? Information is also gathered about the way of breeding, area required, food, and climate in order to survive. It is also important to know why the population has been reduced to the danger point.

viii) Legal Actions : Several legal approaches have been used to preserve species. One is to enact laws regulating the killing of members of certain species, with severe penalties for breaking the law. These laws may be very effective. In certain countries like the United States, the hunting of deer is controlled by allowing hunting only during a specific time of the year and by issuing tags to each person who applies for a hunting license. Those, who are caught with a dead deer and do not carry a tag, or ones who killed out of season are fined heavily. This system permits wildlife agencies to control deer populations very precisely. In many countries it is illegal to kill any member of an endangered species.

Despite the strict penalties, poaching has not been eliminated completely as it brings huge sums of money to the smugglers. In 1975, 81 nations signed the *Convention on International Trade in Endangered Species* (CITES) which prohibits all trade of endangered species or their products. All these laws are good only if they are enforced and are able to save animals, lives.

ix) Public Participation and Awareness : The blame for extinction is usually fixed on a few categories of people such as the smugglers, hunters etc. but in fact, all of us too have some role in making the animals reach their present state. Through excessive consumerism, apathy, unchecked population growth and lack of involvement, we are all a part of the problem. But how can we help?

First, we all can reduce the consumption of energy by minimising wastage, that is, shutting off lights, fans etc. when not in rooms. By many such practices, we can conserve our natural resources especially the products that come from forests. This can reduce destruction/loss of habitat.

Second, we can help others learn to change their wasteful ways. We can begin with our family and then explain to friends and relatives our role in extinction. Also we all can join others to spread the word through educational campaigns, television advertisements, posters, books, pamphlets etc. We can support citizens action groups that fight against pollution, habitat destruction, commercial and trophy hunting, indiscriminate pest and predator control, and collection of plants and animals for research and home use.

14.6.3 Conservation in India

i) Traditional Approach : Conservation of wildlife in our country was uppermost in the minds of ancient Indians. Early Indian literature including the Hindu epics, the Buddhist Jataka-Kathas and the Panchatantra and the Jain Scriptures preached against violence to even the minute life forms. They are eloquent proof of respect accorded to wildlife in ancient India. Even today there are some communities like Bishnois (in North India) which are totally dedicated for conserving wildlife. It is about 390 year old sect which observes some 29 principles of conservation of plants and animals, especially certain threatened species. In Rajasthan and Haryana, many blackbucks and Khejari trees, which are otherwise rare can be seen around Bishnoi villages.

Among the various conservation practices, some involve protecting entire biological communities such as sacred groves and lakes. Near the temple of Rudra Nath, in the Himalayas several hectares are dedicated to the guardians of the god. In these alpine pastures and rhododendron forests, no lopping, grazing or even trampling with shoes is permitted. In Kerala, coastal evergreen forests now survive only in small pockets dedicated as sacred groves to serpent deities.

Traditionally, aristrocacy would set aside hunting preserves. The practice finds a mention in Kautilya's Arthashastra. Even earlier in third century B.C. Ashoka forbade the slaughter of certain birds in his fifth pillar edict. The Mughal rulers were avid hunters, but kept up the preservation tradition. English tea planters also set up their own hunting preserves, for instance, Eravikulam plateau in the High Ranges of Kerala. Besides, the Gir hunting preserve of the Nawab of Junagarh many of our modern wildlife sanctuaries are much old hunting reservations. The tiger reserves of Simplipal, Bandipur and Ranthambor, the bird sanctuary of Bharatpur and Eravikulam National Park are a few examples.

ii) Modern Approach : Modern nature conservation movement had its origin in the interests of sports persons and naturalists. As the populations of the game animals began to decline steeply, particularly during and following World War II, a number of organisations became concerned with the long-term conservation of wildlife. This effort was spearheaded by the *Bombay Natural History Society*, a premier organisation of sports persons and the naturalists of the country. Their efforts culminated in the establishment of the *Indian Board of Wildlife* and a network of Wildlife Sanctuaries and National Parks. At the end of World War II, the concern for wildlife conservation on a world-wide basis led to the founding of *World Wildlife Fund* largely by European aristocrats. A branch of World Wildlife Fund was also established in India in 1952 and it soon became the premier conservation society.

During the last decade, comprehensive legislation was enacted and action programmes were initiated to preserve wildlife in India. Based on the recommendations of the Indian Board for Wildlife, the main advisory body for wildlife conservation to the Government of India, the Wildlife Protection Act was passed by Parliament in 1972. A special feature of this act is a set of provisions for hunting of endangered species. Today, India has 80 National Parks, 412 Wildlife Sanctuaries and 7 Biosphere Reserves. Some well-known National Parks and Sanctuaries, and the Biosphere Reserves are shown in the Fig. 14.11.

iii) Project Tiger : Project tiger was initiated in 1973, in response to alarming decrease in the population of wild tigers from 40,000 at the turn of the century down to 1827 in 1972. The project was launched by Government of India with a grant of Rs.50 million in cooperation with WWF—India and IUCN who together pledged one million dollars for equipment and experts. Like all reserves, India's tiger reserves too have a core zone free from all human interference. All cattle grazing is stopped in the core zone and people from several villages were moved out, and the tigers were allowed a rome free of human interference. In the beginning of the project that is in 1973 nine tiger reserves were established, with a total tiger population of 268. Today, there are 18 tiger reserves in the country (See Fig. 14.12), and the number of tigers has risen to 4,334 as recorded in 1990. Project tiger is a spectacular landmark in our efforts at wildlife conservation.

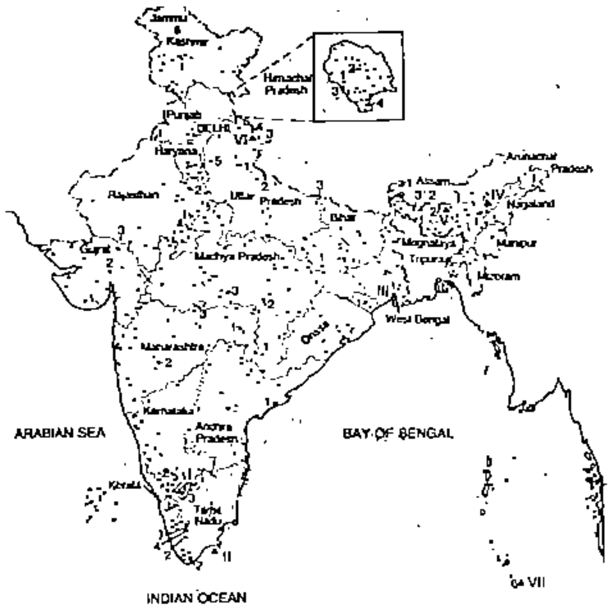


Fig. 14.11 : Biosphere Reserves, National Parks and Sanctuaries in India. For their names see Table 14.3 (a & b).

Table 14.3 a : Biosphere Reserves

I	Nilgiri Biosphere Reserve	V	Manas Biosphere Reserve
II	Gulf of Mannar Biosphere Reserve	VI	Nanda Devi Biosphere Reserve
III	Sunderbans Biosphere Reserve	VII	Great Nicobar Biosphere Reserve
IV	Kaziranga Biosphere Reserve		

Table 14.3 b : National Parks and Sanctuaries. These are marked in the figure by dots, and some of the dots are numbered. These are some well-known National Parks and Sanctuaries. To know their names see the respective number in the particular state.

Andhra Pradesh	1. Kolleru Sanctuary	2. Nagarjunasagar Srisailam Sanctuary	
Arunachal Pradesh	1. Namdapha National Park		
Assam	1. Kaziranga National Park	2. Manas National Park	
Bihar	1. Palamau National Park	2. Hazaribagh Sanctuary	3. Valmiki Nagar Sanctuary
Delhi	1. Indira Priyadarshini Sanctuary		
Gujarat	1. Gir National Park	2. Nalsarovar Sanctuary	
Haryana	1. Sultanpur Sanctuary		
Himachal Pradesh	1. Gobind Sagar Sanctuary 4. Renuka Sanctuary	2. Khokhan Sanctuary	3. Naina Devi Sanctuary
Jammu and Kashmir	1. Dachigam National Park		
Karnataka	1. Bandipur National Park	2. Ranganathittu Sanctuary	
Kerala	1. Eravikulam National Park 4. Idukki Sanctuary	2. Periyar National Park	3. Silent Valley National Park
Maharashtra	1. Tadoba National Park 3. Melghat Sanctuary	2. Great Indian Bustard Sanctuary	
Madhya Pradesh	1. Indravati National Park	2. Kanha National Park	3. Pachmarhi Sanctuary
Orissa	1. Simplipal National Park		
Punjab	1. Abohar Sanctuary		
Rajasthan	1. Ranthambore National Park 4. National Gharial Sanctuary	2. Sariska National Park	3. Mount Abu Sanctuary
Sikkim	1. Singba Rhododendron Sanctuary		
Tamil Nadu	1. Guindy National Park 4. Vedanthangal Sanctuary	2. Kalakad Sanctuary	3. Madumalai Sanctuary
Uttar Pradesh	1. Corbett National Park 4. Valley of Flowers National Park 6. Kedarnath Sanctuary	2. Dudhwa National Park 5. Hastinapur Sanctuary	3. Nanda Devi National Park
West Bengal	1. Sunderban National Park	2. Buxa Sanctuary	3. Jaldpara Sanctuary

Table 14.4 : Tiger Reserves (From Annual Report 1989-90, Ministry of Environment and Forests, Government of India).

S.No	Name of Tiger Reserve	State	Total Area (in sq.km.)
1.	Bandipur National Park	Karnataka	866
2.	Corbett National Park	Uttar Pradesh	521
3.	Kanha National Park	Madhya Pradesh	1,945
4.	Manas National Park	Assam	2,840
5.	Melghat Sanctuary	Maharashtra	1,618
6.	Palamau National Park	Bihar	928
7.	Ranthambore National Park	Rajasthan	825
8.	Simlipal National Park	Orissa	2,750
9.	Sunderban National Park	West Bengal	2,585
10.	Periyar National Park	Kerala	777
11.	Sariska National Park	Rajasthan	800
12.	Buxa Sanctuary	West Bengal	759
13.	Indravati National Park	Madhya Pradesh	2,799
14.	Nagarjunasagar Srisailam Sanctuary.	Andhra Pradesh	2,568
15.	Namdapha National Park	Arunachal Pradesh	1,985
16.	Dudhwa National Park	Uttar Pradesh	811
17.	Kalakad Sanctuary.	Tamil Nadu	800
18.	Valmiki Nagar Sanctuary	Bihar	848
	Total	Area	28,017

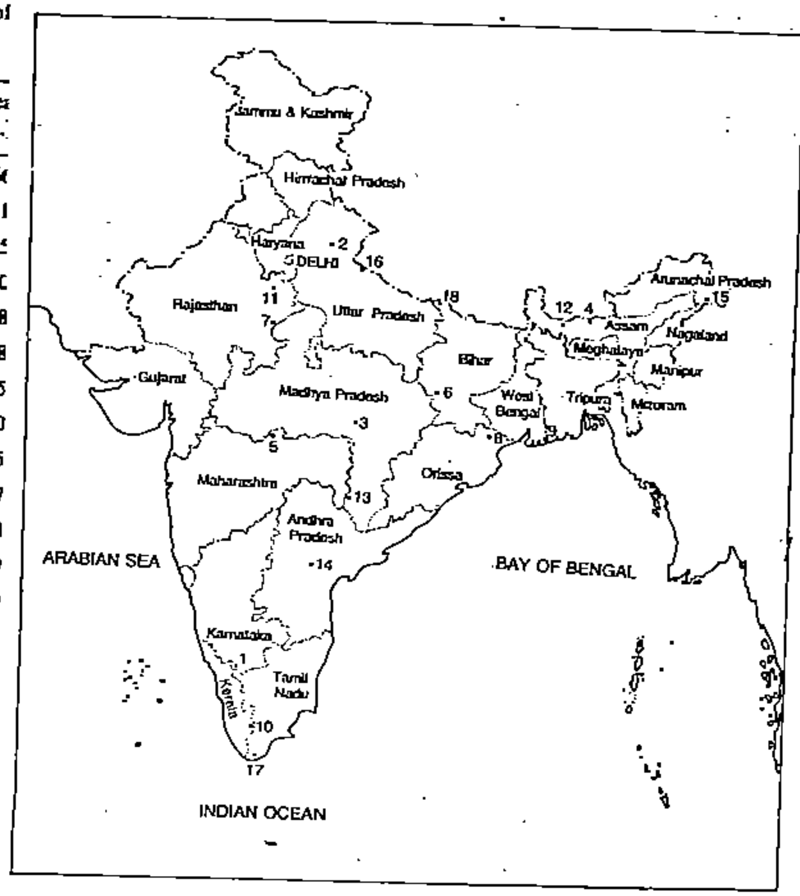


Fig. 14.12 : The Tiger Reserves of our country. See Table 14.4 for more information about these reserves If you see the Tiger Reserve that is numbered 1 in the figure, for its details see S.No. 1 of the Table. Similarly you can read about the remaining 17 Reserves too.

b) India's Biosphere Reserve Programme : The biosphere Reserve Programme was launched on a world scale by UNESCO in 1973, as the Man and Biosphere Programme (MAB). It has led to the creation of over 200 biospheres in about 40 countries so far. In our country Biosphere Reserves have been set in 7 areas (see Fig. 14.11) namely: *Nilgiri Biosphere Reserve, Gulf of Mannar Biosphere Reserve, Sunderbans Biosphere Reserve, Kaziranga Biosphere Reserve, Manas Biosphere Reserve, Nanda Devi Biosphere Reserve,* and *Great Nicobar Biosphere Reserve.*

The most significant aspect of India's Biosphere Reserves Programme is the concept of ecodevelopment. It is an attempt to integrate the restoration of degraded habitats with efforts for water and soil conservation, for reforestation in areas adjoining the reserves, and other programmes of rural development. It also aimed at involving the forest dwellers in such conservation programmes. By bringing direct benefits to local people, ecodevelopment can make them allies in the preservation efforts.

c) The Chipko Movement : The movement to protect trees, is a unique and well known movement of conservation. The story of how this movement started is this. The Chipko movement was born one morning in March 1973 in the remote hill town of Gopeshwar in Chamoli District. On that fateful day, representatives from a sports goods factory situated in Allahabad reached Gopeshwar to cut 10 ash trees near village Mandal. The villagers courteously told them not to do so but when the contractors persisted they hit upon the idea of hugging the ear-marked trees. Therefore, the next day the sports good manufacturers had to return empty-handed.

Some weeks later the same contractor surfaced at Rampur Phata, another village some 80km away from Gopeshwar, with a fresh allotment from the forest department. As soon as the villagers of Gopeshwar learned of this, they marched to Rampur Phata with drums and songs, gathering more people on the way. A confrontation ensued and the agitators hugged the ear marked trees to foil the contractors once again.

The Chipko movement reached its climax in 1974 when the women of village Reni, some 65km from Joshimath got involved in a dramatic way. One day, when their men were away in Joshimath protesting against the auction of a forest neighbouring Reni, the contractor arrived at the village to begin felling, taking this as an opportune movement. Undaunted by the number of men or their axes, the women of Reni, led by Gaura Devi, an illiterate woman of 50, barred the path to the forest which went through the village. As the women stood there, they sang: "This forest is our mother's home, we will protect it with all our might."

The genesis of the Chipko movement has both an ecological and an economic background. The Alaknanda valley in which the movement originated was the scene of an unprecedented flood in 1970. The tragic aftermath of this flood left a deep impression on the hillfolk and, with it, soon followed the appreciation of the vital ecological role that forests play in their lives.

Two leaders — Chandi Prasad Bhatt from Gopeshwar and Sunderlal Bahuguna from Silyara in Tehri region have contributed immensely in making it a big success and also spreading it. They realised that if the local village communities have the right to control their surrounding resources they must also undertake to conserve and develop these resources. Eventually, these two leaders organised one of the country's largest afforestation programmes. Today, the Chipko movement has come a long way and is internationally known. *Now it is not confined to tree protection or plantation only, but also concerns itself with the safety and preservation of the environment as a whole including the habitat and the wildlife therein.*

d) The Appiko Movement : This is a successful conservation movement of south India, and it originated in Karnataka. Karnataka's Uttara Kannada which forms part of the Western Ghats is known as the "forest district". At the time of Independence as much as 82 per cent of the district was covered with forests rich in teak trees. So a large number of forest-based industries mushroomed there resulting in massive tree felling. Also, many big dams were built in the area, that submerged vast tracts of land. All these activities combined, led to drastic drop in forest cover to 20 per cent in 1983-84. Consequently, not only the soil in the area degraded, but also the hydrology was affected. The denudation in Uttara Kannada has destroyed the ecological balance between agriculture and nature. A great impact has been felt on the microclimate also. Earlier, this area had a typical microclimate that was highly suitable for cash crops such as black pepper and cardamom. But in the recent years the microclimate deteriorated and affected the cultivation of spices.

Waking up to the destruction of forests, the local people especially youth were motivated into direct action. They appealed to the people involved in clearing the forests. However, their appeal was ignored. Then the villagers decided to launch the popular Chipko movement. They took oath to protect trees the same way as the Chipko movement activists did. Pandurang Hegde is the leader of this movement. In the recent years the movement also spread to Coorg, Dakshina Kannada and Shimoga districts. The three main objectives of the movement are popularly known in Kannada as 'ulisu' (to conserve); 'belesu' (to grow) and 'balasu' (rational use).

To sum up, Appiko movement has created a mass awakening about conservation in South India and particularly in Karnataka, emphasising the need to involve the local people in saving the Western Ghats.

Critical resources ....

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Captive breeding ....

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Biosphere reserves ....

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SAQ 6

Why there is a need to conserve wildlife? Explain from the angle of human beings. Write your answer in points, with brief description in the space provided below.

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14.8 SUMMARY

In this unit you have learnt that:

- Degradation of ecosystems is brought about by several human activities such as: i) deforestation (due to shifting cultivation; several kinds of development projects; consumption of firewood; raw material for industries; pests, diseases, natural calamities; and defense activities), ii) overgrazing by the domesticated animals, iii) agricultural activities, iv) mining and associated activities, and v) urbanisation.
- Wildlife refers to all forms of life, including the microorganisms of an ecosystem which grow and survive on their own, that is, without human intervention.
- The existence of wildlife is threatened by: i) hunting activities of man; ii) elimination or disturbance of natural habitats of wildlife; iii) selective destruction of species; iv) domestication; v) introduction of new species in an ecosystem; vi) excessive use of pesticides; vii) various kinds of pests; ix) heavy demand of species to be used in medical research and for collection in zoos.
- *Extinct species* are those that could not survive the changed conditions of their environment, so they all perished. *Threatened species* are likely to become extinct if their environment deteriorates further, or their crucial requirements are not met with. *Endangered species* cause concern because their numbers are few or/and their homeland is too small. The *depleted species* are those whose numbers have decreased in the recent years and are continuing to decrease. *Indeterminate species* are organisms about whom not enough information is available to make an accurate estimation of their status. *Out of danger species* — whose existence was in danger, but now they are safe.
- The Red Data Book gives information about the various categories of threatened species. It is issued and continually updated by IUCN.

- Wildlife conservation requires actions in the following spheres: habitat conservation; provision of critical resources; captive breeding programme; development of reserves; control of the introduction of alien species; check on pollution; research and documentation; legal actions; and last but not the least — public participation and awareness.
- In our country conservation has both traditional as well as modern approach. Chipko movement, Appiko movement, Project Tiger and the Biosphere Reserve Programmes are testimony of our commitment towards conservation of ecosystems and the life therein.
- Conservation of wildlife is important because of their: economic importance, medicinal value, use in medical research, potential genetic reservoir, ecological role and aesthetic and recreational significance.

14.9 TERMINAL QUESTIONS

1. In the alphabet square given below, there are 21 words which you have studied in this unit. We have outlined a word — "biomass", to show how to go about doing this game-exercise. Can you now identify the remaining 20 words? List them in the space provided below.

w	i	l	c	l	l	t	e	n	o	p	r	s	s	q	z
e	m	j	h	u	m	n	r	e	s	e	r	v	e	s	q
e	i	n	i	m	i	p	a	s	b	s	c	d	e	p	a
n	d	i	p	j	c	k	a	l	m	t	o	s	p	e	p
d	e	e	k	p	r	m	t	u	v	i	w	x	a	l	p
a	c	e	o	d	o	d	o	w	x	c	n	q	g	e	i
n	e	f	g	j	c	q	s	r	t	i	a	i	o	y	k
g	c	f	b	p	t	r	z	s	g	d	f	j	n	g	o
e	y	r	e	s	i	n	s	a	c	e	d	k	v	g	m
r	e	n	d	e	m	i	c	r	q	s	s	t	d	u	a
e	h	o	r	n	a	d	a	y	o	y	g	z	x	m	k
d	n	t	q	v	t	n	u	n	d	r	y	t	a	s	m
p	o	r	a	r	o	c	h	o	m	j	p	i	l	i	a
r	s	u	d	e	f	o	r	e	s	t	a	t	i	o	n
a	g	r	o	c	h	e	m	i	c	a	l	s	o	x	y
e	h	a	e	m	o	p	h	i	l	i	a	j	n	a	d

2. Write a significant line about each of the above words *in context of this unit.*

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14.10 ANSWERS

Self-Assessment Questions

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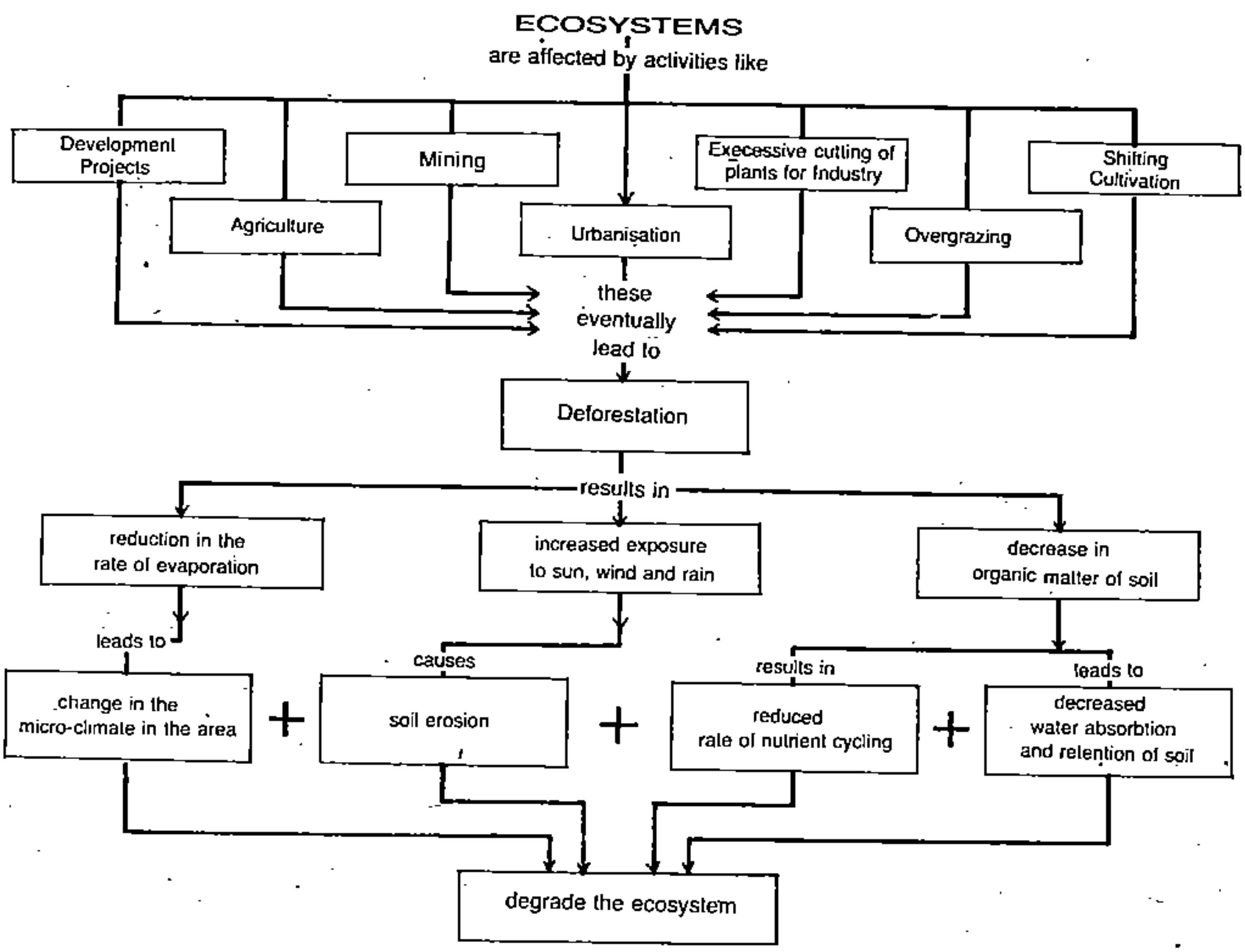


2) d

3) i) c
ii) f
iii) N
iv) a
v) d
vi) b
vii) e
viii) g

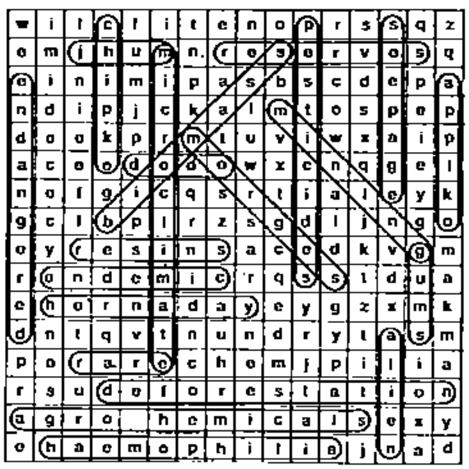
4) I) f
II) d
III) a
IV) e

5) If you are stuck up with any point you are advised to go through Subsection 14.6 again.

6) Refer to Section 14.7 for the major points and their description.

Terminal Questions

1.



These 20 words are: jhum, chipko, endangered, microclimate, morges, reserves, pesticides, seepage, appiko, gum, mining, haemophilia, resins, hornaday, rare, deforestation, agrochemicals, endemic, dodo, alien.

2. i) jhum — shifting cultivation prevalent in several parts of the country

ii) chipko — a movement for conservation, that started in Uttar Pradesh

iii) endangered — species in imminent danger of extinction

iv) microclimate — adversely affected by deforestation

v) Morges — in Switzerland, where International Union of Conservation of Nature is located

vi) reserves — areas earmarked for the conservation of wildlife therein

vii) pesticides — their indiscriminate use causes damage to the ecosystem and the life therein

viii) seepage — problem associated with many irrigation projects that causes degradation of environment

ix) appiko — conservation movement that started in Karnataka

x) gums — important forest produce

xi) mining — removal of earth's crust for extracting minerals and ores, ultimately degrading the ecosystem

xii) haemophilia — Florida manatee, an endangered animal, used for research on this disease

xiii) resins — commercially important forest produce

xiv) Hornaday — associated with the origin of the term wildlife

xv) rare — species that are small in number or are found in particular kind of environment

xvi) deforestation — removal/destruction of vegetation cover of an area by various means

xvii) agrochemicals — pesticides, fertilisers etc., whose non-judicious use has caused adverse effect on the ecosystem

xviii) endemic — species occurring only in a restricted area having particular kind of environmental conditions

xix) dodo — an extinct bird of Mauritius

xx) alien — species introduced to new areas, some of which have adversely affected the species already present there

UNIT 15 ENVIRONMENTAL POLLUTION: CAUSES, CONSEQUENCES AND CONTROL

Structure

15.1 INTRODUCTION

Since the Industrial Revolution, human society has made great progress in technical and industrial spheres. There is considerable growth in coal production, energy generation, petrochemicals, fertilisers, pesticide and chemical industry. These are likely to increase further in years to come. This has been accompanied by considerable degradation of the environment due to large quantities of gaseous, liquid and solid wastes generated by industry and other human activities. Environmental pollution affects human health directly or indirectly by undermining the life support systems of our biosphere.

In this unit, we will illustrate how human activities degrade the environment by polluting air, water and soil. Excess levels of noise and radiation in our environment are also harmful and are referred to as noise pollution and radiation pollution. We will discuss the effect of pollutants on human health, plants, ecosystems, materials and global climate. We will also explain the problems caused by noise and radiation pollution.

Objectives

After studying this unit you should be able to :

- list the major pollutants and their sources,
- list the human activities resulting in pollution and deterioration of environment,
- illustrate with examples the effects of various pollutants on health, plants, ecosystems, climate,
- list the causes of water and land pollution and explain with examples the problems of pollution of lakes, rivers, groundwater and oceans,
- describe the causes and consequences of noise and radiation pollution,
- discuss the control of pollution.

15.2 POLLUTION

Let us first define pollution. **Pollution** refers to any undesirable change in the physical, chemical or biological characteristics of our environment, i.e. air, water and soil that may or will adversely affect humans or other species and life support systems of our biosphere directly or indirectly. A substance whose introduction into a resource damages the latter's usefulness is called a **pollutant.**

Pollutants are grouped into two broad categories: i) biodegradable pollutants and ii) non-biodegradable pollutants. As you have learnt in Unit 16 of FST-1 course, **non-biodegradable** pollutants such as heavy metals, pesticides, move through the food chain and may get magnified to dangerous levels in higher trophic level organisms. Some of these combine with other compounds and produce toxic substances. However, **biodegradable** materials such as human and animal wastes, agro-based residues and fertilisers can also pose a threat if their quantities or inputs exceed the assimilative capacity of the environment.

15.3 AIR POLLUTION

The threat due to air pollution became apparent only when some severe episodes caused human casualty in USA, Britain (London) and Japan. In 1948 in Donara town of USA twenty people died and thousands became ill due to prolonged trapping of pollutants in the atmosphere emitted from steel mills and zinc smelter plants. In 1952 nearly 2,500 people died in London when the city got enveloped by sulphuric acid vapours, particulate matter and sulphur dioxide. As you know one of the most tragic episode in history occurred in December 3rd, 1984 at Union Carbide in Bhopal when approximately 36 tonnes of methyl isocyanate (MIC), an extremely poisonous gas used in the synthesis of sevin—a pesticide, escaped shortly after midnight from a storage tank and spread like mist and cloud over the city. The poison caught people in their sleep, awakening them in choking pain, terror and panic. Many got killed during sleep. It is estimated that around 10,000 people died and more than 2,00,000 were injured. Many survivors suffer from permanent respiratory illness and impairment of vision.

15.3.1 Causes of Air Pollution

You have learnt in Unit 2 about the composition of atmosphere, its major and minor constituents. The composition of atmosphere has remained the same for thousands of years. However, only in the last 100 to 200 hundred years some changes have occurred and their impact on the biosphere is alarming. The major constituents of air N_2, O_2 and inert gases that comprises about 99.9% have not changed. But some minor and trace constituents such as sulphur dioxide (SO_2), oxides of nitrogen N_2O, NO, NO_2 (NO_x) methane (CH_4) chlorofluorocarbons (CFCs) alongwith carbon dioxide (CO_2) unburnt hydrocarbon and suspended particulate matter (SPM) have increased. You know that these are the major air pollutants responsible for the deterioration of air quality.

Various oxides of nitrogen can be represented as NO_x

In order to comprehend the problem of air pollution we must find out the following:

i) the sources of pollutants,

ii) the reasons behind emission increases in the recent past and

iii) their trends in future.

Finally, we must find ways to prevent and control air pollution.

The diagram given on the next page shows the major air pollutants and their sources.

The pollutants listed in Figure 15.1 do not include thousands of hazardous chemicals, and their toxic intermediates, fumes of poisonous metals like lead, mercury and cadmium. They cause localised pollution affecting area and people around.

From the above list you can see that the air pollutants can be broadly classified into the following two categories:

i) **Primary Pollutants**—Pollutants released into the environment as a result of some natural and/or human activity, e.g., carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, suspended particulate matter and hydrocarbons.

ii) **Secondary Pollutants**—Pollutants formed by the chemical interaction of primary pollutants with atmospheric gases and moisture, often catalysed by sunlight are known as secondary pollutants e.g. ozone (O_3), peroxyacyl nitrates (PAN), aldehyde, sulphuric acid and nitric acid. These are formed by reactions given below:

Pollutants	**Sources**
Oxides of Carbon CO_2 and CO	Use of coal and oil for energy production, manufacturing and transport Biomass burning - burning of forests and savannah grasslands for pasture and cropland
Oxides of Sulphur SO_2 and SO_3	Burning of coal containing sulphur Ore smelting - for extraction of metals like Cu and Fe from their sulphide ores Industrial processes Municipal incineration
Oxides of Nitrogen N_2O, NO and NO_2	Use of petrol and diesel for transport vehicles Burning of fuel at the stationary sources Nitrogen Fertilisers Burning of biomass
Methane and Other Hydrocarbons	Burning of fossil fuel Rice cultivation Breeding of domestic animals Burning of forests and savannah grassland Municipal land fill Microbial activity of sewage
Suspended particulate matter (SPM)	Formation of soot, smoke on burning of coal Transport vehicles - raise dust and release smoke Building construction Stone crushing
Chlorofluoro-carbons and chloro compounds	Referigerents, aerosol sprays, Foam plastic for making disposable fast food containers
Photochemical oxidants Ozone and PAN	Photochemical reactions in the lower troposphere, reactions of oxide of nitrogen and hydrocarbons with oxygen

Fig. 15.1 : Major air pollutants and their sources

$$NO_2 + h\nu\,(\text{light}) \rightarrow NO + O$$
$$O_2 + O \rightarrow O_3$$
$$HC(\text{Hydrocarbon}) + O \rightarrow R^0 \text{ Hydrocarbon (radical)} + RCHO \text{ (aldehyde)}$$
$$HC + O_3 \rightarrow RCO_2 + RCHO$$
$$RCO_2 + NO \rightarrow RCO + NO_2$$
$$RCO + NO_2 + O_2 \rightarrow R\text{-}\overset{O}{\overset{\|}{C}}\text{-}O\text{-}O\text{-}NO_2 \text{ (peroxyacyl nitrate)}$$
$$SO_2 + O \rightarrow SO_3$$
$$SO_3 + H_2O \rightarrow H_2SO_4 \text{ (sulphuric acid)}$$
$$NO + O \rightarrow NO_2$$
$$NO_2 + H_2O \rightarrow HNO_3 \text{ (nitric acid)}$$

Pollution sources can be **stationary** or **mobile.** Power plants, manufacturing units are examples of stationary sources, whereas transport vehicles represent **mobile sources.** Pollution due to stationary sources depends upon the location, emission level and quantity of emission from the source. Hence it is possible to install and control a stationary source according to the required air standards quality of that region. Pollution from mobile sources is difficult to control. However, their quantities can be greatly reduced by improving engine design and proper maintenance of the automobiles.

The major causes of air pollution include the following human activities; (i) fossil fuel consumption, (ii) motor transport, (iii) modern agriculture and (iv) industry.

Fossil fuels provide us with energy for cooking, power generation, transport, manufacturing, heating, cooling and lightening our houses and for many other purposes. Among fossil fuels coal and oil are the major sources of energy. As we know coal on combustion produces CO_2. Incomplete combustion yields CO and a variety of hydrocarbons including methane and soot (carbon particles of various sizes, the large ones make up dust and small ones make smoke). Most other fuels except gas contain sulphur and unburnable contaminants. Therefore, burning of coal produces SO_2 and ash also. About 60% of SO_2 emission is due to burning of coal.

You often see trucks, buses, cars, two wheelers and three wheelers belch black smoke from their exhaust. Transport vehicles contribute to NO_x, CO and hydrocarbon emission. They also emit lead because tetramethyl lead is added to petrol as antiknock substance to increase engine efficiency.

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

ammonium nitrate → nitrous oxide

Agricultural activities too, are a major cause of air pollution. About 60 to 65% of carbon dioxide is produced from burning of forests and savannah grassland to clear areas for pastures and cropland and 40% of methane is produced from paddy fields, guts of livestocks and also from burning of biomass. Methane is produced in the guts of livestock on break-down of organic matter by anaerobic bacteria. Nitrous oxide is produced from nitrogen fertilisers, livestock wastes and biomass burning. Hence, we find that all the primary occupations of man—agriculture, animal rearing, lumbering, mining etc. cause pollution of air.

Industrial activity mainly smelting of some metal ores produces **large quantities of** SO_2. Chemical manufacturing units produce thousands of hazardous chemicals. Among these chlorofluorocarbons top the list. These are non-biodegradable with a long life ranging from 7 to 10 years. Before being washed out of the atmosphere each 10 chlorine atoms destroy as many as one million molecules of ozone.

Chemical plants are a large source of industrial emission of toxic air pollutants responsible for about 35% of the total emission. Other major sources are paper, plastic, rubber, automobile industry. Chemical manufacturing units today produce thousands of chemicals along with a number of byproducts that may or may not be useful. Many of these products are carcinogenic. Tobacco smoke, asbestos fibres, nitrosoamine, dioxine, polychlorinated biphenyls (PBCs) and pesticides are the major environmental contaminants.

Suspended particulars matter (spm) is a major air pollutant. Dust is generated from various sources such as coal dust—from power plants, petro coke, oil refineries; cement dust—from cement factories; silica dust—from stone crushing, building construction, etc. A large amount of dust is also blown by transport vehicles. In India, about 80 million tonnes of fly-ash is generated from coal fuelled power plants annually. The country has over 10,000 stone crushers. All these put together let out 1,000 tonnes of stone dust daily in the atmosphere. These particles may remain in the air for a long time.

Since the middle of 19th century the consumption of coal has been extremely high. According to estimates by Miking Hubbert of the U.S. Geological survey, coal supply can serve as a major source of world's industrial energy for another two to three centuries and petroleum can last only for another 70 to 80 years.

Estimates show that the level of air pollution has been increasing since the turn of this century and it will continue to increase if strict measures for its control are not exercised. Can you think why it is so?

Projected Number of Vehicles and Pollution Load in different cities

Name of the City	No. of vehicles	Pollution load (tonnes/day)
Delhi	1599000	1319.96
Bombay	576400	460.80
Calcutta	453400	357.35
Hyderabad	453133	357.13
Ahmedabad	415500	325.48
Madras	415000	325.06
Bangalore	391500	305.30
Pune	279500	211.10
Jaipur	214270	156.25
Lucknow	192600	138.02
Kanpur	160000	110.61
Nagpur	141500	95.05
	7219233	4162.11

Source: Central Pollution Boards document (CPCB) 1988-1989.

The progress and economic development of a nation depends upon the availability of energy. The standard of living maintained by countries like USA, Germany, Japan and some other industrialised nations is largely due to energy access and consumption. They use more than 70% of the world's commercial energy. The share of energy for developing nations is small. Now the world demand for energy is increasing. The world energy consumption rose from 21 exajoule (1 exajoule = 10^{8} joule) in 1900 to 318 exajoule in 1988. Coal, oil and natural gas supply 88% of energy and nuclear energy supply the rest. Now there is growth in energy consumption in developing countries also. Increase in energy production means increase in levels of CO_2 NOx, SO_2 CO and particulate matter. Similarly, industrialisation, modern agriculture, transport vehicles have grown sharply in the latter half of this century and have contributed enormously to air pollution.

In India, during 1947 the total power generation capacity was about 1400 MW. By the end of 1988-89 power generation capacity increased to about 59,000 MW. The consumption of fertilisers in India has also increased from 0.69 lakh tonnes in 1950-51 to 922 tonnes in 1986-87. There has been considerable growth in industrial sector also. Such activities increase the levels of air pollutants.

The intensity of pollution can be expressed as mg/m^3 or part per million (ppm) which means the number of cubic cm of the gas in a cubic metre. The relationship between the two is

$$ppm = mg/m^3 \times \frac{22.4}{\text{MW of pollutant gas}}$$

The level of SO_2 and dust particulates measured in 10 large Indian cities show that the concentration of SO_2 (60 $\mu g/m^3$) in Ahmedabad and Calcutta and the quantity of dust (200 $\mu g/m^3$) in Bombay, Calcutta, Delhi, Kanpur and Hyderabad exceeds the allowable limits. Higher level of emission of NOx, CO and hydrocarbons can also be expected in future because of increase in the number of motor vehicles. In Delhi, the total calculated vehicular pollution has increased from 424 tonnes/day to 865 tonnes/day during 1980-81 to 1986-87.

Before we finish this section let us look at Figure 15.2 showing the concentrations of these pollutants in the past 100 years and their estimated concentrations in year 2030. The amounts are expressed in parts per billion.

SAQ 1

a) Make a diagram to show the sources of primary pollutants and the formation of secondary pollutants in the atmosphere.

b) List the reasons for the increase in the emission of air pollutants in the recent past.

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	Average Concentration 100 years ago (Parts per billion - PPB)	Approximate Current Concentration (PPB)	Projected Concentration in year 2030 (PPB)
CO	? N. Hem. 40 to 80 S. Hem. (Clean Atmospheres)	100 to 200 N. Hem. 40 to 80 S. Hem. (Clean Atmospheres)	Probably Increasing
CO_2	290,000	350,000	400,000 to 550,000
CH_4	900	1,700	2,200 to 2,500
NO_x	.001 to ? (Clean to Industrial)	.001 to 50 (Clean to Industrial)	.001 to 50 (Clean to Industrial)
N_2O	285	310	330 to 350
SO_2	.03 to ? (Clean to Industrial)	.03 to 50 (Clean to Industrial)	.03 to 50 (Clean to Industrial)
CFCs	0	about 3 (Chlorine atoms)	2.4 to 6 (Chlorine atoms)

Fig. 15.2: Concentrations of air pollutants 100 years ago and their projected concentration in year 2030. (Source: Compiled from Sc. Amer 1989, 261 Page 62)

15.3.2 Consequences of Air Pollution

The physiological effects of toxic pollutants on living beings can be of two types: (i) acute effects and (ii) chronic effects.

i) **Acute effects** are immediate but short-lived. They occur when the victim is exposed to a high concentration of toxic pollutant for a brief period. For example, we experience headache while travelling on a busy road. This is due to exposure to carbon monoxide released from transport vehicles. Acute effects result when a pollutant is released in abnormally large quantities e.g. accidental release of poisonous methyl isocyanate gas from the pesticide plant in Bhopal.

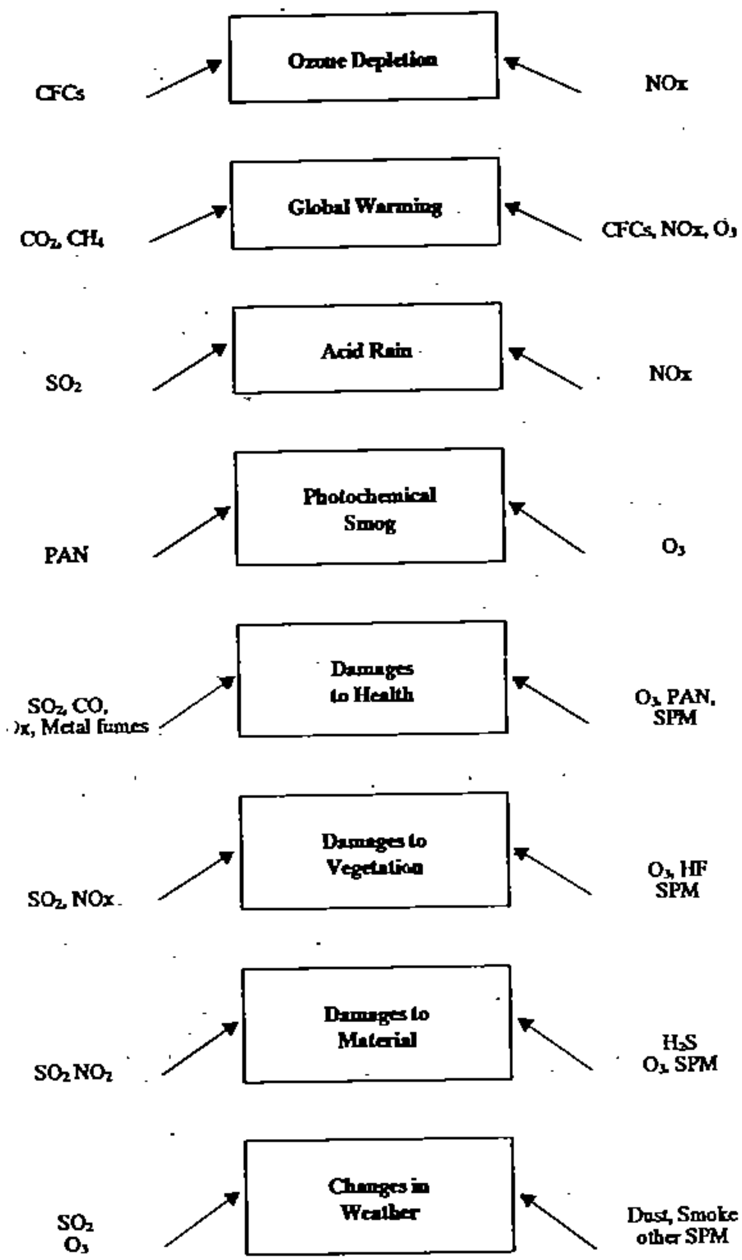


Fig. 15.3 : Effects of major air pollutants

ii) **Chronic effects** are due to short-term exposure for a long period. The effects appear after months or years. For example, exposure to SO_2 may give rise to chronic bronchitis, pulmonary fibrosis or exposure to coal dust may give rise to black lung.

We have broadly outlined the consequence of air pollution in Figure 15.3. You have briefly learnt about them in the FST-1 course. Here you will study them in greater detail. Let us begin with effects on health.

Effects on Health

Since the air pollutants are inhaled they attack various parts of the respiratory system on their route to air sacs. Once they reach the blood, they circulate throughout the body and reach the target organs. The extent of damage depends upon a particular pollutant, its concentration in the air and exposure time. Our body's defence mechanism helps to eliminate them. However, exposure to high level, overloads and degrades the body's defence mechanism.

Evidences show that air pollutants are linked with respiratory and some other diseases in human beings. Sulphur dioxide is a major contributor to lung diseases. It causes irritation to nose and mucous lining, shortness of breath, tissue fluid accumulation, swelling (edema) and bronchospasm. These are the acute effects. Long-term exposure may result in respiratory diseases like—chronic bronchitis, aggravated asthma, emphysema, pulmonary fibrosis and increased stress on heart. Particulate matter potentiates the effect of SO_2. The gas settles on the particles and reaches the deeper parts of respiratory system. Hence the toxicity of low concentration of SO_2 can significantly increase.

The exhaust of buses, trucks and two wheelers causes eye and lung irritation. This is due to oxide of nitrogen. Inhalation in large amounts may give rise to gum inflammation, internal bleeding, pneumonia and cancer. NO_x oxidises lipids in the cells. So the cell membranes are disrupted leading to respiratory edema.

Carbon monoxide is one of the most poisonous gases. When it enters blood circulation it competitively inhibits the combining of oxygen with haemoglobin. Its affinity for haemoglobin is more than 200 times that of oxygen. That is why even extremely low levels of CO are not safe. High concentrations of CO slow down physical and mental activities and may cause asphyxiation, heart and brain damage.

Ozone and peroxyacyl nitrate (PAN) have a remarkable degree of biological activity. Even very small concentration of PAN or ozone causes irritation of eyes. Ozone causes cough, headache, weakness, difficulty in breathing, bleeding, dry throat and constriction of respiratory passage and weakens the lung tissues.

The effects of particulate matter depend upon its nature and size. They cause irritation reactions. Fumes of toxic metals like lead, mercury, zinc and manganese as well as oxides of antimony, arsenic, copper etc. are extremely harmful. Lead damages brain of young children and can cause death. In adults it affects kidneys, blood and liver and can impair the functioning of nervous system. Inhalation of mercury vapours is more dangerous than its digestion. Chronic exposure causes lesions of the mouth and skin and neurological problems. Dust of coal, asbestos, fine fibres of sugar cane, cotton, flax and hemp etc. cause respiratory problems. A long-term inhalation may cause respiratory diseases known as pneumoconioses. So you see that the effects of air pollutants on health are extremely severe. Hydrocarbons like benzypyrene, benzene, chlorinated hydrocarbons, polybiphenyl chloride and many other compounds cause cancer. Air is also polluted due to smoking. Lung cancer, various respiratory and cardiac problems are linked with smoking. Non-smokers have as much risk if they live around a smoker.

Accidents in chemical plants are often reported in the newspapers. A large number of people are affected because pollutants get released in large quantities and cause acute health effects.

Effects on Plants

Air pollutants cause severe damage to the plants because gases such as SO_2, NO_2, O_3 and PAN enter the leaves through stomata and adversely affect important metabolic processes such as photosynthesis, respiration, transpiration as well as overall plant performance. Pollutants can also break down the waxy coating on the leaves that helps to prevent excessive water loss and damage from pests, diseases, draught and frost.

Air pollutants—SO_2, O_3 and NO_2 are strong oxidants and can bring about significant changes in plant cell chemistry. The general effects of pollutants are as follows: i) damage to leaves, ii) inhibition of photosynthesis, iii) reduced nutrient uptake, iv) leaching of plant nutrients in soil, v) release of poisonous metal ions that are normally bound to the soil and vi) killing of essential microorganisms in the soil.

Sulphur dioxide results in foliar injury necrosis, margin and tip burning, chlorosis, defoliation, supression in overall growth, reduction in fruit production and yield. Major damages to vegetation have been observed in industrial areas. Results also point out that low concentrations of SO_2 are incorporated as nutrients in the plant tissue depending upon the S-nutrition state of the plant. You may know that sulphur is a component of many of the proteins, some coenzymes and hormones. In the light of the above results the possibility of using SO_2 in the air as a source of fertiliser is being explored.

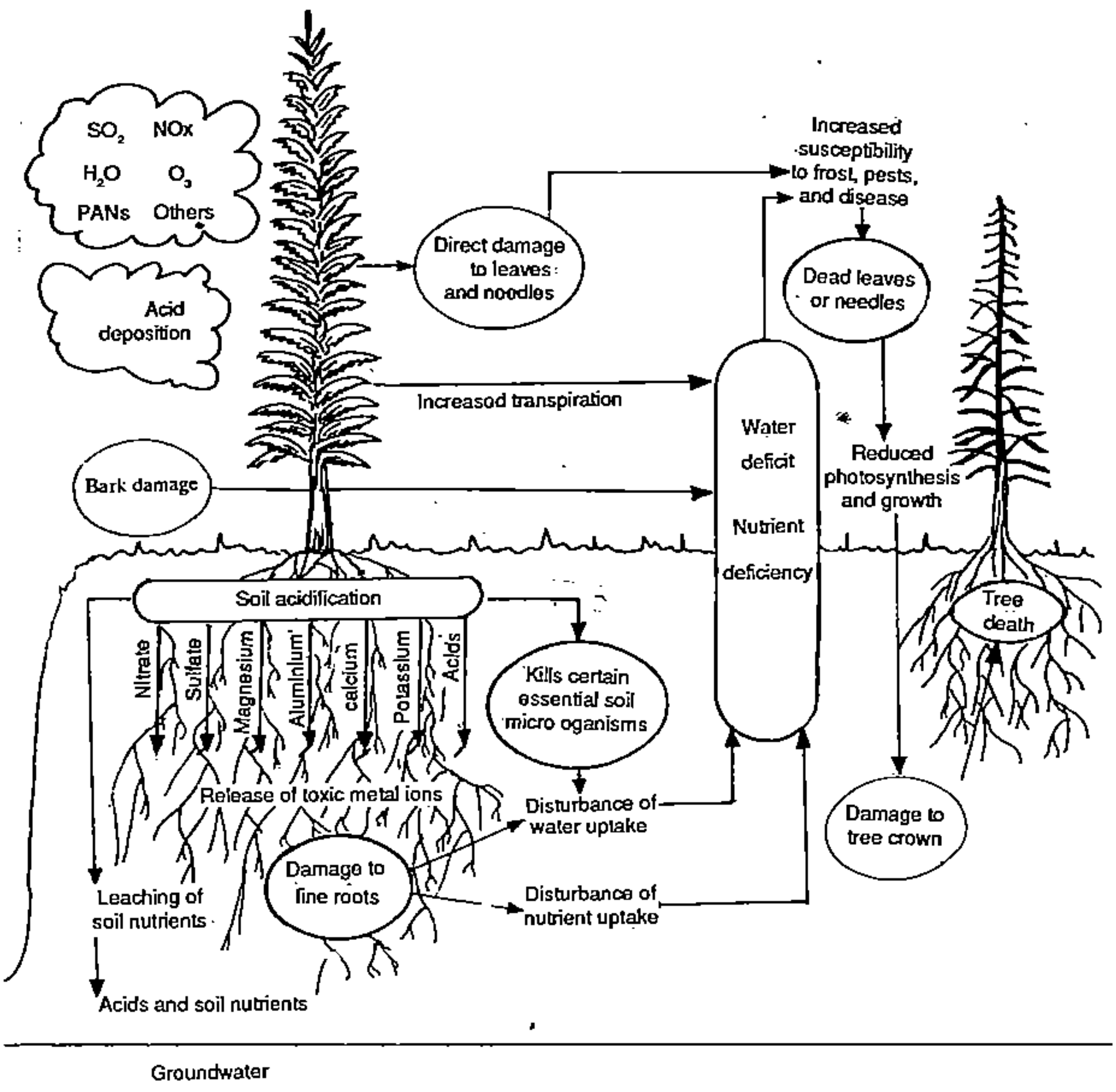


Fig. 15.4: Effects of air pollutants on plants

Particulate matter such as cement, coal, petro coke, dust, and fly-ash screen the light and thus change its quantity and quality. Dust plugs stomata and decreases exchange of gases and transpiration. On wet plant parts dust gives alkalinity to the surface. However, some studies indicate that low concentration of fly ash can enhance the plant growth and may be considered desirable supplement to fertilisers.

Ozone causes chlorosis, spotted leaves due to oxidation, burning of leaf tips, weakening, early leaf fall, reduction in growth and yield. Ozone harms leafy vegetables, field crops, fruits and forests trees. Tobacco is highly sensitive to ozone. Oxides of nitrogen oxidise chlorophyll resulting in chlorosis, leaf damage. They may cause reduction in growth, yield, and fruit fall.

Since air gets contaminated with several pollutants evolved from a single source, damages result from the cumulative effect of two or more gases. Moreover, the observed symptoms cannot be distinguished from those due to physiological stress factors such as light, temperature, humidity, nutrients etc.

Synergetic effect the combined effect of two chemicals is greater than the sum of the effects of two components taken individually.

Mixtures of gases, SO_2 and O_3 SO_2 and HF show synergetic effects. We have mentioned earlier that particulate matter potentiates the effect of SO_2.

Acid deposition can leach vital plant nutrients such as calcium from the soil by forming insoluble salts. It can also release aluminium ions bound to the soil into soi water. Aluminium ions damage fine root hairs, thus reducing absorption of water. Increase in pH kills essential soil microorganisms. Acid deposition can change ion uptake in plants. The effects of pollutants on plants are illustrated in Fig.15.4.

Air pollutants in general are injurious to plants. However, certain species of plants respond to pollutants more than others. For instance, mosses and lichens are highly sensitive to air pollutants and get severely damaged by low levels that do not induce responses in human and other animals. The highly sensitive nature of lichens, mosses and other plants have been used to indicate pollution levels. Such plants are often referred to as **bioindicators** of air pollution.

Scientists in our country are working on plants, particularly higher plants, in order to identify species for degree of susceptibility, tolerance/resistance etc. The identified tolerant species can be used for landscaping polluted areas, while susceptible intolerant species can be used as bioindicators of pollution.

You have learnt that pollutants affect plants adversely. However, plants can also be used for controlling pollution. Certain plants collect dust and thus filter out dust, soot, smoke and many other particulate matter in the air. Evergreen trees with simple leaves having rough and hairy surface are better dust collectors than deciduous trees with compound leaves having smooth surface. Such trees can be used as green belt for abatement of pollution.

Effects on other organisms

You know that biochemical and physiological processes in other animals, particularly in mammals are similar to human beings. So we can presume that wildlife and domestic animals if exposed to pollutants will be affected equally. It has been shown that animals grazing along major highways are poisoned by lead from automobile exhaust. Livestock pastured in and around smelters are poisoned with metals. Poisoning due to lead, fluoride and arsenic causes damages in farm animals.

Effects on Ecosystem

The effects of pollutants on ecosystem become visible after a long period of exposure. In highly industrialised countries the vegetation has been exposed to pollutants for several years. Consequently their devastating effects on terrestrial and aquatic ecosystem has long been observed. These are mainly due to wet (acids like sulphuric and nitric acid dissolved in water) or dry (gases affecting directly vegetation and soil) deposition of acid in combination with other air pollutants such as O_3, hydrogen flouride (HF) and particulates. We had explained acid rain and its effects in FST-1 course. Acid rain is defined as the precipitation of water in the form of rain or snow that possesses a pH between 5.7 and 3.0.

A world-wide destruction of forests has been observed because of acid precipitation and other interrelated changes in the second half of this century. The forest deaths in European countries and United States amount to 7 million hectares. In Germany, the trees of coniferous and deciduous forests stand stark naked, deformed or dead.

Some of the trees are covered with lichens and the fruiting bodies of decomposers. The condition of trees is quite frightening. The forest floor is covered with dry brittle, pealing branches of uprooted trees. Trees such as spruce, pine, birch, ash, alder, maple and oak are among the dead. In 1985, the cost of forest death in Germany was estimated at $ 1 billion. A long-term reduction in radial growth of many kinds of trees is observed in United States. The most severely affected forests were located on the windward slope of mountains enshrouded in cloud or fog and had been under stress for sometime. The damage caused are due to ozone and other photochemical oxidants, sulphur dioxide, deposition of nitrogen compounds, acid precipitation, heavy metal deposition and organic chemicals. In the previous section we have already explained how air pollutants affect plants directly or indirectly by changing nutrient status of the soil. However, our understanding of the acid rain phenomena and its ecological effects is fragmentary. Acid rain affects yield, resistance and species diversity of terrestrial ecosystem.

The severe impact of acid rain on aquatic life of fresh water lakes has been observed in areas where the surrounding soil has little buffering capacity. In Sweden, Canada, Norway, North eastern United States and Scandinavian countries thousands of lakes are devoid of fish. In Sweden alone over 3,000 lakes are already dead i.e., without fish, frog, lily pad or other aquatic organisms, except for some species of acid tolerant algae. The main effects of acid rain on a lake ecosystem are as follows: i) elimination of key organisms at pH 5.3. ii) changes in phytoplankton species, iii) cessation of fish reproduction, iv) disappearance of bottom dwelling organisms and v) appearance of filamentous algae. As you know heavy metals are mobilised, in acidic medium and reach the lakes and reservoirs with run-off water in large quantities. Heavy metals adversely affect reproduction in fish much before their contents reach lethal levels.

Effects on Materials

Most air pollutants are reactive chemicals, so they react with most of the substances around. You may recall from your chemistry lessons in school that SO_2 oxidises to form SO_3 and when dissolved in water it forms sulphuric acid which is highly caustic.

Sulphuric acid reacts with metals and their weak salts and forms corresponding sulphates. In this way, in air polluted with SO_2, aluminium metal can form aluminium sulphate and lime stone and marble can form calcium sulphate called gypsum. Such reactions have caused damage to buildings, sculptures and other historical monuments made up of stone, plaster, marble or metal painted glass works. Some of them are from middle ages or even older. The stone in the Parthenon in Athens, has deteriorated more in the past 50 years from air pollution than it had in the previous 2000 years. Similarly, the statue of liberty is corroded from SO_2 and NO_2 and Taj Mahal from SO_2 emitted by Mathura refineries. The sand stone statues get covered with black coating that contain large amounts of gypsum. When gypsum is formed in cracks, the expansion of its crystals causes the limestone to crumble away. Such damages are indeed costly as well as a great loss to society because many of them are irreplaceable works of art.

Since SO_2, NO_2 and O_3 are strong oxidants, they soil, fade and deteriorate fabrics. Sulphur dioxide affects leather and plastic also. Ozone cracks wind shield wipers, tyres and other rubber products. Hydrogen sulphide reacts with metallic paints and tarnishes them by forming metallic sulphides. It tarnishes silverware and jewellery also.

Particulate matter sully and erode the buildings. Soot and tar sticks to the building stones, painted surface and is difficult to remove. Such damages require a large sum of money for repair and maintenance.

Effects on Weather

Dust, smoke and other suspended particulate matter reduce visibility. Fly-ash also affects visibility by intercepting and scattering solar radiation. Reduction in visibility results in economic burden because air traffic, shipping, harbour operation and road traffic are adversely affected. Certain aerosols such as sulphuric acid mist, ammonium sulphate mist and water vapours influence the vertical temperature profile in the atmosphere which affects thermal mixing, dispersal and the build up of pollutants. Aerosols also affect cloud formation and weather.

Global Effects

In Unit 16 of FST-1 course you have learnt about global effects of air pollution—Green House Effect, depletion of ozone layer. Before you read on it would be helpful if you revise that section.

Green House Effect and Global warming

You know that the temperature of the earth is maintained by re-radiated infrared radiation by CO_4, CH_4, NO_X,O_3 and CFC's and slightly by water vapours in the atmosphere. These gases prevent heat from escaping. This is called—Green House Effect and the gases are known as **Green House Gases** (GHs). In the absence of these gases the average surface temperature of the earth would be —15°C instead of the present average value—+15° C and the earth would be a frozen lifeless planet. Accordingly, increase in GHs level would increase earth's temperature. Therefore, if the present trend of increase of the gases continues, it is anticipated that by 2050 the earth's temperature would increase by 2°C. This would cause thermal expansion of oceans and melting of land based Antarctic ice packs and glaciers. It is predicted that average sea level will rise between 30 to 213cm by 2073. Over the past century the increase in the average global sea level was much less — about 15cms.

An anticipated rise of one and half metre will submerge coastal areas, accelerate erosion of shore line, damage estuaries, increase the salinity of drinking water aquifers. It is estimated that it would flood about 11.5% land area of Bangladesh, flood some areas of Nile Delta and submerge 30 to 80% of coastal wetland of United States and many other coastal areas of the world. Maldives Islands are feared to submerge within a decade.

These changes would affect 50% of the earth's populations that inhabit, coastal regions. The people are dependent upon these areas for their livelihood. Coastal wetlands are crucial for fisheries and other sea food.

The increase in the temperature would affect regional climate, shift climatic zones and rainfall. This would also lead to increase in temperature of middle latitudes: death of forests; loss of yield or failure of major cereals crops including paddy: scorching draught; massive heat wave and drying of lakes.

Ozone Depletion

Traces of ozone (O_3) in the air are harmful to plants, animals and human beings but the ozone layer present in the stratosphere shields the life on earth against almost all solar UV radiations. Ozone absorbs UV radiation and then emits IR radiation as shown below.

$$O_3 + UV \rightarrow O_2 + O \quad \text{...... (1)}$$

$$O_2 + O \rightarrow O_3 + IR \quad \text{...... (2)}$$

$$O_3 + UV + O_2 + O \rightarrow O_2 + O + O_3 + IR$$

Therefore, the net result is change of UV radiation into useful IR radiation. Lower concentration of ozone will slow this conversion and UV radiation will reach the earth.

The layer of ozone is under attack due to the use of CFCs over the past decades. These chemicals have thinned the protective ozone around the globe. CFCs are highly stable and inert substances. They are non-toxic, non-caustic, non-corrosive and non-inflammable. That is why they are ideal for use as aerosol, can propellant, refrigerant, solvent and for making foam plastic objects such as coffee cups and fast food containers. CFCs have been in use since 1955 and their concentration is increasing.

At one time emission of oxides of Nitrogen from high flying aircraft and SSTs operating in stratosphere was also thought to break ozone atom. But they are probably less serious than once feared.

The released CFCs move up in the troposphere and remain there for many years. They gradually move up to stratosphere. Here the CFCs break down and release chlorine atom (reaction 1) which in turn convert O_3 into O_2 (reaction 3). The chlorine atom released starts a whole sequence of reactions all over again. Actually these are chain reactions.

$$CF_2Cl_2 + UV \rightarrow Cl + CF_2Cl \quad ...... (1)$$

$$Cl + O_3 \rightarrow ClO + O_2 \quad ...... (2)$$

$$ClO + O \rightarrow Cl + O_2 \quad ...... (3)$$

Scientists have estimated that emission of CFCs at this rate would reduce average levels of ozone in the stratosphere by 3 to 5% or even more over the next 100 years. A chlorine atom has potential to eliminate 10 thousand ozone atoms. The state of ozone layer is critical in the sense that even if CFCs production is stopped today, the break up of ozone to O_2 will continue for another century. Some estimates show that loss of 1% stratosphere ozone could cause 2 to 5% increase in the incidence of cancer. Advanced and industrialised nations are the culprits as well as immediate victims of consequent increase in UV radiation. For example, in 1987 it was estimated that if CFCs continue to increase at the rate of 5%, 40 million Americans will get skin cancer over the next 88 years and 800,000 will die of it. At south pole a thinner layer of ozone, about 60% only, was detected by scientists in 1985 by Nimbus 7 satellite. It spreads in an area of the size of United States. This is referred to as **Ozone hole.** It is losing ozone rapidly.

In Australia 2 out of every 3 person who live up to 70 suffer from skin cancer at least once in their life time. The high incidence of cancer is directly related to the depletion of ozone (4.9 to 10.6 per cent) Sun Screen over South Australia that allow more ultraviolet radiation to penetrate the earth surface. The ozone hole as big as the United States and as deep as Mount Everest is causing scare in the continent of Australia.

It is proposed that the production and consumption of CFCs must be checked within 5 to 7 years and alternative to CFCs must be evolved. However, the effect of CFC already present, as we have pointed out before will continue on the environment because of their long life.

15.3.3 Meteorological Factors and Air Pollution

Air pollution levels in a region are affected by wind, location, topography, precipitation and temperature inversions. Wind can carry pollutants to a distance of hundreds or perhaps thousands of kilometres. Consequently, gaseous pollutants may travel to great distances. Pollutants recognise no political boundaries. For instance, southern Norway and Sweden get acid rain because of SO_2 blown from industries of England and other parts of Europe. Millions of tons of pollutants thrown into the atmosphere by USA are carried away by strong winds to Canada and precipitate as acid rain. In India, sulphur dioxide released into the atmosphere at Bombay flue stacks is carried away by south westerly wind to Vashi and New Bombay. Also in coastal areas land breezes carry pollution out to the sea and sea breezes bring pollution back to the land.

Local wind pattern is affected by the topography and location of the region. High dispersion of pollutants can be expected in planes and low dispersion in hills and mountains because they inhibit the flow of air leading to a build up. You have already learnt about temperature inversions in Unit 2. Such conditions retard the escape of pollutants and thus tend to concentrate in a smaller area.

Under normal atmospheric conditions the air temperature drops steadily with increasing elevations. When sunlight heats the earth, the heat is transferred to the air immediately above the ground. Pollutants also rise up along with the warm air. Theoretically a pollutant can be carried right through the troposphere, but it cannot penetrate the stratosphere. In fact, air pollution is confined to the first 100 metres of atmosphere above the ground.

But the temperature at elevations may become cooler or warmer than theoretical conditions. Then, in cooler conditions there is turbulence in the atmosphere because cool air, being denser than warm air, tends to fall. If pollutants enter such atmosphere they get dispersed well and are diluted. However, during warmer conditions there is no turbulence and hence pollutants mix to lesser extent.

What would be the situation during atmospheric inversion, when the warm layer of air forms a ceiling over the denser cooler layer?

Then the pollutants will be trapped as shown in Figure 15.5 in the inversion layer because cool air is unable to rise. So the concentration of air pollutants may reach dangerous levels. Sometimes, such inversions are local, cover smaller area, and are short-lived. However, some inversions extend over thousands of square kilometres. These are common in mountain regions especially in winter. As the sun cannot penetrate valley regions because of the shadow of mountains. In many industrialised countries severe air pollution episodes had occurred due to temperature inversion. In 1952 nearly 4,000 people died in London in a five-day inversion at a height of 100-130m where sulphur dioxide, sulphuric acid, and particulate sulphur were trapped. Many more such incidences have occurred in USA, Japan, London and Germany.

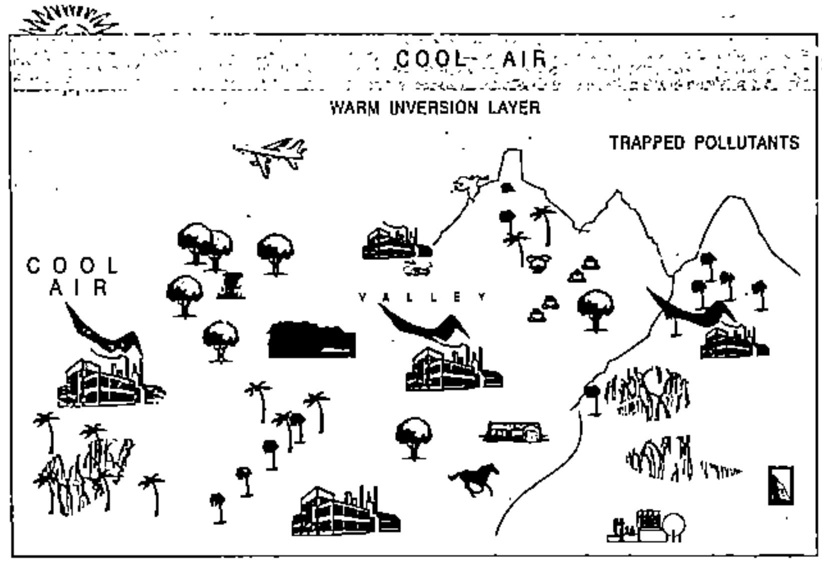


Fig. 15.5 : Trapping of pollutants due to temperature inversion.

Let us look at Fig. 15.6. Such pollution domes have often been observed over the large cities of the world. In cities the heat is evolved from many sources. Cities are like huge islands of heat amidst cooler suburban and rural areas. As warm air carrying pollutants rises it cools, sinks and moves outwards, creating huge dust and pollution dome over the city.

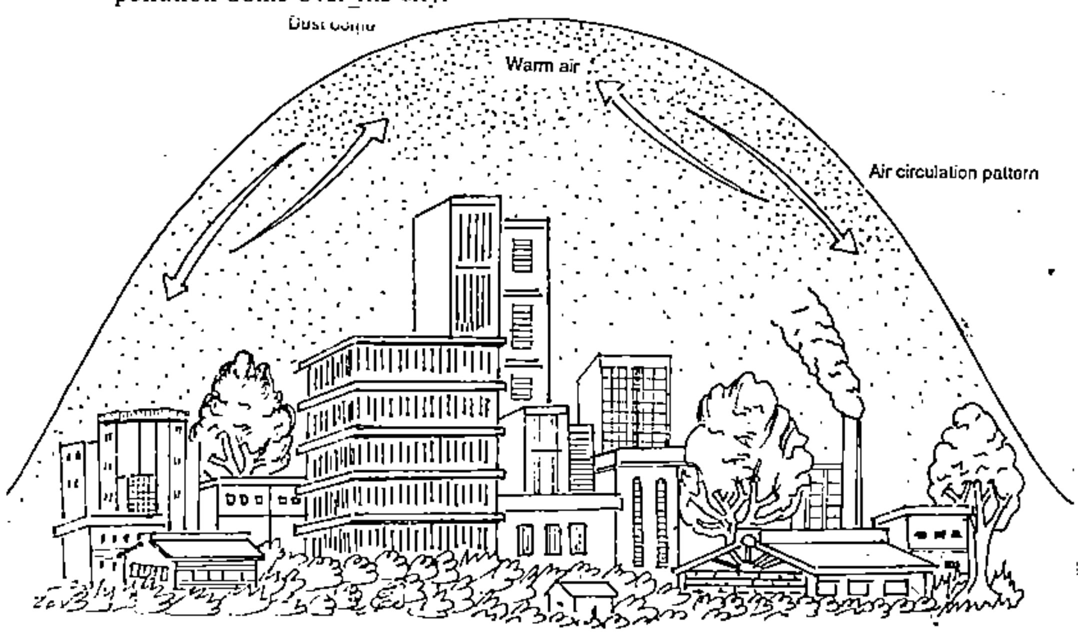


Fig. 15.6 : Pollution dome over the cities.

We hope by now you have learnt a great deal about air pollution. Try the following SAQ before you begin reading the next section.

SAQ 2

a) What happens under the following conditions. Explain with the help of chemical reactions.

i) Coal is burnt in limited air.

ii) Chlorofluorocarbons reach the upper atmosphere.
iii) Burning of sulphur is followed by rain or snow.
iv) Automobiles exhaust in the atmosphere is exposed to sunlight.
b) Draw a diagram of a human body to show the effects of some air pollutions.

15.4 WATER POLLUTION

Water is one of the most essential requirements for the survival of all living organisms. Water is used for household, agricultural, industrial and recreational purposes. The water that is discharged after use is polluted with soluble, insoluble, toxic and innocuous matter as well as pathogens. At present, the pollution in our natural water sources such as rivers, lakes, estuaries is growing all over the world. In this section we will discuss the causes and consequences of water pollution and how it affects human health and well being.

15.4.1 Causes of Water Pollution

Most of the human activities produce liquid effluents which are the prime cause of water pollution. Rapid increase in population, intensive agriculture, growing industrialisation and urbanisation have resulted in progressive deterioration in the quality of water in our natural reservoirs.

You are advised to see video programme on "story of a river".

Water Pollutants

Water pollution can occur on account of any one or more of the following agents:

i) **Biological :** Pathogens such as virus, bacteria, protozoa and worms.

ii) **Chemical :** a) **inorganic:** nitrates, phosphates, chloride and fluoride,
b) **organic :** pesticides, dyes, chloro-compounds, phenols, points and plastics,
c) **heavy metals:** soluble heavy metal ions such as mercury, lead, cadmium, copper, zinc and their organometallic compounds.

iii) **Physical:** Waste heat from industrial plants

Sources of Water Pollution

There are natural sources of water pollutants such as mineral ores from rocks, chemicals, from mines and gases from atmosphere. But we will consider sources arising due to human activities only. These can be broadly grouped into the following categories:

1) Domestic effluents
2) Industrial effluents
3) Surface run-off
4) Waste heat

Point and non-point sources

The discharge of effluents in receiving water body at a specific site are referred to as **point sources** in contrast to the inflow of pollutants in a different manner over a larger area reffered to as **non-point sources.** Generally, point sources bring in very large volumes of effluents at one point in the river such as discharge from sewage treatment plants, thermal power plants and industries. Effluents discharged from point sources are relatively more amenable to checks and control. However, for non-point sources such as run-off from agricultural fields and deforested areas into surface water bodies, seepage into ground from crop lands, logged forests and construction sites are somewhat difficult to control because significant pollution occurs during rain, storm or when snow melts.

1) Domestic Effluents

Liquid waste produced daily in kitchen, bathroom and toilet are discharged directly or through canal, river or any other water body, generally without any treatment. Most of our rivers including the holy Ganges are polluted at stretches on account of indiscriminate discharge of liquid effluents. This is because sewage collection and treatment facilities in our country are inadequate. Even in 1st class cities (Population > 1.0 lakh) only about 60% of the population has access to sewage system. Therefore, raw sewage and other effluents are discharged into rivers, lakes, estuaries and seas.

A number of Indian lakes are getting polluted due to dumping of sewage and urban refuge. For example, the beautiful Dal Lake in Kashmir has been polluted due to the dumping of raw sewage and domestic effluents from house boats, hotels and from neighbouring localities directly into the lake. The lake is foul smelling at places and its surroundings are unhealthy.

The Hooghly estuary is heavily polluted with domestic and municipal waste and effluents from a large number of industries located on its shore.

Domestic effluents and sewage contain pathogens and are rich in inorganic nutrients particularly nitrate and phosphate. Most laundry detergents contain phosphate. Excess of these nutrients in water deteriorates its quality. Many new chemicals now introduced in most households for control of pest and cleaning purposes eventually reach the drainage.

2) Industrial Effluents

Most industrial operations produce effluents that are discharged into nearby river or any other water body. The industrial effluents contain heavy metals such as mercury, cadmium, lead, copper and arsenic. Mercury compounds are used in fields to control seed-born and soil-born diseases of plants. These get washed with rain and become a source of water pollution. Other chemical pollutants are polychlorinated biphenyls,

Table 15.1 : The Major Sources of Pollution of Indian Rivers

Name of the River	Sources of Pollution
Bhadra (Karnataka)	Paper and steel industries
Cauvery (Tamil Nadu)	Tanneries, distilleries, rayon and paper mills
Chambal (M.P.)	Rayon mills, and caustic soda mills
Cooum (Tamil Nadu)	Automobile workshops
Daha	Sugar mills
Damodar (Between Bokaro and Panchet)	Fertilisers, steel mills, power stations and coal washeries
Ganga (Kanpur)	Chemical, metal, and surgical instrument industries; tanneries and textile mills
Godavari (A.P.)	Paper mill
Gomti (near Lucknow)	Paper and pulp mills
Hooghly (near Calcutta)	Power stations, chemical mills, paper pulp, jute, textiles, paint, varnishes, metal, steel, vegetable oils, rayon, soap, match, shellac, and polythene industries
Jamuna (near Delhi)	DDT factory, Mathura Refineries and Indraprastha Power Station
Kali (at Meerut)	Sugar mills, distilleries, soap, paint, rayon, silk, yarn; tin and glycerine industries
Narmada (M.P.)	Paper mills
Siwan (Bihar)	Paper, cement, sulphur and sugar mills
Sone (U.P.)	Paper mills
Suwao (Balrampur)	Sugar industries

phenols, dyes, paints, varnishes, and plastics. Some of these chemicals are carcinogens. Industrial effluents are the most hazardous pollutants on land and water.

The Rhine river in Europe is one of the highly polluted rivers in the world. In the bottom mud of delta and estuaries of the Rhine, heavy metals and toxic chemicals have accumulated. In our country most of the rivers at various stretches suffer from pollution because a large number of industries, given in Table 15.4, discharge their effluents into the river. The Ganges also receives sewage and noxious effluents from chemical factories. A plan for the prevention of pollution in Ganga was formulated in 1985.

3) Surface Run-off

The surface run-off from cultivated lands where inorganic fertilisers, pesticides, insecticides and rich manure are applied and solid waste disposal from urban and industrial sites, bring heavy loads of pollutants into natural water bodies.

Pesticides such as DDT (Dichloro-diphenyl tetrachloro-ethene) 2,4D (Dichloro-phenoxy acetic acid), dieldrin, malathion, carbaryl are used for crop protection. India alone uses approximately 1,00,000 tonnes of pesticides annually. According to an estimate 25 to 50% of pesticides reach target site when applied by aircraft. The remaining spreads in the air and contaminates far off areas. About 25% of the pesticides used on land ultimately drift into sea water.

Application of nitrogen fertilisers and nitrates and ammonia released from manure increase nitrate content of water bodies. As you know soil bacteria convert ammonium ions into nitrate which has high mobility because of its solubility in water and negative charge. It cannot bind to negatively charged clay and humic micells, therefore, nitrate ions gradually leach from the soil by percolating water and eventually find their way into ground water.

4) Waste Heat

Water is used as a coolant in thermal power plants, refineries and various other industries. The waste heat in the form of hot water is discharged into the nearby river, lake or sea which serves as the receiving water body. For example, nuclear power station located in Kota draws cool water from the Chambal river and discharges hot water in it. The heated effluents from power plants are discharged at 8 to 10°C higher than coolant intake waters. The nuclear power stations located near the sea coast release 50% of their heat into the coastal marine water. The disposal of waste heat into a water body increases the temperature of the body, adversely effecting the amount of dissolved oxygen and the aquatic community in general. These will be discussed in detail in the following section.

15.4.2 Consequences of Water Pollution

Now that you are familiar with water pollutants and their sources, let us see how the pollutants affect 1) water bodies, 2) aquatic organisms and 3) human health.

1) Effect on Water Bodies

Let us first see how organic wastes containing phosphates, nitrates and other nutrients affect normal functioning of water bodies.

Dissolved Oxygen (DO)

Most aquatic, organisms respire with oxygen dissolved in water. The quantity of dissolved oxygen in a unit volume of aerated water is only .0084g which is about one thirtieth of that present in the same volume of air at 25°C. The quantity decreases further with the increase of temperature. Hence the availability of oxygen is one of the critical factors for the survival of aquatic species.

The amount of oxygen gas dissolved in a given quantity of water at a particular temperature and atmospheric pressure is referred to as **DO** and generally expressed as parts per million (ppm). DO in natural water is influenced by i) the degree of aeration, ii) the photosynthetic activity in the water column, iii) the consumption of dissolved oxygen by plants, aquatic organisms and decomposers and iv) the ambient temperature.

Discharge of sewage in large quantities results in a drop in DO because decomposer organisms use up a lot of dissolved oxygen in decomposing organic matter. The water containing DO below 8 ppm is considered polluted. The gravely polluted water has DO below 4 ppm to nil.

Volume and flow of water also affect biodegradation because consumed oxygen is rapidly renewed in large flowing water, whereas in stagnant water biodegradation is sharply reduced particularly in summer due to decrease in DO.

Biological Oxygen Demand (BOD)
Addition of biodegradable matter exerts demand on oxygen of the water body. The demand of oxygen is directly related to increasing loads of organic matter and is expressed as **biological oxygen demand** (BOD). It is the measure of dissolved oxygen required by aerobic decomposers to break down organic matter present in a given volume of water over 5-day incubation period at 20° C. It is expressed in parts per million or mg of oxygen per litre. A high value of BOD indicates the high activity of aerobic decomposers which in turn means more organic wastes or sewage in water.

Eutrophication
Moderate quantities of sewage decay naturally in a water body and water gets purified after some time. But the problem arises when the volume and concentration of sewage dumped increases beyond and recovering capacity of the water body. You already know about eutrophication from Unit 16 of FST-1 course and Unit 6 of this course. In general the following events take place in nutrient-rich water body. i)Good nutrition helps in the excessive growth of algae-characterised by algal bloom. ii) The DO of water decreases as the demand for oxygen exceeds production by photosynthesis and reaeration, a few species of fish die. iii) Algae die and aerobic bacterial growth begins on decayed matter. iv) This leads to deoxygenation of water and consequently more aquatic species die. v) Anaerobic bacteria take over and release methane and other gases giving a foul smell.

Contamination due to Pathogens
Sewage is a source of pathogenic viruses, bacteria, worms and other parasites. The extent of contamination by these pathogens in a water body is measured by counting harmless fecal **coliform** bacteria. Otherwise, it is not practical to routinely detect specific disease-causing bacteria in water as it is a time-consuming and costly process. Therefore, an indirect easy method is used. The non-pathogenic naturally occurring coliform bacteria found in human intestine and faeces are monitored. A high coliform count indicates fecal contamination, which is likely to contain more pathogenic agents of water-borne diseases.

2) Effects on Aquatic Organisms
Toxic water pollutants such as metals, pesticides, insecticides and chemicals affect aquatic species directly whereas the non-toxic organic load may eliminate some aquatic species indirectly by reducing the DO of water. The sensitive species such as Trout, and Bass that require high level of oxygen are eliminated first. With further decrease in DO, leeches, catfish and carp get killed and only the resistant species, for example, eel and hardy worms survive. Trout and salmon are excellent indicators of pollution. The aquatic flora of lakes and ponds is also affected by slight variations in sustaining elements, thus affecting the whole ecological system.

Generally plants and animals have the ability to wash out many poisons out of their system but certain chemicals such as pesticides, insecticides, methyl mercury tend to accumulate in the body. For example, DDT, an organochloride, does not dissolve in water but dissolves in fats, therefore, it accumulates in the organism for a long period. This is called **bioaccumulation**. These poisons then move in other organisms through food chain. For example, 0.02 ppm concentration of DDT in a lake entering into a bird through plankton (5 ppm), fish (400-300 ppm) may go upto 2000 ppm. Similarly, spray of DDT on soil (9.9 ppm) reaches 445 ppm in a Robin through plant (44 ppm). The increase in concentration of a toxin in food chain at higher level is called **biomagnification**. Low levels of DO in water body expedite bioaccumulation because the rate of breathing of fish increases with decrease in DO. Hence it is forced to take in large amounts of water which may be polluted with toxic metals and chemicals. So their intake in fish would increase manyfold than in the water body.

DDT and its metabolites cause thinning of bird's eggshells. The egg get crushed by the incubating parent birds. The eggs that remain intact fail to hatch normally. In the 70s in USA a decline in the population of bald eagle, the brown pelican and peragrine falcon occurred because of DDT. Often the birds, eagle and mink consuming fish contaminated with DDT get killed. In case they survive, their infants die within a few days and eventually the whole population is affected. DDT and aldrin have been detected 15 years after a single spray application. If a field is sprayed once, the predators are subject to continuous exposure to pollution for many years.

Large quantities of hot water released from power plants cause ecological imbalance by death of some fish species and other aquatic organisms. An increase in temperature of water increases the metabolism and hence the organisms requires more oxygen. Since the DO of water decreases with increase of temperature this causes suffocation.

You know that a great majority of aquatic animals are ectotherms i.e. their body temperature is determined by the temperature of their environment. Different species have different optimum temperature for growth, development and reproduction. Stenothermal species die due to slight increase in the temperature. Warm water can initiate untimely reproduction in some species but the young ones may not survive in the absence of desirable living conditions like availability of food. Increase in temperature due to thermal pollution at stretches of water body obstructs the migration of fish species and thus interferes with their life cycle.

3) Effects on Health

Water pollution deteriorates the quality of water used for drinking, bathing, swimming, recreation and irrigation. Water contaminated with sewage has foul smell and creates unhygienic conditions in the surroundings and affects our health. Drinking water polluted with sewage is a source of viruses, bacteria, protozoa and worms. Water-borne infectious diseases like cholera, dysentery, typhoid, jaundice and worm infection are still the major public health problems in developing countries. Table 15.2 shows the count of coliform bacteria in major Indian rivers.

Table 15.2 : Toxicity of River Water

River	Faecal Coliform (Number/100 millilitres)
Mahi	550,000
Narmada	260,000
Tapi	37,000
Wainganga	3,699
Cauveri	439
Krishna	57
Godavari	7
Periyar	767
Sabarmati	1,147

Source: World Resources 1987: A report by International Institute for Environment and Development and World Resource Institute, New York basic Books Ins. 1987.

Excess quantities of heavy metals such as mercury, lead, cadmium, zinc and copper are harmful to health. Mercury compounds discharged in effluents are converted into highly toxic methyl mercury by bacterial action in the aquatic environment. In 1952 poisoning in Japan resulted in **"Minamata disease"** due to eating of fish taken from mercury polluted Minamata Bay. In fish methyl mercury can accumulate upto thousand times more than its concentration in the environment. The disease was called **"Minamata Disease"**. The victims developed numbness of the limbs, lips and tongue and lost control. It also caused deafness, blurring of vision; apathy and mental derangement.

Cadmium pollution caused another disease called Itai-Itai which again occurred in Japan due to the consumption of rice affected with cadmium metal. The rice fields were irrigated with effluents released by zinc smelters. **Itai-Itai** is a painful disease of bone and results in the cancer of liver and lungs. Cadmium gets accumulated in liver, kidneys and pancreas and interferes with some enzymes.

Excess of nitrate in drinking water causes **methamoglobinemia.** Nitrate converts haemoglobin to methaemoglobin-oxidised (Fe^{3+}) form of haemoglobin which is non-functional. Nitrate can be fatal to human, especially infants under three months. Such infants are called **"blue babies".**

You know that fluoride toothpastes are used to prevent dental decay but excess causes mottled teeth, stiffening of joints and hardened bones called **skeletal fluorosis** or **knock knees** disease. The deformity of knees may lead to total inability to move. Excess of fluoride in water has been noticed in Tamil Nadu, Kerala, Gujarat, Rajasthan, Punjab, Haryana and Bihar. Chlorination of water produces chlorinated organic compounds. Many of these are known carcinogens and teratogens.

Cases of knock-knees disease in villages of Andhra Pradesh occurred due to high uptake of fluoride in water. The scientists at the National Institute of Nutrition at Hyderabad believe that the changes in the alkalinity of soil due to seepage of dam water led to changes in composition of soil with respect to fluoride, calcium, copper, zinc molybdenum and magnesium. As a consequence there was high uptake of heavy metal by sorghum plant. The intake of such sorghum plants lead to deficiency of copper, and its deficiency leads to high uptake of fluoride causing knock-knees disease.

Pesticides get accumulated in increasing quantities in organisms of higher trophic levels. Pesticides such as DDT, aldrin and dieldrin are suspected carcinogens and teratogens. They cause tremors, convulsions causing damage to kidneys. In **India,** the hazards of pesticides came to light by a case study of the problem called **Endemic Familial Arthritis** which affected poor Harijans of Malnad in Karnataka. The victims had eaten crabs picked from rice fields sprayed with pesticide and suffered from pain in the hips and knee joints and could not stand up because they were crippled. It was reported in 1965 that accumulation of pesticides in the body tissue was highest among Indians. This may be due to wrong handling, continuous exposure, contamination of food and drinks and consumption of cereals and vegetables treated with insecticides.

So far the knowledge of chronic health of numerous synthetic chemicals is unknown, but their long-term effects are feared. Some isolated episodes have also been reported in the past. For example, in 1968 about 1000 Japanese became severely ill after eating rice contaminated with **polychlorinated biphenyls.** Many other chemical are also suspected carcinogens.

SAQ 3

a) Write two sources and effects of each of the major water pollutants listed below.

Pollutant	Sources	Effects
i) Disease causing agents		
ii) Nitrate and phosphate		
iii) Methyl mercury		
iv) Lead		
v) DDT		

b) Outline the various water pollutants and their sources that cause eutrophication of a lake.

c) Why are carnivorous fish generally more susceptible to low [illegible] water than herbivorous fish? Explain.

15.4.3 Ground Water Pollution

A large section of our population is dependent on underground sources of water. However, they are now threatened with pollution due to seepage from refuge dumps, septic tanks, sewer and fuel tanks, agricultural run-offs and industrial effluents.

The frequent incidences of cholera in some Indian cities is due to seepage of sewage into hand pump water. Nitrate contamination due to seepage of agricultural run-offs causes methaemoglobinemia disease. In many parts of India, particularly in arid and semi-arid areas ground water is contaminated with relatively high dosage of toxic metals and fluorides. Heavy metal pollution of ground water has been reported from some industrial cities of Punjab—Ludhiana, Sonepat and Ambala where bicycle and/or woollen garments are manufactured. The polluted water contains metal ions of chromium, nickel, lead, aluminium, copper and even cyanide.

Another example is Pali, in Rajasthan where pollution of underground water is due to discharge of effluents from 450 textile units spread all around the city. The effluents contain dyes, bleaches, acids and other chemicals that are poured into the ground wherever convenient. These effluents percolate down the earth and contaminate ground water. Some of the chemicals, particularly dyes used in textile factories are carcinogenic.

In Ambur and Ranipet towns of Tamil Nadu, ground water is polluted because of effluents discharged from several tanneries present in that area.

The deterioration of quality of ground water is serious because the surface water has capacity to self purify itself in due course of time or can be treated, but the same is not the case with ground water. The pollution in ground water is difficult to detect or rectify, and thus may remain for centuries.

15.4.4 Marine Pollution

The pollutants dumped into the streams, canals and rivers ultimately reach the ocean because most of the rivers drain into the sea. The Indian Ocean near the coast is polluted by the fourteen major rivers which drain their run-off into it. Like rivers and lakes, oceans can dilute, disperse and break down organic matter but their capacity is not infinite. Hence, oceans remain polluted particularly near the coast lines where large cities, harbours and industrial centres are situated. Estuaries and wetlands that protect the coast line from erosion and damage also get highly polluted. You know that estuaries are one of the most productive ecosystem on the earth. The other vulnerable places to pollution are bays, lagoons and inland sea.

India has a coastline of about 7,000km. About 25% of our total population lives in coastal areas and are directly or indirectly dependent on marine resources. The sea near the coastline is dumped with domestic sewage, industrial effluents by industries and solid garbage generated by population. Many oil slicks from tankers and other floating pollutants in the ocean near the coastline have been reported. Accidental discharge of oil or oil spills, as they are called, in the sea is in the order of about 5 million metric tonnes per year.

In general, oceans are polluted in the following ways:

i) **sewage sludge :** The rivers that drain in the sea contain bacteria and virus laden organic matter, toxic metals, synthetic chemicals, and solid remains from waste water at sewage treatment plants.

ii) **Industrial effluents :** Contain hazardous chemicals, plastics, tins, metals scrapping, fertilisers and pesticides.

iii) **Waste heat :** Hot water released from industries is also dumped into the ocean.

iv) **Oil spills and discharge from marine vessels :** These are due to oil tanker accidents offshore oil drilling, mini spills, natural leakage etc.

v) **Toxic wastes in sealed containers :** These are packed with wastes containing poisonous chemicals, radioactive isotopes. Since deep ocean is considered better equipped than land for digesting wastes, tens of thousands of such drums have already been dumped into sea. However, these drums leak sooner or later or break off. Many of these are spotted in the continental shelves and ashore as they are not properly packed or dropped in the right area in the ocean.

All these pollutants have negative and probably long-term impact on marine-environment. Here we must point out that chemicals such as fertilisers, pesticides and herbicides used in intensive agriculture on land adversely affect fisheries. The non-degradable pollutants get biologically magnified in marine organisms.

Crude oil has been a major source of ocean pollution. In March 1978, **223 thousand tonnes** of oil spilled at the **coast of Britany in France** due to wreckage of an oil tanker. Another large oil spill of about **440 thousand tonnes** resulted from offshore drilling in the **Gulf of Mexico.** Massive oil spill in ocean have occurred during the **Gulf War.** Million of gallons of crude oil was pumped into the gulf and many oil wells were set on fire by Iraq. The water desalination plants were shut down to protect them from oil contamination. The death of aquatic organism and loss of flora and fauna is beyond ones imagination. The oil spill drowns large and small marine birds by destroying their natural insulation and buoyancy. The components of oil can kill bottom-dwelling organisms such as fish, crabs, oyster, mussel and clam because gills become tainted with an oily layer.

Another massive spill was reported in 1989 in **coral reefs** near Alaska due to leakage **of 50 million gallon** oil tanker. You may know that coral reefs are rich in biological diversity and therefore they need to be safeguarded against pollution.

15.5 LAND POLLUTION

Generation of Solid Wastes in a few Selected Indian Cities

City	Population (1981)	Solid Wastes (tonnes)
Bombay	8,227,332	3200
Madras	4,276,635	1819
Kanpur	1,688,424	2142
Coimbatore	917,155	175
Indore	827,071	120
Meerut	538,461	120
Jamnagar	317,037	149
Anand	83,815	34
Khopoli	32,108	6
Dehgam	24,817	9

Source : Central Pollution Board document (CPCB) 1988-1989.

Land is polluted with dumping of solid wastes generated in the household and manufacturing units. Some examples of such wastes are given below:

Domestic wastes : Kitchen garbage, other household rubbish, broken bottles and crockery, waste tin cans, plastic bottles, cloth rags, pieces of papers, straw-board boxes, ash etc. These are also generated by commercial establishments.

Industrial wastes : Slag from blast furnace, fly-ash, lime sludge, brine mud, metal scraps, copper slag from large industries or ash, waste from tanneries, dyes, scrapes of wool, thread and paper, plastics and many other wastes from small scale industries.

In addition to the above, domestic and industrial effluents disposed on land, run-off from agricultural fields and sewage also cause land pollution.

One of the problem faced by civic authorities in cities and metropolitan areas is the safe and hygienic disposal of city garbage. The quantity of garbage generated is generally proportional to affluence in the society. For instance, the solid waste generated in affluent areas in Delhi is 800-1000 g/day, whereas in municipal cooperation areas it is about 300 g/day and in rural areas much less.

On an average, the per capita waste generated in Indian cities is 300-400 g/day. This is not much compared to the per capita waste generated in advanced countries. However, the large Indian cities are highly populated so the magnitude of wastes is large and the collection efficiency is low ranging from 50 to 70% only. The remaining wastes create unhygienic conditions in the surroundings.

Industries in India also generate a variety of waste in large quantities. For example, the slag generated by the blast furnace used for integrated iron and steel mills amounts to about 35 million tonnes/year and fly-ash from coal based power station to 80 million tonnes/year. If the waste generated by other large and 2.5 million small scale industries is taken into account the total quantity of industrial solid waste would be very large.

You know that sewage and industrial wastes on land endanger human health and pollute our surface and ground water resources. The fertility of soil is changed by acids and alkali, insecticides, fumigants and herbicides. Modern biological weapons used in Vietnam and other places have brought about drastic changes in the reproduction process of plants, animals and human beings. In the areas of operations of these weapons the soil decays, plants and human beings suffer because of steady deterioration of health followed by death in some cases.

Finally, we illustrate with an example the consequences of indiscriminate dumping of industrial chemical wastes that affected small children of an elementary school.

Disposal of Toxic Chemicals in Love Canal

In 1940, Hooker Chemicals, a chemical manufacturing company, operating at Niagara falls, New York, purchased an abandoned canal called Love canal for disposing its wastes. Approximately 19,000 tonnes of chemical waste was packed into 55 gallon steel drums and dumped in the canal. In 1953, the company covered one of its dump site by dirt and sold it to the Board of Education of Niagara Falls. An elementary school and playground was made on this site. In 1973, due to heavy rains the area turned into muddy swamp due to raised levels of ground water. It was contaminated with poisonous chemicals which floated about in the playgrounds and even entered the basement of nearby houses. Soon, children and adults of nearby area suffered illness such as severe headache, skin sores, rectal bleeding, liver malfunctions and epilepsy. Later miscarriages and birth defects were also reported.

The investigations showed that the chemicals in the swamp were due to leakage in the drums that were buried by the Hooker company a decade earlier.

The above example illustrates how dumpsites of hazardous wastes are like time bombs that can explode anytime without warning. Such dumpsites become permanently unfit for any habitat.

Solid waste management in India, as in many other countries has been traditionally given low priority by civic authorities. The attitude seems to be that solid waste management does not yield adequate returns and can be neglected without endangering public health. The adverse effects of this policy are already visible in some cities. It is desirable to take remedial steps because the problem is already alarming.

SAQ 4

a) Write the pollutants and sources of ground water pollution in any two Indian cities

....

....

....

....

b) Fill in the blank spaces with appropriate words in the following statements:

i) Discharge of waste heat in ocean kill.................., hinder................ and affects.................. of marine organisms.

ii) Oil spills in oceans kill.., drown................................ and affect..................

iii) Low concentrations of heavy metals in effluents discharged into the sea may enter human body in higher concentration through sea food by.................. and.................. of heavy metals in organisms.................. in trophic levels.

15.6 NOISE POLLUTION

Noise is unwanted sound or excessively high levels of sound. Noise pollution is not only an annoyance, but at sufficiently high levels, it may cause loss of hearing. Noise pollution has grown because of increased use of technology. The main sources of noise are: road traffic, railways, industrial operations, construction work, aircrafts, military artillery and ammunition and household electrical appliances.

Sound or noise can affect us because of its loudness and pitch or frequency. Frequency is the number of cycles per second called Hertz (Hz). For example, a radio station uses certain frequencies for the broadcast. The human ear is sensitive to the sound of frequency in the range of 20 to 2000Hz. Loudness is measured in decibel scale (dB), a tenfold increase in sound intensity is represented as 10 dB increase on scale. Table 15.3 shows different sounds on decibel scale. Noise is measured by sound level meter. The sound level meter basically consists of a high quality microphone and amplifier. It has a calibrated attenuator weighting network and a meter calibrated to indicate sound level over the range of 40-120dB.

Table 15.3 : Different sounds on Decibel Scale

Diesel truck, 30 km./hr, at 15 meters away

Sound Intensity Factor	Sound Level dB	Sound Sources	Effects	
			Perceived Loudness	Damage to Hearing
10^{18}	180	Rocket engine		
10^{17}	170			
10^{16}	160			Traumatic injury
10^{15}	150	Jet plane at takeoff	Painfull	
10^{14}	140			
10^{13}	130	Maximum recorded rock music		Injurious range; Irreversible damage
10^{12}	120	Thunderclap Autoborn 1 m away		
10^{11}	110		Uncomfortably Loud	
10^{10}	100	Jet fly-over at 300 m Construction work Newspaper press		Progressive loss of hearing
10^{9}	90	Motorcycle, 8 m away Food blender	Very loud	
10^{8}	80	Garbage disposal		Damage begins afterlong exposure
10^{7}	70	Vacuum cleaner Ordinary conversation		
10^{6}	60	Air conditioning unit, 6 m away Light traffic noise, 30 m away	Moderately Loud	
10^{5}	50	Average living room		
10^{4}	40		Quiet	
10^{3}	30	Library Soft whisper		
10^{2}	20	Broadcasting studio	Very quiet	
10	10	Rustling leaf	Barely audible	
0	0	Threshold of hearing		

Source : Redrawn from Turk et al. (1978). *Environmental Science*. Philadelphia : Saunders, p.523.

Effects of Noise

Noise can affect in the following three ways: i) interferes with communication, ii) diminishes hearing and iii) affects health and even behaviour.

Noise is an irritant which causes psychological and physiological changes, arouses emotional response and affects our health. Noise produces temper tantrum, irritation, anxiety, fatigue and even nausea. Constant excessive noise levels cause lack of concentration, sleeplessness, headache, constriction in blood vessels, change in heart beat, increase of blood pressure, pale skin, nervous breakdown, etc. Noise results in decrease sensitiveness to hearing, finally leading to deafness. Our hearing declines from aging and exposure to noise. Men generally suffer a greater loss of hearing with age than women. High levels of noise may result in temporary loss of hearing and continued exposure to permanent loss. Instantaneous explosions can rupture eardrums and displace the tiny bones in the ear.

Inhabitants of cities are generally subjected to high noise level, which gradually deafens them, as compared to those living in quieter towns. In New Delhi, the noise levels vary from 28-71 dB at different locations at different times, Bombay 64-102 dB, Rourkela and Steel town 70-104 and Ahmedabad on average is 62 dB, in Visakhapatnam it is even higher.

The noise pollution and consequent damages due to supersonic jets (SST) have also been studied. The SST is a passenger aircraft that travels faster than sound and at much higher altitudes than subsonic air planes. It has been stated that the SST on runway would sound like 50 ordinary jets taking off at the same time. As a supersonic jet moves through the air, it creates a high energy, cone shaped wake that trails behind the jet called "sonic boom". The "sonic boom" sounds like a close thunderclap. Depending on the power it generates, the boom can rattle windows or shatter them. In some extreme cases it may damage buildings. Such high noise levels obviously interrupt sleep, conversation and radio and video receptions. Besides, as the jet passes over the houses people get completely startled.

In India comparatively little attention is paid to control of noise. The government must take a serious view of the increasing noise pollution, assess the correct situation within the country and take appropriate measures to protect workers from the hazards of noise. One of the difficulties encountered while assessing noise pollution comes from the fact that it is difficult to distinguish clearly between hearing impairment due to advancing age and impairment due to occupation. Difficulties also arise when employers fear that investigation of the problem may promote litigation and legislation. Occasionally, difficulties arise from the attitudes of the labour organisations as well.

The ambient noise levels recommended by the Central Pollution Control Board (CPCB) committee are:

	Day	Night
Industrial	75	70
Commercial	65	55
Residential	55	45
Silence Zone	50	40

The main methods of control noise are: 1) to reduce the source, 2) to interrupt the path of transmission, and 3) to protect the receiver. Reducing the sources that generate sound is obviously the most straight forward approach in this direction. For example, the number of noisy trucks, motor cycles, etc. playing through residential areas can be reduced by legislation. There are, however, obvious limitations to this type of solution. Even if one is unable to accomplish reduction of such sources, efforts can certainly be made to reduce noise production. Proper oiling of the wheels and redesigning of the machinery can be mentioned in this connection. It should not be very difficult to modify technological approaches, so as to accomplish the objective of generating a lower noise level. Procedures and schedules on work can also be changed to reduce annoyance to people working and living in an area.

15.7 RADIATION POLLUTION

It is unfortunate that harmful radiations cause severe pollution but they cannot be seen or observed by eyes and are difficult to judge, unless present in such concentrations so as to cause an acute effect. These are wastes without weight. The main sources of radioactive pollution are: i) nuclear testing, ii) blast of atomic bombs, iii) exhaust of nuclear power plants or accidents in them, and medical and industrial use of radio isotopes.

One gram uranium 235 corresponds to 81,900 million joules, an energy equivalent of 2.7 metric tons of coal or 13.7 barrels crude oil.

The stores of fossil fuels in the world are limited therefore, more and more nuclear fission reactors are installed as they are clean and cheap source of power generation. However, two problems are associated with them. i) They produce increasingly large radioactive waste and ii) pose a greater risk of accident.

You may be aware of the accident that occurred in Soviet Union in 1986 during the testing of one of the four **Chernobyl reactors.** The safety system was shut down while testing. Suddenly, the fuel rod got heated and ruptured, the water of the cooling system turned into steam which reacted with metal fuel to produce hydrogen gas and perhaps some explosive gases. These blew off the top of the reactor weighing about 1000 ton. The dark clouds containing radioactive waste spread over all European countries. About 31 people died within six months after exposure and millions of cases of cancer were predicted in years to come. It is feared that the long-term effects of radiation would be similar to those observed in Hiroshima and Nagasaki victims. About 30 km of the area around the nuclear reactor has been evaluated.

Before the accident USA, France, West Germany, Japan and Soviet Union had 72% of the world's nuclear power generating capacity. But after the accident many countries have chosen not to develop this energy source and also to close some of the operating reactors.

Man has recently begun adding some entirely new radioactive materials to biogeochemical cycle. For example, when uranium splits in nuclear reactors or nuclear weapon tests, a group of radioactive nucleides called fission products are produced. The fission products are mainly strontium and cesium, which are not essential for life. They get incorporated in food chain and then in the biomass. In human beings strontium is concentrated adjacent to bone narrow. It can interfere with the production of white blood corpuscles and can cause leukemia.

The bioaccumulation of radioactive substances in biomass increases tremendously when compared to its amount in physical environment in which the organisms live. For example, the reactor located at the shore of the Columbia river in USA releases a small amount of radioactive phosphorus but its concentration in yolk of the eggs of wild geese which obtained the food from river water was several thousand times more than in river water.

The most n-polluted spot on the planet.
Karachay lake—a 40-hectare body of water stretches to about 1450 km east of Moscow in Soviet Union. It was dumped with nuclear wastes since 1951. The dumping was continued till accumulation reached 120 million curie. The dose rate on the lake shore near the outlet piple is 600 rein/hr. This high exposure for one hour can kill a person within a few weeks.

The environmental fate of the man-made radioactive substances and their movement in food chain are important for the ecologists as well as to the general public.

15.8 CONTROL OF POLLUTION

We have seen that pollution affects human health, vegetation, crop yield, trees, fisheries, forests, buildings, archaeological monuments, tourism. These adverse impacts can be quantified in concrete monetary terms. It has been estimated that pollution-induced damages amount to 2% in USA, 1% in Canada, 3% in UK and 6% in Germany of their Gross National Product (GNP). Such a data is not available for developing countries.

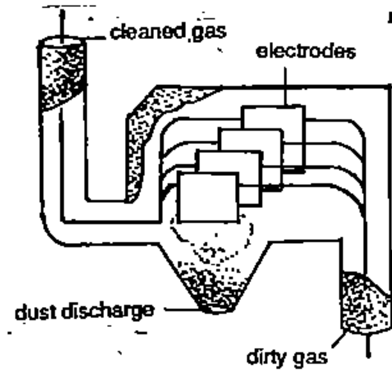
Pollution can be controlled at two levels: i) technological and ii) legal.

Air pollution can be reduced by using bag filters, electrostatic precipitators and cyclone separators that separate large and small particulate matter from emission gases. Sewage treatment plants can be used for the purification of water. These technologies require large investments. However, a cost-benefit analysis of losses due to pollution and gains by using technology indicate that, purely in monetary terms, the gains double up for the money spent.

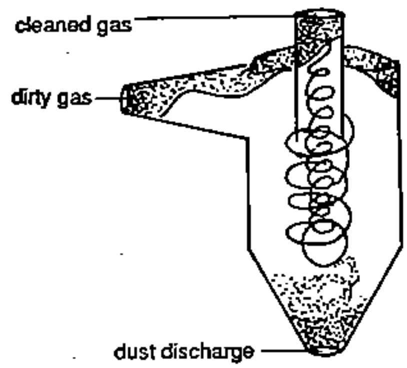
Our country has meagre resources, so a more desirable strategy is the prevention of pollution by waste reduction. Studies have shown that in industrial sector waste reduction makes tremendous economic sense and helps in curbing pollution.

Pollution must be controlled by effective legislation also. The Constitution of India has provision to make environmental legislation. Like USA, Japan, Germany and many other countries a comprehensive legislation for prevention and control of water pollution has also been enacted in India. The Water Act 1974, and Air Act in 1981 are being implemented through the Central Board and State Boards. The Central Board coordinates the regulatory norms and enacts strategies to be undertaken for effective prevention, control or abatement of water and air pollution in the country. It also looks after the pollution control activities in the Union Territories. The Air Act is meant to regulate and control the emissions from automobiles and industrial plants. The state government can declare certain areas as "Air pollution control areas" and the industries cannot operate in such areas without prior permission from the State Board. The Water Act prohibits the dumping of poisonous metals, hazardous chemicals and other pollutants into stream and wells. For dumping of sewage and industrial effluents in water, prior consent of the State Board is necessary.

a) Electrostatic precipitator,—particulate pollutants are electrically charged so that they drift to an electrically grounded wall from which they can be removed easily.



b) Cyclone separators—dust particles are thrown out of air stream in a cyclic motion.



c) Bag house filters particulate pollutants separate from gases as they cannot pass through bags.

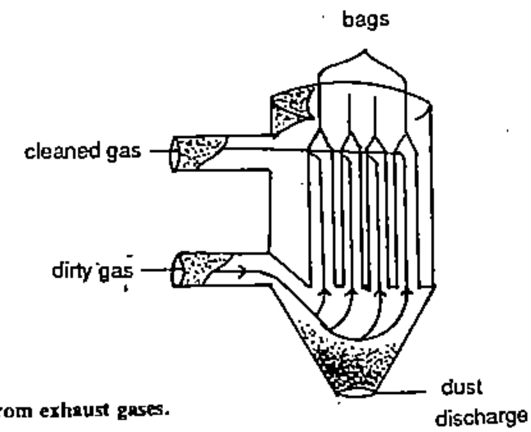


Fig. 15.7 : The devices used for removing particulates from exhaust gases.

In addition to these legislative measures, a nation wide network was set up in 1984 for monitoring ambient air quality. Now, it has 85 stations covering 24 cities. For monitoring the quality of rivers about 170 stations have been set up. Central Board and Department of Ocean Development have jointly identified 173 monitoring stations all along the Indian coast for the purpose of water quality standards. Likewise, in 1968, Insecticide Control Act was enforced to regulate import, manufacture, sale, transport, distribution and use of insecticides. There are also provisions for the regulation of nuclear installation and control on disposal of nuclear wastes.

In spite of legislative activities the air pollution in certain industrial pockets and in major Indian cities seems to be the highest in the world. Our rivers and lakes continue to be choked with sewage and industrial waste. The problem of pollution needs to be tackled more seriously.

SAQ 5

a) List three main health effects due to constant exposure to noise.

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b) List some damages of pollution and show external and human-cost involved.

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15.9 SUMMARY

In this unit you have learnt that:

- The quality of air is progressively deteriorating due to increased emission of air pollutants SO_2, NO_x, CO, dust and hydrocarbons released from fossil fuels, industrial operations, modern agriculture and motor transports. These pollutants form ozone and PAN in the atmosphere.
- Dust, SO_2, NO_x, CO, O_3, and PAN affect human health, vegetation, animals, ecosystems, materials and weather adversely. SO_2 and NO_x cause acid rain that can destroy terrestrial and aquatic ecosystems. Meteorological factors affect the spread of a pollutant released from a source.
- Over the past decade, the layer of ozone in the stratosphere has thinned because of CFCs. Global warming is anticipated due to increase in green house gases. Their further increase in the atmosphere is the cause of concern.
- Pollution in world water resources has been growing due to excessive discharge of domestic and industrial effluents, surface run-off from farms and dump-sites and waste heat. Sewage and effluents containing nutrients reduce DO of water, increase its BOD and upset the aquatic ecosystems. Pathogens result in the outbreak of water-borne diseases.
- Toxic metals and pesticides poison aquatic animals and affect organisms at higher trophic level because of biomagnification. Ground water sources are becoming polluted with nitrate, fluoride, toxic metals and other harmful chemicals. Marine pollution endangers marine life forms and fisheries.
- Solid wastes and liquid effluents discharged on land affect fertility of soil, human health and water resources.
- High levels of noise may cause physical and psychological problems.
- Radioactive fallout due to accidents in nuclear power plants and radioactive wastes are dangerous to human beings. Its far-reaching consequences for coming generations are feared.
- Control of pollution is economically beneficial.
- Pollution can be controlled by appropriate technology and effective legislation.

15.10 TERMINAL QUESTIONS

1) How do you affect your environment? Make a list of substances that you probably add to the environment.

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2) Discuss the ways by which heavy metals in the mine tailing (residues from mining operation) become dispersed in the environment and cause pollution.

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3) List the ecological impacts of acid precipitation.

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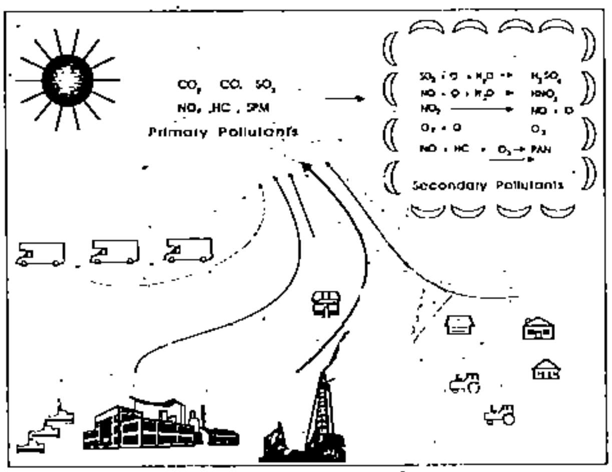
4) Give one word for each of the following:
   i) A material that decomposes in the environment as a result of biological action.
   ii) Deterioration of water quality of a water body because of enrichment with nutrients.
   iii) Increase in toxin concentration within a food chain.
   iv) The cumulative effect of two or more pollutants.
   v) Highly pollutant sensitive plants that can be used to show the level of air pollution.
   vi) Concentration of toxins in biological systems.
   vii) Trapping of air pollutants between the cool air below and warm layer above.
   viii) The abnormal calcification of bones and teeth by excess ingestion of fluoride.

15.11 ANSWERS

Self Assessment Questions

1) a)



b) i) Increase in consumption of energy.
   ii) Burning of forest and savannah grasslands to clear areas for cropland and pasture
   iii) Use of fertilisers and pesticides for modern agriculture
   iv) Increased use of motor vehicles
   v) Extensive industrialisation

2) a) i) Carbon monoxide is formed

$$2C + O_2 \longrightarrow 2CO$$

ii) Chlorofluorocarbons reach the upper atmosphere and destroy ozone by catalysing its decomposition to oxygen. Ozone converts some of the solar UV radiation to IR.

$$Cl + O_3 \longrightarrow 2ClO + O_2$$

$$ClO + O \longrightarrow Cl + O_2$$

Net equation $O_3 + O \longrightarrow 2O_2$

iii) Sulphur on burning forms sulphur dioxide which on oxidation forms sulphur trioxide.

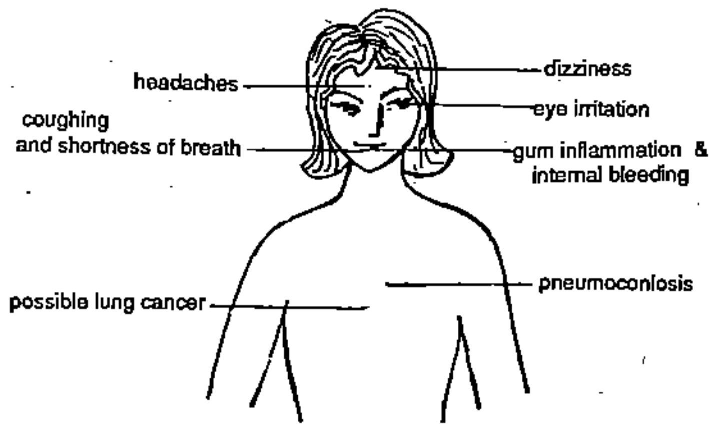
$$S + O_2 \longrightarrow SO_2$$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

SO_3, reacts with atmospheric moisture to form sulphuric acid (H_2SO_4).

a) Oxides of nitrogen react with hydrocarbons in the presence of sunlight to form ozone, peroxyacyl nitrates and aldehydes. For reactions see the text page 61.

b)



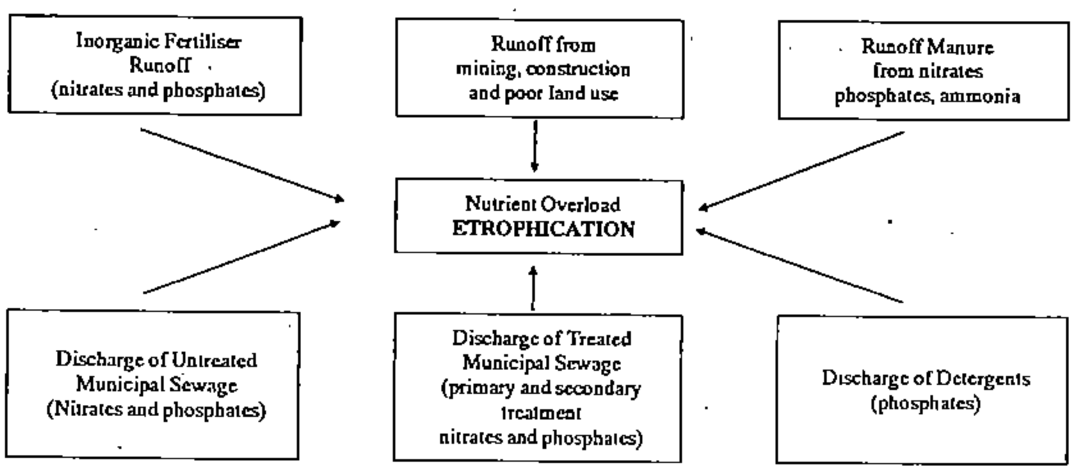
3) a) **Sources:**

i) Domestic sewage, animal wastes.
ii) Agriculture run-offs, mining, phosphate in detergents.
iii) Industrial wastes, fungicides,
iv) Agriculture, pest control.

Effects

i) Outbreak of waterborne diseases such as typhoid, cholera, dysentery
ii) Algal bloom and excessive aquatic growth kill fish—eutrophication
iii) Highly toxic to humans and aquatic species
iv) Toxic to many organisms including humans
v) Harmful to some fish, shellfish, predatory birds and mammals

b)



Sources of Nutrient Overload From Human Activities

c) Biomagnification will increase at higher trophic levels

4) a) **Ludhiana** — Heavy metals chromium nickel, lead, aluminum, due to cycle and woollen garments factories.
Pali — Dyes, bleaches, and acids from handprinting textile units.

b) i) fish, migration, breeding, ii) bottom dwelling organisms, marine birds, flora and fauna, iii) bioaccumulation, biomagnification, higher

5) a) i) Decrease in sensitiveness to hearing, ii) temporary or permanent loss of hearing and iii) change in heart rate, constriction of blood vessels.

b) You may show them as follows:

Health	Illness, long-term effects, lost wages, medical bills
Recreational Loss	Personal loss, business loss—restaurant, tourism hotels, etc.
Material damage	Buildings—cleaning and painting cost corrosion repairs for machinery and equipment
Agricultural damage	Loss of timber, soil damages crop damage and loss of yield
Other organisms	Loss of livestock, loss in fisheries

Terminal Questions

1) Look carefully around your house and make a list of everything your family adds to air, water or soil. For example, CO_2 from fuel NO_x, CO^{Pb} from vehicles, domestic effluents, toilet waste etc.

2) The metallic compounds may get dispersed in the following ways:

   i) **Wind :** It disperses metallic compounds remaining in ash emitted from the smoke stacks of a smelter. These can disperse to far off places and may eventually settle on vegetation or water.

   ii) **Rain Water :** It carries small particles downslop which are eventually deposited in river and flood plains.

   iii) **Leaching :** The metallic salts dissolve in acidic water. These may percolate in the ground and may pollute ground water resources.

3) i) Changes in nutrient budget of forests, agriculture lands, lakes and rivers

   ii) Loss of species diversity of terrestrial and aquatic ecosystem.

   iii) Evolution of resistant species.

   iv) Inactivation of economically and ecologically important soil microorganisms.

   v) Loss in yield of agriculture crop, destruction of forests and fisheries.

   vi) Corrosion of building and historical monuments.

4) i) Biodegradable

   ii) Eutrophication

   iii) Biomagnification

   iv) Synergism

   v) Bioindicator

   vi) Bioaccumulation

   vii) Atmosphere inversion

   viii) Fluorosis

GLOSSARY

ambient air : the air we breathe, the surrounding air

annual average growth rate : increase in population over a given time period divided by initial population

bronchitis : inflammation of the bronchi of the lungs as a result of irritation, often accompanied by a chronic cough

captive breeding : raising plants or animals in zoos or other controlled conditions to produce stock for subsequent release into the wild

demographic transition : the pattern of change in vital rates typical of a developing society showing a shift from high fertility and mortality to low fertility and mortality

demography : study of vital and statistics of population

dredging : a process of mining streambed sands, gravel, and placer deposits through the use of chain buckets and drag lines

emphysema : a pulmonary disorder characterised by over-distention and destruction of the air spaces in the lungs

endangered species : A species considered to be in imminent danger of extinction

extinction : the irrevocable elimination of species; can be normal process of the natural world as species outcompete or kill off others or as environmental conditions change

fibrosis : formation of fibrous tissue around an irritant

fission : the splitting of atomic nuclei into approximately equal fragments

genepool : the genes of all the individual members in a given population

habitat island: a restricted area of habitat that is surrounded by dissimilar habitats

human ecology : the study of interactions of humans with the environment

overburden : the layer of soil and rock that covers deposits of desirable materials

pneumoconiosis : any lung disease caused by dust inhalation

poachers : those who hunt wildlife illegally

rate of natural increase : the different between crude birth and crude death rate

replacement level : the level of the total fertility rate, which if remains unchanged for a generation would lead to zero growth in population

sludge : wet residues removed from sewage

species : a population of morphologically similar organisms that can reproduce sexually among themselves but that cannot produce fertile offsprings when mated with other organisms

total fertility rate : total number of children a women can bear if she experiences the current fertility pattern throughout her reproductive span (15-49 years)

urbanisation : an increasing concentration of the population in cities and a transformation of land use to an urban pattern of organisation

wildlife : plants, animals and microbes that live independently of humans.

SUGGESTED READING

The State of India's Environment : The First Citizen's Report. Third Edition 1987. Centre for Science and Environment, New Delhi.

The State of India's Environment, 1984-85, The Second Citizen's Report, 1986. Centre for Science and Environment, New Delhi.

The Wrath of Nature : The Impact of Environmental Destruction on Floods and Droughts. Centre for Science and Environment, New Delhi.

Environmental Concerns and Strategies, T.N. Khoshoo, 1988. Ashish Publishing House, New Delhi.

Environmental Protection : Problems, Policy, Administration, Law. Deep and Deep Publications, New Delhi.

Dear Student,

While studying the units of this block, you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions, in order to improve the course. Therefore, we request you to fill and send us the following questionnaire, which pertains to this block. If you find the space provided insufficient, kindly use a separate sheet.

QUESTIONNAIRE

LSE-02
Block-4

Enrolment No.

1) How many hours did you need for studying the units?

Unit Number	13	14	15
No. of hours			

2) How many hours (approximately) did you take to do the assignments pertaining to this block?

Assignment Number		
No. of hours		

3) In the following table we have listed 4 kinds of difficulties that we thought you might have come across. Kindly tick (√) the type of difficulty and give the relevant page number in the appropriate columns.

Page Number and Line Number	Types of difficulties			
	Presentation is not clear	Language is difficult	Diagram is not clear	World/Terms are not explained

4) It is possible that you could not attempt some SAQs and TQs. In the following table are listed the possible difficulties. Kindly tick (√) the type of difficulty and the relevant unit and question numbers in the appropriate columns.

Unit No.	SAQ No.	TQ No.	Type of Difficulties			
			Not clearly posed	Cannot answer on basis of information given	Answer given (at end of Unit) not clear	Answer given is not sufficient

5) Were all the difficult terms included in the glossary? If not please list the words in the space given below.

6) Any other suggestion(s) :

To

The Course Coordinator (LSE-02, ECOLOGY)
School of Sciences
Indira Gandhi National Open University
Maidan Garhi
New Delhi-110068.