BLOCK 2 COMMUNITY AND ECOSYSTEM

This Block provides detailed information about the basic concept of ecology, various units of ecology, various components of an ecological system, factors influencing the survival of living components. Besides providing the introduction regarding the plants growing in various habitats such as land and water, information related to various morphological and anatomical modification that help in the survival of plants in dry land and water habitats has been included.

This block contains six units that provide information about various types of ecosystems, the structure and functioning of ecosystem. An introduction about the community, its development, cycling of various elements within the different components of an ecosystem and development of various vegetation zones has been discussed in detail in these units.

Units 5 and 6 provide an introduction to plant communities, various community characters and development of various communities (succession) and various factors regulating the development of communities. Units 7 and 8 discuss the structure of ecosystem, its abiotic and biotic components, and trophic organization. The interrelationship between various living components through food has been explained as food chain and food web. The energy flow among various components of ecosystem has been included in detail.

Units 9 and 10 discuss the cycling of various elements such as carbon, nitrogen and phosphorus among various biotic and abiotic components of the ecosystem and changes in their cycling pattern due to influence of mankind in the recent years. The information about types of vegetation, its distribution around the world, various phytogeographical zones of India, have been explained in detail. The concept of endemism and hotspot areas has also been included in these units.

Objectives

After study of this unit you should be able to:

- describe communities and their development;
- define and discuss ecosystem and its various components;
- outline the flow of elements through various components of ecosystem (biogeochemical cycles);
- describe various biomes such as grasslands, forests and deserts; and
- describe various types of vegetation found all over the world, phytogeographical zones and areas rich in plant diversity.

Unit 5

INTRODUCTION TO PLANT COMMUNITIES

Structure

5.1 Introduction
Expected Learning Outcomes
5.2 What is a Community?
5.3 Community Gradients and Boundaries
5.4 Community Characters
Analytical Characters
Synthetic Characters
5.5. Summary
5.6. Terminal Questions
5.7 Answers

5.1 INTRODUCTION

In (a certain – delete) areas such as forests, rivers, and mountains various species of living organisms co-exist. The species of plants, animals and microbes live together in an area and form an essential component of the community existing in that area. The group of species that occupy a particular area and interact with each other directly or indirectly is called as a biological community. Interrelationships between these organisms determine the functional attributes of an ecosystem such as energy flow or cycling of nutrients. In the present Unit we will study the main features of a community, the level of organization with emphasis to community characteristics.

Expected Learning Outcomes

After studying this Unit you should be able to:

- explain the concept of a biological community,
- describe main features of the community,
- explain community gradients and boundaries,
- describe various analytical characters of the community, and
- define and describe synthetic characters o the community.

5.2 WHAT IS A COMMUNITY?

A Community is an assemblage of species/populations present in a specific area at a particular time. The species are capable of interacting with each other. They represent biotic or living component of the ecosystem. The species are ecologically or dynamically independent of each other but share feeding relationships and habitat. Interactions among species/populations that make up the ecological community give rise to the properties of the community. Example- In field conditions, various types of grasses, insects, worms, birds and mammals interact with each other in various ways. Grasses provide food to insects, mammals and habitat to worms and birds. Insects provide food for birds which feed on worms (and mammals? Do all birds feed on mammals?). All these organisms constitute part of a field community. Similarly various species of living organisms are present in forest, desert, mountain, river, and lakes. They (and – delete) represent an important component of their respective communities. Thus the various species (These all – delete) are important members of natural communities.

In a community the organisms share feeding relationship through food chains. Each species depends upon many other species for food. These species are functionally unrelated. This means that species in a community may not be directly related to each other but indirectly they share various feeding relations.

The size of the community is variable. Areas such as a forest have a large community size with many species of plants, birds, insects, reptiles and mammals living together. In contrast a log of wood represents a small community that supports insect species. Communities such as forests are autotrophic. This is because they include plant species which carry out photosynthesis by deriving energy from sun. Communities found in springs, caves are heterotrophic because they depend upon the organic material such as detritus for energy. If a community is composed of plants of the same species and same age, it is referred to as a stand. The term is applied to a more or less uniform area of vegetation. Example- A wheat field consists of wheat plants almost of same age present in a particular area.

5.3 COMMUNITY GRADIENTS AND BOUNDARIES

It is not possible to define the beginning and end of a community. No specific boundaries are present that can demarcate the beginning of a new community and end of another. Communities grade into each other. Example- In forest communities we cannot differentiate where the boundary of one forest ecosystem starts and other ends. In moving at distances we can make out the differences in species present in an area. The communities can be distinguished on the basis of observable differences in their physical and biological characteristics. The species possess specific characteristics at different physical environments. The species composition changes with changes in physical elevation. Some ecologists have also given the concept of continuum which means that there are no distinct communities with well

defined boundaries but a gradual change in space and time is noted along a gradient. This could be because of change in factors such as moisture, temperature, soil type, altitude or combination of all these. Hence there are no sharp borders or changes in species composition in areas.

Ecotone is the zone of vegetation separating two different types of communities. It is also known as transition zone (Fig 5.1). Examples - an area connecting the forests and grasslands, or a stream running between the meadows. The vegetation of this zone is highly specialized. The region can be narrow or wide. The vegetation is influenced by the environmental conditions. The region between a pond and the surrounding upland is an example of narrow ecotone. It possesses a sufficiently high number of species, i.e. greatest species diversity at a time. The number of species is higher in this region as compared to neighboring areas. This area contains species from both the communities adjacent to each other. Increased variety of plants present at a particular boundary is called edge effect.

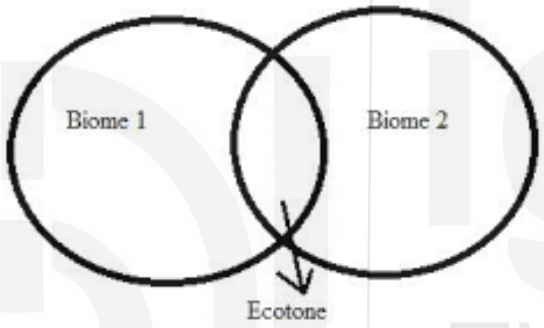

Fig. 5.1: Diagrammatic representation of ecotone.

SAQ 1

Enlist the salient features of a community.

5.4 COMMUNITY CHARACTERS

Communities are characterized by species present in them, their biological structure and physical features.

Form and structure (physiognomy)

The form and structure of a community can be assessed by certain characters and functions. The structure of a terrestrial community is defined in terms of its vegetation. The plants in a community are characterized by various sizes and forms such as tall, medium, short, evergreen, deciduous, woody, herbaceous, herbs, shrubs and so on. Within each category further distinctions are noted. Example- Evergreen trees can be broad leaved or needle-leaved. The vegetation can be made up of succulents, shrubs, rosettes and herbs; or it can be grasses and/or forbs (herbaceous dicots.). Dansereau (1951) proposed a system in which six growth forms, three sizes and four leaf types are

recognized. These include trees, shrubs, herbs, bryoids, epiphytes and lianas. Leaf types are deciduous, semi deciduous, evergreen and succulent. Leaf shapes are needle type or spine, graminoid, broad, compound, small. Leaf textures are filmy, membranous, sclerophyll and succulent.

Each community possesses certain characteristics and these vary according to the level of organization. The characters are of two types- analytical and synthetic.

5.4.1 Analytical Characters

Analytical characters are further characterized as quantitative and qualitative. Qualitative characters are difficult to measure whereas quantitative characters can be measured easily.

Qualitative characters

These mainly include composition, physiognomy, phenology, stratification, abundance, sociability, vitality and vigor, life form (growth form), etc.

1. ***Floristic composition***

This refers to the type of species occurring within a community. In every community some species are abundantly present and are referred as dominant species. In a community both plants and animals are present but the community is named after dominant plant species because plants are stationary and remain in that region throughout their life.

The floristic composition of the community is studied in detail. A list of species present in a community is prepared. Among plants, vascular species are counted. Species appearing in different seasons are considered. The community is named after the species that occurs more frequently and in most of the seasons. Measurement of floristic composition gives us an idea about the following:

- Relationships of a particular species with the environment and with other species occurring in that area.
- The habitat of different species.
- The ecological amplitude of species
- The present conditions and future trends of the community.

For example, *Adhatodha vasica* is a winter annual plant. It grows at low temperature and in association with species such as *Capparis sepiaria*. It shows relationship with environment and other species. The occurrence of this species in hilly and rock areas indicates its habitat. The strong association between the species acts as an indicator of the presence of the other species. Each species possess its own range of tolerance capacity for any environmental condition/factor. The abundance of the species over an area indicates that prevailing conditions exert a favorable effect on its survival. This gives an idea about its ecological amplitude. Floristic composition besides telling us about the presence or absence of a species, also indicates present

conditions and future trends. A decline in the number of a particular species from an area indicates the increase in adverse environmental conditions.

2. Stratification of vegetation

It is another very important feature of a plant community. There are different vertical strata in a community. The growth form of the plant determines the vertical structure which includes their size, branching and leaves. The vertical structure is greatly influenced by physical features such as light.

Stratification occurs because different plant types differ in their requirements and ecological amplitude with respect to light intensity, temperature, moisture conditions, soil and biotic factors. In each community, vertical structure has a stratification of distinct vertical layers. The growth of plant measured in terms of size, branching etc. determines the vertical structure. A well developed forest ecosystem has different layers of vegetation. It possesses species such as trees, shrubs, herbs, grasses. There is canopy layer, understory layer, shrub layer, herb/ground layer and forest floor (Fig 5.2). This type of vertical stratification is seen in tropical forests. In these forests, in addition to all these layers, we find lianas and climbers. Canopy is the site for energy fixation through photosynthesis. The canopy structure influences the other vegetation present in a forest. A canopy is said to be open when light reaches the lower layers. In such areas shrubs and understory vegetation is well developed. In a closed forest, most of the light is intercepted by tree canopies and under story plants remain deprived of light. In these areas, shade tolerant species having poor growth of herbaceous layers develop. A forest with four layers of strata support greater diversity of life forms in comparison to grassland vegetation which has only two strata.

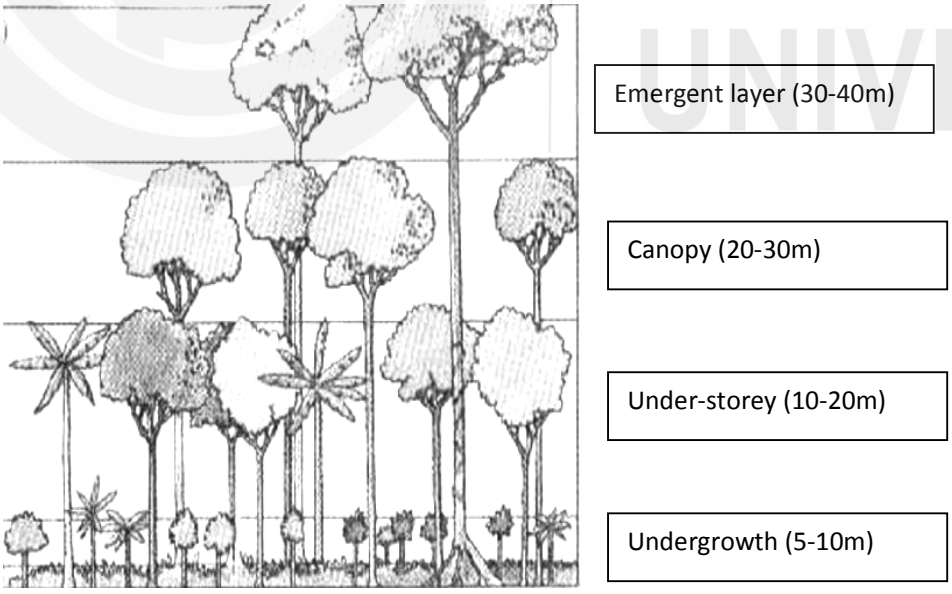

Fig. 5.2: Forest depicting vertical stratification.

Stratification is also exhibited by aquatic ecosystems. The strata of the aquatic ecosystems are determined by the physical characteristics of the water column. In lake and ocean ecosystems, light penetration, temperature and

availability of oxygen varies with depth. In summer, a lake has various stratifications. The upper layer present on the surface is called epilimnion. It possesses a layer of freely circulating water with uniform temperature. The second layer - metalimnion – (and – delete) is characterized by a thermocline, i.e. a rapid decline in temperature. The third layer (is – delete) called hypolimnion (which – delete) is deep with dense water having low oxygen content and mud at the bottom (Fig. 5.3). Upper zone that receives sufficient light is dominated by phytoplanktons and here the photosynthesis occurs at a rapid rate. In the lower layers where light is less, decomposition takes place.

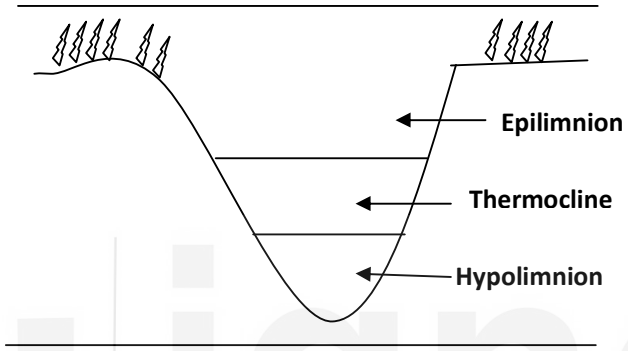

Fig. 5.3: Stratification in a water body.

Stratification has a profound influence in the supporting animal life. It influences the diversity of animals present in a community. A strong correlation has been found between height of vegetation and species diversity of birds. Increased vertical stratification increases the availability of resources and living space. This favors degree of specialization. Grassland with two strata holds 6-7 species of birds and ground nesters, while a deciduous forest supports about 30 species of birds.

3. Periodicity (phenology, aspection)

It refers to the changes in characteristics of community with seasonal changes. Each species has a different requirement for light, temperature, moisture and other environmental factors. Accordingly, the period of growth events such seed germination, vegetative development, flowering and fruiting (reproductive phase), fruit and seed dispersal and seed dissemination varies for each species. A study that collects data for the time of these events is called phenology. It is also referred as "the calendar of events" in a plant's life. A diagrammatic representation of these events is known as a phenogram. Phenology of each species present in the community differs significantly.

Aspection – It is defined as the appearance of the community as a whole in different seasons. Example-(In a community – delete) If four plant species are present and all the species flower at the same time (in the months of July, August), it is easy to describe the community (successively – delete). So the community has a characteristic appearance during the different months of the year. This pattern can be seen every year. If another species develops that flowers in a different month say April, the appearance of the whole community will change. This is also an example of seasonal shift in the community. Hence

from this calendar of events, we can predict the appearance of community at different times of the year.

Animals depend upon the plants for food and other requirements. Therefore, (hence – delete) the activities of the animals coincide with the time of maximum activity in plants. Example *Trioza fletcheri minor* is an insect associated with the tree *Terminila arjuna*. The insect forms galls on the leaves and flowers of the tree. During the growing season of tree, the insect grows actively and forms galls on the leaves because the insect gets sufficient supply of tender leaves and other plant parts for feeding. Young ones of the insects develop on the galls. This insect times its reproductive phase with the growth phase of the tree.

4. Vitality and vigor

Vitality is the capacity of the plant to complete its life cycle. Vigor is the heath or development of the plant at a particular stage in the life cycle. It is determined by the rate and the amount of growth. The parameters include changes in height, area of foliage, color and turgidity of stems and leaves, degree of damage caused by insects, time and appearance of flowers, fruits, development of new stem and leaves. Daubenmire classified according to vitality into different groups:

V1-plants whose seedlings die

V2-seedlings grow but unable to reproduce

V3-reproduce vegetatively

V4-reproduce sexually but are uncommon

V5 reproduce sexually and grow regularly

5. Life forms

The nature of the vegetation tells about the form and structure of the community. Vegetation can be categorized into different types such as herbs, shrubs, trees. The further categorization is done on the basis of height such as tall or short, texture such as herbaceous or woody, nature of occurrence such as evergreen or deciduous. Further divisions have been suggested on the characteristics of the leaves, such as (done like – delete) needle leaved evergreen, broad leaved evergreen, broad leaved deciduous, grasses etc. Raunkier (1903) gave a system in which plants were classified according to the relation of their height above ground to the pernnating organ. The organ that survives from one growth season to the next, (remaining active throughout the summer but inactive during winter period) is referred to as the perennating organ. It generally includes the embryonic or meristematic tissue of buds, bulbs, tubers, roots and seeds. Five forms of plants that have been categorized include

i) Phanerophytes

ii) Chamaephytes

iii) Hemi cryptophytes

iv) Cryptophytes

6. Therophytes

Phanerophytes- The perennating organs which include buds are present on erect, shoots present above the ground. The buds are naked and exposed to external environmental conditions. These include trees, shrubs and climbers present in tropical climate.

Chamaephytes- The perennating organs are present on shoots found close to or just above the ground (Fig 5.4). The buds receive protection from external environmental conditions via fallen leaves and snow cover. These include creeping woody plants and herbs found in cool dry climates, i.e. arctic and alpine regions.

Hemi cryptophytes- The perennating organs are present near the ground and receive protection from fallen leaves and soil cover. These include biennial and perennial herbs growing in rosettes. The plants are found in cold, temperate zones. The aerials parts of the plants die on the onset of unfavorable conditions.

Cryptophytes- The perennating organs or buds are buried in the ground i.e. they are present under the soil cover. The buds are protected from freezing or drying. These include tuberous or bulbous herbs found mainly in the arid zones.

Therophytes- These are annual plants and complete their life cycle in summer or the favorable season. They complete their life cycle in a single season (few months). Seeds (which are the perennating organs) remain dormant during the unfavorable season. These include plants occurring in deserts and grasslands.

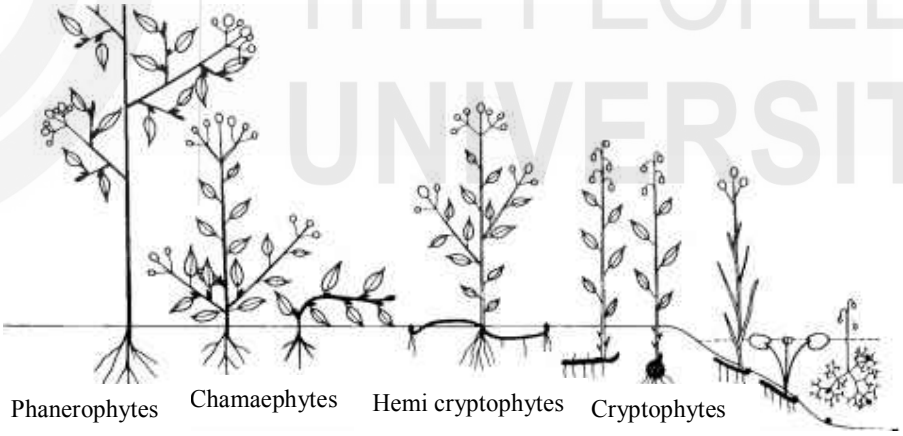

Fig. 5.4: Different plant forms based on their occurrence from the ground (Raunkiers classification of plant forms).

The relative proportion of different types of vegetation tells us about the climatic conditions prevalent in that area. Phanerophytes generally comprise 60-90% of the flora of humid regions. Hemi-cryptophytes occupy around 50% of the cool temperate regions (Fig 5.5).

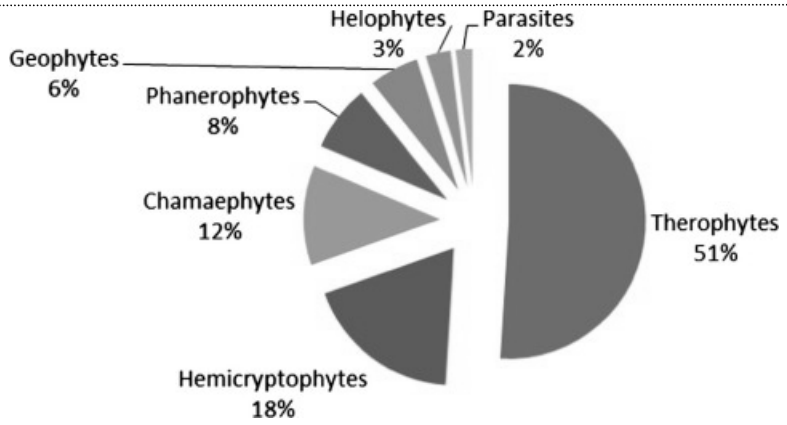

Fig. 5.5: Relative proportion of different plant forms.

7. Sociability

Sociability refers to the nature of grouping of individual plants, whether they grow singly, in patches, in colonies or evenly intermixed. This feature depends upon the life form, its vigor, habitat, competition and relations with the individuals. It represents degree of association of between species. The plants have been categorized into five groups (Sociability Classes S1 to S5) depending upon their sociability.

S1- Plant found separately from each other i.e. grow singly

S2- Group of 4-6 plants growing at a place.

S3- Small group of plants growing at a place.

S4- Big group of plants growing at a place.

S5- A large number of plants occupying an area.

Quantitative characters

These include parameters that can be measured or counted.

1. *Population density*

It depicts number of individuals of a particular species in a unit area. It represents numerical strength of a community. By measuring this parameter we can have an idea about the abundance of a species. It also gives us information about degree of competition between the members of the species. It is expressed as number of individuals per unit area. It can be calculated by the formula

$$\text{Density} = \frac{\text{Number of individuals of a species in all the sampling units}}{\text{Total number of sampling units studied}}$$

Ecological density- It is the density of individuals of a species calculated for a place of their frequent occurrence.

2. Cover (herbage cover)

It refers to the area of the ground occupied by leaves, stem and inflorescence i.e. above ground parts of the plant. Each layer of vegetation is considered

separately. The overlapping units are also considered. The tall vegetation is rated separately from those growing under it. Basal area refers to the ground penetrated by stems i.e. portion of the plant that grows into soil (Fig 5.6). Canopy area is the area below the plant that covers the soil surface?? [Canopy refers to the uppermost layer. Please see the Fig. 5.6 below and correct the statement]. Foliage cover is the soil surface covered with leaves. When the herbage cover forms a continuous cover, it is said to be closed. When the vegetation cover has gaps that get colonized by individuals it is said to be open. If the space between the vegetation is more, it is considered to be sparse.

Herbage cover is very important in study of vegetation. It helps in understanding the nature of community and evaluating the quantitative relationships between the species. Information about herbage cover tells about the changing trends of a community.

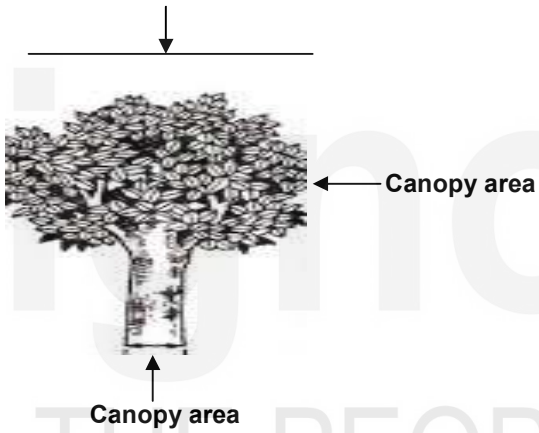

Fig. 5.6: Diagrammatic sketch showing herbage cover and basal area.

3. Plant height

The height of the plant is a good indicator of the performance of vegetation. It is also referred as stratification. It tells us about the success of a species in various habitats. It indicates presence of favorable environmental conditions. Stratification results in upper strata or canopy which receives higher proportion of light. A variation in plant structure and stratification within the community leads to stratification of the environment.

4. Weight of plants (biomass)

It is one of the important quantitative features of the plants. It gives us an idea about growth. It is generally expressed in the form of dry weight of plants. Biomass or the weight can be measured separately for the above ground plants parts such as stem, leaves, fruits and flowers and belowground plant parts such as roots. It is measured after drying the plant at 80^{o}C for 2 days. The data also gives us valuable information about yield of the species or the forage.

SAQ 2

Describe in brief:

1) Stratification

2) Periodicity

3) Vitality and Vigor

4) Sociability

5) Cover

5.4.2 Synthetic Characters

Presence and constancy

It refers to the presence of different strands of a species in the uniformity. Example if a species is present in 15 strands out of 20, the presence or constancy is 75%. Term constancy is used when equal, measured sample areas are used for study. Term presence is used when the area of sampling unit varies from strand to strand. Species in a community can be classified into five classes of constancy according to their periodicity i.e. occurrence in sampling units or strands. 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

Class IV and V include species that occur in large number of strands. The species that occurs in over 80-90% or more number of strands/sampling units is called as **constant species**. These species are the characteristic of a community and help in the distinguishing a community. The species belonging to these classes (IV, V) have wide ecological amplitude and are capable of growing in microhabitats. In many ways, the can be easily compared with the "frequency of distribution discussed below.

Fidelity

It refers to the degree to which a species is restricted in its occurrence to a particular community. Fidelity is the occurrence of a species in different kinds of communities, while constancy is the frequency of occurrence of a species in various strands of a community. The species with low fidelity occurs in different communities while species with high fidelity are restricted to one or only few communities. Five classes of fidelity has been given

A) Characteristic species (character, faithful species)

Fidelity 5 – Exclusive, completely restricted to one kind of a community

Fidelity 4 – Selective, occurring frequently in one kind of a community but rarely in others.

Fidelity 3 – Preferential-occurring more or less abundantly in several kinds of communities. Abundantly present with optimum conditions 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.

A species of fidelity 5 is referred as **indicator species.**

Some species are seen abundantly in a community while other species are rarely seen due to the presence of unfavorable conditions. Ecological amplitude or the capacity to tolerate unfavorable conditions varies for each species. It also depends upon the ability of the species to form association with other species in a community.

Dominance

It represents the presence of species in high numbers in a community. This could be due to the presence of favorable conditions or its capacity to tolerate wide range of ecological conditions. The population of other species is reduced in number and vitality. Cover and population density are the chief features determining dominance. The dominant species possess the capacity to alter the microhabitat. This gives them the chance to grow in wide range of environmental conditions. Example - *Cynodon* is a dominant species occurring in pastures and grasslands. It possesses excellent vitality, rapid rate of multiplication and growth and deep root system.

Physiognomy and pattern

Physiognomy is the general appearance of the vegetation as determined by growth form of dominant species. The variety of plant growth forms are referred as life forms. The commonly described growth forms include herbs, shrubs and trees.

It is based on the appearance of the qualitative characters such as form, height, stratification, cover and association with the species. Example a community having large number of trees as compared to herbs and shrubs is generally considered as forest.

The groups or clumps of individuals or in any other non-random arrangement of individuals in a community are referred as **pattern.**

Frequency

The degree of spread or distribution of individual species present in an area is dispersion. It describes the structure of an ecological community. Three basic patterns of dispersion are known. These include random, uniform or regular,

clumped or contagious. It is usually expressed as percentage. It can be studied by sampling the study area randomly at different intervals.

Frequency = Number of sampling units in which species occurred x 100
Total number of sampling units studied

Raunkier recognized 5 Frequency Classes in natural vegetation.

Class A – Plants showing frequency distribution of 0 – 20 %

Class B - Plants showing frequency distribution of 21 – 40 %

Class C - Plants showing frequency distribution of 41 – 60 %

Class D - Plants showing frequency distribution of 61 – 80 %

Class E - Plants showing frequency distribution of 81 – 100%

Suppose a species occurs in five sampling units out of 20, then its frequency is 25%. A species that is uniformly spread over an area will show frequency of about 100%. In contrast a poorly dispersed species with large number of individuals aggregated at one place will show low frequency. A high frequency shows greater uniformity and dispersion. Frequency of a species relative to other species in a community is referred as relative frequency.

Relative frequency = Frequency of a species x 100
Total frequency of all the species

Importance value index (IVI)

In a community, the parameters density, frequency, cover, and pattern have their own importance. Each parameter determines a specific feature. Example -frequency tells about the dispersion of a species over an area. Density gives us an idea about the numerical strength of a species present in a community. The ecological importance of a species in a community can be assessed by studying the parameters such as relative frequency, relative density and relative abundance. These values are added together to get 300 which is considered as importance value index (IVI) of the species. This value is represented diagrammatically. A circle is drawn and divided into four equal (halves – delete) quarters (because you can halve only 2 equal halves and not 4, but you can have 4 equal quarters) by drawing two line segments at right angles to each other passing through the center. Each of the three radii is divided into 100 parts from the centre to the circumference and the fourth into 300. Zero to 100 scales are marked and the values of relative frequency on A, relative density on B and relative dominance on C and IVI values on D are marked (Fig 5.7). All the points are joined. Such illustrations help to provide sociological features and IVI of a species. Thus IVI gives the composite picture of sociological status of the species in a community.

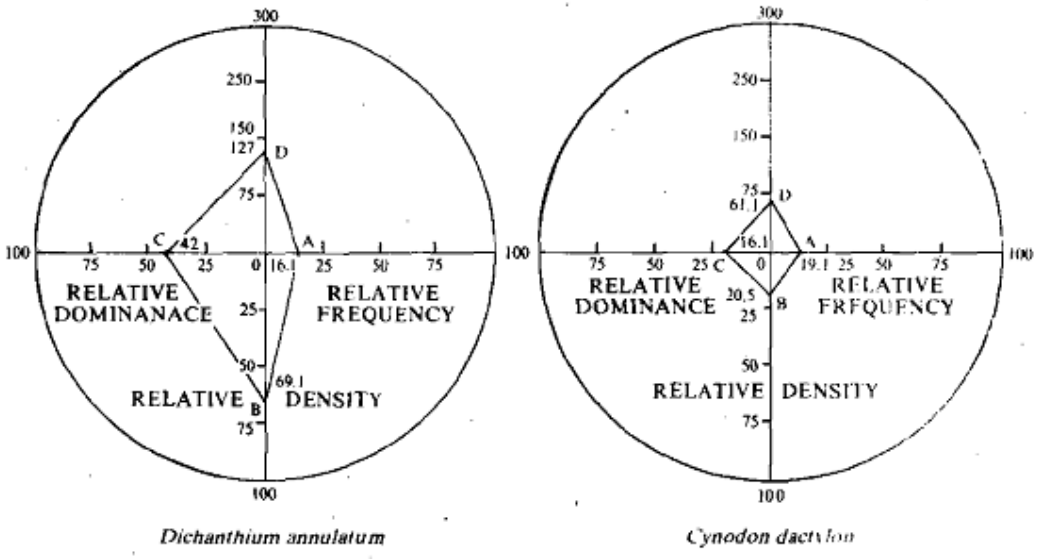

Fig. 5.7: Diagrammatic representation of relative density for plant species.

Species diversity

It is one of the most important characteristic of the community. It is measured by counting the number of species present in a given area. It can easily be calculated for plant species. More time is required to calculate species diversity for wider areas such as forests. An elaborate study needs to be undertaken to determine the exact value of species diversity. Example- In a comparison of two samples of species A and B with 100 individuals each.

Sample	Number of individuals of species A	Number of individuals of species B
I	50	50
II	99	1

In sample I, there are 50 individuals of A, and 50 individuals of B. In sample II, there are 99 from A and 1 from B. Is the species diversity of the two samples same? If we measure the diversity as number of species present in each sample, it is yes, but according to ecologists consider the community with 50A and 50 B to be more diverse than 99 A and 1B. The species diversity is determined by using an equation known as Shannon's Index of Diversity (H').

$$H' = -\sum_{i=1}^{i=S} p_i \log_e p_i$$

H'- Index of species diversity

S- Number of species

P- Proportion of total samples belonging to the *i*th species calculated by dividing the number of individuals in species (*i*) by total number of individuals in the sample.

e- base of the natural logarithms (log p_i= 2.302 x log $_{10}$ p*i*)

- means adding of expressions for values of *i* (from *i*=1 to *i*=S)

The larger is the H' value, the greater is the uncertainty about predicting the next species to be encountered and greater is the diversity of the species.

For the above example

Sample I

H'= -[0.50 x log $_e$ 0.50) = (0.50 x log $_e$ 0.50)]

= - [2 (0.50 x-0.69)]

=0.69

Sample II

H'= - [0.99 x loge 0.99) = (0.01 x log e 0.01)]

= - [(0.99 x-0.01) + (0.01x -4.61)]

= -[(0.01) + (-0.05)]

=0.06

Hence sample I have greater species diversity.

SAQ 3

Define

1) constancy
2) fidelity
3) dominance
4) physiognomy
5) dispersion

SAQ 4

How is species density important in a community?

5.5 SUMMARY

In this Unit we have learned many aspects of community such as its structural composition and various characters.

- Communities are made up of populations of organisms occupying a particular area and interacting with each other.

- The size of the community is variable. It can be very large or small.
- Based on the presence of species, the community can be autotrophic or heterotrophic. Autotrophic communities possess the capacity to use solar light energy.
- The community does not possess any sharp boundaries. The communities blend together to form a continuum along the environmental gradient.
- The area where the two communities overlap is called ecotone. This zone has high species richness.
- The study of the analytical and synthetic characters is required to get an idea about the structure of the community. The communities are recognized by characters of plants.
- Study of qualitative characters includes floristic composition, stratification, periodicity, vitality and vigor, life forms and sociability. Quantitative characters include population density, herbage cover or cover area, height and weight of plants.
- The synthetic characters mainly include constancy, fidelity, dominance, frequency and species diversity.

1.6 TERMINAL QUESTIONS

1. Write one word for the following:
   a. The area where the two adjacent communities merge.
   b. An area having species of same kind and age.
   c. The plants having high fidelity.
   d. The plant species present abundantly over an area at a given time.
   e. The weight of plant present at a given time.
2. Describe classification of plants forms given by Raunkier.

1.7 ANSWERS

1. Community
   - represents biotic components of an ecosystem
   - consists of various organisms interrelated to each other via feeding relationships
   - species may not be directly related to each other
   - vary in size
   - may be autotrophic or heterotrophic in nature
   - may consist of many strands

- beginning and end of a community cannot be defined i.e. no specific boundaries represent beginning of a new community and end of another.

2.

1) Stratification

The different types of species such as trees, shrubs, herbs, grasses present as layers is called stratification. Vertical strata s commonly reported in a community. Stratification occurs because different plant types differ in their requirements and ecological amplitude with respect to light intensity, temperature, moisture conditions, soil and biotic factors.

2) Periodicity

It refers to the changes in characteristics of community with season. Each species have different requirement for light, temperature, moisture and other environmental factors. Accordingly growth events such seed germination, vegetative development, flowering and fruiting (reproductive phase), fruit and seed dispersal and seed dissemination vary for each species.

3) Vitality and vigor

Vitality is the capacity of the plant to complete its life cycle.

Vigor is the heath or development of the plant at a particular stage. It is determined by the rate and the amount of growth. The parameters include changes in height, area of foliage, color and turgidity of stems and leaves, degree of damage caused by insects, time and appearance of flowers, fruits, development of new stem and leaves.

4) Sociability

It refers to the nature of grouping of individual's plants whether they grow singly, in patches, colonies or evenly intermixed. This feature depends upon the life form, its vigor, habitat, competitions and other relations with the individuals. It represents degree of association of between species.

5) Cover

It refers to the area of the ground occupied by leaves, stem and inflorescence i.e. above ground parts of the plant. Foliage cover is the soil surface covered with leaves. Basal area refers to the ground penetrated by stems i.e. portion of the plant that grows into soil. This property is important in study of vegetation and understanding the nature of community particularly in evaluating the quantitative relationships between the species.

3. Define

Constancy

It refers to the presence of different strands of a species in the uniformity. Equal measured sample areas are used for study.

Fidelity

It refers to the degree to which a species is restricted in its occurrence to a particular community. The species with low fidelity occurs in different communities while species with high fidelity are restricted to one or only few communities.

Dominance

It represents the presence of species in high numbers in a community. The presence of favorable conditions or capacity to tolerate wide range of ecological conditions supports the property. The dominants possess the capacity to alter the microhabitat which gives them the chance to grow in wide range of environmental conditions.

Physiognomy

The visible structure or external morphology of a plant is the basis of its classification. The structure of the dominant species defines physiognomy. Broad physiognomic types include forest, shrub, and grass/herbaceous types.

Dispersion

The degree of spread or distribution of individual species present in an area is dispersion. It describes the structure of an ecological community. Three basic patterns of dispersion are known. These include random, uniform or regular, clumped or contagious.

4. It is one of the most important characteristic of the community. It enumerates the number of species present in a given area. It is measured by counting the number of species present in a given area. It can easily be calculated for plant species but is an elaborate exercise taking good amount of time. It is an important property because it helps to determine the diversity of the species population present in a given area.

Terminal questions

1.

a. The area where the two adjacent communities merge- Ecotone

b. An area having species of same kind and age- Stand

c. The plants having high fidelity- Indicator

d. The plant species present abundantly over an area at a given time- Dominant

e. The weight of plant present at a given time-Biomass

2. According to Raunkier, five major plant forms have been categorized

- Phanerophytes
- Chamaephytes
- Hemi cryptophytes
- Cryptophytes
- Therophytes

Phanerophytes – The perennating organs which include buds are present on erect, shoots present above the ground. The buds are naked and exposed to external environmental conditions.

Chamaephytes – The perennating organs are present on shoots present close to just above the ground. The buds receive protection from external environmental conditions via fallen leaves and snow cover.

Hemi cryptophytes – The perennating organs are present near the ground and receive protection from fallen leaves and soil cover. These include biennial and perennial herbs growing in rosettes.

Cryptophytes – The perennating organs or buds are buried in the ground i.e. they are present under the soil cover. The buds are protected from freezing or drying. These include tuberous or bulbous herbs.

Therophytes – These are annual plants and complete their life cycle in a single season (few months). Seeds remain dormant during the unfavorable season. These include plants occurring in deserts and grasslands.

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Unit 6

SUCCESSION IN COMMNITIES

Structure

6.1 Introduction
Expected Learning Outcome
6.2 What is Succession?
6.3 Processes in Succession
6.4 Types of Succession
Hydrarch
Xerarch
6.5 Summary
6.6 Terminal Questions
6.7 Answers

6.1 INTRODUCTION

Ecosystems are dynamic entities in which a large number of events takes place. The biotic communities present in an ecosystem undergo changes with time. The changes can occur naturally or can be induced by man. The changes can be short term or long term. Long term changes permanently change the characteristics, organization or composition of the ecosystem. The long term changes are caused by natural events such as volcanic eruptions, landslides, floods, hurricanes and human interventions such as mining and deforestation. All these changes alter the community structure to a significant extent. The species present in a habitat change with passage of time. (Variety of – delete) Many new species invade the area with passage of time. These new species then develop into a community with the passage of time. One community replaces the other until a stable mature community develops.

In the present Unit, we will focus our study on the large scale changes that occur in a community with the passage of time. These changes are referred as ecological succession. The processes involved in succession will be discussed. The process of succession shall be explained with the help of examples.

Expected Learning Outcome

After the study of this Unit, you would be able to:

- define succession,

- differentiate between primary and secondary succession,
- (make out – delete) know the differences between autogenic and allogenic succession,
- compare autotrophic and heterotrophic succession,
- describe the various processes involved in succession,
- explain stages of succession (noted – delete) observed in terrestrial and aquatic habitats, and
- list the various models used to study succession.

6.2 WHAT IS "SUCCESSION"?

The changes in the environmental conditions affect the ecosystem considerably. The structure of the community changes considerably by replacing one species by other species which develop in the area over the period of time. Within any community some species become less abundant or disappear over period of time. Some species within the community become more abundant or new species invade into the community from adjacent ecosystems over the time. The process of change in the species structure over time is termed as 'succession'. The change in the composition of species of an ecological community of an ecosystem (noted – delete) recorded/ observed in an interval of time is referred as 'ecological succession'. According to Odum, plant succession can be defined as "an orderly process of community change". Succession can be defined as a directional non-seasonal change in the species composition of an area with passage of time. It involves various stages such as colonization, establishment, and extinction.

A set of environmental conditions is required for the optimum growth and reproduction of a species. In a given ecosystem, species can grow most efficiently and produce viable offspring. They become abundant with time because of favorable environmental conditions. The species flourish till the environmental conditions remains constant. Under the change of environmental conditions, the survival of dominant species gets affected and other species appear in the area. Each stage of ecological succession takes a few years or a few hundred years.

Ecological succession may also occur when environmental conditions change drastically. Forest fires, wind storms and human activities such as agriculture alter the conditions of an environment to a great extent. These massive forces destroy species and thus alter the dynamics of the ecological community. The survival of the dominant species gets affected. The process of succession begins in an area partially or completely devoid of vegetation because of a disturbance such as fires, wind storms, volcanic eruptions, climate change, severe flooding, and disease or pest infestation. Succession stops when species composition does not change with passage of time. The community present at that point of time is refereed as climax community. The establishment of the climax community provides stability to the community and the region remains in an equilibrium within an ecosystem. The concept of

succession was given by Frederic Clements. Some species become dominant because of their size, abundance and ability to compete successfully with the associated species. The presence of a particular dominant species usually referred as pioneer community consisting of different group of plants invades the community and eventually replaces the original colonizers. Climatic and topographic changes bring marked changes in the community structure over a period of time and this affects the plant associations with other species. The succession may be rapid or extend over many years until stability is attained through the establishment of vegetation.

A single case of plant succession at a particular kind of habitat is usually referred to as a sere. The various stages of a sere are called seral stages.

Plant succession is two types

(i) Primary succession

It begins in area which is originally/*ab initio* bare i.e. without any plants. It could be just water, bare rock, or sand. Thus, the area does not have any existence of vegetation previously. The process of succession begins with the colonization and establishment of pioneer species in/on the bare area.

(ii) Secondary succession

This kind of succession begins in area where the vegetation was present previously but it got destroyed or disturbed. It occurs in areas of forest fires, deforestation, flood, erosions or abandoned agricultural lands.

Based on the causes of succession, it has been categorized as

Allogenic succession – Succession is caused by change in environmental conditions. It changes the composition of the plant community.

Autogenic succession - Succession occurs due to changes in soil structure, composition and activities of plants. The changes in the plant community support growth of few species and causes adverse effects on growth of other.

Succession can be also be categorized as

Progressive succession – It is a type of succession in which sequential development of community occurs. A simple community with few species and low productivity develops into a complex community that contains more species and greater productivity.

Retrogressive succession – It is a kind of succession where the community becomes simplistic and contains fewer species and less biomass over time.

Table 1 Changes in the characteristics of plant at early and late stages of succession.

Attribute	Early stage of succession	Later stage of succession
Plant Biomass	small	large

Plant height	short	long
Plant morphology	Simple	complex
Seed longevity	long	short
Species type	r	k
Plant species diversity	low	high
Species stability	low	high
Net primary productivity	High	Low Please check
Plant canopy structure	Multilayer	Monolayer Please check

SAQ 1

Answer the correction option

1) Primary succession takes longer time than secondary succession because it involves
   a. development of soil
   b. accumulation of seeds
   c. colonization by organisms
   d. destruction of habitat by catastrophe
2) Secondary succession takes place on
   a. rock
   b. grassland
   c. land destroyed by a catastrophe
   d. volcanic land
3) Autogenic succession is brought about by
   a. human activities
   b. physical conditions of the environment
   c. living inhabitants of that area
   d. natural disasters
4) The plants that act as pioneer communities
   a. mosses
   b. shrubs

c. grasses

d. trees

6.3 PROCESSES IN SUCCESSION

Generally the process of plant succession consists of nine steps. The steps include nudation, migration, germination, ecesis, colonization and aggregation, competition, invasion, reaction and stabilization.

1. Nudation

An area in which no living form is present is referred as nude area. The process of establishment of a species or primary succession occurs in this area (Fig 6.1). In this stage, one pioneer species establishes itself. It can be a seed or bacteria or an insect. Pioneer species thrive well in the new habitat. These species are 'r-selected' species that are fast growing and well-dispersed. Early succession is therefore dominated by so called 'r-selected' species.

2. Migration

The seeds, spores and other structures involved in the propagation process establish in the nude area.

3. Germination

The process involves the germination of seeds or spores on the onset of favorable conditions.

4. Ecesis

Successful germination of propagules and their establishment in a bare area is known as ecesis. The pioneer species establishes itself in an ecosystem and is able to sustain its basic needs – such as food, water and safe habitat.

5. Colonization and Aggregation

In this stage of succession, the individuals of the species increase in number as the result of reproduction. The life form begins to enter into a pattern that allows for a cycle of life to continue in the ecosystem. There is little migration outside of the ecosystem. As succession continues, more species enter the community and begin to alter the environment. These are called 'k-selected' species. Life forms are breeding and growing.

6. Competition and Co-action

Species compete (inter and intraspecific competition) with each other for resources. The better suited species begin to succeed over the other species. These are superseded by new species. The species with better vigor dominates the area while weaker species get eliminated.

7. Invasion

Species from other areas invade come and try to establish themselves in the spaces left by the elimination of plants due to competition.

8. Reaction

The new plants invade the area and affect the growth and survival of the earlier existing ones. As a result of reaction, the environment is modified and becomes unsuitable for the existing community. The existing community gets replaced by other community.

9. Stabilization

Finally, a stage is reached in which plant species gets successfully established in an area and gets stabilized with the passage of time. Community is thus dominated by stable and small number of prominent species. The stage is called climax or the state of equilibrium. The climax community maintains itself in equilibrium with the climate of the area. The climax community has larger size of individuals, complex organization with efficient use of energy and nutrients.

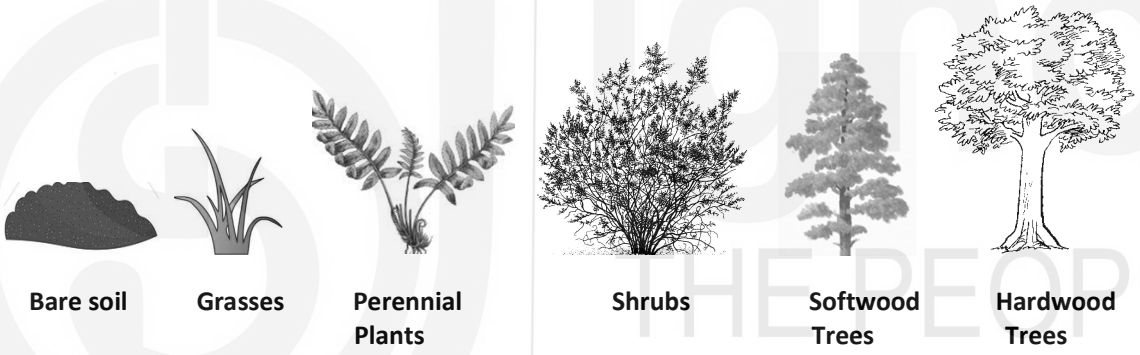

Fig. 6.1: Stages of succession in establishment of vegetation.

During succession there is:

1. an increase in structural complexity.
2. an increase in diversity of species.
3. increase in biomass and standing crop.
4. decrease in net community production.
5. increase in non-living matter.
6. increase in complexity of food chain relationship.
7. narrowing of niche.
8. increase in energy use and nutrient conservation efficiency.
9. increase in stability.

SAQ 2

Discuss the positive changes in community structure after succession.

Examples of succession

Oak Forest

Dwight Billings (1930) studied the succession of plant species that occurred on abandoned agricultural fields in North Carolina (Fig. 6.2). Since the area was under cultivation in the past, there was proper soil available for plant growth. Thus the process of formation of a new community takes place by "secondary succession". He proposed detailed sequence of events during succession of plant communities in the area. The first stage of succession includes (characterization – delete) the invasion of the bare ground area by pioneer species. These annual species had short lifespan (one growing season) and showed rapid maturity. The annual species were then replaced by biennial plants and grasses in the coming years. After about 3 to 4 years, the biennial and grass species gave way to perennial herbs and shrubs. These plants live for many years and have the ability to reproduce several times in their lifespan. After about 5 to 15 years, the sites were colonized by softwood tree species including loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), Virginia pine (*Pinus virginiana*), and sweetgum (*Liquidambar styraciflua,* Family Altingiaceae). As the softwoods increased in their numbers and grew in height, they began forming a forest canopy. This canopy reduces the amount of light reaching the forest floor. The resulting shaded understory conditions caused the exclusion of many light loving perennial herb and shrub species. Perennial herb and shrub species that were adapted to low light conditions now began to take over the ground cover. The canopy also changed the microclimate of habitat near ground level. It was now more humid, has moderated temperatures, and less wind. These conditions allowed the germination of hardwood species like oak (*Quercus s*pp.) and various species of hickory (*Carya* spp). The seedlings of these tree species also tolerate low light levels.

By about 50 to 75 years after the initial colonization of the pioneer species, the hardwoods started to replace the softwood species in the developing forest. At this stage in the succession, the pines had maximum heights of about 25 meters, while the oaks and hickories were on an average about 10 meters tall. Because of their shorter lifespan (50 years), many of the softwood species died. The gap that was created by loss of softwood trees was filled by subdominant hardwood tree. Hardwood species, like oak and hickory live for more than 100 years. Sites more than 100 years old were found to be dominated by mature oak forests.

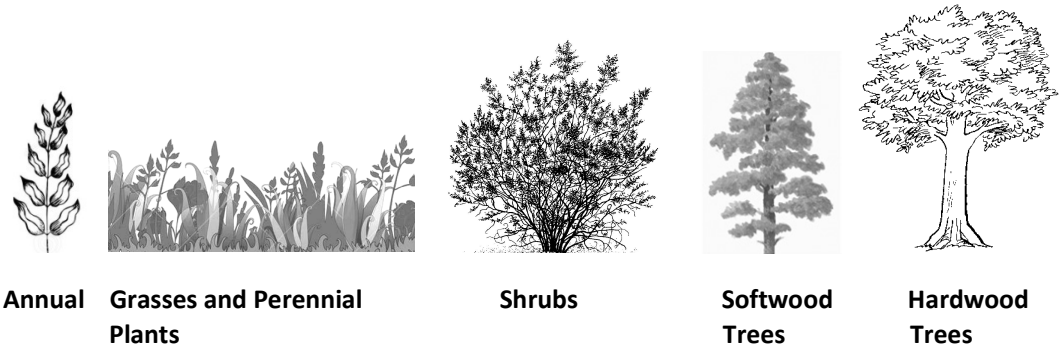

Fig. 6.2: Succession of plant species in abandoned fields of North Carolina.

Other examples of observable secondary succession include:

1. The growth of hardwood trees (including ash, poplar and oak) within the red pine planting area. The consequence of this hardwood tree growth is the increased shading and subsequent mortality of the sun loving red pines by the shade tolerant hardwood seedlings. The shaded forest floor conditions generated by the pines prohibit the growth of sun-loving pine seedlings and allow the growth of the hardwoods. The consequence of the growth of the hardwoods is the decline and senescence of the pine forest.

2. The raspberry thickets growing in the sun lit forest sections beneath the gaps in the canopy generated by wind-thrown trees. Raspberry plants require sunlight to grow and thrive. Beneath the dense shade canopy particularly of the red pines but also beneath the dense stands of oaks, there is not sufficient sunlight for the raspberry's survival. The place in which there has been a tree fall the raspberry canes, dense thickets proliferated. The macro-ecosystem change within the red pine stand and all along the more open sections of the trail has been noted. Within these raspberry thickets, dense growths of hardwood seedlings were found. The raspberry plants are generate a protected "nursery" for the seedlings and also protect tree seedlings from being destroyed by young trees. By providing a shaded haven for growth of raspberry plants, future tree canopy was protected.

Besides the above mentioned examples of secondary succession (include – delete), the following may also be interesting:

- The renewal of a forest after a fire: The fire itself destroys different types of trees and plant life. Because seeds and roots and other plant and tree parts remain in the soil, gradually the plants and trees begin to grow again and eventually return to the state of the original ecosystem. Some species show a very fast occupation of the burnt forest floor and become responsible for the sequence of succession.

- The renewal of a crop after harvesting: A crop is completed harvested when it becomes ripe. Without new seeds being planted, the crop can regenerate the following year due to the plants and seeds that remained after harvesting. For example, when the sugarcane crop is harvested,

the shoot is cut just above the soil. The basal part of the stem along with the root system remains in the field. New shoots arise from the axillary buds giving rise to a “ratoon crop”. This matures faster allowing earlier harvest of the crop for commercial gains. After a few years, the yield get reduced and the field is cleared of all the existing plants. New plants are then introduced for a better yield

- A forest renews after logging: Very often a large (amount – delete) number of trees are chopped down by loggers in order to create building materials. This leads to a kind of secondary succession. Over time, trees grow in and the area returns to its previous state.
- A volcanic eruption: In an area where a volcano erupts, lava may cause some damage to the plant and tree life. Over a span of years, the seeds, plant parts and roots grow on the land that had been affected by the eruption.
- On the island of Lawahii, several centuries ago, a fire erupted that caused the destruction of all plants and vegetation. Many years later, the plants and vegetation of the area returned to the original state as the nutrients, seeds and soil that remained in the soil grew back.
- Renewal after disease: A plant population can be very negatively affected by a variety of infectious plant diseases. The entire population dies but the soil and roots remain which help in the reestablishment of vegetation in the area (secondary succession).
- A flood can ruin farmlands. The soil that remains after water recedes supports the growth of vegetation over the course of time. The area gets revegetated.
- Plants can be very susceptible to attack from pests. The plant population in area gets completely destroyed. With the passage of time, the pest population reduces, the plants are able to live again and thrive in the soil.
- Potato scab is a tuber disease that grows on potatoes. If this disease affects a large amount of potatoes, the potatoes may not grow or may be harvested and thrown away. Over time, once the disease has been eradicated, healthy potatoes grow again.

The process of succession has been explained with the help of various models. Joseph Connell and Ralph Slatyer, (an – delete) American naturalists (1977), proposed three models for this. The first (**facilitation**) is the classical explanation most often invoked in the past, while the other two (**tolerance** and **inhibition**) have been frequently been overlooked.

The essential feature of **facilitation succession**, in contrast with either the tolerance or inhibition models, is that changes in the **abiotic environment** are imposed by the developing **plant community**. Thus, the entry and growth of the later species depends on earlier species preparing the ground.

The **tolerance model** suggests that a predictable sequence is produced because different species have different strategies for exploiting resources.

Later species are able to tolerate lower resource levels due to competition and can grow to maturity in the presence of early species, eventually out competing them.

The **inhibition model** applies when all species resist invasions of competitors. Later species gradually accumulate by replacing early individuals when they die. An important distinction between models is the cause of death of the early colonists. In the case of facilitation and tolerance, they are killed in competition for resources, notably light and nutrients. In the case of the inhibition model, however, the early species are killed by very local disturbances caused by extreme physical conditions or the action of predators.

SAQ 3

Discuss the phenomenon of succession giving an example.

6.4 TYPES OF SUCCESSION

Depending upon the nature of the habitat, plant succession have been classified into seven types

1. Hydrosere – succession starts in an aquatic habitat.
2. Xerosere- succession initiates on a dry, bare land.
3. Lithosere – succession starts on a bare rock surface.
4. Psammosere – succession starts on sandy habitats. The pioneer community comprises of sand-binding grasses with runners, e.g. *Spinifex, Ipomoea biloba*.
5. Halosere – succession starts in saline soil or water. The pioneer plants usually have succulent species of *Asclapias*.
6. Senile – It is the succession of micro-organisms and lower plants on dead plant parts and bodies.
7. Eosere or Geosere – It is the development of vegetation in an era.

In broad terms, succession has been classified into two categories:

A. Hydrarch – When the succession takes place in a wet area, it is called as hydrarch. It is further divided into two types- hydrosere- when the succession takes place in freshwater ecosystems (ponds, lakes) and halosere- when the succession takes place in saline water ecosystems (mangroves, estuaries)

B. Xerarch – The succession that takes place in dry areas is referred as xerarch. It is further divided into two categories namely lithosere- the succession that takes place on bare rocks and psammosere- the succession that takes place in sandy areas.

Hydrosere

When the succession of a community occurs in an aquatic or wet area, it is called a hydrosere. It may proceed in open bodies of water, such as ponds, lakes, and marshes etc (Fig 6.3). Seven seral stages have been (noted – delete) recognized during this kind of succession

(1) Phytoplankton stage

The water is poor in nutrients and incapable of supporting life**.** Phytoplanktons consisting of algae begin to multiply and act as pioneer species. After death of these phytoplanktons and other animals dependent upon them, bacteria and fungi bring about decomposition of organic material. The enrichment of water bodies with minerals creates conditions supporting growth of other plant forms.

(2) Submerged stage

In this seral stage, submerged aquatic plants, such as *Hydrilla, Elodea, Potamogeton, Ceratophyllum, Najas, Vallisnaria, Utricularia, Ranunculus* and algae occupy the shallow pond or lake. Oxidation of flora and fauna results in the formation of humus that makes the bottom of the water body richer in nutrients.

(3) Floating stage

In this stage, plants rooted in the mud inhabit the area. Their broad leaves float on the surface of the water. These plant species include *Nymphaea, Polygonum, Limnanthemum* and *Castalia*. Free floating plants like *Azolla, Eichorrnia* and *Lemna* are also present. The death and decay of the submerged and free floating plants raises the level from the bottom of the lake and contributes to the soil-building process.

(4) Reed-Swamp stage

This stage is initiated in extremely shallow waters (one to four feet deep). The area is invaded by amphibious plants like *Scirpus, Typha, Phragmites* etc. These plants remain partly submerged in water. Their rhizomes are profusely branched. The plants are rooted in the bottom of the lake. These plants obstruct light for submerged and floating plants which consequently die. The remains of dead plants settle down on the lake bottom raising its level further. Another group of plants such as *Sagittaria, Alisma* and *Acorus* called emergents occupy the area. With time there is a buildup of enough soil to support terrestrial species. Habitat becomes unfit for submerged plants and other of reed-swamp stage.

(5) Sedge meadow stage

This stage of succession is characterized by plants like *Carex, Juncus* and *Eleocharis*. The level of soil continues to rise and build up the organic matter. Dominant plant species such as *Mentha, Caltha, Iris, Galium, Campanula* and *Teuricum* invade the area. The area becomes dry and unfit to support hydrophytic vegetation.

(6) Woodland stage

The heath land formed after the drying of soil remains saturated with water in spring and early summer. Sub-climax vegetation dominated by shrubs and small trees make their appearance in this area. Plant species noted during stage include *Salix, Cornus, Cephalanthus, Alnus* and *Populus.* Due to shade of these plants, grasses and sedges disappear from the area. Shrubs and trees further lower the water table and bind the soil.

(7) Climax forest stage

More and more plants occupy the area leading to competition among them. Soil organic matter increases, soil becomes more fertile and consequently the area gets invaded by larger trees. Competition becomes less as the community becomes stable and a climax state is reached.

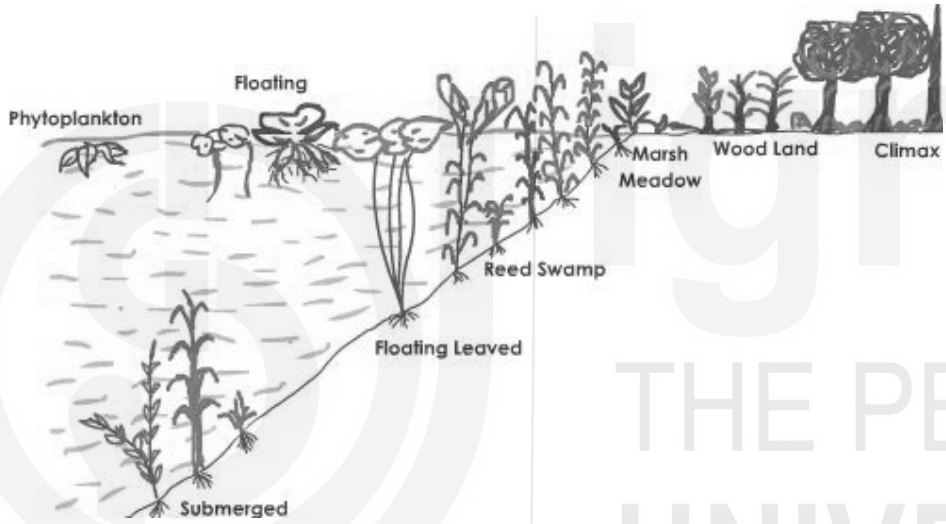

Fig. 6.3: Stages of succession in hydrosere.

Xerosere

The following observations would help you to understand the process of plant succession.

1. When we visit a mountainous region, we come across hard bare rocks without any sign of plant life.
2. But there are certain patches on the rocks where we can observe the presence of lichens. This is the first sign of plant succession.
3. You are aware that the lichen is a symbiont made up of two components – an alga and a fungus. Individually these organisms were unable to survive on the bare rock. But as a combination in the form of a lichen, this organism is able to establish itself on the bare rock. Therefore, the occurrence of a lichen on a bare rock indicates the initiation of succession.
4. The lichen thallus may be in the form of a crust (crustose lichen) which

is very firmly attached to the underlying rock. This lichen crust cannot be separated from the rock, but it survives.

5. There are also other patches where a more elaborate type of lichen can be found. This refers to the foliose lichens. The thallus is able to spread out on a larger area of the rocky substratum.

6. Often, we also come across the highly elaborate "fruticose lichens" in other parts of the rocky substrate.

7. Where there is shade, the presence of patches of mosses can be observed.

8. If there is greater availability of water, then we may find patches of liverworts growing luxuriantly.

9. As we continue to observe the changes on the rocky substratum, we find small ephemeral herbs growing in the open spaces provided by the dead liverworts/mosses.

10. The next important observation is finding larger herbs, grasses and small shrubs constituting the community.

When we correlate the sequence of our observations, we understand the concept of succession on bare rock called "lithosere". It is one type of a xerosere.

When succession starts on a dry, bare area, it is referred as xerosere. The vegetation present in the area is xerophytic (Fig. 6.4). The development of **xerosere includes six seral stages.**

(1) Crustose lichen stage: Crustose lichens act as pioneers and establish on the bare area. These lichens migrate to the rocks by means of wind-borne spores and soredia. The lichens grow in moisture rich areas. The lichens release carbon dioxide during respiration which reacts with water and forms weak acid. The mechanical and chemical action of the lichens loosens particles of the underlying rock. Lichens after death and decay form a thin layer of soil on the surface.

(2) Foliose lichen stage: With passage of time, crustose lichens get replaced by larger, leafy foliose lichens. The species mainly include *Parmelia, Dermatocarpon. Umbilicaria.* They grow on the soil and humus. Foliose lichens further loosen the rock particles. They overshadow the crustose lichens which eventually die and decay thus increasing the amount of humus in the soil.

(3) Moss stage: Lichens are succeeded by mosses. The mosses are xerophytic in nature. Important species include *Polytrichum* and *Tortula*. They form an open community connected with a dense rhizoid system which binds soil particles together. The mosses stabilize the soil surface and increase its water-holding capacity.

(4) Herbaceous stage: The moss plants increase in number and form a close carpet over the soil. The mosses shade the lichens and

successfully compete with them for water and nutrients. Eventually lichens die and add organic matter in the soil and further increasing the water- holding capacity of the soil. The soil becomes unsuitable for growth of lichens and mosses, hence gets inhabited by plants over the period of time. Consequently a community of herbaceous plants such as *Festuca, Verbascum, Poa, Potentilla and Solidago* etc. develops in the area. The herbaceous plants shadow the mosses, compete with them for space, water and nutrients. The disintegration of the rock leads to thickening of soil. The decay of the plant parts increases the availability of nutrients for higher community dominated by shrubs.

(5) **Shrub stage:** Shrubs such as *Rhus* (Family Anacardiaceae), *Physocarpus* (Family Rosaceae), and *Symphocicarpous* (Family Caprifoliaceae) invade the area. The herbaceous plants disappear. The death and decay of the herbaceous plants enrich the soil. The shrubs grow in size and number and continue to modify the soil and make the habitat more and more suitable for the support of higher plants and trees.

(6) **Climax forest stage:** The xerophytic tree species invade the area. With increase in soil moisture, xerophytes get replaced by mesophytic species. These species grow successfully in environment and become dominant. Competition gradually becomes less intense and the community becomes stable. A climax state is reached.

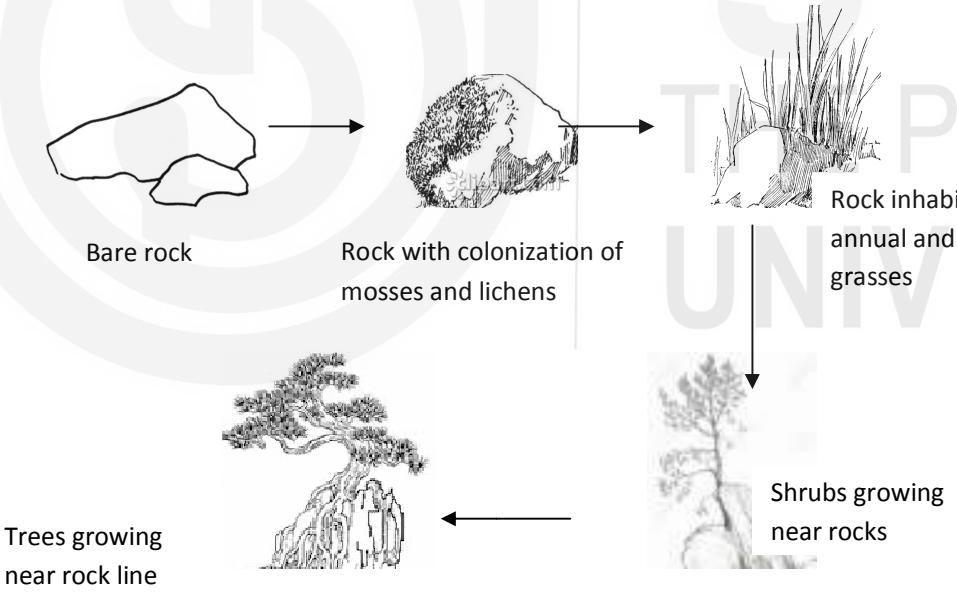

Fig. 6.4: Stages of succession in xerosere.

6.5 SUMMARY

- The species present in a habitat change with passage of time. New species invade the area and replace the existing communities over a time period. The process is called succession. With the continuation of succession, more species enter the community and alter the environment.

- At the beginning of ecological succession, pioneer species inhabit the new habitat. It helps in building up the area suitable for growth of preceding species. The final stage of succession is called climax stage and is represented by climax community.
- Pioneer species can be 'r or k selected. The 'r-selected' species are fast growing and well-dispersed. The 'k-selected' species are more competitive and fight for resource and space.
- At the climax stage, a stable and small number of prominent species (climax community) inhabit the area and a state of equilibrium is reached.
- In primary succession, pioneer community colonize bare rocks while in secondary succession, plants re-colonize the established area.
- Succession in which autotrophs i.e. green plants are more in quantity is termed as autotrophic succession, while succession in which heterotrophs are more in number is termed as heterotrophic succession.
- The processes involved in succession include- nudation, invasion or migration, ecesis, aggregation, competition, reaction and stabilization (climax).
- Depending upon the nature of the habitat, plant succession can be named as hydrosere or xerosere. In hydrosere, the succession starts in an aquatic habitat whereas in xerosere, the succession initiates on a dry, bare land.
- The succession in hydrophytes begins with increased nutrient sedimentation, encroachment by shore plants followed by development of emergent and terrestrial communities.
- In xeric habitat, succession begins on bare rock. Pioneer species help in formation of soil followed by further establishment of plants such as mosses, lichens, grasses, shrubs and trees.
- The process of succession is characterized by increased productivity, movement of nutrients from reservoirs, increased biodiversity.

6.6 TERMINAL QUESTIONS

1. Differentiate between

   1) progressive succession and retrogressive succession

   2) hydrosere and xerosere

   3) autotrophic succession and heterotrophic succession

   4) pioneer species and climax species

2. Define

   - Secondary succession

- Allogenic succession
- Ecesis
- Aggregation

3. Explain the process how a barren rock gets inhabited by plants over a period of time.

6.6 ANSWERS

Self assessment questions

1.

1) a. development of soil
2) c. land destroyed by a catastrophe
3) c. living inhabitants of that area
4) a. mosses

2.

Succession leads to development of a community that has an

- increase in structural complexity.
- increase in diversity of species.
- increase in biomass and standing crop.
- complexity of food chain relationship.
- increase in energy use and nutrient conservation efficiency.

Such community is more stable as compared to the pioneer or other communities.

3.

Succession is the process of change in vegetation over an ecological time scale. It can be understood with the help of an example.

Oak Forest

Dwight Billings (1930) studied the succession of plant species that occurred on abandoned agricultural fields in North Carolina (Fig. 6.2). Based on the observations, he proposed detailed successional sequence of plant communities of the area. The first stage of succession included characterization of the area by pioneer species on bare ground and nutrient poor soils. These annual species had short lifespan (one growing season), rapid maturity. The annual species were replaced by biennial plants and grasses in the coming years. After about 3 to 4 years, the biennial and grass species gave way to perennial herbs and shrubs. These plants live for many years and have the ability to reproduce several times in their lifespan.

After about 5 to 15 years, the sites were colonized by softwood tree species including loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), Virginia pine (*Pinus virginiana*), and sweetgum. As the softwoods increased in their numbers and grew in height, they began forming a forest canopy. This canopy reduces the amount of light reaching the forest floor. The resulting shaded understory conditions caused the exclusion of many light loving perennial herb and shrub species. Perennial herb and shrub species that were adapted to low light conditions now began to take over the ground cover. The canopy also changed the microclimate of habitat near ground level. It was now more humid, has moderated temperatures, and less wind. These conditions, plus the development of a soil litter layer, allowed for the germination of hardwood species, like oak (*Quercus s*pp.) and various species of hickory (*Carya* spp). The seedlings of these tree species also tolerate low light levels.

By about 50 to 75 years after the initial colonization of the pioneer species, the hardwoods started to replace the softwood species in the developing forest. At this stage in the succession, the pines had maximum heights of about 25 meters, while the oaks and hickories were on average about 10 meters tall. Because of their shorter lifespan (50 years), many of the softwood species were beginning to die out and the gap that was created was then filled by a subdominant hardwood tree. Hardwood species, like oak and hickory, can live for more than 100 years. Sites more than 100 years old were found to be dominated by mature oak forests.

Terminal questions

1. a) Progressive succession – It is a type of succession in which the community becomes complex and contains more species and biomass over time.

   Retrogressive succession – It is a kind of succession where the community becomes simplistic and contains fewer species and less biomass over time.

   b) Hydrosere – the succession takes place in freshwater ecosystems (ponds, lakes). The vegetation present in the area is hydrophytic. The development of hydrosere **includes seven seral stages**

   Xerosere – the succession starts on a dry, bare area. The vegetation present in the area is xerophytic. The development of **xerosere includes six seral stages.**

   c) Allogenic succession – Succession is caused by change in environmental conditions. It changes the composition of the plant community.

   Autogenic succession - is a succession where both the plant community and environment change. The change is caused by the activities of the plants over time.

   d) Pioneer species- The species that establishes itself in an a bare area. It can be a seed or bacteria or an insect. Pioneer species

thrive well in the new habitat. These species are 'r-selected' species that are fast growing and well-dispersed.

Climax species – The species that is present after the end of succession. the species composition does not occur with changes in time. The species remains in an equilibrium within an ecosystem.

2. Secondary succession – The succession which begins in area where the vegetation was present previously but it got destroyed or disturbed. It occurs in areas of forest fires, deforestation, flood, erosions or abandoned agricultural lands.

   Ilogenic succession – Succession is caused by change in environmental conditions. It changes the composition of the plant community.

   Ecesis – The process of successful establishment of a species in a new area after adjusting to the prevailing conditions is termed as ecesis. In the condition, seeds germinate and grow under favorable conditions and show an ability to reproduce itself to increase the numbers.

   Aggregation – The capacity of a species to reproduce to increase its number after successful establishment in an area. This results in larger aggregates of a species present in an area.

3. The process of development of vegetation on a dry, bare area is called as xerosere. The development of vegetation **includes six stages.**

   (1) Crustose lichen stage – Crustose lichens act as pioneers and establish on the bare area. These lichens migrate to the rocks by means of wind-borne spores and soredia. The lichens grow and release carbon dioxide during respiration which reacts with water and forms weak acid. This acid loosens particles of the underlying rock. Lichens after death and decay form a thin layer of soil on the surface.

   (2) Foliose lichen stage – With passage of time, crustose lichens gets replaced by larger, leafy foliose lichens. They grow and further loosen the rock particles. The crustose lichens die and eventually after decay increase the amount of humus in the soil.

   (3) Moss stage – After death and decay of lichens mosses appear. These mosses are xerophytic in nature. They increase in number and form a close carpet over the soil. The dense rhizoids bind the soil particles together. The soil gets stabilized and increases the water-holding capacity.

   (4) Herbaceous stage – Eventually lichens die and add organic matter in the soil. The place becomes unsuitable for growth of lichens and mosses, hence the space gets occupied by higher plants. A new community of herbaceous plants develops in the area. The herbaceous plants shadow the mosses, compete with them for space, water and nutrients. The decay of the plant parts increases

the availability of nutrients for higher community dominated by shrubs.

(5) Shrub stage – The herbaceous plants disappear and shrubs invade the area. The death and decay of the herbaceous plants enrich the soil. The shrubs grow in size and number and continue to modify the soil. The habitat becomes more suitable for the growth of higher plants i.e. trees.

(6) Climax forest stage – The xerophytic tree species invades the area. Gradually with increase in soil moisture, xerophytes get replaced by mesophytes. These species grow successfully in environment and become dominant. Competition gradually becomes less intense and the community becomes stable. A climax state is reached.

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Unit 7

ECOSYSTEM STRUCTURE

Structure

7.1 Introduction

Expected Learning Outcomes

7.2 Ecosystem as a Unit of Nature

Links to other Ecosystem

Structural Complexity

Resilience

Dynamic Stability

7.3 Components of Ecosystem

Abiotic

Biotic

7.4 Trophic Level

7.5 Summary

7.6 Terminal questions

7.7 Answers

7.1 INTRODUCTION

Ecosystems are dynamic entities in which a large number of events takes The introduction about the term 'ecosystem' has been provided in the Unit 1. Ecosystems are functional units of the biosphere and are found throughout the biosphere. The word ecosystem is made of two parts 'eco' and 'system'. The word 'eco' means the habitat and the word 'system' means complex set of interconnected components or processes. The term 'ecosystem' was (given – delete) first used by Sir Arthur Tansley in 1935. According to him 'ecosystem' means the tangible relationships that exist between organisms in the biological world.

Living organisms cannot live isolated from the non-living environment. An interaction occurs between a living beings and environment to produce a stable system. Therefore ecosystem is considered as a natural functional ecological unit comprising of living organisms (biotic community) and their non-living (abiotic or physio- chemical) environment. Both the components interact to form a stable self-supporting system. A pond, lake, desert, grassland, forest etc. are some of the common examples of ecosystems. This Unit provides you information about the concept of an ecosystem, its different types, components, trophic structure and its functioning.

Expected Learning Outcomes

The study of this Unit will provide information about:

- various components of ecosystem.
- characteristic features of an ecosystem.
- trophic levels in an ecosystem.
- functional role of producers, consumers and decomposers in an ecosystem, and
- different types of ecosystems.

7.2 ECOSYSTEM AS A UNIT OF NATURE

An ecosystem is considered as a functional unit of nature. It represents complex interactions and relationships between living and non-living components. The study of any ecosystem involves description of its various components and their functioning. Non-living components provide materials and energy for the survival of the living components. Ecosystems represent enormous contrast in size and complexity. The size of the ecosystem can be as small as a bowl filled with water or large areas such as forests and oceans. In some ecosystems, boundaries are well recognized while in others the boundaries are not well defined. The boundaries of pond, river and lake ecosystems are well defined. In contrast, in grasslands, village or town ecosystems sharp boundaries are not found.

Characteristics of ecosystems

Ecosystem is a unit that shows integration of living and non-living components. All the living or the biotic components share various relationships with each other and their survival is regulated by physical or abiotic components of the ecosystem. Ecosystems such as forests, grasslands, rivers, and oceans exhibit different physical conditions or environments. All the living organisms present in an ecosystem are well adapted to the environment they inhabit. The physical environment varies among different ecosystems.

The main characteristics of an ecosystem are its:

- links to other ecosystem
- structural complexity
- resilience
- dynamic stability

8.2.1 Links with Other Ecosystems

No ecosystem can exist alone (i.e in isolation). The ecosystems are connected together via input and output of materials. These are called links. The output of one ecosystem such as nutrients, gases, water etc. can form the input of

another ecosystem. Example- A river receives many inputs from the terrestrial ecosystem (from where – delete) through which it flows.

8.2.2 Structural Complexity

The structural complexity of an ecosystem occurs due to

- variation in species composition of plants, animals and microbes
- variation in environmental factors such as seasonal changes, tidal changes, nutrient levels, sediments etc.
- presence of distinctive habitats within an ecosystem such as mangrove, sea etc.

8.2.3 Resilience

The property of an ecosystem to return to its original state after being exposed to stress situations is termed as resilience. It is a common feature of all the ecosystems and depends upon the intensity of the stress to which an ecosystem is exposed.

8.4.4 Dynamic Stability

Ecosystems are not static. They always undergo changes, hence are also termed as dynamic systems. The changes takes place both in the biotic and abiotic components. Natural ecosystems are somewhat static in nature and dynamically stable. The future state of an ecosystem is determined by the current status. The internal characteristics get affected by few external influences which ultimately alter the state of equilibrium. A diverse biological system is dynamically more stable. This is because the diverse biotic interactions play a major role in stabilization of the ecosystem and species success in comparison to the physical environment.

7.3 COMPONENTS OF ECOSYSTEM

All ecosystems possess both biotic and abiotic components (Fig 7.1).

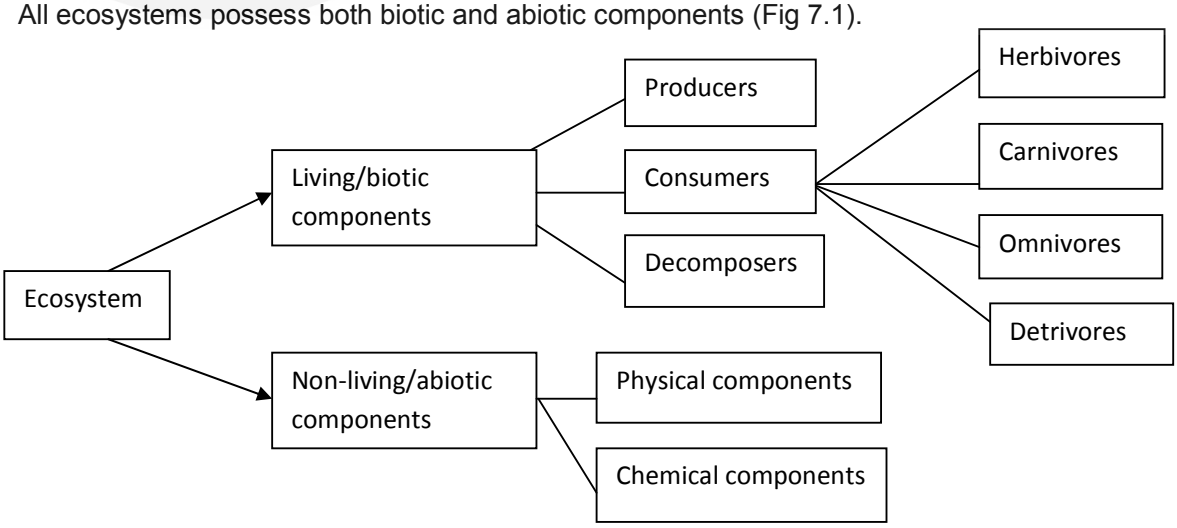

Fig. 7.1: Components of an ecosystem.

7.3.1 Abiotic Components

The non living factors or the physical environment prevailing in an ecosystem form the abiotic components. They have a strong influence on the structure, distribution, behavior and inter-relationship of organisms. The major abiotic factors include nutrient elements, physical conditions, inorganic elements, climatic factors and dead organic matter. All these components support the survival of biotic components to a greater extent.

Abiotic components mainly include inorganic, organic substances and climatic factors.

i) Inorganic substances – These include elements that are required for functioning of various essential processes in living organisms. The plants require some elements in large quantities. These are called as macronutrients while other elements that are required in less quantity or trace amounts are called as micronutrients. Macronutrients mainly include carbon, hydrogen, oxygen, nitrogen, potassium, calcium, phosphorus, magnesium, and sulphur. Micronutrients include iron, chlorine, copper, manganese, zinc, molybdenum and boron

ii) Organic substances – These include carbohydrates, proteins, lipids and their derivatives produced from the waste products of plants and animals or remains of dead plants and animals. Organic fragments of different sizes and composition formed as a result of decomposition are referred as organic detritus. Decomposition of organic matter releases nutrients leading to the formation of a dark, amorphous, colloidal substance called humus which is an important fertility component of the soil.

iii) Climatic Factors – This includes physical factors such as temperature, rainfall, humidity, and light.

iv) Edaphic factors – These include soil and minerals. Soils contain a mixture of weathered rock fragments, mineral particles, organic matter and living organisms. Soils provide nutrients, and water, as well as a substrate or growing medium for organisms. The vegetation found growing on top of a soil is closely linked to soil through nutrient cycling.

The atmosphere provides carbon dioxide for photosynthesis and oxygen for respiration. The processes of evaporation, transpiration and precipitation cycles water between the atmosphere and the Earth's surface. Solar radiation is used to heat the atmosphere, evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis. Photosynthesis provides the energy for plant growth and metabolism, and the organic food for other forms of life. Water forms a major component of the living tissues. Water is essential for carrying out the protoplasmic activities. It is the medium by which mineral nutrients enter and get translocated in plants. It is also necessary for the maintenance of leaf turgidity and photosynthetic chemical reactions.

7.3.2 Biotic Components

The living organisms including plants, animals and micro-organisms (bacteria and fungi) form the biotic components of the ecosystem. The organic matter is derived from plants and animals after their death and decay. It is essential for cycling of nutrients in an ecosystem.

Biotic components have been categorized on the basis of source of energy and nutrients.

i) Producers – They are also called as autotrophs. These mainly include green plants that can make food from simple inorganic materials. The process of formation of food i.e. organic compounds such as carbohydrates is called photosynthesis. In this process, green plants use carbon dioxide, water, minerals to produce carbohydrates. Oxygen is produced as a byproduct in the process. During photosynthesis, radiant energy of sunlight is converted into chemical energy and is stored in the chemical form.

$6CO_2 + 6\ H_2O$+ Light energy $\longrightarrow$ $C_6H_{12}O_6 + 6O_2$

In terrestrial ecosystems, the primary producers are predominantly herbaceous and woody plants, whereas in aquatic ecosystems (freshwater and marine) primary producers are algae. Some prokaryotic organisms such as blue green algae and bacteria are also called as primary producers. Certain chemosynthetic bacteria are also autotrophic. They obtain the energy for the synthesis of organic compounds (amino acids, proteins) from sources other than solar energy. The sources are ammonia (NH,), methane (CH,), [In both cases, the numeral cannot be read. It needs to be clear.] and hydrogen sulphide (H_2S). Organisms like crabs, molluscs and giant worms present at or near the oceanic floor get their food from chemosynthetic bacteria.

ii) Consumers – These are also called as **phagotrophs or heterotrophs.** These organisms cannot manufacture their own food. They obtain energy and nutrients by feeding on other organisms. They eat green plants (producers) to get their food supply and are called herbivores**.** In terrestrial ecosystem, herbivores mainly include insects, birds, rabbit, deer, goat, cattle and mammals. Herbivores are also referred as **primary consumers.** The parasites are also included in this category. In aquatic ecosystems (freshwater and marine) herbivores are small crustaceans and molluscs. These organisms include water fleas, copepods. The animals which depend upon herbivores for food are called as **secondary consumers**. They are also called as **carnivores**. The animals that feed on secondary consumers are known as **tertiary consumers**. Secondary and tertiary consumers include predators which capture and kill the prey. Parasites depend on the metabolism of their host for supply of energy. Some animals have quite flexible food habits as they eat both plants and animals. They are known as **omnivores**. Example - man.

iii) Decomposers – Also known as saprotrophs. They are mostly microscopic and heterotrophic in nature. These organisms obtain their

energy and nutrients by degrading dead organic matter. After death of plants and animals, their bodies act as a source of energy and nutrients. The organic remains are decomposed by micro-organisms such as fungi and bacteria. They secrete digestive enzymes that help in the decomposition of dead and waste materials. During the decomposition of wood, fungi produce an enzyme cellulase that softens the wood. Fragments of decomposing material are called detritus. The animals that help in the breakdown of detritus are called detritivores. The decomposition of materials occurs with the combined activity of true decomposers (fungi and bacteria) and detritivores (animals). All these organisms are referred as decomposers. Some typical terrestrial detritivores are earthworm, woodlice, millipedes, mites, springtail and nematodes. The decomposer's activity results in the formation of inorganic nutrients. Decomposers play a vital role in regenerating ecosystem fertility by releasing nutrients for utilization by plants that were locked up in the organic matter.

SAQ 1

Fill in the blank with appropriate word

a. An ecosystem is a natural unit consisting of non-living components and ----------

b. All ecosystems do not have well defined----------

c. All ecosystems are of ------size.

d. All ecosystems are ------- because they are well insulated from the outside influences.

SAQ 2

Enlist the major living and non-living components of the ecosystem.

Tolerance range and limiting factor

Abundance or distribution of an organism is controlled by several factors (climatic, topographic, environmental and biological). Organisms survive within limits of environmental factor such as water, light and temperature. These are called the tolerance limits. There is a maximum and minimum limit of tolerance for each factor. The range of the tolerance is called tolerance range. Different organisms have different tolerance ranges. The range between two limits is known as limit or zone of tolerance (Fig 7.2). The range of minimum and maximum limits signifies the tolerance capacity of an organism. Beyond the tolerance range, species cannot survive. Organisms show variation in tolerance to factors. They may have high range of tolerance for one factor and less for another factor.

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. In all ecosystems usually abiotic factors limit the growth of organisms and therefore are called as limiting factors. It is the primary determinant of growth because it lies beyond the minimum and maximum limits of tolerance range. For example, phosphorus is a limiting factor in aquatic ecosystems. When phosphorus is reduced, the growth of algae is impaired. Soil nutrients are important for the growth and development of plants. Uptake of any of the nutrients in excess limits the uptake of the other nutrient, restricting the growth of the plant.

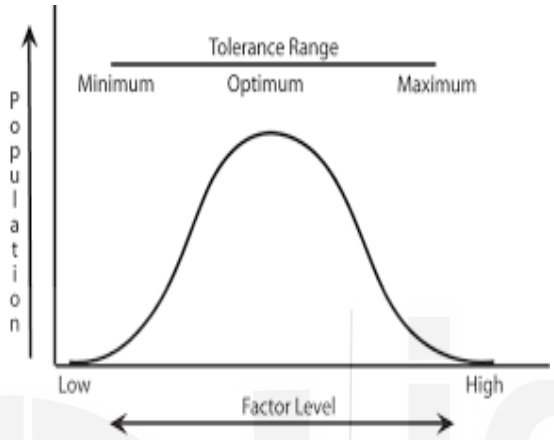

Fig. 7.2: Diagrammatic representation of the tolerance range.

7.4 TROPHIC LEVEL

In an ecosystem, various biotic components are related to each other. Each biotic component is categorized into a trophic level according to (their – delete) its source of nutrition. The trophic levels are recognized as first, second, third, and fourth or more depending upon the type of feeding. The producer organisms form the first trophic level, primary consumers (herbivores) form the second trophic level, secondary consumers (carnivores) form the third trophic level and tertiary consumers (top carnivores) form the fourth trophic level. Man, an omnivore belongs to more than one trophic level. There are usually four or five trophic levels in a community.

The plants or producers form the first trophic level. They obtain their energy (light) from sun and nutrients from soil and water. They transform the light energy (it – delete) into chemical energy as food. The animals eating the plants are called the herbivores, and they form the second trophic level. They use some part of food energy and rest is stored as fats into tissues. The animals eating the herbivores are called carnivores, and they form the third trophic level. Both herbivores and carnivores are referred as consumers. Carnivores are further eaten up by other carnivores. Thus the carnivores which consume the herbivores form the first level. When these are eaten by larger animals, they form the second level of carnivores. These, in turn can then be consumed by the (and – delete) top level carnivores. All these trophic levels form the trophic structure of an ecosystem (Fig 7.3). Some organisms occupy more than one trophic level because they feed on both plants and animals. Example- Humans eat both plants and animals (Fig. 7.4).

Decomposers form an important component of ecosystem because they assist in breakdown of dead matter into organic content via metabolic processes.

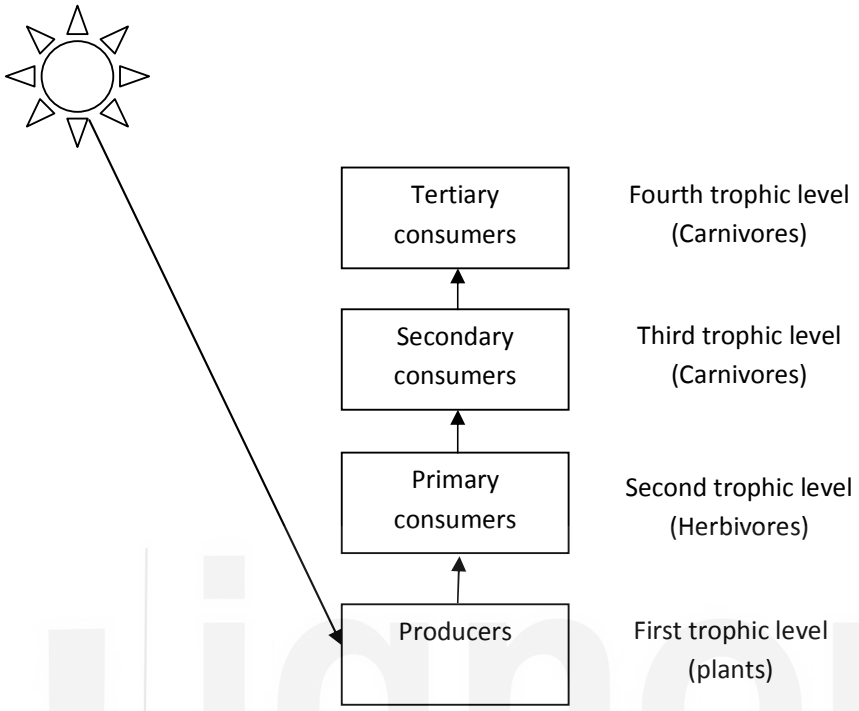

Fig. 7.3: Diagrammatic representation of trophic levels in an ecosystem.

Fourth trophic level			**Man**	Tertiary consumer
Third trophic level		**Man**	Fish	Secondary consumer
Second trophic level	**Man**	Goat	Insects	Primary consumer
First trophic level	Plants	Grass	Plants	Producer

Trophic level ↑

Fig. 7.4: **Diagrammatic representation of trophic levels in an ecosystem.**

The study of trophic levels gives us an idea about the energy transformation in an ecosystem. It provides us information about mode of feeding in various groups of organism and interrelationship between different groups via feeding pattern or relationships. The trophic levels are numbered according to the organisms which act as the source of food or energy. Thus, the (primary) producers (plants) form base of the food chain and are recognized as the first trophic level. The different consumers occupy the higher trophic levels, i.e. second, third, fourth and so on.

SAQ 3

Which organisms form the first trophic level in ecosystem? Why are they important?

Types of ecosystems

An ecosystem is a natural self-sufficient unit. It is defined by relationship between the living and non-living components. Ecosystems can be natural or man-made (artificial). Example- aquarium is an example of man-made ecosystem. Other examples are villages, townships. The natural ecosystems are of two types- terrestrial and aquatic.

Terrestrial ecosystem

A terrestrial ecosystem consists of abiotic factors (like climate, soil or rock, altitude, temperature, nutrients, minerals) and biotic components (including producers, herbivores, carnivores (consumers) and decomposers). The soil is the main abiotic (element – delete) component which supports the growth of the plants by providing nutrients and other essential elements. Terrestrial ecosystems have trees, shrubs, herbs, grasses, and mosses. These contribute to the productivity of the ecosystem. Terrestrial ecosystems are part of other larger ecosystems called biomes.

Depending on the changes in the abiotic factors, terrestrial habitats have been classified into different types. These mainly include:

1. ***Forest ecosystems***

They are the ecosystems in which there is an abundance of (flora, or – delete) plants. In forest ecosystems the density of living organisms is quite high. A small change in this ecosystem affects the ecological balance. They are further divided into three different types depending upon the climate. These are tropical, temperate or boreal.

Tropical forests: They are the forests in the tropical regions of the world. They (that – delete) receive a mean rainfall of 80 inches for every 400 inches of rainfall annually. The temperature and light remain constant throughout the year. These forests are characterized by dense vegetation and (comprises – delete) and are identified by tall trees of different heights. The vertical structure is divided into different layers- emergent trees, upper canopy, low tree stratum, shrub understory, and ground layer (grasses and herbs). The warm, moisture-laden environment supports the growth of trees. Trees grow tall and the foliage is lush and dense. Tropical rainforests are also characterized by the occurrence of lianas or climbing vines, and epiphytes growing on the trees. They support high levels of primary productivity. High rainfall and warm temperature result in high rates of decomposition and nutrient cycling. They have a high biodiversity (of animals – delete) and the ecosystem supports various animal species.

Temperate forests: Broadleaf deciduous forests are found in the temperate regions. These include beech-maple and oak forests. They exist in the areas/regions where the climate changes significantly from summer to winter. The region receives sufficient rainfall. Trees lose their leaves during the winter months. Well developed deciduous forest possesses four strata- upper canopy, lower canopy, shrub layer and ground layer.

In temperate zones, forest ecosystems may be deciduous and shed their leaves each season or they may be coniferous (which – delete) and remain evergreen all the year around. Trees develop spiked leaves to minimize transpiration. Summers and winters are clearly defined and the broadleaved trees shed the leaves during the winter months.

2. Tundra

They extend beyond the tree line in the Northern Hemisphere. They are simple ecosystems and support restricted life because of harsh conditions. A tundra forest/ecosystem is characterized by low temperature and low precipitation. The ground remains frozen for most time of the year. The condition is called permafrost. Lichens and small flowering plants form the major part of the vegetation. The regions include polar areas. Communities known as alpine tundra are found at high elevations.

3. *Taiga*

The region is situated in Northern Latitudes, between 50^0N to70^0N, just before the arctic region. The area is dominated by evergreen conifers. The temperature is below zero almost all the year round. It is characterized by cold climate. The area consists of four zones- the forests, boreal woodland, boreal forest and boreal-mixed forest. Spruce, pines, birch and poplar are commonly present in the region. The area shows the presence of migratory birds and insects.

4. Deserts

These regions occupy about 17% of total world land. They receive annual rainfall less than 25 centimeters (or 10 inches) per year. Due to the high temperatures, low water availability and intense sunlight, the fauna and flora are scarce and underdeveloped. The vegetation mainly includes shrubs, bushes, few grasses and rare trees. The stems and leaves of the plants are modified to conserve water.

5. *Grassland ecosystems*

These ecosystems are typically found in tropical and temperate regions of the world. Grasslands share the climatic characteristic of semi-aridity. Different types of grassland ecosystems are found. These include prairies, savannas and steppes. The grasslands that exist in colder areas are known as Siberian steppe. The area receives rainfall of about 250 to 800 mm. These are characterized by ephemeral herbaceous vegetation that arises from crowns, nodes and rosettes of the plants. The main vegetation includes grasses, herbaceous plants especially (and – delete) legumes (that belong to – delete) and members of the Compositae family. The ground layer possesses well developed root system. Flowers may be interspersed with the grasses. The temperate grasslands are completely devoid of large shrubs and trees. Grasslands are categorized as mixed grass, tall grass and grassy meadows. Grasslands provide an ideal environment for grazing animals. Savannas are characterized by grasses and woody plants.

6. Swamp

These are wetland ecosystems in different parts of the world. These are characterized by mineral soils with poor drainage. They exist in areas with poor drainage and sufficient water supply. The flow of water through wetlands is slow because of low gradients and retarding effects of the vegetation. Decay of the dead vegetation quickly uses the available oxygen. Due to lack of oxygen, decomposition is retarded and accumulation of the more resistant fraction (humates and tannins) in the substratum takes place. Some swamps are situated just before the Arctic regions. The vegetation is dominated by trees (Trees are – delete) mainly evergreen conifers. Besides the trees, in marshy habitats, the plant life consists largely of grasses. (Swamps are found throughout the world. –delete) Cattails (*Typha*) and common reeds (*Phragmites*) are the swamp species found in warm/moderate climates all around the world. *Papyrus* (sedge) and tree species such as palms are widespread in the tropics. Besides these gums, willows, alders, and maples are also found. Mangroves are located in tropical and subtropical regions.

7. Shrubland

This kind of ecosystem (region – delete) possesses densely branched, woody plants. (The region – delete) The shrublands lie between 30^{o} to 40^{o} latitude and are characterized/dominated by evergreen shrubs and sclerophyll trees. The vegetation is adapted to dry summers and cool, moist winters.

Aquatic ecosystems

Ecosystems associated with water bodies such as ponds, lakes, rivers, estuaries, oceans are termed as aquatic ecosystems. Based on the water which can be freshwater or saline, they have been categorized as freshwater and saline ecosystems.

Producers are autotrophic organisms like chemosynthetic and photosynthetic bacteria, blue green algae, and green plants. Algae are the important producers of aquatic ecosystems. In estuaries and marshes, grasses act as producers. Abiotic components in an aquatic ecosystem include dissolved gases, water, salinity, light intensity etc. In aquatic ecosystems, floating plants called phytoplankton and shallow water rooted plants called macrophytes are the dominant producers.

Freshwater Ecosystems

Freshwater ecosystems can be found in streams, rivers, springs, ponds, lakes, bogs and freshwater swamps. Algae, plankton, insects, amphibians and underwater plants inhabit the area. They are subdivided into two classes: those in which the water is stationary, such as ponds, and those in which the water flows, such as creeks. Pond ecosystems are relatively small. They include various types of plants, amphibians and insects. These are mostly created by humans.

Marine Ecosystems

Marine ecosystems contain saltwater which supports different types of species. They are the most abundant ecosystems in the world. They

encompass ocean floor, surface and (but – delete) tidal zones.
Ocean ecosystems are the biggest ecosystems which cover around 71% of Earth's surface and contain 97% of water. They can be shallow waters, deep waters and the deep ocean surface. The planktons form the base of the food chain. The plankton and other plants carry out about 40% of photosynthesis that occurs on Earth. Herbivorous such as shrimps eat the plankton which are usually eaten by bigger animals such as fish. Other organisms that live in marine ecosystems include brown algae, corals, cephalopods, echinoderms, dinoflagellates and sharks.

Examples of ecosystems

1. Lakes

A lake includes both biotic and abiotic (things – delete) components interconnected with physical and chemical interactions. It is an example of a stationary ecosystem. The biotic components include fish, bacteria, phytoplanktons and zooplanktons while the abiotic factors include the water, light, and rocks underneath the lake.

2. Deserts

The desert is considered as an ecosystem because it has an ecology characterized by both biotic and abiotic functions. It includes both plant, animal, and bacterial populations. They interact with air and soil. Both plants and animals are adapted to withstand the harsh prevailing conditions. Plants such as cacti have their needle like (shape – delete) leaves to reduce transpiration and thick stems for storing water. Animals living in the desert including scorpions, desert snakes, and lizards equally have their special adaptations (techniques – delete) for surviving the in the desert.

3. Forests

In this ecosystem, many plant and animal species interact with non-living things. Plants form the primary producers which are eaten up by herbivores (primary consumers). The primary consumers are later preyed on by secondary consumers i.e. carnivores. A continuous flow of food energy takes place via food chain and food web. The dead animals are decomposed by detrivores (bacteria). They are broken down into nutrients which are absorbed by the plant roots and the cycle starts again.

4. Ponds

A pond refers to a small lake or a pool of water. It is considered as an ecosystem because it contains both living and non-living things. They depend on each other for their survival. Various living microorganisms that live in the ponds are supported by the prevailing environmental condition of the pond. The water plants form the producers which provide food source for birds, insects, amphibians and reptiles.

5. Gardens

Gardens encourage natural processes and various functions. They help in buffering the detrimental impacts of strong winds, regulating water drainage,

and providing shelter and support wildlife through food. Soil microbes and wildlife species such as pollinator birds and insects, rodents, geckoes and frogs survive in urban areas. They are mostly dependent on each other (together – delete) and get non-living elements from the garden areas.

6. Oceans

The oceans have diverse range of natural components. There is a constant exchange of materials between living and non living things. Aquatic animals such as fish obtain essential nutrients such as phosphorous, nitrogen, oxygen and food from water. The plants also get nutrients from water and sediments. It can be categorized as mangroves, deep sea habitats, the sea floor, estuaries, coral reefs, and intertidal zones. The vegetation differs in each type. These ecosystems are extensive and possess high biodiversity. The Coral reefs provide shelter and food for marine fish and plants. They also serve as breeding grounds for the aquatic species.

7. Grasslands

Grasslands are ecosystems in temperate regions. The living organisms constantly interact with their physical environment. The grasslands supports animal species namely buffalo, wolves, lions, zebras, and antelopes and plants species such as wild oats, buffalo grass, foxtail, and needle grass.

8. Cities

Cities are perfect examples of an artificial ecosystem. Humans depend on each other and various non-living things to survive. We need air to breathe. Without the buildings, we cannot have shelter and without the raw materials sourced from earth, we cannot get clothes, food, wood and many other basic materials.

7.5 SUMMARY

- Ecosystems are functional units of nature. They vary in sizes i.e. have no specific size and boundary (limit).
- Ecosystems are composed of abiotic and biotic components. The biotic components and abiotic components interact with each other to form a system.
- Biotic components i.e. producers, consumers differ for each type of ecosystem.
- The biotic components in an ecosystem are arranged in the form of trophic levels that are related to each other via feeding relationships.
- Ecosystems are of two types-terrestrial and aquatic ecosystems. Terrestrial ecosystems develop near the land surfaces while aquatic ecosystems develop in water bodies.
- 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.

7.6 TERMINAL QUESTIONS

1. What is the limiting factor in most terrestrial ecosystems?
2. Explain the tem
   a. Producers
   b. Consumers
   c. Decomposers
3. Give two examples of terrestrial and aquatic ecosystems.
4. What do you mean by artificial ecosystems? Explain using examples.
5. Describe the characteristics of trees found in tropical and temperate forests.
6. How do you distinguish littoral zone of the lake from the limnetic and profundal zone?

7.7 ANSWERS

Self assessment questions

1.
   a. An ecosystem is a natural unit consisting of non-living components and living or biotic components
   b. All ecosystems do not have well defined boundary.
   c. All ecosystems are of different size.
   d. All ecosystems are self stabilized because they are well insulated from the outside influences.
2. Ecosystems are made of two components

Abiotic or non-living – these include inorganic, organic substances and climatic factors. Inorganic substances include elements required for functioning of various essential processes in living organisms. The elements required in large quantities are called as macronutrients. These mainly include carbon, hydrogen, oxygen, nitrogen, potassium, calcium, phosphorus, magnesium, and sulphur. Some elements are required in trace amounts are referred as micronutrient. These include iron, chlorine, copper, manganese, zinc, molybdenum and boron. Carbohydrates, proteins, lipids and their derivatives produced from the waste products of plants and animals or remains of dead plants and animals are the organic components. Decomposition of organic matter releases nutrients leading to the formation of a dark, amorphous, colloidal substance called humus which is an important fertility component of the soil. Climatic Factors or physical factors such as temperature, rainfall, humidity, and light also regulate the growth and formation of various biotic components. Apart from all these edaphic factors that include soil and minerals also represent a major category of abiotic factors. Soils provide nutrients, water, a home, and a structural growing medium for organisms.

Abiotic constituents are very important for the survival of living beings present in an ecosystem.

Living or biotic components – The living organisms including plants, animals and micro-organisms (bacteria and fungi) form the biotic components of the ecosystem. The dead organic matter derived from plants and animals is important for recycling of organic matter and nutrients. Biotic components have been categorized on the basis of source of energy and nutrients.

Producers or autotrophs mainly include green plants that can make food from simple inorganic materials. Green plants use carbon dioxide, water and some minerals, to produce carbohydrates via process of photosynthesis. In terrestrial ecosystems, the primary producers are predominantly herbaceous and woody plants, whereas in aquatic ecosystems (freshwater and marine) primary producers are algae. Consumers or heterotrophs include organisms that cannot manufacture their own food but obtain their energy and nutrients by feeding on other organisms. Organisms that eat green plants (producers) to get their food supply are called herbivores**.** Herbivores mainly are also referred as primary consumers**.** Organisms that depend upon herbivores for food are called as carnivores or secondary consumers. The animals that feed on secondary consumers are known as tertiary consumers. Secondary and tertiary consumers include predators. Decomposers or saprotrophs mostly include microscopic organisms which are heterotrophic in nature. These organisms obtain their energy and nutrients by degrading dead organic matter. After death of plants and animals, their bodies act as a source of energy and nutrients. They secrete digestive enzymes that help in the decomposition of dead and waste materials. They play a vital role in regenerating ecosystem fertility by releasing nutrients for utilization by plants that were locked up in the organic matter.

3. Plants also called the producers form the first trophic level. They procure energy from sun and nutrients from soil and water. They synthesize organic compounds such as carbohydrates via a process called photosynthesis. They are important because they act as food source for other organism dependent upon them i.e. herbivores. Herbivores act as food source for other organisms i.e. carnivores. Hence they form the basic component of the feeding relationships occurring between organisms n an ecosystem.

Terminal questions

1. Living organisms depend upon various environmental factors for their survival. If supply of any one of the environmental factors such as light, water gets short s or excess the growth and development of organisms is affected, hence they act as limiting factors. In a terrestrial ecosystem, water and light act as limiting factors and regulate the survival of plants and animals.

2.

   a. Producers or autotrophs mainly include green plants that can make food from simple inorganic materials. Green plants use carbon dioxide, water and some minerals, to produce

carbohydrates via process of photosynthesis. In terrestrial ecosystems, the primary producers are predominantly herbaceous and woody plants, whereas in aquatic ecosystems (freshwater and marine) primary producers are algae.

b. Consumers or heterotrophs include organisms that cannot manufacture their own food but obtain their energy and nutrients by feeding on other organisms. Organisms that eat green plants (producers) to get their food supply are called herbivores**.** Herbivores mainly are also referred as primary consumers**.** Organisms that depend upon herbivores for food are called as carnivores or secondary consumers. The animals that feed on secondary consumers are known as tertiary consumers. Secondary and tertiary consumers include predators.

c. Decomposers or saprotrophs mostly include microscopic organisms which are heterotrophic in nature. These organisms obtain their energy and nutrients by degrading dead organic matter. After death of plants and animals, their bodies act as a source of energy and nutrients. They secrete digestive enzymes that help in the decomposition of dead and waste materials. They play a vital role in regenerating ecosystem fertility by releasing nutrients for utilization by plants that were locked up in the organic matter.

3. **Terrestrial ecosystem**

Terrestrial ecosystems have trees, shrubs, herbs, grasses, and mosses that contribute with varying importance to the production of the ecosystem. A terrestrial ecosystem consists of abiotic factors like climate, type of soil or rock, altitude, temperature, nutrients, minerals and biotic components including producers, herbivores, carnivores (consumers) and decomposers. Depending on the changes in the abiotic factors, terrestrial ecosystems are of different types. Example

Forest ecosystems – They are the ecosystems in which an abundance of flora, or plants, is seen so they have a big number of organisms which live in relatively small space. The density of living organisms is quite high. A small change in this ecosystem could affect effectively bring down the whole ecosystem. They are further divided as tropical, temperate or boreal.

Grassland Ecosystems – These ecosystems are typically found in tropical and temperate regions of the world. Trees are sparse or nonexistent, but flowers may be interspersed with the grasses. The main vegetation includes grasses, plants and legumes that belong to the composite family. Grasslands provide an ideal environment for grazing animals. Grasslands could be categorized as mixed grass, tall grass and grassy meadows.

Aquatic ecosystems

Ecosystems that develop in water bodies are termed as aquatic ecosystems**.** Producers are autotrophic organisms like chemosynthetic and photosynthetic bacteria, blue green algae, algae and all other green plants. Algae are the

important producers of aquatic ecosystems, though in estuaries and marshes, grasses act as producers. Abiotic components in an aquatic ecosystem include dissolved gases, depth of water, salinity, pH of water, light intensity etc. Examples include

Freshwater ecosystems such as streams, rivers, springs, ponds, lakes, bogs and freshwater swamps. Freshwater ecosystems are home to more than just fish: algae, plankton, insects, amphibians and underwater plants also inhabit them.

Marine ecosystems which contain saltwater. Include oceans, water swamps, mangroves and coral reefs. Organisms that live in marine ecosystems mainly include brown algae, corals, cephalopods, echinoderms, dinoflagellates and sharks

4. The ecosystems that are created by man and not do not develop naturally are called artificial ecosystems. Diversity is less in these ecosystems as compared to natural systems. The artificial ecosystem is practical with well defined goals but most of them are fragile and vulnerable to failure due to lack of diversity and strong self regulatory systems. There is a scope of improvement in design which can enhance their sustenance capacity in a given space. Example- Modern cities. In artificial ecosystems, most of the inputs, outputs and interactions are planned or ill-planned by man. Another example is aquarium. It is a man made ecosystem that consists of a glass tank or bowl filled with water and supports living organisms such as fish, some small plants. It represents a small scale aquatic ecosystem. An aquarium survives on dissolved oxygen content and fishes form dominating organisms in this ecosystem. Each living (fishes, fungal plants, etc.,) and non living organisms (sand, water) in this man made ecosystem interact closely with each other and the change in ones content significantly affects other.

5. **Tropical forest:** The forests are characterized by dense vegetation and comprises of tall trees of different heights. The warm, moisture-laden environments support the growth of trees. Trees grow tall and foliage is lush and dense.

   Temperate forest: These have good number of trees like mosses and ferns. They exist in the areas/regions where the climate changes significantly from summer to winter. Trees are deciduous and shed their leaves each season or coniferous which remain evergreen all the year around.

6.

Limnetic zone

This zone is present beyond the littoral zone. The zone extends at a depth where sunlight can penetrate. This zone consists of phytoplankton and zooplankton. Most photosynthesis occurs in this part of the lake. Small crustaceans and a variety of freshwater fish also live in this zone.

Profundal zone

This zone is present below the limnetic zone. The zone is much colder and dense. Sunlight cannot penetrate this zone. The process of photosynthesis is not possible in this zone. Low levels of oxygen are present. Organisms in this zone have adapted to cooler temperatures and lower levels of oxygen.

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Unit 8

ECOSYSTEM FUNCTIONING

Structure

8.1 Introduction
Expected Learning Outcomes
8.2 Ecological Pyramids
8.3 Energy Flow in an Ecosystem
8.4 Food Chain
8.5 Food Web
8.5 Summary
8.6 Terminal Questions
8.7 Answers

8.1 INTRODUCTION

Each organism exists in relationship with other organisms and the non-living environment. Living organisms are related to each other in various ways. They share food with each other and transfer energy. Hence flow of energy and cycling of nutrient materials takes place in an ecosystem**.** Ecosystems are open systems. They are driven by the continuous input of energy and nutrients from their environment. (outside boundary – delete). The functioning of an ecosystem can be understood by study of processes of flow of energy and cycling of nutrients. In this Unit we will study in detail the concept of energy, its flow through the ecosystem, the productivity of ecosystems, energy efficiency of ecosystems, ecosystem control and homeostasis.

Expected Learning Outcomes

After studying this Unit, you should be able to:

- recognize different types of ecological pyramids,
- explain the process of energy flow through ecosystems,
- describe various types of productivity,
- describe terms such as gross primary production, net primary production and secondary production,
- define ecological efficiency and explain its importance for ecosystems, and

- outline the basic principles involved in ecosystem control and homeostasis.

8.2 ECOLOGICAL PYRAMIDS

In an ecosystem, the organisms are organized into different trophic levels. These trophic levels get arranged in the form of a pyramid to depict the relationships such as energy, biomass and numbers in an ecosystem. The base of each pyramid represents the first trophic level i.e. producers (or – delete) while the top represents the tertiary trophic level i.e. consumers. The primary or secondary level consumers occupy the space in between. The ecological pyramids are of different types depending upon the type of function they depict. These include pyramid of numbers, biomass and energy.

Pyramid of Numbers

It is the graphical representation of the total number of individuals of species belonging to each trophic level in the form of pyramid like structure. It consists of horizontal bars. Each bar depicts a specific trophic level. The producers are shown at the base followed by primary consumers i.e. herbivores on its top and carnivores further on top and so on. The length of each bar represents the total number of individuals present in each trophic level in an ecosystem. The number of individuals decreases with movement to the next (higher) trophic level. The higher trophic levels are occupied by relatively large-sized animals which are less in number as compared to plants representing the first trophic level or small animals representing the next trophic level (Fig 8.1).

For most of the ecosystems, the pyramid of numbers is upright because the number of organisms decreases successively at higher trophic levels. In some ecological systems, the pyramid of number may be inverted. A tree represents an example of an inverted pyramid. Tree supports innumerable insects and bird species. Tree is a primary producer and represents base of the pyramid. Insect and bird population that is dependent on it represent the second and third trophic levels. Similarly the parasitic food chain is represented by an inverted pyramid. The shape of pyramid to be upright or inverted depends upon the number of producers. The producers vary greatly in size for each type of ecosystem.

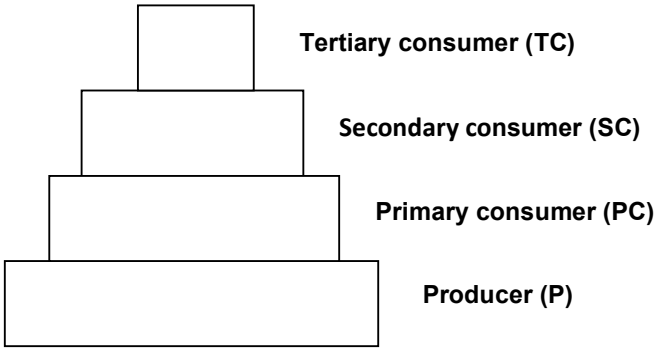

Fig. 8.1: Diagrammatic representation of pyramid of numbers.

Pyramid of Biomass

Biomass represents the total dry weight of species present in each trophic level at a particular time. It is measured by taking dry weight of all the organisms occupying one trophic level. Biomass is measured in g/m^2. The representation of organisms in terms of biomass eliminates size difference between them when present in the same trophic level. The amount of biomass present in an area at a given time is called as standing crop or standing biomass. The biomass of producers is generally much higher than that of herbivores. The biomass of herbivores is greater than the biomass of carnivores and so on. The biomass decreases at each trophic level while going from producer to consumers. The diagrammatic representation of biomass of individuals belonging to the different trophic levels shows the shape of an upright pyramid. In some aquatic ecosystems such as lakes and oceans, the pyramid of biomass is inverted. Since microscopic phytoplanktonic algae are primary producers in the aquatic system. They have a short life span and thus reproduce rapidly. Being single-celled organisms, they do not accumulate much biomass and they are eaten up faster by organisms like zooplankton, fish etc. The consumers in these ecosystems are presented by small microscopic zooplanktons to large organisms like whales. The weight or the standing crop of phytoplankton is less as compared to herbivores or other consumers. Hence the pyramid of biomass is inverted in aquatic ecosystem.

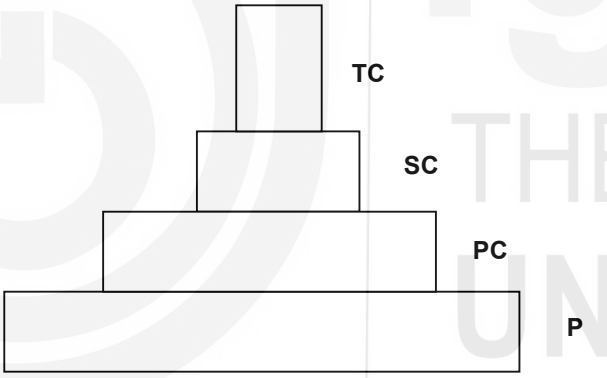

Fig. 8.2: Diagrammatic representation of pyramid of biomass. P-Primary producer, PC- primary consumer, SC-secondary consumer, TC-tertiary consumer.

Pyramid of Energy

The functional role of the trophic levels in an ecosystem is well represented by pyramid of energy. The drawbacks related to number and biomass of species can be overcome by representation of trophic levels in terms of energy. This pyramid accurately reflects the laws of thermodynamics. Loss of energy and its transfer takes place at each trophic level. Each bar represents the amount of energy utilized at each trophic level in a given time per unit area. The amount of energy is based on determination of the actual amount of energy that individuals utilize during metabolism and that remains unutilized (waste products and stored in the body tissues). Each trophic level always has smaller energy content than the trophic level below it. The pyramid of energy

is always upright (Fig 8.3). The unit of measurement of energy is kcal/m^2yr^{-1}. The pyramid of energy is important because:

i) it takes into account the rate of production.

ii) it is based on the amount of energy per unit area or volume that flows through that trophic level in a given time period.

iii) the relative importance of populations within one ecosystem can be compared.

iv) inverted pyramids are not obtained.

Though the pyramids represent the relationship between each trophic level in terms of number, biomass or energy but still they show some limitations. These include:

i) Some species practice more than one mode of nutrition or belong to two or more trophic levels. This is true for 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 ecosystems 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.

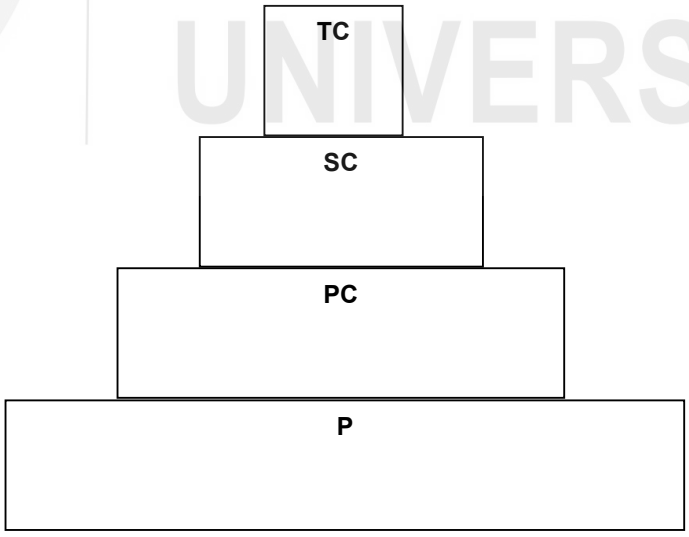

Fig. 8.3: Diagrammatic representation of pyramid of energy.

SAQ 1

Write the correct option:

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?

SAQ 2

Why pyramid of biomass in some aquatic ecosystems like lakes and oceans acquires an inverted shape?

SAQ 3

Why are pyramids of biomass inverted?

8.3 ENERGY INPUT IN ECOSYSTEM

Survival of living organisms present in an ecosystem depends upon the input of energy. Continuous flow of energy is essential for supporting diverse ecosystem processes. For any ecosystem, the ultimate source of energy is sunlight. Energy flow occurs when a primary consumer (herbivore) eats a producer, and is itself eaten by secondary consumers.

On an average the total amount of solar energy that reaches the earth's surface is about 3,400 kcal/m^2/day. The solar influx received at the surface of the earth depends on various climatic, geographic and other environmental factors. It varies significantly from one place to another. It decreases with latitude and also varies during different seasons at any given location. 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 is known as solar constant.

Thirty 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. Out of the (only a – delete) small fraction of sunlight (3-6%) reaching plants, only 0.023% is used in photosynthesis and all the organisms depend upon this small fraction of energy. Producers trap a small amount (about 1 %) of solar energy and make it available for primary, secondary and tertiary consumers. During photosynthesis, plants convert solar energy into chemical energy and produce carbohydrates and a host of other nutrients. When animals (herbivores) eat plants and these animals are eaten by other animals (carnivores), the chemical energy flows from producers to consumers. Part of this chemical energy is utilized in respiration and for the growth and development of living beings. A large part of it, is however lost as heat at several steps, and cannot be reutilized. The continuous input of energy from the sun, its conversion to other forms of energy by other organisms and its flow back to the environment maintains life on the earth.

Energy flows from lower (producer) to higher (herbivore, carnivore, etc.) trophic level. The flow of energy is unidirectional. Some amount of energy is lost as heat at every successive step via transfer from green plants to herbivores and then to carnivores (Fig 8.4).

The process of energy flow is governed by two physical laws i.e. first and the second law of thermodynamics**.** According to the first law of thermodynamics, energy can neither be created nor destroyed but may be transformed from one form into another. This law deals with conversion of energy**.** For example, the energy of visible light is transformed into chemical energy of the glucose molecule synthesized by green plants through photosynthesis. The living organisms including plants utilize glucose during respiration, which releases chemical energy.

The second law of thermodynamics states that in every energy transformation, some energy is always lost in the form of heat. All living organisms use the stored chemical energy for their metabolic activity. Some of the energy is dissipated as heat which escapes into the surrounding environment. Energy stored in the body is used in doing some work, while some of the useful energy is lost as body heat. Thus, energy transformation is less than one hundred percent efficient. Energy inflows balance outflows at each trophic level (as per first law of thermodynamics) and energy transfer is accompanied by dissipation of energy into unavailable heat i.e., respiration as per the second law of thermodynamics.

Important features of energy flow in an ecosystem are:

- Flow of energy in an ecosystem is unidirectional i.e. solar energy trapped by the autotrophs or producers do not revert back to the sun. This means that in an ecosystem, energy is transferred in an orderly sequence. Energy flows from producers (autotrophs) to herbivores and from herbivores to carnivores. The energy transfer is unidirectional and does not flow back to the system. As a consequence of this unidirectional and continuous energy flow, the ecosystem maintains its entity and prevents collapse of the system.
- At each trophic level, the energy content decreases progressively. This is because at each trophic level some amount of energy is used for metabolic processes such as respiration, some amount is lost as heat and some amount is stored as fats in animal bodies. As much as 80-90% of energy is lost at every link in a food chain.
- The net energy inflow to an ecosystem balances with the net energy outflow from the ecosystem. This maintains a dynamic equilibrium state in the ecosystem.

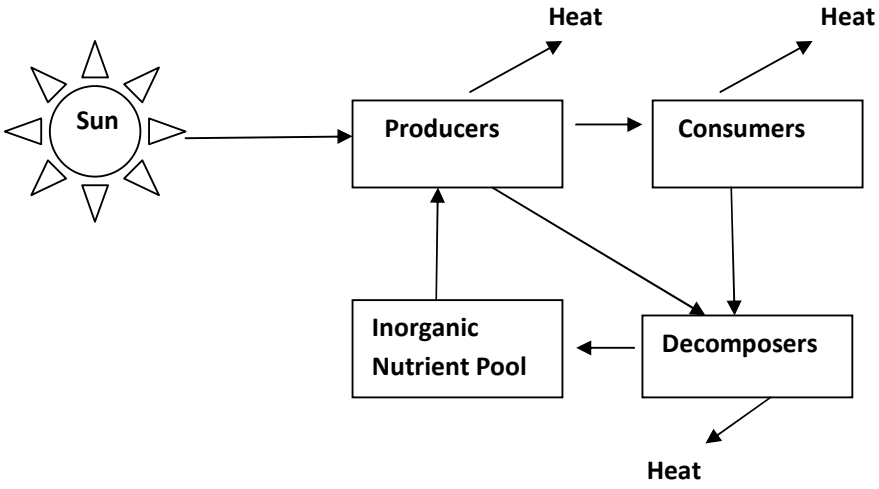

Fig. 8.4: Energy flow through different components of an ecosystem. Producers capture a small amount of solar energy and make it available for the subsequent biotic components of the ecosystem, whether they are herbivores, carnivores, top carnivores and decomposers.

Energy flow models

The flow of energy through various trophic levels in an ecosystem can be explained with the help of various energy flow models.

1. **Single Channel Energy Flow Model:** The flow of energy takes place through a single channel from green plants or producers to herbivores and carnivores. There is unidirectional flow of energy. The energy captured by autotrophs passes to herbivores and does not revert back. The flow of energy is stopped if the primary sources of energy (i.e., sun) are removed. The energy flow is greatly decreased at each successive trophic level starting from producers (autotrophs) to herbivores and carnivores. Some amount of energy is utilized for carrying out metabolic reactions (respiration) and some is lost as heat (unutilized energy). Thus according to an estimate, out of the total 3,000 kcal of light received by plants, 1,500 kcal (50%) is absorbed by them. About 1% (15 kcal) is converted by autotrophs (first trophic level) and the net production is 15 kcal. At successive trophic levels i.e. primary and secondary consumers (herbivores and carnivores), secondary productivity (P_2 and P_3) tends to be about 10%.

2. **Y-Shaped or Double Channel Energy Flow Model:** This energy flow model was given by H.T. Odum in 1956. This model shows flow of light and heat energy as well as the import, export and storage of organic matter. Decomposers are placed in a separate box for separating the grazing and detritus food chains. In all ecosystems the grazing and the detritus food chains are interconnected so that shifts in the flow of energy can occur quickly in response to any changes. These can be depicted by a Y shaped or two channel energy flow diagram (Fig 8.5). In this model, two food chains are interconnected with each other. This model is more realistic and practical than the single-channel energy flow model because:

(i) it conforms to the basic stratified structure of ecosystems.

(ii) it separates the two chains i.e., grazing food chain and detritus food chain in both time and space.

(iii) microconsumers (e.g.. bacteria, fungi) and the macroconsumers (animals) differ greatly in size-metabolism relations in two models.

3. **Universal Energy Flow Model:** E.P. Odum (1983) gave a generalized model by combining both single channel model and Y-shaped models applicable to terrestrial and aquatic ecosystem. This model is known as Universal energy flow model. In this model appropriate energy inputs and links with other species are shown in a population. A discrete energy level is represented in the form of flow of biomass and energy channels. Many populations are supported by the same energy source.

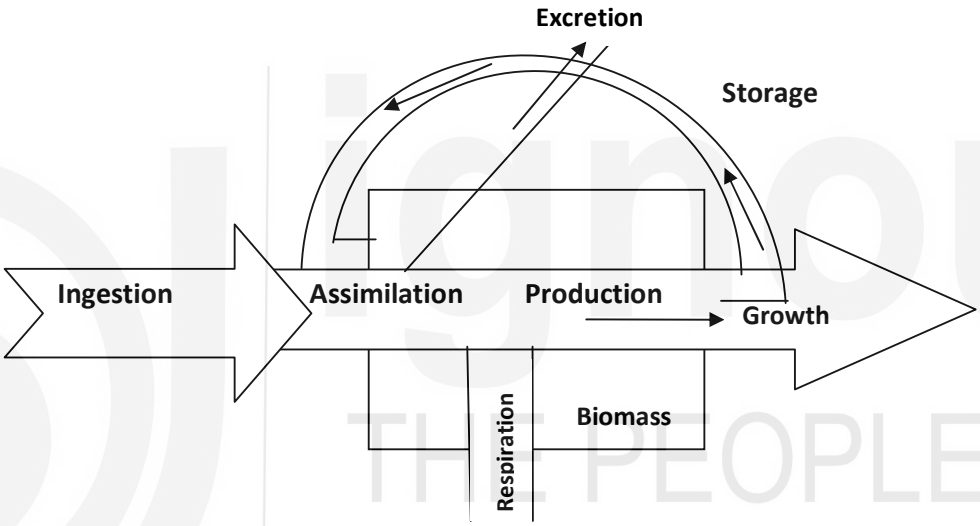

Fig. 8.5: The Y-shaped energy flow model.

I- Incident solar rays; A- Assimilated energy; P-net production; G-Growth; B-Biomass; R-Respiration; S-Stored energy; E-Excreted energy; NU-Unutilized energy.

Energy Budget

The flow of energy through the ecosystem can be quantified easily. After an input in an ecosystem there is a subsequent transformation of energy from one trophic level to another. The energy transfer can be expressed in terms of calories. Energy input is in the form of solar radiation. Heat dissipated represents the energy output. The study of ecosystem energetics gives information about energy budget at individual, population and ecosystem level. The first step of energy flow is measured at the level of producers. The incoming solar energy can be monitored with instruments such as a net radiometer or a pyranometer/solarimeter. According to an estimate, about 90 per cent of the energy is lost as heat when we proceed from one trophic level to the next higher level (Fig 8.6). In other words, only 10 per cent energy is incorporated into the tissues of the next trophic level. Example- If 1,000 kcal of plant energy was consumed by herbivores, about 100 kcal would be passed to

herbivores, 10 kcal to the carnivores and only 1 kilocalories to the top carnivores.

In aquatic ecosystems the primary production is measured by observing the change in oxygen or carbon dioxide levels in water. The energy flow is measured by quantifying amount of energy of every species population at each trophic level. The addition of these figures for energy gives the overall energy flow for each trophic level. The weight, food intake, faecal output and respiration of a few individuals are measured and their assimilation and production rates are calculated. All living (things – delete) organisms use energy to grow, maintain themselves and reproduce. Each individual has an 'energy budget' i.e. it allots different amounts of energy for various activities.

Most of the energy input is in the form of solar radiation while the output of energy is represented by heat dissipated from the system. The total energy input amounts to 410486 kcal/m^2/yr (410,000 kcal/m^2 solar energy and 486 kcal/m^2/yr form of organic matter imported into the system) matches with the output of energy (407986 kcal/m^2/yr) lost as waste heat and (2500 kcal/yr exported from the system in the form of organic matter). [It is observed that the total energy input amounts to 410486 kcal/m^2/yr, (410,000 kcal/m^2/yr of solar energy and 486 kcal/m^2/yr of organic matter imported into the system). About 407986 kcal/m^2/yr of energy is lost as heat and 2500 kcal/m^2/yr of energy is exported from the system in the form of organic matter. – This is a mere repetition of the earlier statement and should be deleted.] Thus, energy enters the ecosystem as free solar energy and leaves it as heat.

In some shallow waters and in a heavily grazed pasture or grassland, 50% or more of the net production may pass down the grazing path. In contrast, marshes, oceans and forests and other natural ecosystems operate as detrital systems. In these ecosystems about 90% of autotrophic production is not consumed by heterotrophs.

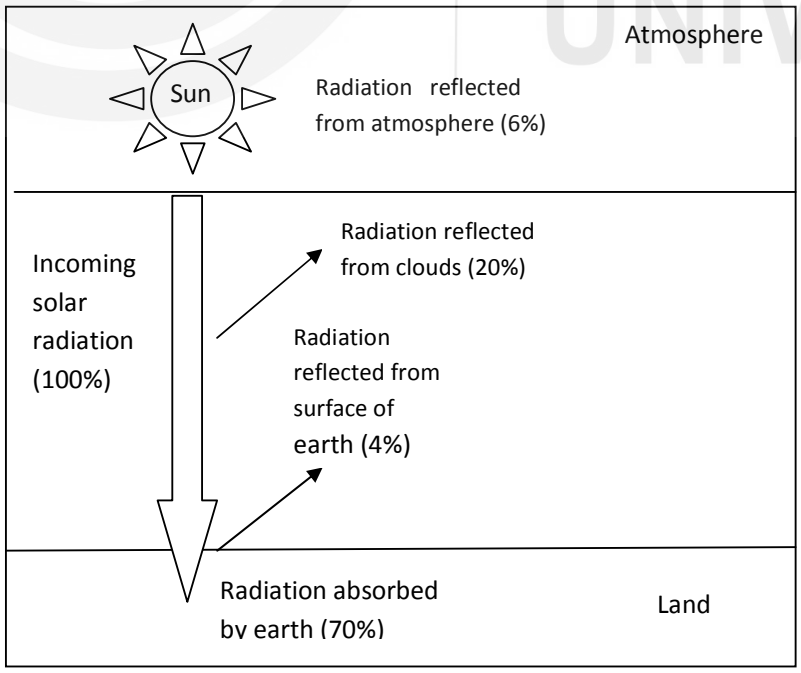

Fig. 8.6: Diagrammatic representation of energy budget in an ecosystem.

Energy efficiency in ecosystems

Ecosystems are generally very inefficient in use of available energy. This is because:

- Green plants make use of only about 5% of the solar radiation available to them.
- Only a small but variable fraction of the energy available at any particular trophic level is passed on to the next one, the rest is lost during respiration.
- The animals representing the second trophic level use more energy during respiration, in comparison to plants which represent the first trophic level. The relative loss of energy increases successively with each trophic level (higher). Example- Energy flow studies through an ecosystem were conducted in Silver Spring Florida in 1957 by Odum. The study of energy flow through Silver Springs Florida showed that just over 5 % of energy produced by the primary producers becomes available to the top carnivore.

The efficiency with which parts of an ecosystem use available energy is termed as **ecological efficiency**. It is the ratio between energy flows at different points along the food chain and is expressed as a percentage. Ecological efficiencies are of considerable importance in comparing ecosystems and are of practical significance to many ecologists/ environmentalists to study the influence the energy flow of ecosystems on the environment. The ecological efficiencies can be calculated for various populations or different trophic levels.

Concept of production

Solar energy enters the biotic components of the ecosystem through primary producers. The plants store solar energy in the form of chemical bond energy through the process of photosynthesis. It is usually expressed as the energy or the biomass accumulation over a period of time and designated as kilocalories per square metre (kcal/m^2). It is also expressed as dry organic matter in grams per square metre (g/m^2). One calorie (cal) is the amount of heat needed to raise the temperature of one cubic centimetre of water through one degree centigrade.

One kilocalorie (1 kcal = 1000 cal)

The rate of production over time is called productivity and its units are g/m^2/year or kcal/m^2/year. This describes the productivity of trophic level of the ecosystem or the productivity of the ecosystem as a whole. It is an important characteristic of ecosystem and depends on the availability and movement of energy through the ecosystem. The productivity of ecosystems is determined by the amount of solar radiation that is available to the primary producers for photosynthesis and efficiency with which the autotrophs convert the solar energy into usable form through photosynthesis.

The productivity of ecosystems can be expressed through many different parameters, viz. **Gross Primary Productivity** (GPP), **Net Primary**

Productivity (NPP), **Net Community Productivity** (NCP) and **Secondary Productivity** (SP).

During photosynthesis plants convert the solar energy into chemical energy. The amount of sugar produced in plants provides an index of the energy uptake and gives the measure of their productivity. Productivity is the rate at which organic matter is created by photosynthesis. The rate at energy accumulates is known as primary productivity. Technically it is defined 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 ($kcal/m^2$) – delete). It is expressed in terms of kcal m^2/yr or g/m^2/yr. Photosynthesis is the first and the basic form of energy (storage – should it not be conversion because the light energy is converted into chemical energy), hence it is referred as **primary production**. The rate at which primary production occurs over time is referred to as **primary productivity**.

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. The total energy accumulated in the plant during primary productivity is known as **Gross Primary Productivity.**

GPP - R = NPP or GPP = NPP + R

A considerable portion of the solar energy fixed by plants (GPP) is utilized by plants in respiration (R) to get the energy needed for their metabolism and other vital functions. The amount of energy left after being consumed in respiration (R) is used for growth or producing new individuals i.e. reproduction. Plants spend some energy in their maintenance and in reproduction. The organic compounds formed during photosynthesis are oxidized to derive the energy during respiration in plants. The energy remaining after respiration is stored as organic matter and is called **net primary productivity (NPP).** 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

Net primary productivity can be expressed as

NPP = GPP - R

where R is the energy used up in respiration, GPP is the gross primary productivity

Energy fixed by plants (GPP) is used for their own maintenance (R) and only remaining (NPP) is available to be transferred to the next trophic level. Net primary production is the only energy available for the next trophic level. Net primary production accumulates as plant biomass. The amount of accumulated organic matter found in an area at a given time is referred to as the **standing crop biomass**. Biomass is usually expressed as grams of organic matter per square metre (g/m^2) or as calories per square metre (cal/m^2). Biomass is the amount of organic matter present at any given time.

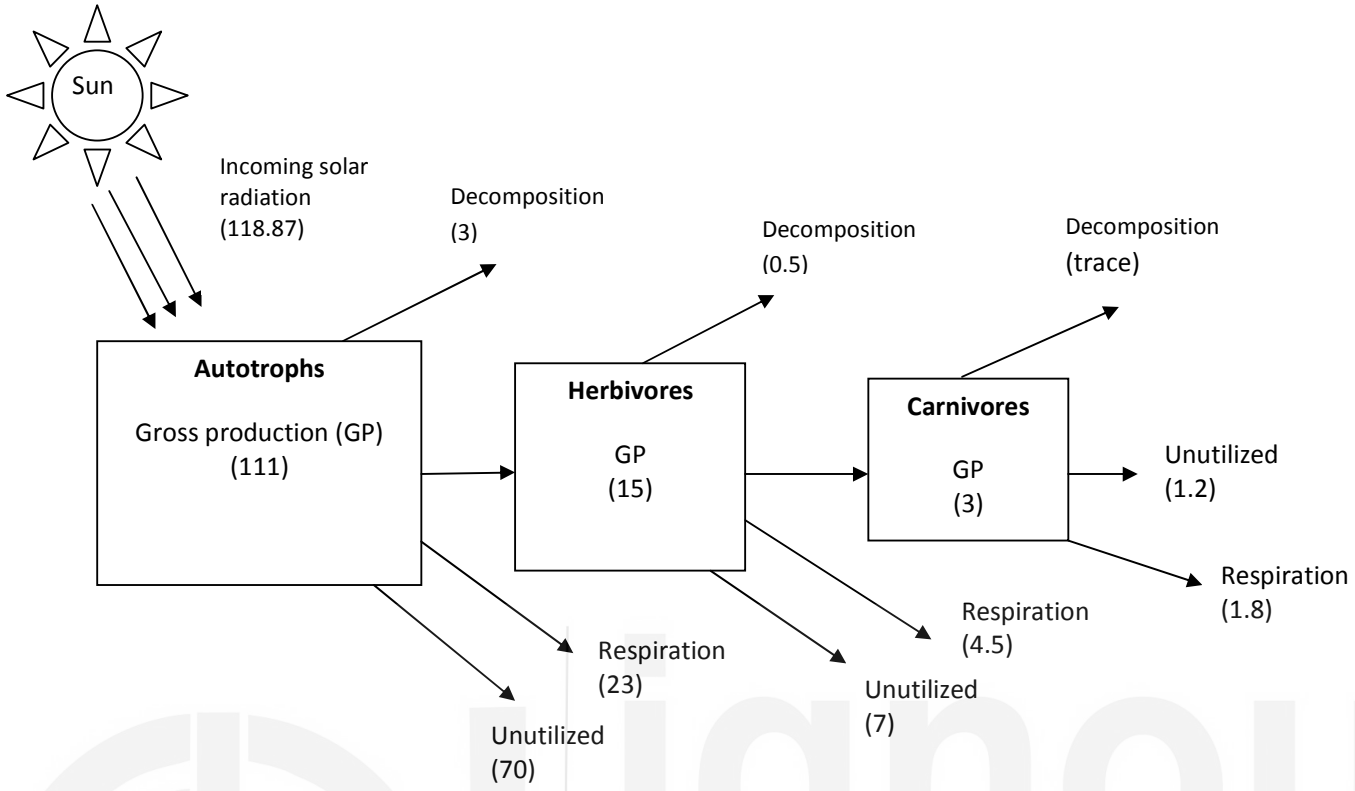

Fig. 8.6: Depiction of energy flow and productivity among various trophic levels in an ecosystem.

The productivity of terrestrial ecosystems is influenced by the climate. Thus, the production varies in different global ecosystems due to change in climate. In contrast, in aquatic ecosystems, the primary productivity is limited by nutrient availability. In most ecosystems a separation between the zone of primary productivity, decomposition, and release of nutrients occurs. In terrestrial plants, height allows them to extend into both zones with their canopy and root system. In aquatic environments, particularly in the oceans, phytoplanktons are near the surface. Nutrients in the deeper waters must be transported to the surface waters where light is available to drive photosynthesis. As a result, nutrients particularly nitrogen, phosphorus and iron, are a major limitation on primary productivity in the oceans. The most productive waters of the oceans are coastal environments and coral reefs. This is because in these environments the water depth is low. Less vertical separation causes greater transport of nutrients to surface waters through changing tides. Estuaries receive a large input of nutrients carried from terrestrial ecosystems by rivers and streams. The net primary productivity does not remain stable over a period of time in ecosystems.

Rapid growth or bloom type systems (rapid production for short periods) such as the alfalfa field tend to have a high net primary production. The blooms have a high net community production. Alfalfa fields are human managed ecosystems and here the consumers like the herbivores are not encouraged. Hence the energy loss by heterotrophic respiration in such systems is reduced. In steady state communities like the rain forests the gross primary production tends to be dissipated by the combined autotrophic respiration (RA)

and heterotrophic respiration (RH). Thus little or no net community production is noted at the end of the cycle. The communities with their large biomass or standing vegetation require respiration for maintenance hence, a low NPP / GPP ratio is noted.

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. 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 % but the average for green plants, on the whole is only a small fraction of sunlight, i.e., 0.02% reaching the atmosphere. The production efficiency 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%. The plants which have low maintenance requirement due to minimum non-photosynthetic (non green) tissues such as grasses, algae and phytoplankton are the most efficient. Algae and crops like corn have an efficiency of about 80 to 85%, submerged aquatic plants 60 to 75%, deciduous forests about 42 %. Different ecosystems have different productivities.

Productivity of ecosystems depends on a variety of factors such as sunlight, temperature, rainfall and the availability of nutrients. Warm, moist, sunny areas with high levels of nutrients in the soil are ideal. Deserts have low productivity because water is scarce. Arctic areas too have low productivity because temperature is low. 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. Some agricultural systems also have high productivity, e.g., sugarcane has a productivity of 1.700 to 1,800 glyr; corn 10.000 glyr; and some tropical crops up to 3,000 glyr.[In this sentence, it is necessary to define “glyr”] High production usually results from an additional input of energy available to the system. The energy supply can be in the form of high ambient temperature, rainfall, or inflow of nutrients.

Secondary Production

Net primary production is the energy available to consumers or heterotrophs. A part of the energy of the lower trophic level is not used at higher trophic levels. Secondary production depends upon the primary production for energy. Herbivores feed on grasses and other plants and utilize primary production. The food is processed in the stomach of animals. For instance, some of the energy of plants will not be used by herbivores since all parts of the plant are not eaten by them. Digested material is assimilated in the body and the unutilized material is excreted. Some of the energy is used up in respiration and other metabolic processes of the body such as maintenance and repair of tissues. The remaining part is utilized for producing new tissues or reproduction. The production of biomass, growth or addition of new individuals is referred to as secondary production. Secondary productivity is the rate of

formation of new organic matter by heterotrophs. Only 10% of the energy gets converted from the total intake of 100%. A rabbit has 0.1 kcal of secondary production for every 1 kcal of food eaten. Most of the energy is used in respiration or for the maintenance of its body functions. A certain amount is not assimilated at all and is therefore excreted in the faeces. Relatively less amount of energy is left for the production of new body tissues. For every 10 kcal of plant tissue available to herbivores, about 1 kcal is eaten up and only about 0.1 kcal is stored in the form of body weight.

The secondary production is greatest when birth rate of the population and the growth rate of the individuals in a population are at their highest. Secondary production depends on primary production for energy. Hence any environmental constraint on primary productivity, such as climate, will constrain secondary productivity within the ecosystem. Increase in net primary productivity provided the food source for the herbivore population. Herbivores are the source of energy for carnivores. Like herbivores, carnivores cannot use all of the energy in their food for production. Metabolic losses for heat production, maintenance and respiration occur. When studying the concept of primary and secondary productivity, a significant amount of energy is lost in various life processes in an ecosystem at different levels. This brings us to the concept of energy efficiency in an ecosystem.

This can be understood with reference to the “Law of Diminishing Returns”. According to this fundamental principle of economics, there is “the decrease in the output of a production process as the amount of a single factor of production is incrementally increased”. Thus, in the case of an ecosystem, when the trophic level increases incrementally, the energy efficiency decreases.

Similar to primary production at the first trophic level, the rate of storage at the consumer trophic levels (1st, 2nd and 3rd) is referred to as **secondary production**. You know that consumers feed on organic food already prepared in the first trophic level, and there are losses of energy due to respiration, removal of faecal matter etc.

The rate of production of organic matter not used by heterotrophs is referred as net community production (NCP). It is the net primary production minus heterotrophic consumption for the period under consideration.

Light is the major factor affecting the productivity of ecosystems particularly the aquatic ecosystems. In a lake, the depth to which the light can penetrate determines the zone of productivity. The photosynthetic rate and the gross primary productivity of phytoplankton are highest at the intermediate levels of PAR. In oceans the nutrients need to be transported to the surface where the light is available to carry out photosynthesis.

SAQ 4

Sun is the ultimate source of energy for earth. Explain.

SAQ 5

Define :

- net primary productivity
- gross primary productivity
- standing crop
- biomass

Ecosystem control and self regulation

The changes occur in an ecosystem and it possesses the capacity to recover from disturbances. An ecosystem can be disturbed naturally or by human interference (induced). An example of a natural disturbance is a hurricane or a tornado. An example of a human-induced or anthropogenic disturbance is tillage or pesticide application. The capacity of an ecosystem to self-regulate or self-maintain is called homeostasis. It is an ability of ecosystems to recover from certain perturbations. In grassland, grasses do not grow well under drought conditions. The mice that eat the grass become malnourished. The birth rate of mice decreases. The hungry mice move to burrows and sleep. Sleeping reduces their requirement for food. In this way, they are less exposed to predators. Their behavior protects their own population and balances. Such a mechanism is known as feedback regulation. It is very important to maintain the ecological balance. It is the prime regulatory mechanism for the ecosystem as a whole.

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 have considered a very small group of organisms primarily the mice and the plants. 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 specialized 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. The balanced ecosystems contain different species.

Some ecosystems e.g., rainforests or tundra, if left undisturbed, remain the same for years. This is because ecosystems that have evolved over long periods of time reach steady state equilibrium through ecosystem control and self-regulation.

Removal or addition of any species or community can trigger changes that are linked by the flow of energy and nutrients, hence altering the response or output of the ecosystem. For example, the removal of a section of trees from a forest ecosystem will upset the natural balance. This will let in more sunlight which would allow shrubs and bushes to grow. Any disturbance to either the inputs or components of an ecosystem brings alterations to its prevailing equilibrium state. A feedback occurs when a change in one element in the ecosystem produces a sequence of changes in other elements, and this ultimately leads back to the element whose initial change set off the sequence. There are two different types of feedback links: positive and negative. These have radically different impact on the environment.

This is why such ecosystems appear stable in the absence of external change. They can usually adjust to external change. **Ecosystem resistance** is the ability of a system to withstand or resist variation. It is measured by the degree to which the system is changed from an equilibrium level as a result of disturbances. It is the ability of an ecosystem to remain stable in the face of disturbance. **Resilience** is the speed with which a disturbed system returns to equilibrium or the same general state after being changed. It is the ability of an ecosystem to recover after disturbance.

Ecosystems like tropical rainforests have a large biotic structure and are most resistant to change. This is because they have nutrients stored mainly in the standing biomass, the trees. Forest trees can withstand environmental disturbances, sharp temperature changes, drought and insect outbreaks. The forest ecosystem is able to draw on stored reserves of nutrients and energy. The very complex feedback mechanisms of complex food webs and the high diversity of the community can restore equilibrium rapidly. On the other hand, simple ecosystems are comparatively less resistant. Simple ecosystems like the tundra or a human managed monoculture system, e.g., cotton fields or paddy fields with a simple biotic community have a few inter-specific interactions or simple food webs. They may be drastically changed with sharp changes in temperature, drought and insect attack. The response of rainforests to large disturbances as opposed to small ones may be very different. For example, if large areas within the forest were to be cleared by felling trees or if they were exposed to fire, the initial disturbance would be much greater. Loss of trees would prevent rapid nutrient cycling mechanisms within the forest and the soil would rapidly become exhausted through leaching of the nutrient materials. The surface of the soil would be dried out by the direct radiation from the sun and in some instances harden irreversibly to a pavement like surface. In such situations the re-establishment of the rainforest vegetation would be very slow. In other words the return to the original steady state conditions would be slow. Under such large disturbances the rainforests are found to have low resilience.

Unlike the rainforests, aquatic ecosystems, which lack any long term storage of energy and nutrients in biomass, exhibit little resistance. Aquatic ecosystems are more resilient. Frequent flooding dislodges stream invertebrates, create mosaics of empty patches. These patches are re-colonized by different subsets of stream invertebrates available for recruitment. Although the recovered patches may hold a different set of

organisms, the stream is returned to its original conditions. For example, a lake that is used as a basin for sewage disposal receives a large input of organic nutrients, such as phosphorus. Such inputs result in eutrophication and change the structure of the lake ecosystem. However, once the sewage inputs are diverted from the lake, organic nutrient levels in the lake decline, and the lake can return to its clear condition.

8.4 FOOD CHAIN AND FOOD WEB

Food provides energy and nutrients like carbohydrates, fats, and proteins essential for living organisms. The flow of energy in the ecosystem is linked closely to the nutrient flow in it. This means that chemical energy in the form of carbohydrates, fats, protein and other nutrients gets transferred to consumers. Nutrients are recycled through the ecosystem and the energy within the ecosystems help in the re-cycling of nutrients.

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 (Fig 8.7). The 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:

Grass → Goat → Man

In the transfer of food energy, some proportion of energy is lost as heat. The number of links or steps in a food chain is usually four to five. In aquatic ecosystems, microscopic green plants called phytoplankton and algae play the role of producers. Three types of food chains can be distinguished on the basis of organisms that constitute the first trophic level. These are:

i) grazing food chain, ii) detritus food chain, and iii) auxiliary food chain.

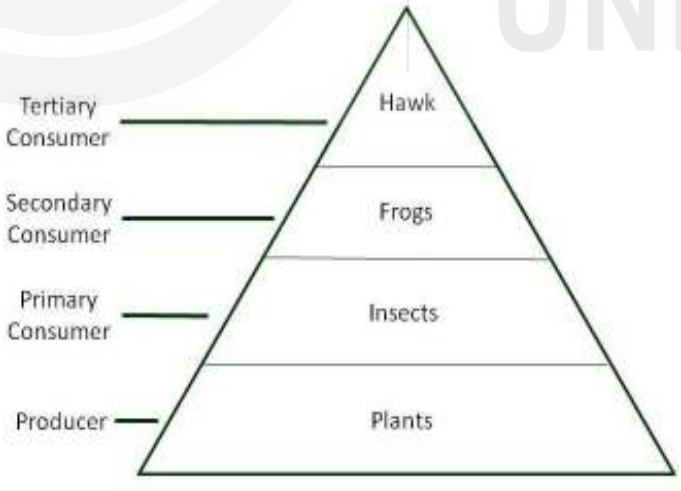

Fig. 8.7: Depiction of a food chain.

i) ***Grazing food chain*:** In these food chains green plants or autotrophs form the first trophic level. Cow or deer grazing in a field represent 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 energy flows through grazing food chains. At each step, significant amount of organic matter is transferred to detritus food chain through death, decay and excretion by living organisms. Ocean food chains are among the longest having up to five links, while forest types consist of three or four links. The long length of grazing food chains in aquatic ecosystems occurs because phytoplankton and zooplankton are small in size. They 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. 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. 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 the process they release various nutrients, locked in dead organic matter, which are used readily by the green plants. These types of food chains are present in all ecosystems such as forest ecosystems and shallow water communities. Detritus food chains are interconnected with grazing food chains and other auxiliary food chains through certain specific organisms to permit transfer 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 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. They are necessary for self-sustenance and maintenance of ecological balance. Detritus food chains are of great value for modern man for maintenance of activities such as sewage treatment and control of water pollution.

Most of the natural ecosystems possess both grazing and detritus types of food chains. Their relative importance varies from ones ecosystem to another. In terrestrial and shallow water ecosystems, detritus food chains dominate because a major proportion of the energy flow occurs through this circuit. In 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.

ii) ***Auxiliary food chains*****:** In addition to grazing and detritus food chains there are other auxiliary food chains operating 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. The parasites are transmitted through various vectors or unrelated intermediary host organisms.

8.5 FOOD WEB

In nature no food chain is isolated. Food chains are interconnected to form a web like structure called the food web. This is because a plant may serve as a food source for many herbivores simultaneously. Example- Grass can support many animals like deer, cow, grasshopper or rabbit. Similarly, herbivore may act as a food source for many carnivorous species. Also food availability and preferences of herbivores as well as carnivores may shift seasonally. A food web illustrates, all possible transfers of energy and nutrients among the organisms in an ecosystem (Fig 8.7), 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. Example, in a stream-side ecosystem, if grasshoppers become scarce or their population is wiped out because of some calamity, the frogs preying on grasshoppers do not die or move out of that place but instead they feed on other organisms such as flies or butterflies. A food web introduces a strong element of stability into an ecosystem. Larger the number of components involved, more stable is the ecosystem.

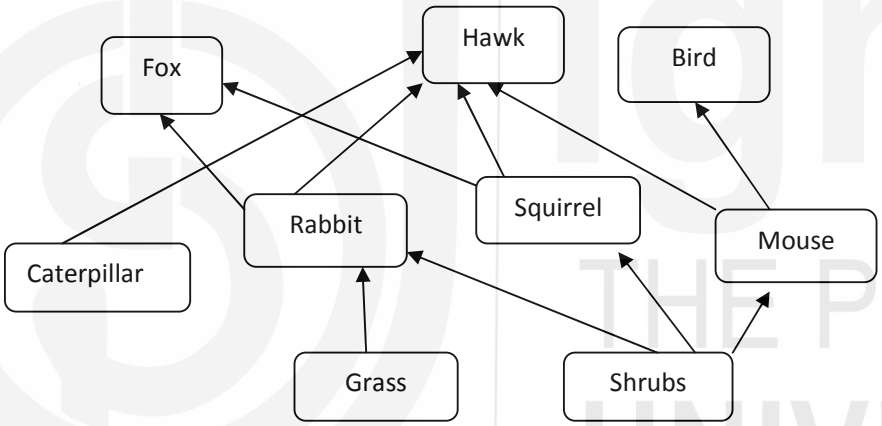

Fig. 8.7: A simple representation of a food web in a grassland.

A typical food web consists of a basal species connected to top predators through various intermediate species. The basal species is eaten up by other species. Intermediate species feed on other species and become prey of some species (Fig. 8.8). Top predators feed on intermediate and basal species. Food webs prove useful in analyzing the structure of communities. The maximum number of links in a food web indicates species richness. The length of a food chain within a food web is measured as number of links between the top predator and the basal species. The measure of average number of links per species in a food web gives the linkage density.

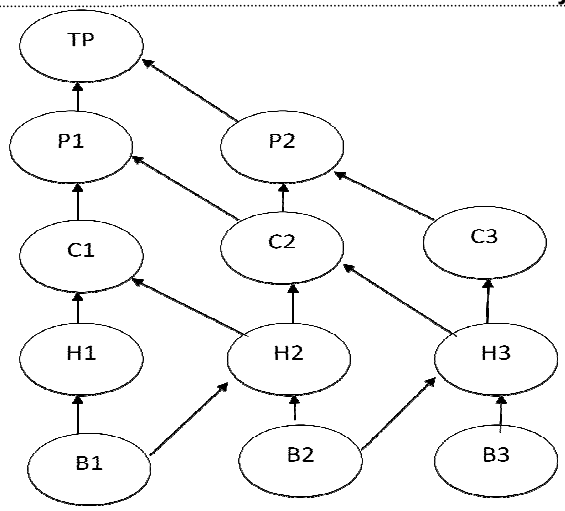

Fig. 8.8: Graphical representation of a food web. TP- top predator, P-predator, C-carnoivores, H-herbivores, B-basal species

8.6 SUMMARY

In this Unit, you have studied about how solar energy is converted to various other forms of energy after utilization by living organisms in an ecosystem. You have also studied related concepts such as the efficiency of energy use, feedback, control and self regulation in ecosystems. In this unit we have learnt that:

- Ecosystems are functional units of nature. They have no specified size or limits.
- Ecosystems comprise different biotic and abiotic components which are functionally related to each other and operate in an integrated, holistic manner.
- Trophic relationships of an ecosystem can be represented graphically in the form of ecological pyramids. The base of the pyramid represents the producers and the successive tiers represent the subsequent higher trophic levels.
- Ecological pyramids are of three types. Pyramid of number depicts the number of individual organisms at each trophic level, Pyramid of biomass represents total weight of the living organisms at each trophic level, pyramid of energy shows the amount of energy utilized at successive trophic levels.
- Ecological pyramids give useful information about the functional structure of an ecosystem. The major limitations include no depiction of decomposers, no account of organisms which take food from different trophic levels, no idea about the seasonal and daily variations and no account of rate of transfer from one trophic level to another.
- Energy is transferred in an orderly sequence, i.e., from sun to producers, to consumers to decomposers. Energy flow is unidirectional. There is a

loss of energy as it transfers from one trophic level to another. The net energy flow into the ecosystem balances the net outflow of energy.

- 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 amount of energy or matter gets incorporated into the plant bodies. Net primary productivity is less than gross primary productivity because some of the energy is lost during plant metabolism.
- Productivity varies from one kind of ecosystem to another and from one time to another. The availability of water, minerals and other factors in addition to incident radiation limit productivity in different ecosystems.
- Ecosystems are highly dynamic entities. They have evolved effective homeostatic mechanism for self-regulation through feedback control.

8.7 TERMINAL QUESTIONS

1. Discuss the factors that influence productivity of an ecosystem.
2. Cite few examples of the most productive ecosystems.
3. What is secondary production? How does it differ from primary production?
4. In what way food web relationships promote ecosystem stability? Support your answer with a suitable example.
5. What do you understand by ecosystem resistance and resilience?
6. What will be consequences if shark like animals disappear from oceans?

8.8 ANSWERS

Self-assessment Questions

1. a) pyramid of energy

   b) decomposers

2. In aquatic ecosystems, the primary producers are algae which are single celled living organisms. They perish in short span of time in comparison to fishes and other aquatic animals which form the other trophic levels. Moreover these animals are bigger in size and weight. Hence the biomass of producers is less in comparison to consumers, so the pyramid is inverted in shape.

3. In ecosystems, the primary producers are algae or plants which have a lower weight in comparsion to animals which form the second trophic level i.e. consumers. Since the animals are bigger in size and weight. The biomass of producers is less in comparison to consumers, so the pyramid is inverted in shape.

4. In an ecosystem, producers use solar energy and store it in the food which is mainly carbohydrates. The plant tissues have stored solar energy which gets transferred to them via feeding. Herbivores pass the energy to carnivores and so on. Hence ultimate source of energy is sun which is used by producers and transferred to other trophic levels.

5.

- net primary productivity

  Plants expend some energy in their maintenance and in reproduction. The organic compounds formed during photosynthesis are oxidized to derive the energy during respiration in plants. The energy remaining after respiration is stored as organic matter and is called **Net Primary Productivity (NPP).**

- gross primary productivity

  Gross primary production refers to the total amount of solar energy fixed into organic matter by primary producers through photosynthesis. The total energy accumulated in the plant during primary productivity is known as **Gross Primary Productivity.**

- standing crop

  At the time of sampling, the amount of biomass present in area is called as standing crop or standing biomass.

- biomass

  Biomass is weight of organic matter present in living organisms. It is expressed as grams per square meter (g/m^2) or as calories per square meter (cal/m^2).

Terminal Questions

1. The productivity of an ecosystem is influenced by various factors. The production in terrestrial ecosystems varies mainly because of changes in climate, while that of aquatic ecosystems is regulated by availability of nutrients. In most ecosystems primary productivity and decomposition, release of nutrients occurs. Productivity is also influenced by a various physical factors such as sunlight, temperature, rainfall.

2. The most productive ecosystems on Earth include coral reefs, tropical forests, coral reefs and mangrove forests. Rain forests are the most productive ecosystems on Earth. They use the energy generated for self-maintenance, reproduction and growth. The forests produce biomass throughout the year and maintain a steady state. The conditions such as a continuous supply of light and rainfall in a warm climate favor

plant growth. The organisms that depend on plants and predators that feed on these organisms thrive well under these conditions. This contributes to a high degree of biodiversity. The conditions also favor the growth of fungi, bacteria and other microorganisms.

Corals represent one of the most productive ecosystems on Earth. They inhabit the shallow, clear and warm waters of the tropics and support a wide diversity of marine life (about 25 % of all species) in various stages of growth. They serve as nurseries and habitats for many species of vertebrates and invertebrates.

Wetlands are also highly productive ecosystems of the world. They support innumerable varieties of plant and wildlife species. Some species of birds use this ecosystem to rear their young ones. Fishes, reptiles and amphibians use wetlands as permanent habitats for them. Dead plant matter decomposes in the water and feeds aquatic insects, shellfish and small fish, forming the base of the productive food chain.

Mangrove forests are also one of the most productive ecosystems present on the earth. These include many trees and shrub species that have evolved to thrive in the inter-tidal zones between land and ocean. They store large amounts of nutrients which feed many species of mollusks, fish and crustaceans. They form shelter and nurseries for various other predators.

3. 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 utilize the stored energy of plants, for building their bodies. It is defined as the rate of storage of energy at the consumer level.

4. A food web shows the feeding relationships which exist between various food chains found within an ecosystem. It has number of alternative routes o energy flow, and these help in promoting ecosystem stability.

5. Ecosystem resistance is the ability of a system to withstand or resist variation or recover after disturbance. Resistance is the ability of an ecosystem to remain stable in the phase of disturbance. It is the speed with which a disturbed system returns to equilibrium or the same general state after being changed An ecosystem gets disturbed naturally via hurricane or a tornado or by anthropogenic activities such as excessive tillage or pesticide application. It is measured by the degree to which the system is changed from an equilibrium level as a result of disturbances.

   Disappearance of shark can result in massive increase in the number of small fish. This is likely to exert tremendous pressure on the population of phytoplanktons. When the phytoplankton population will be low, there won't be enough food for the fish and fish mortality will increase. Thus the entire food chain would be disrupted.

Unit 9

BIOGEOCHEMICAL CYCLING

Structure

9.1 Introduction
Expected Learning Outcomes
9.2 Biogeochemical Cycling
9.3 Cycling of Carbon
9.4 Cycling of Nitorgen
9.5 Cycling of Phosphorus
8.5 Summary
8.6 Terminal questions
8.7 Answers

9.1 INTRODUCTION

In the previous Units an introduction about the various abiotic components of the ecosystem has been given to you. Abiotic factors such as climatic conditions, soil, characteristics of the area such as altitude, elements such as carbon, hydrogen, macro and micronutrients assist in the survival, maintenance and functioning of various biotic components of an ecosystem. The elements need to flow through different components of an ecosystem in a cyclic manner to ensure their continuous supply. In this Unit we will study the dynamics of major nutrient elements present in the biosphere. We will study various chemical forms in which they occur in nature and their flow through various parts of the ecosystem. The cyclic flow of nutrients helps in maintenance of ecological balance and is crucial for ecosystem functioning. The study of this Unit will help you to understand how the elements get cycled through various components of the ecosystem.

Expected Learning Outcomes

After reading this unit you will be able to:

- define the term biogeochemical cycle
- distinguish between gaseous and sedimentary cycles
- outline the cycling of carbon, nitrogen , sulphur and phosphorus
- describe the importance of living organisms in cycling of nutrients

- ❖ identify the reasons how the human interference affects the nutrient cycles.

9.2 BIOGEOCHEMICAL CYCLING

A biogeochemical cycle is defined as the movement or circulation of elements through organisms and the environment. The term consists of two parts - bio, meaning biological organisms like bacteria, plants, animals and geochemical involves geological and chemical processes such as the formation of molecules. Elements within biogeochemical cycles flow in various forms from the nonliving (abiotic) components of the biosphere to the living (biotic) components and back. In order to survive, all the chemical elements need to be recycled continuously to maintain the survival of living components of ecosystem. The term was given by Russian geographer named B. B. Polynov in 1937. It is also referred as the study of exchange of materials between living and non-living components of the biosphere. The rapid exchange of elements occurs between the biotic and abiotic components of an ecosystem.

The biogeochemical cycles are of two types: gaseous and sedimentary. The classification has been given on the basis of primary source of nutrient input into the ecosystem.

- Gaseous- In these cycles the gaseous phase is dominant. The main pool of nutrients is atmosphere and oceans. Cycling of [carbon itself is not a gas; should it be carbon dioxide], nitrogen represents gaseous cycles. Gaseous cycles tend to move more rapidly than do sedimentary ones and adjust to changes in the biosphere because of the large atmospheric reservoir.
- Sedimentary- In these cycles, the circulation of various elements such as carbon, nitrogen, phosphorus, sulphur occurs. The nutrients are released from lithosphere (main reservoir) via weathering of rocks. The main pool of elements is rocks, soil and minerals. Sedimentary cycles get disrupted by local disturbances as the material remains immobilized in the earth's crust.
- What about the water cycle?

Sedimentary cycles vary from one element to another. Each cycle consists of a solution phase (water-related) and a rock phase (sediment). In the solution phase, weathering releases minerals from Earth's crust in the form of salts. The minerals dissolve in water, pass through a series of organisms, and ultimately reach the deep seas, where they get stored as reserves and move out of circulation. In the rock phase, salts deposit as sediment eventually that get weathered and recycled.

Reservoirs or pool of nutrients include atmosphere or rocks. These are generally large in size. The nutrients move to different areas/compartments during cycling. The effect of human activities on nutrient cycles needs to be assessed. Disturbances such as global warming, wildfires and storms seriously affect the capacity for self-adjustment. Accumulation of gases such as carbon dioxide (CO_2) are dissipated by winds or taken up by plants.

Biogeochemical cycles are said to be perfect or imperfect. In perfect cycles, nutrients get replaced with the same pace as they are used up. Most of the gaseous cycles are considered to be perfect. In contrast, sedimentary cycles are considered to be imperfect because some of the nutrients are lost into soil and sediments as reserves and is not available for recycling. Some part of nutrient stagnation occurs in lakes and oceans.

Both the nutrient cycles involve the biological, non-biological processes and are driven by flow of energy through ecosystem. Water as the medium helps in the movement of elements and other materials through the ecosystem.

Plants and some animals obtain nutrients present in various components of the environment. Animals get the nutrients through the plants and animals. After the death of an organism, the elements fixed in its body are returned to the environment through the action of decomposers (decay organisms such as bacteria, insects, and fungi) and become available to other living organisms.

Nutrient cycles

These cycles consist of two parts- the environmental phase and the organism phase. In the environmental phase, cycling of nutrients by different components of environment such as air, water, soil occurs whereas in organism phase transfer of nutrients to plants, animals and microorganisms occurs. Many nutrient cycles operate simultaneously in biosphere to ensure the availability/supply of chemical nutrients to all living organisms.

9.3 CYCLING OF CARBON

The carbon cycle is the biogeochemical cycle by which carbon is exchanged between the biosphere, lithosphere, hydrosphere, and atmosphere of the Earth. Carbon is the basic constituent of all organic compounds and is the major element forming around 49% of the weight of the organisms. The atmosphere also consists of around 0.032% carbon. Carbon is fixed in the form of energy by plants through photosynthesis. During photosynthesis carbon dioxide present in the air (atmosphere) and dissolved in the water is used. A large amount of carbon dioxide is also found dissolved in oceans. Oceans comprise of 50% more carbon dioxide in comparison to atmosphere. The major source of carbon in all living beings, dead organic matter and fossil deposits is in the form of carbon dioxide. In the environmental phase, carbon dioxide resides in the reservoirs or sinks such as atmosphere or the surface water. The surface water is present in lakes, rivers and oceans. The four main reservoirs of carbon namely atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans and sediments (includes fossil fuels) are interconnected with each other. About 99% of the total carbon is present on the earth's crust as deposits of coal, petroleum, peat and limestone. Weathering of rocks, burning of fossil fuels, volcanic activity returns the bound carbon to the atmospheric-aquatic reservoir. The exchange of carbon between reservoirs occurs because of various chemical, physical, geological, and biological processes. The oceans contain largest pool of carbon near the surface of the Earth. According to estimates carbon pool involved in global carbon cycle is around 55000 gigatons. The oceans contain around 38000 gigaton of active carbon pool as bicarbonate and carbonate ions.

The carbon dioxide (gaseous form of carbon) from the atmospheric reservoir is taken up by the producers and then transferred to consumers to decomposers and back to reservoir. Atmospheric carbon dioxide is absorbed by plants and other photosynthetic organisms present in the terrestrial ecosystem. This way the carbon enters the organismic phase. About 4-9x 10^{13} kg of carbon dioxide is fixed through photosynthetic activity of plants each year. The living organisms convert carbon dioxide into organic food materials which are passed to other trophic levels of the food chain. Carbon dioxide enters the environmental phase via cellular energy production i.e. respiration of the organisms in the grazing and detritus food chains.

In aquatic environment dissolved carbon dioxide is utilized by phytoplankton. Carbon present as bicarbonates and carbonates gets converted into carbon dioxide that is used by phytoplanktons. The carbon dioxide released during respiration is also reutilized by the phytoplankton to produce more biomass (Fig. 9.1). The carbon bound in the shells of snails, foraminifera as carbonates is also deposited in sediments after the death of animals. A significant fraction of carbon gets buried in the sediment and is removed from circulation.

The carbon dioxide present in atmosphere exists in dynamic equilibrium with that present in oceans. Atmospheric carbon dioxide gets easily dissolved in water or the aquatic phase through precipitation. The dissolved carbon dioxide forms carbonic acid which dissociates to form hydrogen and bicarbonate ions. The bicarbonate ions further dissociate to form hydrogen and carbonate ions. The rate of reaction depends upon the concentration of carbon dioxide. All these events shift the equilibrium of the carbon concentration. Some amount of bicarbonate ions are used by aquatic plants during photosynthesis. Other molecules of carbon are carbon monoxide (CO), methane (CH_4), calcium carbonate ($CaCO_3$), and glucose (in plant organic matter, $C_6H_{12}O_6$), and many others, as well as many ions containing carbon. The global carbon budget is the balance of the exchange (incomes and losses) of carbon between the reservoirs or one specific loop (e.g., atmosphere-biosphere) of the carbon cycle. An examination of the carbon budget of a pool or reservoir can provide information about whether the pool or reservoir is functioning as a source or sink for carbon dioxide. The difference between the carbon uptake by plants during photosynthesis and released through respiration gives the net primary productivity. The rate of primary productivity and decomposition determines the rate at which carbon cycles through the ecosystem. In warm wet ecosystems such as tropical rainforests, the production and decomposition rates are high, hence the carbon is cycled quickly. In cooler ecosystems, the decomposition is slow, hence the dead organic matter accumulates. The production and use of carbon dioxide varies depending upon the temperature availability.

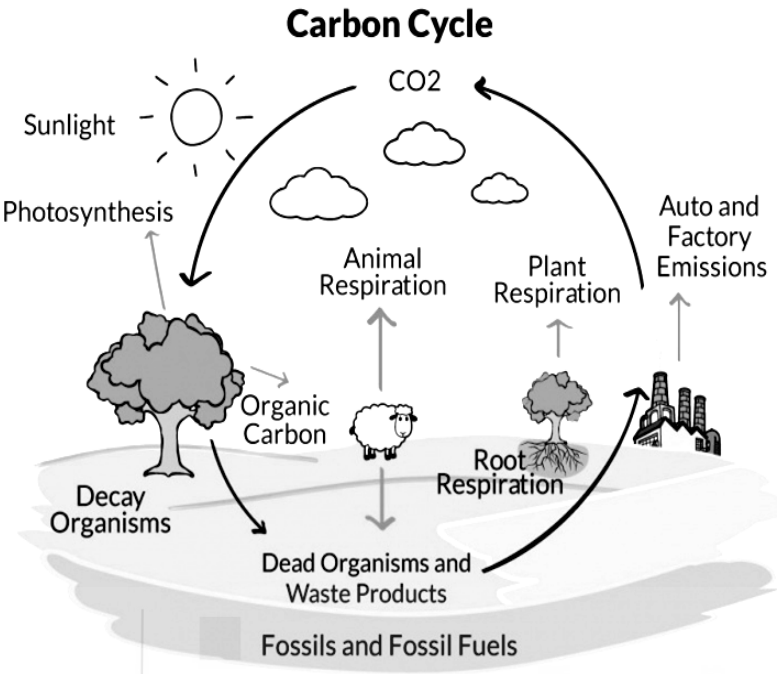

Fig. 9.1: Biogeochemical cycling of carbon through various components of an environment.

Human impact on carbon cycle

Industrial revolution and increasing human activities such as large scale fossil fuel burning have increased the concentration of carbon dioxide in the environment. Before the industrial revolution, a balanced amount of carbon dioxide present globally was getting absorbed by plants. Today, the amount of carbon dioxide has increased several hundred folds. According to an estimate around 8 billion tons of carbon dioxide is added to the atmosphere each year and levels have increased by 35% in the last 130 years. The amount has increased mainly due to combustion of fossil fuels and deforestation. As the level of carbon dioxide increases (rises – delete), the global temperature also increases. This is because carbon dioxide traps the heat escaping from earth. The rise in temperature alters the rainfall pattern affecting the agricultural production. The changes in food production can affect the survival of species present in an area. Indirectly the rise in temperature can lead to melting of glaciers, raising the sea level by several meters and hence threatening the survival of organisms living in the coastal areas.

SAQ 1

How has the human activities changed the carbon levels?

9.4 CYCLING OF NITROGEN

Nitrogen is an important element that forms a major portion of proteins (present in the amino acids) and nucleic acids such as DNA and RNA (present in nitrogenous bases). The largest reservoir of nitrogen is the atmosphere

which contains about 78% of nitrogen gas (N_2). Nitrogen is fixed through a process called nitrogen fixation or nitrification. Nitrogen fixation combines nitrogen with oxygen to create nitrates (NO_3). Nitrates can then be used by plants or animals (which eat plants, or eat animals that have eaten plants). Nitrogen gets fixed with the help of free nitrogen-fixing bacteria present in the soil or roots of legumes or through addition of fertilizers. Both symbiotic and non-symbiotic nitrogen fixing bacteria play an important role in cycling of nitrogen. The free-living aerobic and anerobic bacteria that help in nitrogen fixation include species such as *Azotobacter, Clostridium and Rhizobium*. *Rhizobium*, a symbiotic nitrogen fixing bacterium living in the nodules present in the roots of legumes fixes a good quantity of atmospheric nitrogen. Nitrogen fixation is also assisted by blue-green algae (cyanobacteria) present in the free forms or in symbiosis with fungi as in certain lichens, mosses, ferns. Nitrogen-fixing bacteria use certain enzymes that are capable of fixing nitrogen gas into nitrates and include free bacteria in soil, symbiotic bacteria in legumes, and also cyanobacteria, or blue-green algae, in water. During nitrogen fixation, nitrogen is converted to ammonia. Ammonia gets converted to nitrite and nitrate. Nitrates are used by plants to form amino acids and nucleic acids.

Many heterotrophic bacteria, actinomycetes and fungi metabolize the organic nitrogen and release it in an inorganic form such as ammonia. The process is known as ammonification or mineralization. Ammonia gets converted to nitrate. The process is termed as nitrification. Nitrates are used by autotrophic and heterotrophic organisms. Ammonia further gets oxidized and forms nitrites. The process is facilitated by bacteria *Nitrosomonas*. Nitrite is further oxidized and gets converted to nitrate by *Nitrobacter*. Nitrates get leached in soil readily. They are lost through denitrification process. In this process, molecular or gaseous oxygen, nitrous oxide, and nitric oxide is formed from nitrates. The bacteria use nitrates as a source of oxygen. The total nitrogen fixed annually is estimated to be around 92 x 10^6 metric tons, while the amount of nitrogen returned back via denitrification is estimated to be around 83 x 10^6 metric tons. Nitrogen fixation and nitrification mediated by bacteria are influenced by environmental factors such as temperature, moisture content.

Nitrogen gets added to the soil as nitrate after decomposition and decay of animal and plant wastes. Decomposers and detritivores ingest the detritus from plants and animals and nitrogen is changed into ammonia or nitrogen (Fig 9.2). Ammonia is converted to nitrite then to nitrate. Some nitrate also gets converted to nitrite and then to nitrous oxide by denitrifying bacteria. Nitrous oxide also gets converted into nitrogen gas and is released back into atmosphere. The nitrite that is not used by plants and animals gets converted to nitrate by denitrifying bacteria that can be used by plants and animals.

Human impact on nitrogen cycle

Humans alter the cycling of nitrogen by different ways.

1. Application of excess of nitrogen containing fertilizers affects the distribution of nitrogen. Around 30 x 10^6 metric tons of nitrogen is fixed annually in the commercial production of fertilizers.

2. The disposal of nitrogen rich wastes in water (particularly irrigation, drinking and sewage waters) leads to its entry into the aquatic ecosystem through run off and leaching. Presence of nitrogenous compounds in high amounts promotes growth of algae and phytoplankton leading to nutrient depletion. The process is termed eutrophication.

3. Burning of fossil fuels leads to release of nitrogen oxides. Nitrous oxide gets converted to nitrogen dioxide after oxidation. It combines with ozone in the atmosphere. All these activities increase the concentration of nitrogen in the environment leading to an ecological imbalance. Nitrogen oxides released in the environment particularly atmosphere get converted to nitric acid that comes down on earth along with rain or precipitation. This changes the pH of the soil and aquatic ecosystems.

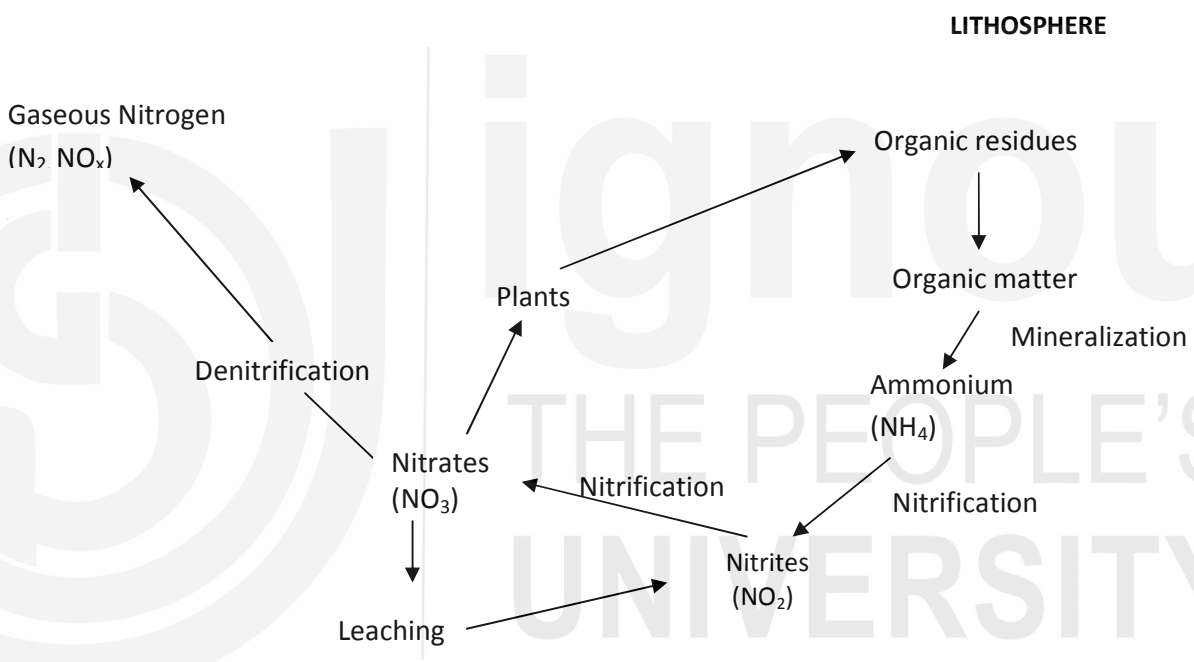

Fig. 9.2: Schematic representation of the flow of nitrogen through the environment.

SAQ 2

Define:

- Eutrophication
- Denitrification
- Ammonification

SAQ 3

Discuss the role of microbes in nitrogen cycling.

9.5 CYCLING OF PHOSPHORUS

Phosphorus is an important element for all forms of life. The most abundant form of phosphate is orthophosphate. It forms an important component of nucleotides, nucleic acids (DNA, RNA) and ATP (cellular energy molecule). In the human body, 80% of phosphorous is found in teeth and bones. Phosphorus is derived from calcium phosphate and phospholipids present in biological membranes. Phosphorus is generally found as phosphates in ocean sediments or rocks. Much of it gets deposited in the sea and shallow sediments. The sedimentary rocks are the largest reservoir of phosphorus. The phosphorus cycle begins in these rocks. The phosphorus is released from these deposits by weathering, leaching and mining. When it rains, phosphates are removed from the rocks (weathering) and distributed in soil and water. Geologic processes bring ocean sediments to land, while weathering adds terrestrial phosphates back to the ocean. Some of phosphorus returns to freshwater and terrestrial ecosystems via death and decay of plants, grazers, predators and parasites. Phosphates also enter water via fertilizer runoff, sewage seepage, natural mineral deposits and wastes from industrial processes. The phosphate settles down at the bottom of ocean and lakes.

Phosphates move quickly through plants and animals (Fig 9.3). The movement of phosphorus through soil or ocean is very slow, hence it is considered one of the slowest biogeochemical cycles. The atmosphere does not play a significant role in the movement of phosphorus. Small amounts of phosphoric acid (H_3PO_4) enter the atmosphere and bring about acid rain. At Earth's normal temperatures and pressures, phosphorus does not act as a gaseous form, hence the major part of it gets circulated though lithosphere and hydrosphere. Plants absorb phosphates from the soil. The phosphorus is mainly taken in the form of phosphate ions from the soil. The phosphates then moves from plants to animals when herbivores eat plants and carnivores eat plants or herbivores. The plants are consumed by herbivores, which in turn are eaten up by carnivores. The phosphates absorbed by animal through consumption eventually returns to the soil through the excretion of urine and feces. After death and decay of plants and animals, the phosphates are returned to the soil. Runoff carries phosphorus back to the ocean. The phosphates may reenter the phosphorus cycle and become available to aquatic organisms through erosion. Water plants take up the waterborne phosphate which then travels up through successive stages of the aquatic food chain.

Human influence

The mining of phosphates for production of fertilizers, detergents, animal feed, medicines, pesticides, and numerous other products adds enormous quantities of phosphorus in soil. The extensive agricultural practices removes natural phosphates present in the soil but addition of fertilizers results in high concentration of phosphates in the soil. The addition of calcium, iron and aluminum supplements immobilizes phosphates present in the soil. Phosphates get extracted from the soil and enter water via leaching from soil. High quantities of detergents, food processing wastes, animal feed add high quantities of phosphorus in water. High levels of phosphates make the water

bodies rich in nutrients. This is known as eutrophication. This supports excessive growth of water plants and algae populations.

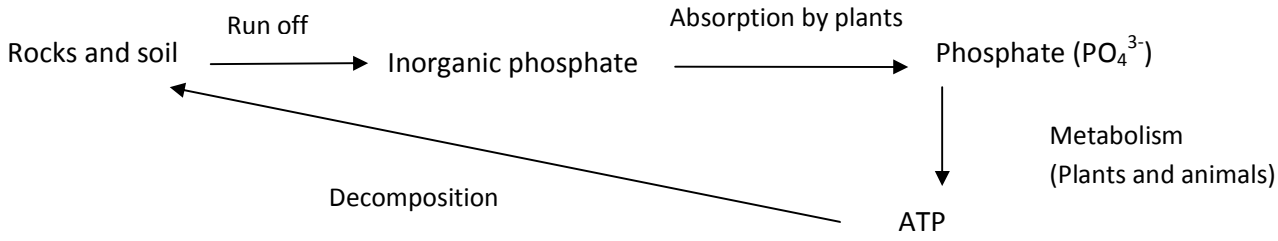

Fig. 9.3: Movement of phosphorus via different components of an ecosystem.

SAQ 4

How has the increase in phosphorus affected the survival of organisms in water bodies?

9.6 SUMMARY

- Circulation of nutrients from environment to various living organisms and back to environment is referred as biogeochemical cycle.
- Nutrient or biogeochemical cycles are of two types- gaseous and sedimentary. Gaseous cycles are represented by elements such as carbon and nitrogen, while sedimentary are represented by elements such as sulphur and phosphorus.
- Carbon cycle involves assimilation of carbon dioxide by plants, conversion of carbon into carbohydrates by plants and their utilization to release energy via respiration. The release of carbon back into environment occurs via decomposition. The equilibrium of carbon dioxide between atmosphere and land gets disturbed by rapid release of carbon dioxide caused due to human (anthropogenic) activities.
- Nitrogen cycles are characterized by fixing of atmospheric nitrogen by microbes mainly bacteria. The processes such as nitrification, ammonification and denitrification help in fixation and conversion of atmospheric nitrogen to other forms that can be taken up by plants and animals. Nitrogen gets assimilated as nitrate and ammonium by plants. Human activities release high amounts of gases such as nitrogen oxides into the atmosphere and leads to high inputs in the form of nitrate into water bodies.
- Phosphorus cycling occurs via weathering of rocks which act as reservoir of phosphates. Plants take up inorganic phosphorus (phosphates) and transfer it to consumers which release it back after death and decay. Some amount of phosphorus gets leached into water bodies and leads to eutrophication (nutrient enrichment).

- Nutrients present in various abiotic components of environment are taken up by plants followed by their transfer to consumers. The decomposers release the nutrients back into the environment. Hence the biotic components play an important role in recycling of elements and nutrients. Inflow and outflow of nutrients gives the nutrient budget of ecosystem.

9.7 TERMINAL QUESTIONS

1. Give the characteristic features of two types of biogeochemical cycles.
2. Describe the pathways by which atmospheric nitrogen is fixed by plants.
3. Discuss how human interferences increase the carbon dioxide levels in the environment.
4. Why is phosphorus cycle considered an imperfect cycle?

9.8 ANSWERS

Self Assessment Questions

1. Industrialization and increasing anthropogenic (human) activities via large scale fossil fuel burning has increased the level of carbon dioxide in the environment by several fold. Around 8 billion tons of carbon dioxide is added to the atmosphere each year and according to an estimate about 35% increase in the global carbon dioxide levels has been noted in the last 130 years. Most of the carbon dioxide is released by combustion of fossil fuels and deforestation. Trees act as the biggest source for absorption of the carbon dioxide. Carbon dioxide traps the heat escaping from earth. As the level of gas rises, global temperature increases. The rise in temperature alters the rainfall pattern affecting occurrence and productivity of crop plants. The changes in food production can affect the survival of species present in an area. The rise in temperature can also lead to melting of glaciers, raising the sea level hence threatening the survival of organisms living in the coastal areas.
2. Eutrophication- *E*nrichment of water by addition of nutrient salts leading to deterioration of water quality. The water bodies show increased production of algae, aquatic plants and decrease in fish species.

   Denitrification – The reduction of nitrate or nitrite to form gaseous or molecular N (N_2 or oxide of N) with the help of microbes.

   Ammonification –The process by which heterotrophic bacteria, actinomycetes and fungi metabolize the organic nitrogen and release it in an inorganic form such as ammonia.
3. Both symbiotic and non-symbiotic bacteria play an important role in fixation or cycling of nitrogen. Both free-living aerobic and anerobic bacteria also help in nitrogen fixation. Nitrogen fixation is assisted by blue green algae or cyanobacteria. These include species such as *Azotobacter* and *Clostridium*. Symbiotic nitrogen fixing bacteria

Rhizobium forms nodules in the roots of legumes. Nitrogen-fixing bacteria contain enzymes that fix nitrogen gas into nitrates. During nitrogen fixation, many heterotrophic bacteria, cyanobacteria, actinomycetes and fungi metabolize the organic nitrogen and release it in an inorganic form such as ammonia. The process is known as ammonification or mineralization. Ammonia gets converted to nitrite and nitrate. The process is termed as nitrification. Nitrates get used by plants to form amino acids and nucleic acids. The oxidation of ammonia to nitrites is facilitated by bacteria *Nitrosomonas*. Nitrite is further oxidized and gets converted to nitrate by *Nitrobacter*. Nitrates get leached in soil readily. They are lost through denitrification process. In this process, molecular or gaseous oxygen, nitrous oxide, nitric oxide is formed from nitrate by bacteria. The bacteria use nitrate as a source of oxygen. According to estimates around 92 x 10^6 metric tons of nitrogen is fixed annually by microbes and 83 x 10^6 metric tons returns back via denitrification.

4. Addition of compounds such as detergents, fertilizers released from human industrial, domestic, agricultural activities, discharge from sewage treatment plants contaminates water bodies and adds excess of nutrients such as phosphorus leading to eutrophication. Enrichment of water with minerals and nutrients induces excessive growth of plants and algae. Algal blooms or high quantity of phytoplankton have been noted in water bodies as a response to increased levels of nutrients. The process results in depletion of oxygen from the water body. The death of organisms depletes oxygen levels, creating state of hypoxia or oxygen poor water. The bacterial degradation of their biomass consumes the oxygen in the water thereby creating hypoxia. Few aquatic animals can survive in these conditions. The condition poses a huge threat to biodiversity in aquatic ecosystems.

The availability of phosphorus generally promotes excessive plant growth and decay, favoring simple algae and plankton over other more complicated plants, and causes a severe reduction in water quality.

- Increased biomass of phytoplankton, zooplankton
- Increased biomass of benthic and epiphytic algae
- Changes in macrophyte species composition and biomass
- Decreases in water transparency (increased turbidity)
- Depletion of dissolved oxygen
- Increased incidences of fish kills
- Decreases in perceived aesthetic value of the water body

When an ecosystem experiences an increase in nutrients, primary producers are benefitted. Aquatic species such as algae show an increase in population (called an algal bloom). Algal blooms limit the sunlight available to bottom-dwelling organisms and cause decline the amount of dissolved oxygen. Oxygen is required by all respiring organisms i.e. plants and animals. Under

eutrophic conditions, dissolved oxygen greatly increases during the day, but is greatly reduced after dark by the respiring algae and by microorganisms that feed on the increasing mass of dead algae. When dissolved oxygen levels decline to hypoxic levels, fish and other marine animals could not survive. Fish, shrimp, die off. In extreme anaerobic conditions growth of bacteria such as *Clostridium botulinum* that produces toxins deadly to birds and mammals is promoted. Hence an overall decrease in biodiversity is noted.

Terminal Questions

1. Biogeochemical cycles are of two types

   - Gaseous, in which the reservoir is the air or the oceans i.e. atmosphere or hydrosphere (via evaporation). these cycles include those of nitrogen, oxygen, carbon, and water.
   - Sedimentary, in which the reservoir is Earth's crust or lithosphere. These cycles include those of iron, calcium, phosphorus, sulfur, and other more-earthbound elements.

2. Most of the nitrogen fixation is carried out by microorganisms. Both symbiotic and non-symbiotic bacteria play an important role in fixation or cycling of nitrogen. Symbiotic nitrogen fixing bacteria *Rhizobium* forms nodules in the roots of legumes. Nitrogen fixation is assisted by blue green algae or cyanobacteria. Both free-living aerobic and anaerobic bacteria also help in nitrogen fixation. These include species such as *Azotobacter* and *Clostridium*. Nitrogen-fixing bacteria contain enzymes that fix nitrogen gas into nitrates. During nitrogen fixation, many heterotrophic bacteria, cyanobacteria, actinomycetes and fungi metabolize the organic nitrogen and release it in an inorganic form such as ammonia. The process is known as ammonification or mineralization. Ammonia gets converted to nitrite and nitrate. The process is termed as nitrification. Nitrates get used by plants to form amino acids and nucleic acids. The oxidation of ammonia to nitrites is facilitated by bacteria *Nitrosomonas*. Nitrite is further oxidized and gets converted to nitrate by *Nitrobacter*. Nitrates get leached in soil readily. They are lost through denitrification process. In this process, molecular or gaseous oxygen, nitrous oxide, nitric oxide is formed from nitrate by bacteria. The bacteria use nitrate as a source of oxygen. According to estimates around 92 x 10^6 metric tons of nitrogen is fixed annually by microbes.

3. Rapid industrialization and large scale fossil fuel burning releases large quantities of carbon dioxide in the environment. Around 8 billion tons of carbon dioxide is added to the atmosphere each year, most of which is added via combustion of fossil fuels. Deforestation has also emerged as another major cause for increase in carbon dioxide. All these factors have caused an increase in global carbon dioxide levels by 35% in the last 130 years. Carbon dioxide traps the heat escaping from earth. As the gas level rises, global temperature increases. The rise in temperature alters the rainfall pattern affecting the agricultural production. The changes in food production can affect the survival of species present in an area. Indirectly the rise in temperature can lead to

melting of glaciers, raising the sea level by several meters and hence threatening the survival of organisms living in the coastal areas.

4. The *Phosphorus Cycle* is said to be "*imperfect"* because all the phosphate does not get recycled. Some amount simply drains off into lakes/oceans and some gets stored in rocks and sediments as reserves.

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Unit 10

PHYTOGEOGRAPHY

Structure

10.1 Introduction
Expected Learning Outcomes
10.2 Type of Vegetation
10.3 Distribution of Vegetation all Over the World
10.4 Phytogeographical Zones of India
10.5 Endemism
10.6 Hotspots of India
10.7 Summary
10.8 Terminal questions
10.9 Answers

10.1 INTRODUCTION

Phytogeography or botanical geography is the branch of science that deals with study of geographic distribution of plant species. The term is derived from two words ‘phyto’ meaning plant and ‘geography’ meaning distribution. It covers all aspects of plant distribution including the individual species and the factors that regulate the composition of communities and flora. Phytogeography encompasses various fields such as environment, flora (taxa), vegetation (plant community) and origin.

- plant geography or phytogeography- deals with the distribution of flora or vegetation in various regions of earth (floristics).
- plant sociology (or phytosociology, synecology) deals with plant association with each other or other scomponents of the environment.
- historical plant geography (paleobotany, paleogeobotany)

Phytogeography is often divided into two main branches: ecological phytogeography and historical phytogeography. Ecological phytogeography deals with the role of biotic and abiotic interactions on plant distribution, while the historical phytogeography is related to historical reconstruction of the origin, dispersal, and extinction of taxa. Alexander von Humboldt is called as the "father of phytogeography". This branch of science helps in understanding the patterns of adaptation of species to the environment. This is done by

studying the specific traits of a population. These patterns are termed as ecogeographical rules.

Expected Learning Outcomes

After reading this Unit you should be able to:

- define the term 'phytogeography',
- describe different types of vegetation,
- identify various phytogeographical zones of India,
- understand the concept of endemism, and
- enlist the hotspots of biodiversity of India.

10.2 TYPES OF VEGETATION

Vegetation refers to the plant cover or the plant community present on earth. It includes both man-made vegetation and natural vegetation. The term describes the total plant cover in an area or on the surface of the earth as a whole. The **'flora'** refers to plants of a particular region present at a time. Plant community which grow naturally without human aid and remains left undisturbed for a long time is called as virgin vegetation. Vegetation is present as a rich diversity of plants. They range from redwood forests, sphagnum, coastal mangroves, desert plants, weeds and cultivated plants. Vegetation plays a vital role in the ecosystem. It supports the biosphere in various ways. It regulates flow of numerous biogeochemical cycles, most importantly water, carbon and nitrogen. It contributes to energy balance at the local and global levels. The two major types of vegetation include:

1. **Natural vegetation** – The plants which are found naturally in an area. This type of vegetation is formed naturally without human intervention or without agricultural practices. It includes virgin vegetation generated by natural means. The spread of this vegetation is controlled by climatic conditions of the region.

2. **Man-made vegetation or cultural vegetation** – It includes plant species cultivated by man. The plantations are done for the production of wood and fiber, protection of soil and conservation of biological diversity.

Vegetation is of different types. The type of vegetation formed within an area is influenced by the soil formation, topography, climate and human impact. The various types of vegetation include:

1. Forests
2. Grasslands
3. Deserts
4. Tundra/Alpine areas

Forest vegetation: It refers to plant community where a large area is covered with tall trees. The foliage covers large areas on the ground and shows stratification with more than one layer. Trees found in the forest vegetation mainly include pine, mahogany, willows, maple, birches, rosewoods, mangroves and oaks. The forests are further characterized as evergreen, coniferous, deciduous and rainforests depending upon the growth pattern followed by trees or the availability of water in the region.

Grassland vegetation: It includes plant cover dominated by grass or grass-like vegetation. The grasslands are called by different name in different parts of the world. They are called Steppes in Russia, Savannahs in Central Africa, Prairies in North America, Pampas in South America and Downs in Australia. Most of the grasslands are located in the temperate zone (between latitude 23 ½^{0}N and 66 ½ ^{0}N in the Northern hemisphere and between latitude 23 ½ ^{0}S and 66 ½^{0}S in the southern hemisphere).

Desert vegetation: This type of vegetation is found in dry regions covered with sandy soil and rocky soil. The short shrubs occur in patches and are characterized with thorns, thick stems, long roots, wax coated leaves and stems. Plants found in desert areas include cactus, date palms, acacia, thorny bushes and coarse grasses. The area has high temperature and receives little amount of rainfall. The regions include south West Australian desert, Arabia, Indian desert, Sahara desert, Atacama Desert, Kalahari Desert.

Tundra vegetation: This type of vegetation is found in North America, Europe and Asia. The subsoil is covered with permafrost and it is about 1500 ft deep. The area possesses fewer trees with stunted shrubs, lichens, mosses and sedges. The winters are dry and long. The plants found in tundra region include birches, willow trees, junipers, mosses, lichens and arctic bluegrasses, poppy, and catchfly.

The virgin vegetation present in an area or restricted to an area is referred as **endemic or indigenous species** but vegetation or species which have come from outside or are introduced are called as **exotic species.**

Importance of vegetation to man

The vegetation is very useful to humans because of various direct and indirect benefits provided by it. The vegetation possesses materials of ecological and economic use.

1. The plants serve as the main source of food for humans. The food is in the form of vegetables, fruits, grains, cereals, leaves, seeds.
2. Vegetation is also a natural source of materials like rubber, gum and paper.
3. The plants serve as a source of fibers such as cotton and jute.
4. The trees provide wood for construction of houses, bridge, poles and furniture.
5. The vegetation provides various herbs for medicinal use.

6. The plants provide oil used for cooking.

7. Plants regulate flow of elements such as carbon, nitrogen through biogeochemical cycles and contribute to the local and global energy balances.

8. The plants play an important role in ecosystem. They act as primary producers (provide food to animals) and form the first trophic level in the food chain.

9. Plants also affect soil formation and influences soil volume, chemistry, texture and structure.

SAQ 1

What do you mean by 'phytogeography'?

10.3 DISTRIBUTION OF VEGETATION

The vegetation of the world has been arranged in the form of bands aligned linearly along the latitudes. The vegetation differs while going from northward of equator to southward direction. More land is present in the north of the equator, hence banding pattern is less pronounced in the Southern Hemisphere. The pattern gets disturbed by high mountains and varies with climate change. The changes in temperature and precipitation with altitude affect the vegetation. **Timberline is the** upper limit of tree growth and separates the alpine tundra from the coniferous forests. It is present at about 10,000 feet in the Mountains. Plants show different tolerance ranges to different environmental conditions. Extremes of temperature and precipitation affect development of vegetation and can result in disappearance of flora from the region. The number of species inhabiting a region varies due to changes in climatic conditions and altitudinal differences. In the tropical regions about 40,000 species of vascular plants are found while in the Canadian arctic only 425 species are reported.

The rainforests are predominantly are found in the tropical areas near the equator while deciduous forests are found in the temperate region. The vegetation bands are sparsely spread in the Southern Hemisphere because less land is present here. Tundra is found on the top of high mountains, coniferous forests in middle slopes and deciduous forests at the base of mountains.

Tropical rain forests occur in the hottest, wettest regions of the world, deserts in the hottest, driest areas while tundra in the coldest, driest region of the earth. The tropical rainforests occupy the regions near the equatorial band in the Northern Hemisphere, while deciduous forests occupy temperate areas. The coniferous forests occupy the arctic tundra. Treeless alpine (low-alpine) or montane vegetation is characterized by meadows, shrubs and sporadic dwarfed trees. Vegetation in tropics includes rain or coniferous forests.

Conifers forests consist of evergreen trees which bear needles instead of leaves, and cones instead of flowers. They survive in very cold or dry areas. Some of the common conifer species are spruces, pines, and firs. Coniferous forests found in the northern hemisphere are called the taiga. Deciduous forests are located in the mid-latitude areas. The leaves of the trees fall before the onset of winter. The deciduous forests get about 20 to 60 inches of precipitation throughout the year. Monsoon and rain forest zones are located along the equator. The rainfall is high (> 1500 mm per year) and results in formation of evergreen rainforests with increased biodiversity. The duration of the dry season is limited to maximum of two months.

Tundra is located at the top of the world, near the North Pole. The most distinctive characteristic of tundra soil is its **permafrost**, a permanently frozen layer of ground. During brief summers, soil may thaw allowing plants and microorganisms to grow and reproduce. The tundra has cool summers and cold winters. During the summer, temperatures range between 37°C to 54°C. During winter the temperature goes down up to -94° F. The temperature conditions restrict plant growth. Greenland coasts and the Canadian archipelago are covered by tundra.

Semi-evergreen rainforest are found in the areas having two to three arid months. The area receives rainfall of about 1100 to 1500 mm per annum. Rainforests are of two types - tropical and temperate. Tropical rainforests are found closer to the equator where it is warm. Temperate rainforests are found near the cooler areas near north or south of the equator. The tropical rainforest is a hot, moist biome where it rains all year long. It is known for its dense canopies of vegetation that form three different layers. Monsoon forests are deciduous tropical humid forests. The tropical coasts are lined with mangrove forests. The equatorial monsoon and rainforest zones are connected to open land forms of the savanna. The sclerophyll forests are found in arid Mediterranean regions. The trees possess a protective layer on leaves (small, thick and wax-coated) that prevents evaporation. Wetlands are found located along the humid coastal regions of North and South America.

Grasslands grow under hot, dry climatic conditions. They are characterized by scattered trees and a continuous tall grass understory. The annual rainfall is about 20-50 inches per year, with 6-8 months of rain. High-mountain grasslands are spread in the interior of the Rocky Mountains (the Great Basin), in the high mountain valleys of the Andes. The Steppe is a dry, cold, grassland dominated by short grasses and no trees. Steppe is located away from the ocean and close to mountain barriers. Steppes are mainly found in Central Asia, Eastern Europe, East Asia and east of the Andes in South America (Fig. 10.2). Pampas temperate grassland located in South America.

Semi-desert and desert areas are distributed along the tropic lines. Most of the hot and dry deserts are located near the Tropic of Cancer or the Tropic of Capricorn, while cold deserts are present near the Arctic region of the world. The rainfall is low (< 200 mm annual rainfall on average) and vegetation is sparse in these regions.

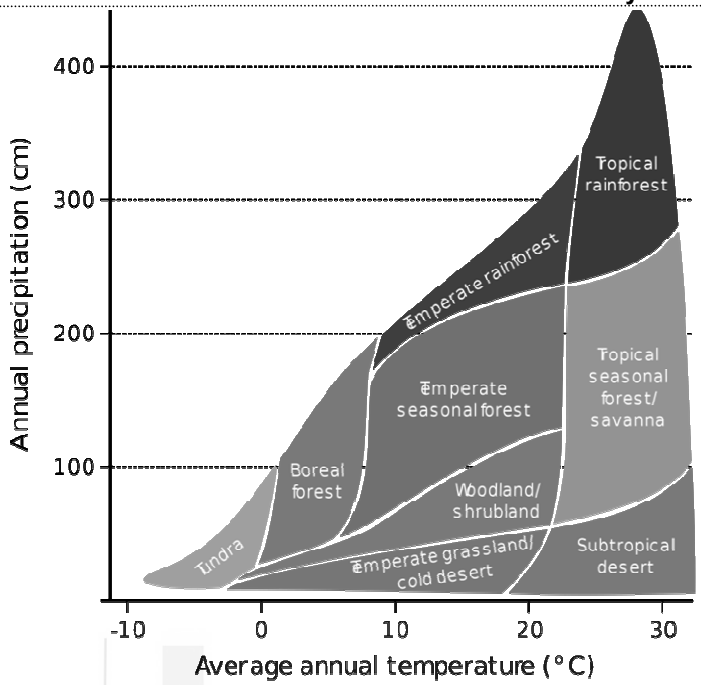

Fig. 10.1: Diagrammatic representation to show that vegetation types are related to temperature and precipitation.

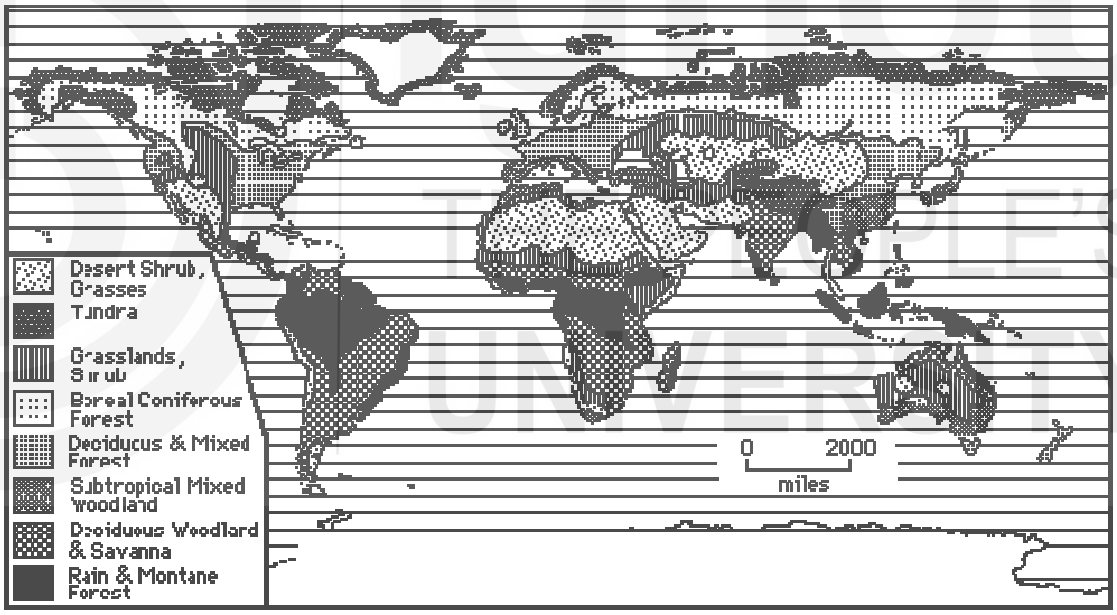

Fig. 10 2: Types of vegetation found in different parts of the world.

SAQ 2

The distribution of vegetation varies across the latitudes. Explain.

India is a country with variable landscapes and topography. The type vegetation present in each region varies. The vegetation types include thick forests, mangroves and desert plants.

Tropical Evergreen Forests

They occupy about seven per cent of the earth's land surface. These forests usually occur in areas receiving **more than 200 cm of rainfall**. They are found

mostly near the equator. Region is warm and wet throughout the year. The region harbors more than half of the world's vegetation and fauna. **The vegetation includes** trees, shrubs, and creepers giving it a multilayered structure. Trees reach great heights up to **60 meters or even above.** In India, evergreen forests are found in the western slopes of the Western Ghats in States such as Kerala and Karnataka. The major tree species found in the region are rosewood, mahogany, ebony, bamboo and reeds.

Tropical Deciduous Forests

They are the **most widespread** forests of India. They are also known as **monsoon forests. They** spread over the region receiving **rainfall between 70 and 200cm.** These forests are further divided into moist and dry deciduous on the basis of the availability of water. Trees s**hed their leaves for about six to eight weeks** in dry summer. **Moist deciduous forests are** found in areas receiving rainfall between 200 and 100 cm. Exist mostly in the eastern part of the country – northeastern states, along the foothills of the Himalayas, Jharkhand, West Orissa and Chhattisgarh and on the eastern slopes of the Western Ghats. Teak is the most dominant species of this forest. Bamboos, sal, shisham, sandalwood, khair, kusum, arjun, mulberry are the commercially important species reported from the region.

The Thorn Forests and Scrubs

These are found in the regions with less than 70 cm of rainfall. The natural vegetation consists of thorny trees and bushes. Trees are scattered and have long roots penetrating deep into the soil in order to get moisture. The stems are succulent to conserve water. Leaves are mostly thick and small to minimize evaporation. *Acacia*, Palms, *Euphorbia* and Cacti are the main plant species present in the region. They are found in the northwestern part of the country including semiarid areas of Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Uttar Pradesh and Haryana.

Montane Forests

In mountain areas, the vegetation changes with decrease in temperature at increasing altitude. The wet temperate types of forests are found between a height of 1000 and 2000 meters. Evergreen broadleaved trees such as oaks and chestnuts predominate. Coniferous trees like pine, deodar, silver fir, spruce and cedar, are found at altitude of 1500 and 3000 meters. They cover the southern slopes of the Himalayas. At higher elevations, temperate grasslands are common. At high altitudes, generally more than 3,600 meters above sea level, temperate forests and grasslands get replaced by Alpine vegetation. Silver fir, junipers, pines and birches are the common trees found in the region. At higher altitudes, mosses and lichens form part of tundra vegetation.

Mangrove Forests

These are found in the coastal areas. Dense mangroves are the common trees found in the region. The roots of the plants submerged under water. The deltas of the Ganga, the Mahanadi, the Krishna, the Godavari and the Kaveri

are covered by such vegetation. Palm, coconut, keora, agar are the common trees found in the region.

10.4 PHYTOGEOGRAPHICAL REGIONS OF INDIA

A phytogeographical region is defined as an area of uniform climatic conditions that possesses distinctly recognizable vegetation. India can be divided into nine phytogeographical regions (Chatterjee, 1962). The original classification is listed below. There is the absence of the term "Flora of…" in the classification of the vegetation. The sequence must also be maintained.

1.	Flora of Deccan	1.	Western Himalayas
2.	Flora of Malabar	2.	Eastern Himalayas
3.	Flora of Indus Plain	3.	Indus Plain
4.	Flora of Gangetic Plain	4.	Gangetic Plain
5.	Flora of Assam	5.	Central India
6.	Flora of Eastern Himalayas	6.	Deccan
7.	Flora of Central Himalayas	7.	Western coasts of Malabar
8.	Flora of Western Himalaya	8.	Assam
9.	Andaman and Nicobar Islands	9.	Bay Islands of Andaman and Nicobar

The sequence as mentioned above should be followed in the discussion below.

(*Flora of* - delete) Deccan

The Deccan region comprises southern part of the country. It is also known as Peninsular India, and starts from southern Madhya Pradesh up to Kanyakumari excluding the Western Ghats. The region is characterized by presence of black soil which supports growth of cotton. The average annual rainfall in the region is about 100 cm. The vegetation consists of dry evergreen, dry deciduous and swamp forests. The important trees of the region are *Michelia champaca, Dillenia aurea, Chloroxylon swetenia, Cedrela toona, Santalum album* and *Pterocarpus sentalinus*. Shrubs mainly include *Hibiscus, Zizyphus numularia, Grewia, Bauhinia, Woodfordia, Capparis, Lagerstroemia, Holarrhena, Cassia auriculata, Acacia arabica, Parkinsonia aculeata, Calotropis procera, Jatropha grandiflora.* Climbers include *Hiptage, Cassytlea, Dioscorea, Ipomoea, Vitis and Smilax.* (Herbs – delete) Grasses and palms such as *Bambusa arundinacea*, *Dendrocalamus*, *Borassus flabellifer, Phoenix* sp. are commonly found in the region. Some mangrove plants such as *Brugiera, Ceriops, Avicennia* are also reported from the region.

(Flora of – delete) **Malabar**

The region extends from Gujarat to Kanyakumari along Western Ghats. The area includes states of Kerala, Maharashtra, Gujarat and Karnataka. The

climate is warm, humid with an annual rainfall of over 400 cm. The climate is tropical in the coastal areas and temperate in the hills. The vegetation consists of wet evergreen, moist evergreen and moist deciduous forests. Wet temperate forests (Sholas) are present in Nilgiri while mangrove forests are found in the saline swamps on the coasts. The various types of forests found in the area are:

(a) Temperate evergreen forests- The area includes Nilgri, Palni, Annamalai and Tirunevelly hills. The vegetation includes trees with red tinged leaves. (Example – delete) Some of the common species are - *Meliosma wightii*, *Michelia nilgirica, Rhododendron nilgiricum, Toddalia, Clematis, Impatiens, Arisema, Cymbopogon* etc.

(b) Subtropical evergreen forests -The dominant vegetation of this area is characterized by *Memecylon, Syzygiun, Etnblica officinalis, Murraya koenigii, Rhododendron nilgiricum, Smilax, Piper, Clematis* etc.

(c) Tropical evergreen forests- The area of includes Mysore plateau, western side of Western Ghats, Coorg and Annamalai Hills etc. Dense evergreen vegetation includes species such as *Dillenia pentogyna, Terminalia balerica, Artocarpus peltata, Cinnamomum zeylenicum, Areca, Calamus, Croton, Ixora* etc.

(d) Tropical semi-evergreen forests- The area includes the plateau of Western Ghats. The species such as *Dipterocarpus, Lagerstroemia, Xylia, Rauwolfia serpentina*, and *Terminalia* etc. are present in the area.

(e) Tropical deciduous forests- Wet and dry vegetation is found in the area. Wet type of vegetation is common in Cochin, west coast of Karnataka and Travencore. Dominant vegetation includes *Tectona grandis, Grewia tiliaefolia, Butea monosperma, Dalbergia latifolia, Mitragyna parviflora, Bombax malabaricum, Adina cordifolia, Xylia xylocarpa, Anogeissus latifolia, Santalum album, Erythrina variegata, Lantana, Clerodendron, Woodfordia, Kydia calycina, Bambusa arundinacea, Terminalia tomntosa, Gardinia latifolia* etc.

(f) Mangrove forests- The vegetation is found in areas of Elora, Elephanta, Bombay suburbs, Mudh Island, Arabian seashore etc. The major plant species found in the region are *Rhizophora, Bruguiera parviflora, Ceriops tagal, Kandelia candel, Xylocarpus grantum Acanthus illicifolius, Sonneratia* etc.

(Flora of – delete) **Indus Plain**

The area comprises of Gujarat, Delhi, Rajasthan, Haryana and Punjab. It includes dry region, plains, deserts and irrigated lands. The climate has dry and hot summers alternating with dry and cold winters. The annual rainfall is generally less than 70 cm. The vegetation consists of tropical thorn forests and grasslands. Indus plain has been divided into 3 types of vegetation i.e. tropical dry deciduous, tropical thorny and dry shrubs. The area is divided into five zones on the basis of topography

(a) Aravallis

Anogeissus pendula, Butea, Acacia catechu, Bombax, Zizyphus, Grewia salvifolia, Maytenus (syn. Gymnosporia), Balanites roxburghii, Boswelia serrata, Nyctanthes, Carissa, Euphorbia nivulia, Mangifera indica etc. are prominent species present in the region.

(b) Irrigated or Riverine Lowlands

Dalbergia sisso, Populus, Butea, Mangifera, Anthocephalus, Amoora, Bombax, Acacia, Melia azadarach, Azadirachta indica, Polyalthia longifolia, Albizia lebbeck, Eucalyptus, Cordia, Lagerstroemia, Ficus religiosa, F. benghalensis are commonly reported from the region.

(c) Kutch

The vegetation consists of thorny plants. example - *Acacia nelotica, A. Senegal, Salvadora, Cassia, Tinospora, Tamarix, Tragia, Rivea, Vitis, Apluda, Cymbopogon, Eragrostis, Paspalidium, Cenchrus, Peristrophe, Grewia populnifolia, Commiphora wightii* etc.

(d) Arid Sandy zone

It includes sandy areas of Rajasthan and Punjab mainly. The plants mainly include xerophytes species such as *Argemone, Tephrosia, Acacia leucophloea, Prosopis, Salvadora, Butea, Opuntia, Agave, Calotropis, Tamarix, Sueda, Salsola, Solanun surattense, Tribulus, Capparis, Boerhaavia, Echinops* etc.

(e) Desert zone

It includes Rajasthan and other adjoining areas. Sand, gravel and rock communities reported from the region include *Calotropis procera, Calligonum, Capparis, Citrullus, Aerua, Indigofera, Zizyphus, Farsetia, Salvadora, Tecomella, Maytenus, Tribullus terrestris, Fagonia, Boerhaavia diffusa, Eleusine aristata, Aristida mutabilis, Poinciana, Ficus religiosa, Melia azadirachta, Convolvulus, Lepidagathis, Achyranthes* etc.

(Flora of – delete) **Gangetic Plain**

The area extends from Delhi to Sundarbans of Bengal passing through Bihar, Orissa and Uttaranchal. It includes dry deciduous (scrub) and moist deciduous vegetation. The average annual rainfall ranges from 50 to 150 cm. The vegetation consists of tropical moist deciduous forests, dry deciduous forests, thorn forests and mangrove forests. The Indus region and Gangetic region possess similar type of vegetation, hence called as Indo Gangetic plain. The plain is divided into upper Gangetic plain, Lower Gangetic plain and Sundarbans.

(a) Upper Gangetic plain

The vegetation is dominated by *Acacia nilotica, Balanites, Jatropha, Flacourtia, Capparis decidua, Butea monosperma, Madhuca, Zizyphus, Dalbergia, Phoenix, Nyctanthes, Woodfordia*, *Adhatoda, Terminalia, Prosopis, Tinospora, Vitis, Cocculus, Ixora, Carissa, Hemidesmus* and many types of grasses.

(b) Lower Gangetic plain

The vegetation is dominated by *Shorea robusta, Artocarpus, Lagerstroemia, Ptersopermum, Bombax, Ehertia, Adhatoda, Murraya koenigii, Pogosternon, Aegle marmelos, Holoptelea, Areca, Borassus, Pagostemon* etc.

(c) Sunderbans

The largest mangrove forest of the world is of sunderbans covering an area of over 15,000 sq. km. The main vegetation includes *Typha elephantina*, *Phragmites karka*, *Ipomoea biloba, Bruguiera conugata, Aviecnnia officinalis, Aegiceras, Sonneratia, Nipa fruiticans, Pheonix paludosa, Cocos nucifera, Rhizophora mucronata, Acanthus illicifolius, Panicum repens, Sueda maritima, Salicornia* and *Allophylus.*

(*Flora of* - delete) **Assam**

The area includes Valleys of Brahmaputra, Jaintia, Khasi and Garo hills, Mishmi hills, North Himalayas, Santosh River, Naga, Cachar and Mizo hills, Mizoram, Meghalaya, Nagaland, Manipur, Tripura and Assam region. The climate is characterized by high temperature and rainfall. The vegetation consists of tropical evergreen and wet temperate forests in the lower plains while hilly tracts up to 1700 m altitude have subtropical pine forests. The region receives good rainfall and is characterized by dense vegetation. The different type of vegetation present in the area include

(a) Tropical forest

It is the low foot hill, valley and plains zone.

(b) Evergreen forest

Vegetation includes *Dipterocarpus, Artocarpus, Ficus, Mesua, Amoora, Ficus elastica, Persea, Calamus, Talauma, Cinnamomum, Sterculia, Adina, Vernonina, Mimusops hexandra, Diospyros ebenum, Ixora parviflora, Carissa carnadas, Asparagus, Derris, Acacia intsia* etc.

(c) Deciduous forests

It is dominated by *Tectona grandis* and *Shorea robusta*. The other plants are *Kydia, Terminalia, Dipterocorpus* etc.

(d) Wet temperate forests

The main vegetation consists of bamboos and shrubs. The trees are taller in height. The major species reported from the region include *Rhododendron, Alnus, Betula, Michelia, Magnolia, Quercus, Carpinus, Acer, Prunus, Pyrus and Bucklandia (Symingtonia)*.

(e) Pine forest

The area is 1200-2000 meter above the hill. Pine (*Pinus)* constitutes the majority of plants in the region. Other vegetation includes *Acer, Myrica, Camellia, Lithocarpus, Quercus griffithii, Rhus, Prunus, Rubus, Bambusa, Viburnum, Arundinaria* etc.

(f) Riverine forests

Vegetation is found along the banks of rivers and streams. Vegetation is evergreen and deciduous. The main plants found in this region are *Pterospermum, Mesua, Salix, Amoora, Anthocephalus, Albizzia procera, Acacia catechu, Dalbergia sisso, Terminalia, Bombax, Sterculia* etc.

(g) Swamp forests

Swampy areas are common in Assam. The important plants of this region are *Cephalanthus, Glochidion, Ficus heterophylla, Dracaena, Marsilea, Scirpus, Cyperus, Panicum, Azolla, Salvinia, Euryale, Nymphaea, Nelumbo, Barringtonia, Alpina* etc.

(h) Grasslands

Grasslands are generally found in plains in Assam. The plants of this region are mainly *Paspalidium, Phragmites, Arundo, Panicum, Erianthus, Apluda, Sorghum, Themeda, Saccharum, Andropogon, Cymbopogon* etc.

(*Flora of* – delete) **Eastern Himalayas**

Eastern Himalayas comprises of mountain ranges from Sikkim to Arunachal. More than 4000 sp. of phanerogams belonging to 160 families and lower plants are found in this region. The Eastern Himalayas are chiefly distributed into 3 regions i.e., Tropical, Temperate and Alpine zones.

(a) Tropical zone

The region receives heavy rainfall for long period. The vegetation of the region includes sal forests, mixed deciduous forests, semi-evergreen, evergreen and subtropical forests. Savannah grassland includes species such as *Albizzia, Bombax, Bischofia, Erianthus, Cymbopogon, Microstegia*. The forest vegetation includes *Quercus, Cycas, Pinus, Populus, Salix, Pandanus, Dillenia, Sterculia, Toona ciliata, Lagerstroemia, Bombax, Shorea robusta, Amoora, Terminalia, Bauhinia, Michelia, Artocarpus, Syzygium, Cinnamomum, Alnus, Rhus, Entada, Beaumontia grandiflora, Hiptage, Tinospora cordifolia* and *Bambusa* etc.

(b) Temperate zone

The area covers an altitude of 2000 to 3540 meter. The region includes broad leaved deciduous and coniferous forests. The vegetation comprises of mainly *Quercus, Magnolia, Pyrus, Abies, Larix, Picea, Tsuga, Juniperus, Taxas, Betula, Acer, Arundinaria, Lyonia, Syringa, Sorbus, Ilex, Fraxinus, Camellia kissi* (wild tea) etc.

(c) Alpine zone

This zone ranges from 3690 to 5540 meter. Vegetation consists of species like *Artemisia, Potentilla, Carex, Astragalus, Juncus, Rheum, Ephedra, Berberis, Abies, Rhododendron, Primula, Salix, Pedicularis, Meconopsis, Corydalis, Polygounm, Lonicera, Caranga* and *Saussurea* etc.

(*Flora of* – delete) **Central Himalayas** This is not mentioned in the classification above!!

Central Himalayan region includes Nepal, Kumaon Himalaya in west and Sikkim Himalaya in east. The region is divided into western, central and eastern Nepal. The area consists of species namely *Acer cappadoscicum, Quercus floribunda, Populus ciliate, Shorea robusta, Bombax, Gmelina, Petalidium, Clerodendron, Bauhinia vahlii, Quercus, Alnus, Rhododendron, Pinus, Eriobortya, Lindera, Berberis, Tsuga, Abies, Juniperus, Lonicera, Primula, Caranga, Pennisatum, Artemesia, Lyonia, Spiraea, Cornus, Zanthoxylum, Bauhinia, Albizzia, Saccharum arundinaceum, Cymbopogon martini, Quercus, Acer, Alnus, Mesua, Cyathea, Fraxinus, Polygonum, Pedicularia, Mecenopsis*..

(*Flora of* – delete) **Western Himalaya**

The region of Western Himalaya extends from Kumaon to Kashmir. The climate is dry and cold with annual rainfall of 100-200 cm. The vegetation of this region consists of species like *Acacia modesta, Euphorbia royleana, Bombax ceiba, Themada, Chrysopogon serrulatus, Bauhinia vahlii, Shorea robusta, Cassia fistula, Lagerstroemia parviflora, Murraya keonigii, Zanthoxylum alatum, Terminalia, Anogeissus latifolia, Toona ciliata, Zanthoxylum alatum, Adhatoda, Rubus, Syzygium, Crataegus, Diospyros, Emblica, Picea, Pinus wallichiana, Cedrus deodara, Rhamnus, Salix, Berberis, Smilax, Arundinaria, Fraxinus, Fragaria, Artemesia, Rheum, Sedum, Betula, Anemone, Saxifraga, Geranium*, etc. The region is subdivided into three zones.

1. **Submontane (lower, tropical and subtropical) zone:** This zone includes outer Himalayas i.e. regions of Siwalik Hills and adjoining areas from 300 to 1500 m altitude. Average annual rainfall of the zone is around 100 cm. The vegetation consists of subtropical dry evergreen, subtropical pine and tropical moist deciduous forests.

2. **Temperate (montane) zone:** This zone extends in the Western Himalayas between the altitudes 1500 and 3500 m. The climate is wet between the altitudes 1500 and 1800 m and is dry at higher altitude. The vegetation consists of wet forests, moist and dry temperate forests.

3. **Alpine zone:** This zone extends between 3500 m and 5000 m altitudes. The rainfall is very scanty and climate is cool and dry. The vegetation consists of alpine forests.

[Flora of Eastern Himalayas

This region extends in the Himalayas from east of Nepal to Arunachal. The climate is warmer and wetter. The tropical temperature and rainfall conditions support development of vegetation with high species diversity, greater variety of oaks. This region is also divided into three zones.

1. **Submontane (lower, tropical and subtropical) zone:** This zone extends from the foothills up to 1850 m altitude. The climate is tropical

and subtropical. The vegetation consists of subtropical broad-leaved forests, pine forests and wet temperate forests.

2. **Temperate (montane) zone:** The zone extends from 1850 m to 4000 m altitude, about 500 m higher than in the western Himalayas. The vegetation consists of typical temperate forests with oaks and *Rhododendron* at lower and conifers at higher altitudes.

3. **Alpine zone:** This zone extends from 4000-5000 m altitude. The climate is very cool and dry. The vegetation consists of alpine forests. – delete, as this is a mere repetition of the paragraphs above on pages 19 – 20]

Andaman and Nicobar Islands

(This region includes Andaman and Nicobar Islands – delete).A large number of islands constitute this region. Very few large islands are inhabited by humans, while a large number of small islands have virgin vegetation because of the absence of humans. The climate of the region is warm and humid with very high temperature and annual rainfall. The vegetation consists of littoral mangrove, evergreen, semi-evergreen and deciduous forests. The region is very rich in biodiversity.

SAQ 3

Mention the main phytogeographical areas of India with prominent vegetation present in each.

10.5 ENDEMISM

Endemism means the confinement of a particular species, genus or groups of plants and animals to a particular area. The plant and animal lives restricted in a particular location such as an island, habitat type or nation. Taxa occurring in a restricted geographical area are termed as endemics.

Endemism is basically of three types

(a) Neo-endemism:

A taxon is young and not spread over the new area. The species has recently appeared or formed. Example- *Senecio combrensis*. It was discovered in 1948 from north-east Wales, and described in 1955.

(b) Palaeo-endemism

The taxon is now present in a restricted area but earlier it was widely distributed. The restriction of species occurs due to physical barrier (like deserts, mountain, sea), change in climate or soil.

(c) Epibiotics or Relic, endemics

The plants belong to fossil groups and are restricted to few areas due to favorable climate, lack of competition. Example- *Ginkgo biloba* is restricted to China but widely distributed in the North Temperate zone as a fossil.

Ginkgo biloba or the "Maiden Hair Tree" has been known from the Mesozoic to the mid-Cenozoic times throughout the world. However, today, natural/wild trees of this Gymnosperm are found only in some parts China and Japan (where they have been preserved around temples). Interestingly, the species is now cultivated in many parts of the world, especially as an avenue tree.

The plants which are not of recent origin but have retained a narrow distribution are called as Holoendemics. Activation of Palaeoendemics leads to evolution of new endemic species called active epibiotics.

Endemic types develop on islands because they are isolated. This includes remote island groups like the Hawaiian and Galápagos Islands. Endemism can also occur in areas which are separated from regions of natural vegetation by some kind of barriers. These include highlands of Ethiopia or large bodies like Lake Baikal. About 85% of flora of Hawaii islands and 72% of New Zealand is endemic. Mountains also have more endemic species because they are isolated. Example - 70% species of Himalayas are endemic. Similarly, there are a large number of endemics in the Western Ghats. Endemics can easily become endangered or extinct because of their existence in a small area. They are also vulnerable to the actions of man such as introduction of new organisms. Endemism richness of plants and vertebrates is strongly related. More species of endemic plants are found on islands. Islands are centers of range-restricted species. An index combining both endemism and species richness ("endemism richness") provides insight into relative conservation value of islands and mainland. The degree of isolation of the area is proportional to the percentage of endemic species in flora. The degree of isolation is measured either as the distance from other similar areas or the time period for which the area has been isolated.

Recent estimates have shown that richness of global vascular plants range up to 422,000 species. Endemism richness of vascular plants is unevenly distributed and varies by 3 orders of magnitude. The island of New Caledonia has the highest value with 1,350 range equivalents per 10,000 km^2. Values are high for island regions. According to the World Wildlife Fund, highest percentage of endemic plants has been reported from the following regions.

- Fynbos in Cape region (South Africa)
- Hawaiian tropical dry forests (United States)
- Hawaiian tropical rainforests (United States)
- Kwongan heathlands (Australia)
- Madagascar dry deciduous forests (Madagascar)
- Madagascar lowland forests (Madagascar)
- New Caledonia dry forests (New Caledonia)
- New Caledonia rain forests (New Caledonia)
- Sierra Madre de Oaxaca pine-oak forests (Mexico)
- Sierra Madre del Sur pine-oak forests (Guatemala)

- Luzon montane rainforests (Philippines)
- Luzon rain forests (Philippines)
- Luzon tropical pine forests (Philippines)
- Mindanao montane rain forests (Philippines)
- Mindanao-Eastern Visayas rain forests (Philippines)
- Palawan rain forests (Philippines)

Endemism represents a unique step in the process of evolution. The species that perpetuated was sustained in the locality depending on the environmental quality. Larger areas usually have a greater proportion of endemics than smaller areas. The number of species endemic to the eastern Alps and western Alps add together to make about 78% of the total endemic species. When endemics are restricted to a small area, they are termed as local endemics. Endemics arising due to mutation are called pseudo endemics.

Neoendemics are differentiated into three types:

(a) Schizoendemics

Derived from a taxon of same chromosome number.

(b) Patroendemics

Restricted diploids given rise to polyploids.

(c) Apoendemics

Restricted polyploids that give rise to diploids.

Characters of Endemics

1. They are localized in distribution because of their narrow ecological amplitude.
2. They lack potentially to migrate because of saturated genomes.
3. Real endemics never migrate while neoendemics have the potential to migrate.
4. The dispersal propagules are not able to sustain during migration to other area. It may be due to physical barriers.

Theories of Endemism

There are two main theories of endemism. The first theory believes that the last survivors of once flourishing flora which is now declining are the relics or epibiotics which are endemics. The theory is supported by geographers. Example- *Sequoia semipenirens* of the central Valley of California and Oregon, *S. gigantea* of Sierra Nevada which are endemic to their respective native homes, were extensively distributed in Cretaceous and Tertiary periods.

The second theory is known as Age and Area hypothesis. It states that area is directly proportional to its age in the scale of evolution. [Example- *Primula,*

Impatiens, Rhododendron etc. The recent and youthful forms are in course of gradual extinction. – This needs to be explained!]

Coleus species namely *C. elongatus* and *C. barbatus* are distributed on the dry Ritigala mountains in Sri Lanka. The former species is endemic while the later is widely distributed in tropical Asia and Africa. It is believed that *C. elongatus* is derived from *C. barbatus*.

Factors responsible for endemism

Natural crossing among the closely related plants and mutations leads to development of endemic species. Climate is one of the factors leading to formation of endemics. Example- North of Himalaya is dry plateau of Tibet and South Himalayan range has alluvial fertile soil. According to Chatterjee (1978), percentage of endemic dicot plant species in India is more than 50. Maximum endemic plants are found in the Himalayas and South India. Indo-Gangetic plains have small number of endemic species. Endemic species found in India include

Rhododendron (Ericaceae)

Beaumontia grandiflora (Apocynaceae)

Eleusine coracana (Poaceae)

Caryota urens (Arecaceae)

Aegle marmelos (Rutaceae)

Crotolaria juncea (Fabaceae)

Ficus religiosa (Moraceae)

Seasamum indicum (Pedaliaceae)

The other species belong to families like Rubiaceae (6 genera), Rosaceae, Asteraceae, Primulaceae, Acanthaceae etc.

Endemism richness of plants showed a relatively strong correlation with the entire group of vertebrates. Endemism and species richness gives an index of endemism richness. Global patterns of endemism richness of vascular plants (i.e., ferns, gymnosperms, and angiosperms) are calculated. The calculation can be done by two methods

(i) Taxon-based method (plants and vertebrates): Endemism richness is calculated as the sum of range size extrapolated to the total flora (e.g., by multiplying the resulting values by 20 when range maps were available for 5% of the flora) and corrected for area using a standard area of 10,000 km^2. Large data sets with large number of vascular plant species are available for several regions such as Africa, Bolivia and Australia. Range size is measured as the number of grid cells or ecoregions in which a species occurs. Ecoregion-based data is available for Indo-Malayan region.

(ii) Inventory-based method (plants only): This method is based on the number of species of endemics and on the chorology, i.e., the affiliation of a species to a broader biogeographic group. High values of endemism richness

are noted on islands. The flora of each region is divided into chorological groups based on the literature. The amount of range equivalents attributed to the region is calculated as the fraction of the region of each chorological group multiplied by the number of species of the chorological group. The values for all chorological groups are summed up to yield the total number of range equivalents for the region. This total figure is divided by the area size of the region in km^2 and multiplied by 10,000 to yield the number of range equivalents per 10,000 km^2. Flora and fauna present on island maintain a high degree of endemism because of their geographic isolation and the limited interchange with neighboring mainland or island biota.

Volcanic archipelagos like the Canary Islands or Hawaii are good examples of recent and rapid adaptive radiations that result in development of neoendemic taxa. Among mainland areas, regions having Mediterranean-type climate emerge as global centers of plant endemism richness. The South African Cape region rank second among 90 biogeographic regions having exceptionally high tropical plant richness and endemism. There is high overlap between regions of highest endemism richness and "biodiversity hotspots". About 1,500 endemic plant species and the loss of ≥70% of its original vegetation occur because of human activities. Among the 20 regions with highest endemism richness, sixteen overlap with recognized hotspots.

Human impact showed a strong positive correlation with endemism richness. Mainland regions are predicted to lose more of their original land cover because of climate change. Small area and high degree of infrastructure (compare high human impact index for islands) make islands more vulnerable to habitat destruction.

SAQ 4

Define endemism. Enlist some endemic plant species of India.

10.6 HOTSPOTS OF BIODIVERSITY

A biogeographic region in which high diversity of plant and animals are present is referred as hot spot of biodiversity. These regions act as significant reservoir of biodiversity and hence considered as endangered terrestrial ecoregions. They represent just 2.3% of Earth's land surface, but they support more than half of the world's plant species as endemics. (It includes – delete) These ecoregions also have nearly 43% of bird, mammal, reptiles and amphibian species as endemics. Around the world, 36 areas have been identified under the category. The remaining natural habitat in these biodiversity hotspots amounts to just 1.4% of the land surface on the planet and support nearly 60 percent of the world's plant, bird, mammal, reptile, and amphibian species.

Forests are also considered as biodiversity hotspots. The concept was given by Norman Myers in 1988. He identified twenty-five biodiversity hotspots. He considered tropical forest as one of the 'hotspots' of biodiversity. Hot spot regions show exceptionally high levels of plant endemism and support about

60% of the world's plant, bird, mammal, reptile, and amphibian species. For any region to be identified as hotspot, it must meet two strict criteria:

1. **Species endemism:** The region must contain at least 1,500 species of vascular plants (> 0.5% of the world's total) as endemics i.e. high percentage of plant life found in the region.

2. **Degree of threat:** The region has to have lost at least 70% of its original habitat o original natural vegetation or primary vegetation under threat of extinction.

Three factors that determine hotspot areas include:

1. Number of **total species** (species richness).

2. Number of **unique species** (endemism).

3. Number of s**pecies at risk** (threat of extinction).

Hot spots are the richest but most threatened reservoirs of plant and animal life of the earth. Each area possesses unique biodiversity and represents a high level of floral and faunal endemism. They have **maximum number of endemic species.** Earlier the hotspot areas used to cover about 15.7% of the Earth's land surface but today they occupy only 2.3 % of the Earth's land surface. Around 86 % of the hotspots habitat has been destroyed. They contained 150,000 plant species as endemics and 11,980 terrestrial vertebrates as endemics. About 22,022 terrestrial vertebrate species reside in hotpot areas (77% of the world's total). Reptiles and amphibians are more prone to endemism in comparison to mammals and birds. Hotspot areas contain around 50% of the world's endemic plant species and 42% of all terrestrial vertebrates. Hotspots have lost around 86% of their original habitat and additionally are considered to be significantly threatened by extinction induced by climate change. The patterns of biological diversity result from i**nteraction of topography, climate change, soil characteristic and patterns of seasonal rainfall.** Species endemism has been studied considering the number of endemic plants/area ratio (species per 100km^2) and endemic vertebrates/area ratio (species per 100km^2).

Identification of these areas increases the likelihood of conservation. The "International Union for the Conservation of Nature and Natural Resources" (IUCN) categorized the hotspots (I-VI) on the basis of protected area. The Critical Ecosystem Partnership Fund (CEPF) is an alliance formed by grouping of seven non-governmental and private sector organizations (such as Conservation International). It provides grants to organizations working to help protect biodiversity hotspots around the world.

Biodiversity Hotspots across the World

The eight hot spot areas have been identified all over the world. These include:

1. Madagascar

2. Philippines

3. Sundaland (South East Asia)
4. Brazil's Atlantic Forest
5. Caribbean
6. Indo-Burma
7. Western Ghats and Sri Lanka
8. Eastern Arc and Coastal Forests of Tanzania/Kenya

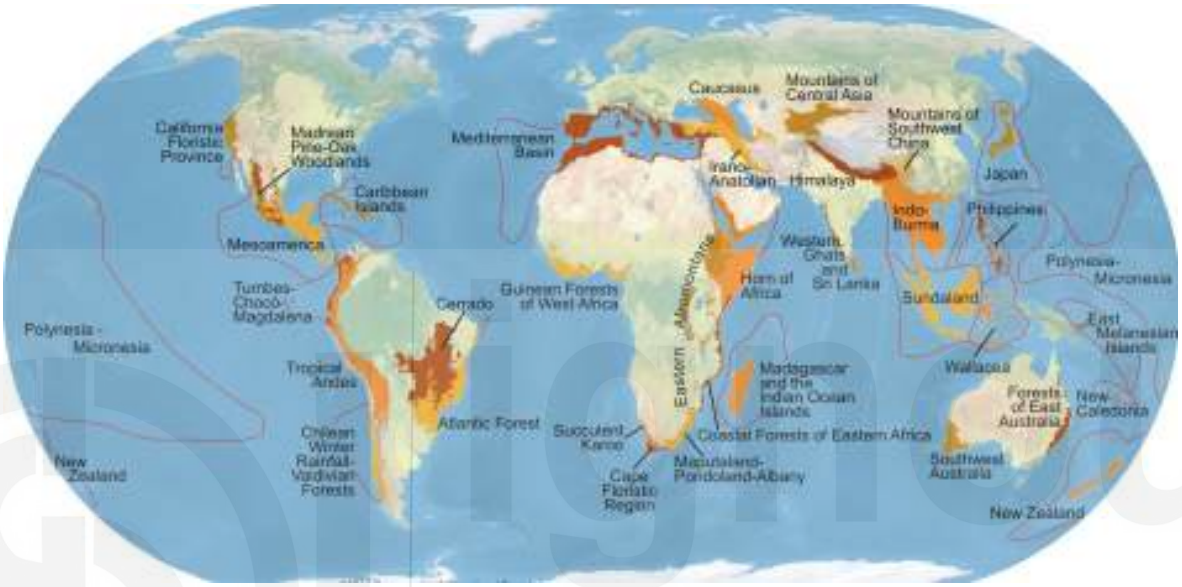

Fig. 10.3: Map indicating hot spot areas of the world.

Biodiversity Hotspot areas in India

The Western Ghats and (Himalaya – delete) the Eastern Himalayas have been identified as the two major biodiversity hot spots of India.

The Eastern Himalayas

This region comprises of Nepal, Bhutan, states of East and North-East India and some part of Yunnan province in South-Western China. The region possess distinct flora and is estimated to have about 9000 plant species, out of which 3500 are endemic. In the Indian region, 5800 plant species are found out of which nearly 2000 are endemic. The area has been recognized as a rich centre of primitive flowering plants and is popularly known as the 'Çradle of speciation'. Plant species commonly found in the region include monocotyledons and dicotyledons belonging to the families Orchidaceae, Zingiberaceae and Arecaceae. The flowering plants endemic to the region include pitcher plant (*Nepenthes khasiana*). The area is rich in plants of economic significance such as rice, banana, citrus, ginger, chilli, jute and sugarcane. The region has been recognized as the centre of origin of palm species such as coconut, arecanut, palmyra palm, sugar palm and wild date palm. The Taxol plant (*Taxus wallichiana*) distributed in the region is listed as threatened species in the red data book. The plant has been overexploited for drug used against cancer.

Out of the estimated 10,000 plant species found in the Himalayas, about one-third are endemic. The plants belong to the families Tetracentraceae, Hamamelidaceae, Circaesteraceae, Butomaceae and Stachyuraceae. Most of these species are found at high altitudes. [Example, plant species *Ermania himalayensis* is found at an altitude of 6300 meters in northwestern Himalayas. The discussion is on Eastern Himalayas.!!] The following example may be included.

Paphiopedilum spicerianum (Rchb.f.) Pfitzer, is commonly known as the lady's slipper orchid. This terrestrial herb is endemic to the North-Eastern region of India. Habitat fragmentation, overexploitation, grazing pressure and rampant poaching are some of the reasons due to which population size of the rare species is continually declining. This endangered plant is protected under IUCN red list, Appendix I of CITES, Schedule VI of Wildlife Protection Act of India and Red data book on Indian Orchidaceae.

About 63% of the genera of land mammals (faunal diversity) of India are found in this region. Two new mammal species namely- Golden Langur (Assam-Bhutan region) and Namdapha Flying Squirrel (Arunachal Pradesh) have been discovered from the region. The region is also a rich centre of avian diversity with more than 60% of the bird species. The area also possesses endemic species of lizards and reptiles. The Eastern Himalayan region contain nearly 163 globally threatened species including the one-horned rhinoceros (*Rhinoceros unicornis*), the wild Asian water buffalo (*Bubalus bubalis (Arnee)*) and 45 mammals, 50 birds, 17 reptiles, 12 amphibians, 3 invertebrate and 36 plant species. A few threatened endemic bird species such as Himalayan Quail, Cheer pheasant, Western tragopan are also reported from the region. Some of the Asia's largest and most endangered birds such as the Himalayan vulture and White-bellied heron are also reported from this region. Golden langur, Himalayan tahr, pygmy hog, Langurs, Asiatic wild dogs, sloth bears, Gaurs, Muntjac, Sambar, Snow leopard, Black bear, Blue sheep, Takin, the Gangetic dolphin, wild water buffalo, swamp deer are some of the animal species found in the region. The endemic species is the Namadapha flying squirrel. It is critically endangered.

Western Ghats

(The region comprises of Bhutan, northeastern India, southern, central and eastern Nepal. – delete as it is INCORRECT information) The Western Ghats Biodiversity Hotspot region is spread (into – delete) across 6 states of India (Gujarat, Maharashtra, Karnataka, Goa, Kerala and Tamil Nadu). The region receives high rainfall and is rich in moist deciduous and rain forests. The region shows high species diversity and high level of endemism. It is considered as one of the richest centers of endemism. The vegetation mainly includes scrubs, grasslands present at low altitudes and dry, moist deciduous forests, montane grasslands, shoals, tropical evergreen, semi evergreen forests present at the other end. The region is considered as an active zone of speciation because of the varied topography and microclimatic regimes. Complex topography and high rainfall retains the biodiversity of the region. The region has 490 arborescent taxa (tree species), of which about 308 are endemic. About 1,500 endemic dicotyledonous plant species are reported

from the region. The region possesses about 4,780 species of flowering plants (species – delete). The region possesses about 6,000 species of vascular plants (Pteridophytes, Gymnosperms and Angiosperms) out of which more than 3,000 (52 percent) are endemic. The Agasthyamalai Hills in the Western Ghats harbor the highest levels of plant diversity and endemic species. 245 species of orchids are found in the region of which 112 species are endemic. Over 6000 species of vascular plants are present in the region, of which over 3000 are endemic. Many species of spices such as black pepper and cardamom have originated in the region. The highest concentration of species is present in the Agasthyamalai Hills in the Western Ghats. The vegetation use to extend over 190,000 square km but today the area has been reduced to 43,000 square km.

The region also harbors over 450 bird species, about 140 mammalian species, 260 reptiles and 175 amphibians. About 315 species of vertebrates are endemic. These includes 12 species of mammals, 13 species of birds, 89 species of reptiles, 87 species of amphibians and 104 species of fish. The extent of endemism is high amongst amphibian and reptile species. Of the 165 species of reptiles found in Western Ghats, 88 species are endemic. Rare fauna of the region include – Lion tailed macaque, Nilgiri langur, Nilgiri tahr, Flying squirrel, and Malabar gray hornbill. The *Sibynophis* snakes, the Purple Frog and Sri Lankan lizard is found in the region.

Indo-Burma

The region encompasses several countries. The Indo-Burma region is spread over 2 million sq. km of tropical Asia. It covers Eastern Bangladesh, Malaysia, North-Eastern India, Myanmar, the southern part of China's Yunnan province, Cambodia, Vietnam, Thailand and the Andaman Islands (of India). Mixed wet evergreen, dry evergreen, deciduous, montane forests, floodplain swamps, mangroves and seasonally inundated grasslands are found in the region. It is estimated about 13,500 plant species are present in the region out of which half are endemic. Ginger is one the species native to the region.

This area is home to several primate species such as monkeys, langurs and gibbons. Many of the species of freshwater turtles are endemic to the area. Species of large mammals including Large-antlered muntjac, Annamite muntjac, Grey-shanked douc, striped rabbit, leaf deer, and Saola have been reported from the region. [Almost 1,300 bird species exist in the region. In view of the next statement, this should be deleted!!]. Over 1,260 bird species are found in Indo-Burma region, out of which more than 60 are endemic. These include threatened white-eared night-heron, the grey-crowned crocias, and the orange-necked partridge. About 430 mammal species are found in the region, out of which more than 70 species and seven genera are endemic. The region supports **highest diversity of freshwater turtles (**53 species that represent one-fifth of the world's species).

Sundaland

Sundaland is a region in South-East Asia that covers the western part of the Indo-Malayan archipelago. It includes Thailand, Malaysia, Singapore, Brunei and Indonesia. India is represented by Nicobar Islands. The islands have a

rich terrestrial and marine ecosystem that includes mangroves, coral reefs and sea grass beds. The marine biodiversity includes several species such as whales, dolphins, dugong, turtles, crocodiles, fishes, prawns, lobsters, corals and sea shells.

Fig. 10.4: Hot spot areas in India.

Threats to biodiversity

Increasing population and over-exploitation of biotic resources is causing huge loss of biodiversity. The major threats to biodiversity include land use change, pollution, climate change, rise in atmospheric CO_2 concentration, acid rain and introduction of exotic species.

Habitat destruction

About 30 years ago, most of the biodiversity hotspot regions were inaccessible and remote but now due to better infrastructure and transportation facilities, these areas have come within the reach of humans. Human activities such as logging of wood, extensive agriculture, habitation, mining, construction, deforestation, pollution has resulted in reduction of ranges of species.

Resource mismanagement

Increased tourism without regulation has led to pollution and environmental degradation. Illegal immigration from other countries has threatened plant life in the area.

Poaching

Unchecked hunting and poaching for valuable products such as tusks, teeth, skin and horns has resulted in extinction of large mammals such as the tiger, rhinoceros and elephant.

Climate change

The rise in temperature and an increase in the concentration of greenhouse gases cause warming which result in melting of glaciers. Climate change

significantly affects rainfall pattern. Changes in temperature alter water cycle and availability of nitrogen and other nutrients. Warming increases primary productivity yielding new plant biomass, increases organic litter and food supplies for animals and soil flora (decomposers) in tropical areas.

Warming may increase net primary productivity (NPP) because of increase in plant biomass leading to more nitrogen uptake from the soil followed by sequestration in the plant bodies. This leaves less nitrogen for the growth of additional plants. Hence NPP increases over time (due to limited availability of nitrogen). These events change the distribution of species and other ecosystem processes in complex ways. In tropical forests, warming increases evapotranspiration and soil moisture levels. Warming accelerates plant growth and spread pathogens because of increased humidity under heavy plant cover.

Forest Fragmentation

Logging and conversion of land for agricultural purposes results in fragmentation of forests. This decreases the probability of maintaining reproductive units of plant and animal populations. Species extinctions occur more frequently in fragments. Trees of many species become isolated and pollinators cannot cross the unforested areas. The trees in these areas become inbred and lose genetic variability and vigor. Species which have more wide-ranging pollinators suffer less from fragmentation. The fragmentation of forests also occurs by logging and agricultural conversion. Pathogens introduced through human activities prove lethal to forest plants and animals. Intensive hunting inhibits plant reproduction as seeds cannot be dispersed and flowers cannot be pollinated.

Introduction of exotic species

Humans have intentionally or accidentally introduced exotic species (species belonging to some other place) in many regions. The exotic species disrupt local ecosystems and lead to extinction of native species. Introduction of exotic species prove detrimental to forest health. Exotic organisms interrupt the forest ecosystem. They are difficult to eradicate because they have few or no natural enemies in the environment. Some exotic species introduced into India have become very difficult to eradicate. These include *Lantana camara, Eichhornia crassipes, and Parthenium hysterophorus.*

Overgrazing

The feeding of the livestock in the forests and grasslands for fodder leads to loss of biodiversity.

Natural Calamities

Catastrophic events like floods, droughts, cyclones, volcanoes, fires, etc. cause severe biodiversity loss from time-to-time.

Endangered and Endemic species of India

International Union for Conservation of Nature and Natural Resources (IUCN) categorized living organisms as vulnerable, rare, threatened and endangered

species (Table 1). Many plant species are getting threatened due to changes in their habitats caused by human activity. Besides trees and shrubs, climbers extremely specific to habitats are endangered. Herbs are threatened due to loss of habitat, while orchids and medicinal plants are under threat of extinction due to overharvesting for their products.

Among animals, mammal species such as the Indian Cheetah, Rhinoceros are under threat of extinction. Some species of birds have gone extinct in recent times. These include Pink-headed Duck (*Rhodonessa caryophyllacea*) and the Himalayan Quail (*Ophrysia superciliosa*).

Table 10.1: Number of the species of plants and animals under threat of extinction.

Group	Number	Species (%)
Mammals	350	7.6%
Birds	1224	12.6%
Amphibians	197	4.4%
Reptiles	408	6.2%
Fishes	2546	11.7%
Flowering plants	15000	6%

There is huge species diversity in India, with several of the species being endemic to their native ranges. Volcanoes and climatic change cause extinction of many endemic Indian forms. Among Indian species, 12.6% of mammals, 4.5% of birds, 45.8% of reptiles and 55.8% of amphibians are endemic.

SAQ 5

Biodiversity loss is occurring at a faster rate. Explain.

10.7 SUMMARY

- Phytogeography describes the geographic distribution of flora/plant species or vegetation in various regions of earth.
- Vegetation provides many direct and indirect benefits to humans.
- Vegetation has been categorized into two types – natural and manmade vegetation. The plants which are found naturally in a location are referred as natural vegetation while those cultivated by man is called as manmade.
- The vegetation of the world varies according to latitude ranging from equator to northward and southward. The changes arise mainly due to

difference in pattern of temperature and precipitation. The vegetation also changes with increase in altitude.

- India can be divided into nine phytogeographical regions namely [Flora of Decca, Flora of Malabar, Flora of Indus Plain, Flora of Gangetic Plain, Flora of Assam, Flora of Eastern Himalayas, Flora of Central Himalayas, Flora of Western Himalaya, and Andaman and Nicobar Islands. This statement needs to be corrected as discussed above in the text – page 12 onwards]
- Some species, genus or groups of plants are restricted to a particular area. Taxa occurring in a single restricted geographical area are termed as endemics. Endemism is of two types- palaeo and neo endemism. When taxon is young and not spread over the new area i.e. it has recently appeared it is called as neoenemism. The taxon which is now present in a restricted area but earlier was widely distributed is referred as paleo endemism.
- The regions with high levels of plant and animal diversity are referred as hot spot of biodiversity. They are called as reservoir of biodiversity. 25 terrestrial hot spots have been identified for the conservation of biodiversity. They occupy 1.4% of the earth's surface and 20% of worlds the human population lives in these areas.
- The 34hot spot areas cover over 50% of the world's plant endemic species and 42% of all terrestrial vertebrate endemic species are endemic.
- In India, (three ?, it should be 2) biodiversity hot spots have been identified. They include **The Eastern Himalayas [Arunachal Pradesh, Bhutan, Eastern Nepal], Indo-Burma and [Purvanchal Hills, Arakan Yoma, Eastern Bangladesh], and The Western Ghats (and – delete) [Sri Lanka is NOT a part of India, but a separate country.}**
- The changes in land use, atmospheric and climatic conditions, pollution, introduction of exotic species have been identified as the major threats to biodiversity.

10.8 TERMINAL QUESTIONS

1. List some of the benefits provided by vegetation.
2. Describe the characteristics of Tundra vegetation.

10.9 ANSWERS

Self assessment questions

1. The branch of science that deals with study of geographic distribution of flora/plant species or vegetation in various regions of earth is known as phytogeography. The term is derived from two words 'phyto' meaning plant and 'geography' meaning distribution. It covers all aspects of plant distribution

ranging from individual species and factors that govern the distribution, composition of plant communities and floras.

2. The vegetation of the world varies from region to region across the globe. From equator northward and southward, vegetation changes because of variation in temperature and precipitation. The tropical rainforests are found near the equator in the Northern Hemisphere while deciduous forests are found in the temperate region. Tropical rain forests occur in the hottest, wettest regions of the world, deserts in the hottest, driest areas, while tundra in the coldest, driest, and so forth. Tundra is found on the top of high mountains, coniferous forests in middle slopes and deciduous forests at the base of mountains. Latitudinal bands of vegetation on the continents are replicated on a smaller scale by the altitudinal bands of vegetation on mountains.

3. India can be divided into nine phytogeographical regions.

   i) Flora of Deccan
   ii) Flora of Malabar
   iii) Flora of Indus Plain
   iv) Flora of Gangetic Plain
   v) Flora of Assam
   vi) Flora of Eastern Himalayas
   vii) Flora of Central Himalayas
   viii) Flora of Western Himalaya
   ix) Andaman and Nicobar Islands

Flora of Deccan – The area includes entire southern peninsula, South of Ganges ranging from Madhya Pradesh to Kanyakumari. The average annual rainfall of the region is about 100 cm. The vegetation consists of tropical dry evergreen, dry deciduous and swamp forests. The important trees of the region are Michelia champaca, Dillenia aurea, Chloroxylon swetenia, Cedrela toona, Santalum album, Pterocarpus sentalinus, Soyamida etc. Shrubs mainly include species such as Hibiscus, Zizyphus numularia, Grewia, Bauhinia, Woodfordia, Capparis, Lagerstroemia, Holarrhena, Cassia auriculata, Acacia arabica, Parkinsonia aculeata, Calotropis procera, Jatropha grandiflora. Climbers like Hiptage, Cassytlea, Dioscorea, Ipomoea, Vitis, Smilax, Euphorbia nerrifolia and E. tortilis etc. are common Herbs such as Bambusa arundinacea, Dendrocalamus, Borassus flabellifer, Phoenix sp. belonging to Lamiaceae, Amaranthaceae, Acanthaceae, Commelinaceae, Orchidacee etc. are reported from the region.

Flora of Malabar – This is a small region extending from Gujrat to Kanyakumari along Western Ghats. The area includes states of Kerala, Maharashtra, Gujarat and Karnataka. The climate is warm humid having annual rainfall over 400 cm. The vegetation consists of tropical wet evergreen, moist evergreen and moist deciduous forests. The vegetation shows red

tinged leaves of the trees, e.g. Meliosma wightii, Michelia nilgirica, Rhododendron nilgiricum, Toddalia, Clematis, Impatiens, Arisema, Cymbopogon etc. The dominant vegetation of this area includes Memecylon, Syzygiun, Etnblica officinalis, Murraya koenigii, Rhododendron nilgiricum, Smilax, Piper, Clematis. Mangrove forests vegetation found in the regions include Rhizophora, Bruguiera parviflora, Ceriops tagal, Kandelia candel, Xylocarpus grantum Acanthus illicifolius, Sonneratia etc.

Flora of Indus Plain – The region comprises a part of Punjab, Delhi, Rajasthan, a part of Gujarat and Cutch. The climate has dry and hot summers alternating with dry and cold winters. The annual rainfall is generally less than 70 cm. The vegetation consists of tropical thorn forests and grasslands. *Anogeissus pendula, Butea, Acacia catechu, Bombax, Zizyphus, Grewia salvifolia, Maytenus (syn. Gymnosporia), Balanites roxburghii, Boswelia serrata, Nyctanthes, Carissa, Euphorbia nivulia, Mangifera indica etc*. are prominent. Among trees, *Dalbergia sisso, Populus, Butea, Mangifera, Anthocephalus, Amoora, Bombax, Acacia, Melia azadarach, Azadirachta indica, Polyalthia longifolia, Albizia lebbeck, Eucalyptus, Cordia, Lagerstroemia, Ficus religiosa, F. benghalensis, F. infectoria, Ficus sp.* etc. Thorny plants such as *Acacia nelotica, A. Senegal, Salvadora, Cassia, Tinospora, Tamarix, Tragia, Rivea, Vitis, Apluda, Cymbopogon, Eragrostis, Paspalidium, Cenchrus, Peristrophe, Grewia populnifolia, Commiphora wightii* etc.

Flora of Gangetic Plain – The area extends from region of Delhi to Sundarbans of Bengal passing through Bihar, Orissa and U.P. The vegetation consists of tropical moist deciduous forests, dry deciduous forests, thorn forests and mangrove forests. Average annual rainfall ranges from 50 cm to 150 cm. The vegetation is dominated by *Acacia nilotica, Balanites, Jatropha, Flacourtia, Capparis decidua, Butea monosperma, Madhuca, Zizyphus, Dalbergia, Phoenix, Nyctanthes, Woodfordia, Adhatoda, Terminalia, Prosopis, Tinospora, Vitis, Cocculus, Ixora, Carissa, Hemidesmus, Shorea robusta, Artocarpus, Lagerstroemia, Ptersopermum, Bombax, Ehertia, Adhatoda, Murraya koenigii, Pogosternon, Aegle marmelos, Holoptelea, Areca, Borassus, Pagostemon* and many types of grasses.

Flora of Assam – The area includes valleys of Brahmputra, Jaintia, Khasi and Garo hills, Mishmi hills, North Himalayas, Santosh River, Naga, Cachar and Mizo hills, Mizoram, Meghalaya, Nagaland, Manipur, Tripura and Assam region. The climate is characterized by very high temperature and rainfall. The vegetation consists of tropical evergreen and wet temperate forests in the lower plains.

Vegetation includes *Dipterocarpus, Artocarpus, Ficus, Mesua, Amoora, Ficus elastica, Persea, Calamus, Talauma, Cinnamomum, Sterculia, Adina, Vernonina, Mimusops hexandra, Diospyros ebenum, Ixora parviflora, Carissa carnadas, Asparagus, Derris, Acacia intsia, Tectona grandis, Shorea robusta, Kydia, Terminalia, Dipterocorpus* etc. etc. Grasses found in the region mainly include *Paspalidium, Phragmites, Arundo, Panicum, Erianthus, Apluda, Sorghum, Themeda, Saccharum, Andropogon, Cymbopogon* etc.

Flora of Eastern Himalayas – The region comprises of mountain ranges from Sikkim to Arunachal. More than 4,000 sp. of phanerogams belonging to 160 families and lower plants are found in this region. Region comprises of sal forests, mixed deciduous forests, semi-evergreen, evergreen and subtropical forests. The main vegetation includes Quercus, Cycas, Pinus, Populus, Salix, Pandanus, Dillenia, Sterculia, Toona ciliata, Lagerstroemia, Bombax, Shorea robusta, Amoora, Terminalia, Bauhinia, Michelia, Artocarpus, Syzygium, Cinnamomum, Alnus, Rhus and others like Entada, Beaumontia grandiflora, Hiptage, Tinospora cordifolia, Bambusa *etc.*

Flora of Central Himalayas – The flora of Nepal or central Himalaya is a mixture of eastern and western Himalayas. Vegetation consists mainly *Shorea robusta, Bombax, Gmelina, Petalidium, Clerodendron, Bauhinia vahlii, Ehertia, Rhus, Olea, Quercus, Alnus, Rhododendron, Pinus, Eriobortya, Lindera, Berberis, Tsuga, Abies, Juniperus, Lonicera, Primula, Caranga, Pennisatum, Artemesia, Lyonia, Spiraea, Cornus, Zanthoxylum in western Nepal; Bauhinia, Kydia, Spathodea, Albizzia, Shorea robusta, Trema, Bombax, Saccharum arundinaceum, Cymbopogon martini, Quercus, Acer, Alnus, Mesua, Cyathea, Rhododendron, Camellia, Fraxinus, Pinus, Taxus, Syringa, Barberis, Polygonum, Pedicularia and Mecenopsis* etc., in central Nepal and *Shorea, Lagerstroemia, Cassia, Sterculia, Flacourtia, Dendracalamus, Smilax, Beaumontia, Euphorbia, Woodfordia, Schima, Quercus, Prunus, Boehmeria, Camellia, Arundinaria, Betula, Eragrostis, Sedum, Saxifrega, Carex, Agrostis, Potentilla, Sedum* etc., in Eastern Nepal. Certain species of *Acer* such as *Acer cappadoscicum*, *Quercus floribunda* and *Populus ciliata* etc. are present in Central Himalaya.

Flora of Western Himalaya – The region extends from Kumaon ranges to Kashmir. The region has a cold and dry climate. Average annual rainfall in the region is 100-200 cm. The vegetation of this region consists of *Acacia modesta, Euphorbia royleana, Olea, Bombax ceiba, Themada, Chrysopogon serrulatus, Bauhinia vahlii, Shorea robusta, Cassia fistula, Lagerstroemia parviflora, Murraya keonigii, Zanthoxylum alatum, Terminalia, Anogeissus latifolia, Toona ciliata, Zanthoxylum alatum, Adhatoda, Carissa, Rosa, Rubus, Syzygium, Crataegus, Diospyros, Emblica, Picea, Pinus wallichiana, Cedrus deodara, Rhamnus, Salix, Berberis, Smilax, Arundinaria, Fraxinus, Fragaria, Viola, Artemesia, Rheum, Sedum, Betula, Anemone, Saxifraga, Geranium*, etc. The region is subdivided into three zones.

Flora of Eastern Himalayas –This region extends in the Himalayas from east of Nepal up to Arunachal. The climate is warm and wet. Tree line and snow line are higher by about 300 m than in the western Himalayas. Vegetation mainly consists of consist of variety of oaks, conifers.

Andaman and Nicobar –The climate of the region is warm and humid with very high temperature and annual rainfall. The vegetation consists of littoral mangrove, evergreen, semi-evergreen and deciduous forests.

4. The confinement of a particular species, genus, or groups of plants and animals to a particular area is termed as endemism. Taxa occurring in a single restricted geographical area are termed as endemic. The endemic species include taxa whose distribution is confined to a restricted area

due to their specific ecological niches and edaphic gradients. Endemic species once lost, it is a loss of biodiversity of these species forever. In India there are about 5725 endemic taxa of angiosperms (33.5% of Indian flora) are present and these are located in 25 hot spots. There are about 1272 species of endemic angiosperms out of 3800 species occurring in Kerala which represent 22.6% of Indian endemics.

State	Endemic species	Family
Assam	*Acacia diadenia* Parker	Mimosaceae
	Acranthera tomentosa	Rubiaceae
	Adhatoda cymosa	Acanthaceae
	Agapetes kanjilali	Ericaceae
	Agapetes variegata	Ericaceae
	Ardisia pardalina	Myrsinaceae
	Artabotrys cubittii	Annonaceae
	Bambusa cacharensis	Poaceae
	Bambusa mastersii	Poaceae
	Begonia tessaricarpa	Begoniaceae
	Beilschmeidia gammieana	Lauraceae
	Beilschmeidia pseudomicropora	Lauraceae
	Bousigonia angustifolia	Apocyanaceae
Arunachal Pradesh	*Begonia aborensis*	Begoniaceae
	Begonia burkillii	Begoniaceae
Andhra Pradesh	*Acacia campbellii* Arn.	Fabaceae
	Albizia thompsonii Brandis	Fabaceae
Bihar	*Agrostis brachiata*	Poaceae
	Chrysopogon hamiltonii	Poaceae
	Clematis roylei	Ranunculaceae
	Dendrocalamus strictus	Poaceae

5. Increasing population pressure and over-exploitation of natural resources is leading to loss of biodiversity. The major threats to biodiversity decline are changes in land use, pollution, habitat destruction of habitat, changes in atmospheric CO_2 concentrations, climate alterations, and the introduction of exotic species. Anthropogenic activities such as logging of wood, increased agriculture, increased habitation, mining, construction of large dams and highway has led to

destruction of natural habitats reducing the range of species. Rise in earth surface temperature (global warming) is likely to increase the risk of extinction of forests and dependent animal species. Climate change associated alterations in rainfall pattern and water table affect the distribution and growth of vegetation.

Terminal questions

1. List some of the benefits provided by vegetation.

   The vegetation is very useful to humans because of various direct and indirect benefits provided by it. Some of the major important uses of vegetation is listed below.

   - The plant species serve as the main source of food for humans. These include vegetables, fruits, grains, cereals, leaves, seeds.
   - The plants provide natural materials like rubber, gum, paper, cotton, jute, medicines and oil.
   - The trees provide a source of wood for construction of houses, bridge and poles.
   - Vegetation comprising of plants play an important role in ecosystem as they represent the primary producers and form the first trophic level. They provide food for animals (consumers).
   - Plants regulate the flow of elements such as carbon, nitrogen through biogeochemical cycles and contribute to the local and global energy balances.
   - Vegetation also affects soil formation and influences soil volume, chemistry, texture and structure.

2. Describe the characteristics of Tundra vegetation.

   Tundra regions are found in the northern and southern hemispheres. The biome stretches across northern Canada and Alaska, Siberia and northern Scandinavia in the north to Arctic Circle. Plants that are commonly found in the region include dwarf shrubs, grasses, sedges, mosses and lichens. Some of the major plants species include arctic moss, arctic willow, bearberry, caribou moss, diamond-leaf willow, labrador tea, pasque flower, tufted saxifrage.