PREFACE

In a bid to standardize higher education in the country, the University Grants Commission (UGC) has introduced Choice Based Credit System (CBCS) based on five types of courses viz. *core, generic, discipline specific elective, ability and skill enhancement* for graduate students of all programmes at Honours level. This brings in the semester pattern which finds efficacy in sync with credit system, credit transfer, comprehensive continuous assessments and a graded pattern of evaluation. The objective is to offer learners ample flexibility to choose from a wide gamut of courses, as also to provide them lateral mobility between various educational institutions in the country where they can carry their acquired credits. I am happy to note that the university has been recently accredited by National Assessment and Accreditation Council of India (NAAC) with grade “A”.

UGC (Open and Distance Learning Programmes and Online Programmes) Regulations, 2020 have mandated compliance with CBCS for U.G. programmes for all the HEIs in this mode. Welcoming this paradigm shift in higher education, Netaji Subhas Open University (NSOU) has resolved to adopt CBCS from the academic session 2021-22 at the Under Graduate Degree Programme level. The present syllabus, framed in the spirit of syllabi recommended by UGC, lays due stress on all aspects envisaged in the curricular framework of the apex body on higher education. It will be imparted to learners over the six semesters of the Programme.

Self Learning Material (SLMs) are the mainstay of Student Support Services (SSS) of an Open University. From a logistic point of view, NSOU has embarked upon CBCS presently with SLMs in English / Bengali. Eventually, the English version SLMs will be translated into Bengali too, for the benefit of learners. As always, all of our teaching faculties contributed in this process. In addition to this we have also requisioned the services of best academics in each domain in preparation of the new SLMs. I am sure they will be of commendable academic support. We look forward to proactive feedback from all stakeholders who will participate in the teaching-learning based on these study materials. It has been a very challenging task well executed, and I congratulate all concerned in the preparation of these SLMs.

I wish the venture a grand success.

Professor (Dr.) Subha Sankar Sarkar
Vice-Chancellor

Netaji Subhas Open University

Under Graduate Degree Programme

Choice Based Credit System (CBCS)

Subject : Honours in Botany (HBT)

Course : Plant Ecology and Taxonomy

Course Code : GE-BT -21

First Print : November, 2021

Printed in accordance with the regulations of the
Distance Education Bureau of the University Grants Commission.

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UG : Botany
(HBT)

Plant Ecology and Taxonomy
GE-BT-21

Unit 1 ❒ Introduction to Ecology

Structure

1.0 Objective

- In this unit you will get an overview of ecology and its divisions, its hierarchy and application.
- This will help you to understand about the basic aspects of ecology and make you aware about its significance to science and society.

1.1 Introduction

We are living in this World with all other living organisms and our physical environment. There is a constant interaction between the biotic and abiotic components of the World, i.e. there is a reciprocal relationship between the two. The study of this reciprocal relationship between the living organism and their physical environment is known as **ecology**. A functional system thus formed by the living communities and their physical surroundings is known as ecosystem. Actually the environment influences the life and development of organismsin a particular area. An ecosystem is always a dynamic structure and continuously changing in terms of space and time.

❐ There are two basic components in the World- living or biotic components and non-living or abiotic components. The biotic components include different forms of life on earth like plants, animals, bacteria, etc., while the non-living components include the no-living materials like soil, water, air, etc and also the forces of nature like gravity, light, energy, etc. All the life forms in the World is influenced by the abiotic components and on the other hand the environment is also affected by the living organisms. Actually the organisms form interacting systems or communities and these communities are coupled with the environment by the transfer of matter and energy. So, the communities and environment are interrelated. So, an interrelationship exists between the abiotic and biotic components. The particular aspect of biology that deals with the interrelationships between biotic and abiotic components on earth is called ***ecology***. According to M.E. Clark (1973) "ecology is a science of ecosystems or totality of reciprocal interactions between living organisms and their physical surroundings". Thus a functional system formed by the communities and their environment is called ***ecosystem***.

Although the origin of the term Ecology is still uncertain, there is a general agreement that modem term Ecology is derived from "***Oekologie***". The word 'ecology' (oekologie), first proposed by Earnst Haeckel (1869), a German Biologist, is derived from Greek words, *oikos* meaning the dwelling place or home and logos meaning the discourse or study; thus, the word ecology literally means the study of living organisms, both plants and animals in their natural habitats or homes.

It can also be defined as the study of life in relation to environment; the environment being the aggregate of all external conditions and influences which affect the life and development of organisms at a given spot. Eugene P. Odum (1963) has defined ecology "as the study of the structure and the function of nature". According to Charles J. Krebs (1972), "Ecology is the scientific study of interactions that determine the distribution and abundance of organisms". Smith R.L. (1972) in his book Elements of Ecology and Field Biology has defined ecology "as multidisciplinary science which deals with organisms and their environment, both biotic and abiotic".

1.2 Ecology and its divisions

Ecology may be subdivided into autecology and synecology.

Autecology:

Autecology is concerned with the study of individual animal or plant species or its population throughout its life history in relation to the habitat in which it grows. In other words, it is the study of interrelationships between individual species and its environment.

Synecology:

Synecology is concerned with many species. It is the study of whole communities or major fractions of communities and its ecosystems. In some countries the term biocoenology or biosociology is also used instead of synecology (Whittaker, 1970). This field of ecology is basically associated with the structure, development, nature and distribution of communities in nature. Autecological studies basically form the basis for synecological studies.

The study of structure of plant communities is known as **phytosociology** or **plant sociology**. On the other hand, the study of distribution of plants on or near the surface of earth and water is known as **phytogeography**. It also deals with the migration of the species. The study of plant ecology basically merges with plant geography or phytogeography. Actually speaking there is no sharp distinction between plant ecology and plant geography. According to Turrill (1938), "plant ecology is intensive while plant geography is extensive in outlook, but both are concerned with plants and in attempting to correlate observed structure and behaviour of plants with causes, both refer to the same sum total of environmental factors though the emphasis varies".

Ecology can also be subdivided according to the following manner:

I. Organism level:

1. Autecology:

Ecology of species and individual

2. Population ecology:

Study of population

3. Community ecology:

Synecology.

II. Habitat or Ecosystem level:

A. Terrestrial Ecosystems :

1. Forest ecology
2. Grassland ecology
3. Desert ecology
4. Wetland or Marsh ecology

B. Aquatic Ecosystems :

1. Marine ecology
2. Lagoon ecology
3. Estuarian ecology

4. Fresh water ecology or Limnology
   (i) Lotic waters (running water bodies e.g., rivers and streams)
   (ii) Lentic waters (standing water bodies like lakes and ponds)

III. Applied Ecology :

It deals with the applied aspects of ecology, i.e., application of ecological concepts in human welfare including conservation of natural resources, forestry, wild life management, etc.

It includes the following:

1. Agricultural ecology:

Agricultural ecology or crop ecology.

2. Paleoecology:

It is concerned with the organisms and geological environments of the past Paleontology and radioactive dating have helped significantly in the study of Paleoecology.

3. Cytoecology:

It deals with the cytological details of the species or populations in relation to different environmental conditions.

4. System ecology:

It deals with the structure and working of ecological systems in relation to space and time and also with the analysis of components of ecosystem using applied mathematics, bioinformatics and statistics. In this, special emphasis is laid on the reciprocal relationship between living and non-living systems.

5. Conservation ecology or Resource ecology:

It is concerned with the proper management of plant animal, soil, water and mineral resources for human welfare.

6. Ecological energetic and Production ecology:

These modem branches of ecology are still in developing stage. These deal with the mechanisms and quantity of energy conversion and flow of energy through organisms. Energy production processes, rate of increase in organic weights of organisms in relation to space and time are also discussed in this branch of ecology.

7. Landscape ecology: study of variation in landscape pattern, change in landscape patter through ages, distribution of different organisms in different landscape, etc.

8. Radiation ecology: The branch of ecology concerned with the effects of radioactive materials on living systems and on the pathways by which they are dispersed through ecosystems, including their dispersal through the abiotic environment. The term is used especially with regard to those materials released through human agency.

9. Eco-physiology: It is the study of how the environment, both physical and biological, interacts with the physiology of an organism. It includes the effects of climate and nutrients on physiological processes in both plants and animals, and has a particular focus on how physiological processes scale with organism size.

10. Ecological genetics: is the study of genetics in natural field populations. It focuses on traits involved in interactions between and within species, and between an organism and its environment, particularly those that determine fitness.

1.3 Ecological hierarchy

Ecological Level # 1. Organisms:

They make the basic unit of study in ecology. At each level, the biological unit has a specific structure and function. At this level, the form, physiology, behaviour, distribution and adaptations in relation to the environmental conditions are studied. The organisms of the similar type have the potential for interbreeding, and produce fertile offspring, which are called species. The organism performs all the life processes independently. However, parts of organism cannot exist independently of one another. An organism is fully adapted to its environment. It has a definite life span including definite series of stages like birth, hatching, growth, maturity, senescence, aging and death. Competition, mutualism and predation are various types of interaction between organisms.

Ecological Level # 2. Population:

In ecology, a population is a group of individuals of the same species, inhabiting the same area, and functioning as a unit of biotic community.

For example, all individuals of the common grass, Cynodon, in a given area constitute its population. Similarly, the individuals of elephants or tigers in an area constitute their population.

The interaction between populations is generally studied. These interactions may be a predator and its prey, or a parasite with its host. Competition, mutualism, commensalism, parasitism, and predation are various types of interactions.

Ecological Level # 3. Biological Community:

Biotic community organisation results from interdependence and interactions amongst population of different species in a habitat. This is an assemblage of populations of plants, animals, bacteria and fungi that live in an area and interact with each other.

A biotic community is a higher ecological category next to population. These are three types of biotic community, they are: animals, plants and decomposers (i.e., bacteria and fungi). A biotic community has a distinct species composition and structure.

Ecological Level # 4. Ecosystem:

The ecosystems are parts of nature where living organisms interact amongst themselves and with their physical environment. An ecosystem in composed of a biotic community, integrated with its physical environment through the exchange of energy and recycling of the nutrients. The term ecosystem was coined by Sir Arthur Tansley in 1935.

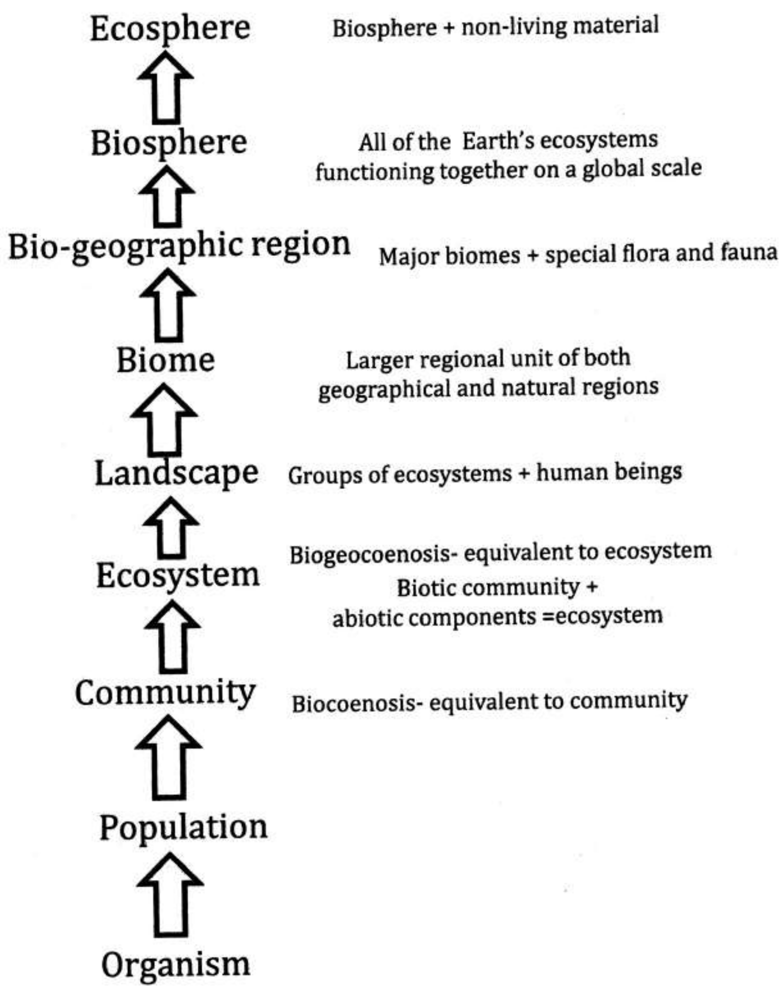


Fig. 1.1. Ecological hierarchy

Ecological Level # 5. Landscape:

A landscape is a unit of land with a natural boundary having a mosaic of patches, which generally represent different ecosystems.

Ecological Level # 6. Biome:

This is a large regional unit characterised by a major vegetation type and associated fauna found in a specific climate zone. The biome includes all associated developing and modified communities occurring within the same climatic region, e.g., forest biomes, grassland and savannah biomes, desert biome, etc.

On a global scale, all the earth's terrestrial biomes and aquatic systems constitute the biosphere.

Ecological Level # 7. Biosphere:

The entire inhabited part of the earth and its atmosphere including the living components is called the biosphere.

The global environment consists of three main sub-divisions:

(i) The hydrosphere which includes all the water components,

(ii) The lithosphere comprises the solid components of the earth's crust, and

(iii) The atmosphere formed of the gaseous envelope of the earth. The biosphere consists of the lower atmosphere, the land and the oceans, rivers and lakes, where living beings are found.

1.4 Relationships of plant ecology and other branches of science

Ecology is a synthetic branch of biological science which draws source materials from many other sciences. It is fundamentally related to morphology, taxonomy, physiology, biochemist, cytology genetics, etc. Various other sciences, such as physics, chemistry, geology, geography, meteorology, climatology, hydrology, paleontology, anthropology, sociology, mathematics statistics are also being increasingly used in the study of ecological problems. Application of radioactive isotopes, use of many modem and advanced instruments like spectrometer, infrared gas analyzer, flame photometer, computers in the analysis of data, calorimeters, phytotrons for culturing the plants in environment controlled chambers and many other equipment's are common in ecological researches. Besides botany, zoology, chemistry and physics, the knowledge of climatology, geography, pedology and geology is also essential in the study of complicated problems of plant ecology.

1.5 Application of plant ecology

I. The study of plants in their environment provides aids to the science of conservation of natural resources.

II. The knowledge of ecology is of great help in controlling soil erosion, reforestation, restoration of wild animals as well as grassland vegetation and flood control.

III. Plant ecology is directly related to silvics (general characteristics and life history of forest trees) and silviculture and other branches of forest biology.

IV. Knowledge of ecology is applied in agriculture, food production and horticulture. The soil conservation practices are also used in agronomy.

V. The International Biological Programme (IBP) was launched since July 1, 1967 to study the biological basis of organic productivity and conservation of natural resources in relation to human welfare. Launching of this programme has given impetus to the ecologists all over the world and over 70 nations including India have participated in the IBP at either national or international level. The future of ecology and indeed of biology is likely to be changed by some international programmes such as 'Man and Biosphere' (MAB).

1.6 Summary

From this chapter we have got an idea about the ecology and ecosystem. The word '***ecology'*** *(oekologie),* first proposed by Earnst Haeckel (1869), a German Biologist, is derived from Greek words, *oikos* meaning he dwelling place or home and logos meaning thediscourse or study. According to M.E. Clark (1973) "ecology is a science of ecosystems or totality of reciprocal interactions between living organisms and their physical surroundings". Thus a functional system formed by the communities and their environment is called ***ecosystem***. Autecology is concerned withthe study of individual animal or plant species or its population throughout its life history in relation to the habitat in which it grows, whereas synecology is thestudy of whole communities or major franctions of communities and its ecosystems is the study of whole communities or major fractions of communities and its ecosystems. Ecology can be further subdivided based on organism level, habitat or ecosystem level and applied aspects. There can be further subdivided into many other aspects. Ecosystem hierarchy starts from organism or single individual to population, then to community to ecosystem and ultimately to landscape, biome and biosphere according totheir hierarchical level. Applied aspect of ecology include conservation of natural resources, protection of environment, silvics, agriculture, etc.

1.7 Questions & Answers

Q1. Define Ecology.

Ans.: According to M.E. Clark (1973) "ecology is a science of ecosystems or totality of reciprocal interactions between living organisms and their physical surroundings".

Eugene P. Odum (1963) has defined ecology "as the study of the structure and the function of nature".

According to Charles J. Krebs (1972), "Ecology is the scientific study of interactions that determine the distribution and abundance of organisms".

Smith R.L. (1972) has defined ecology "as multidisciplinary science which deals with organisms and their environment, both biotic and abiotic".

Q2. Who introduced the term ecology?

Ans.: The word 'ecology' (oekologie) was first proposed by Earnst Haeckel (1869), a German Biologist. It is derived from the Greek words, *oikos* meaning the dwelling place or home and *logos* meaning the discourse or study.

Q3. What is autecology?

Ans.: Autecology is concerned with the study of individual animal or plant species or its population throughout its life history in relation to the habitat in which it grows. In other words, it is the study of interrelationships between individual species and its environment.

Q4. What is synecology?

Ans.: Synecology is the study of whole communities or major fractions of communities and its ecosystems. This field of ecology is basically associated with the structure, development, nature and distribution of communities in nature.

Q5. Comment on the different subdivisions of ecology.

Ans.: vide section 1.2

Q6. Write a brief note on ecological hierarchy.

Ans.: vide section 1.3

Q7. What is population?

Ans.: A population is a group of individuals of the same species, inhabiting the same area, and functioning as a unit of biotic community.

Q8. What is ecosystem?

Ans.: The ecosystems are parts of nature where living organisms interact amongst themselves and with their physical environment. An ecosystem is composed of a biotic community, integrated with its physical environment through the exchange of energy and recycling of the nutrients.

Q9. Who did coin the term ecosystem?

Ans.: The term ecosystem was coined by Sir Arthur Tansley in 1935.

Q10. What is landscape?

Ans.: A landscape is a unit of land with a natural boundary having a mosaic of patches, which generally represent different ecosystems.

Q11. What is biome?

Ans.: This is a large regional unit characterised by a major vegetation type and associated fauna found in a specific climate zone. The biome includes all associated developing and modified communities occurring within the same climatic region, e.g., forest biomes, grassland and savannah biomes, desert biome, etc.

Q12. What is biosphere?

Ans.: The entire inhabited part of the earth and its atmosphere including the living components is called the biosphere.

Q13. Comment on the significance of ecological studies.

Ans.: vide section 1.5

Unit 2 ❒ Ecological Factors

Structure

2.0 Objective

This unit will help you understand that

- How a plant adopt itself in an environment.
- How the growth and development of a plants is influenced by the environment.

2.1 Introduction

There are diverse forms of factors that influence the development and survival of a species in an ecosysem. They actually affect the survival, presence or absence, distribution, growth, etc. of a living organism or community. So different communities are distributed in different manner on the earth surface. The factors can be broadly subdivided into physical or abiotic and biotic factors. Physical factors further include climatic, topographic and edaphic factors. in this chapter we shall discuss about the different physical or abiotic factors that affect the communities in an ecosystem. We shall also discuss about the adaptive features or hydrophytes (aquatic plants) and xerophytes (xeric plants) in this chapter.

❒ Diverse forms of factors which are intricately mixed and interdependent on each other play a significant role as ecological factors. These factors singly or in combination influence the presence or absence, vigour or weakness and relative success or failure of various plant and animal communities in a particular habitat. The environment of an organism may be subdivided into physical and biotic components. The physical factors include mainly atmosphere, lithosphere and hydrosphere and a variety of other physical factors like light, temperature, pH, etc.

All these ecological factors can be broadly classified into the following divisions:

(i) Climatic or Aerial factors:

(a) Light;

(b) Temperature;

(c) Water;

(d) Rainfall;

(e) Humidity;

(f) Atmospheric gases (wind).

(ii) Topographic or Physiographic factors:

(a) Altitude;

(b) Direction of mountain chains and valleys;

(c) Steepness and exposure of slopes.

(iii) Edaphic factors:

These deal with formation of soil, its physical and chemical properties and details of related aspects.

(iv) Biotic factors:

These are all kinds of interactions between different forms of life. These are plants, animals, micro-organisms etc.

(v) Limiting Factors:

A limiting factor is that substance of quality in the environment, the supply of which is least abundant or over abundant in relation to the need of the living organism concerned.

2.2 Climatic Factors

2.2.1 Light

Light is the most important abiotic factor without which no life can sustain. It plays an important role in the species composition and development of vegetation. Light is abundantly received on the surface of the earth and on an average approximately only 2-3 % of this solar energy is used in Primary Productivity. Solar energy reaches the earth in the form of radiant energy and the radiation that penetrates the earth's atmosphere consists of electromagnetic waves of a wide range of wavelengths. The light energy also considered as a shower of particles called photons. Each photon carries a certain amount of energy called quantum. The solar radiation that penetrates the earth's atmosphere composed of a small portion of UV rays, visible light spectrum and infrared radiation. Within the visible light spectrum blue and red light spectrum are utilized for photosynthesis. Infrared radiations cause heating of earth surface and most of the part radiates back after heating the surface.

Light intensity shows special variations due to the factors like atmospheric water layer, particles dispersed in the air, etc. Further, the vegetation of an area may also affect the light intensity. In deep shade under trees, or under water, light becomes limiting below which photosynthesis is not sufficient for effective growth.

- **Effect of Light on Plants:**

Light plays a vital role directly or indirectly in regulating the growth (structure, form, size), metabolism, development and distribution of plants.

The plants are influenced by light in the following ways:

1. Effect on Chlorophyll synthesis:

The synthesis of chlorophyll in green plants can take place only in the presence of light. It is seen that if a plant is kept in prolonged darkness, the amount of chlorophyll practically disappears.

2. Effect on number and position of Chloroplasts:

Light has marked effect on the number and position of chloroplasts, the chlorophyll bearing organelle. The upper surface of leaves which receive maximum sunlight has the largest number of chloroplasts arranged in line with the direction of light. On the other hand, the leaves of the plants which shade chloroplasts are very few in number and arranged at right angles to the light rays, thus increasing the surface of absorption.

3. Effect on Photosynthesis:

Photosynthesis is a process of conversion of solar energy (light) into chemical energy (in presence of chlorophyll) which is subsequently used for the preparation of carbohydrate from carbon dioxide and water.

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H1_2O_6 + 6O_2 + 6H_2O$$

From the above statement, it is clear that light is highly essential for photosynthesis. The rate of photosynthesis is slower at lower intensity and it increases linearly with increasing light intensity up to a particular point, known as "Saturation point," and after attaining this point, it remains constant. The intensity of light at which the plants no longer carry on photosynthesis or when the photosynthesis balances respiration is called compensation intensity.

4. Effect on Respiration:

In plants, respiration is a process of the oxidation of carbohydrate (produced in the photosynthesis) into carbondioxide and water. According to Calvin (1958), the rate of respiration increases at higher light intensity and it decreases at lower light intensity.

5. Effect on Transpiration:

The rise in atmospheric temperature which may be due to the conversion of solar radiation into heat increases the rate of transpiration. The process of opening of stomata (which depends upon light) leading to loss of water from the aerial surface of plants is known as transpiration.

6. Effect on Production of Hormone:

Light inhibits the synthesis of auxins or growth hormones in plants as a result of which the shape and size of the plants gets modified.

7. Effect on development of Flowers, Fruits and Vegetative parts:

The intensity of light largely influences the growth and development of flowers, fruits and vegetative parts of plants. Light of higher intensity favours development of flowers, fruits and seeds but light of lower intensity promotes the development of vegetative parts and causes delicacy.

8. Effect on formation of Anthocyanin Pigment:

Intense light helps in the formation of anthocyanin pigments in plants. The plants in Alpine regions have beautiful flowers containing this pigment.

9. Effect on Movement:

The effect on sunlight in modulating the movement of plants is called phototropism or heliotropism. The elongation on stem towards light is known as positive photo-tropism and the movement of roots away from light is known as negative photo-tropism. The leaves grow transversely to light.

10. Effect on Photoperiodism:

The response of plants to the relative length of the day (known as photo-period) is known as photoperiodism. According to the response of the plants to the length of the photo-period, the plants have been classified into three groups:

(i) Long Day Plants (L.D.P.):

The plants which bloom when the light duration is more than 12 hours per day e.g. radish, potato, spinach, etc.

(ii) Short Day Plants (S.D.P.):

The plants which bloom when the light duration is lesser than 12 hours per day e.g. cereals, tobacco, cosmos, dahlia etc.

(iii) Day Neutral Plants (D.N.P.):

The plants which show little response to the length of the day light e.g. cotton, balsam, tomato, etc.

11. Effect on Seed Germination:

The germination of seeds is largely influenced by light. In most of the plants, the red light induces seed germination and in some plants blue light promotes the process. In some cases, far-red light is seen to inhibit seed germination.

12. Effect on Distribution of Plants:

The duration and intensity of light plays an important role in determining the distribution of plants. Hence the vegetations of different geographical regions are different from one another (Krebs 1972).

13. Effect on Photomorphogenesis:

The development of plants in seedling stage is controlled by light. The seedlings present in dark condition are non-green and highly elongated with poorly developed root system and no-foliage. However, an exposure of the dark grown seedling to light makes it normal.

2.2.2 Temperature

Temperature is a measurement of the degree of heat. Like light, heat is a form of energy. The radiant energy received from the sum is converted into heat energy. Heat is measured in calories. The temperature at which physiological processes are at their maximum efficiency is called optimum temperature.

The minimum, optimum and maximum temperatures are called cardinal temperatures. The cardinal temperature varies from species to species and in the same individual from part to part. The distributions of plants, animals are also influenced by temperature.

According to heat requirement of plants, Raunkier classified vegetation into following types:

a) **Megatherms:** these plants require hogh temperature throughout the year. These plants are usually found in tropical regions like desert regions.

b) **Mesotherms:** these plants grow in a habitat which is neither too hot nor cold. They cannot withstand much heat or cold. They are usually found in tropical and sub-tropical regions like plain land.

c) **Microtherms:** these plants require low temperature for their growth and prefer temperate habitat. They cannot tolerate high temperature. They are also found in tropical and subtropical regions with higher elevation where temperature conditions are less extreme.

d) **Hekistotherms:** these are plants of alpine region with very low temperature. They can withstand long and severe winter.

- **Effects of Temperature on Plants:**

Temperature plays an important role in affecting the structure, physiology, growth and distribution of plants.

The effects of temperature on plants are briefly listed below:

(i) Effect on Cell and Protoplasm:

In the extremely low temperature, the protoplasm may be frozen to ice. On the other hand, in the extremely high temperature, the protein may coagulate.

(ii) Effect on Metabolism:

In the presence on different enzymes, various metabolic activities in the living organisms are carried out. With a slight increase in temperature, the metabolic activities may increase. However, the metabolic rate may decrease when there is higher increase in temperature. Finally, there will be no such activities when enzymes become defunct.

(iii) Effect on Respiration:

The rate of respiration usually doubles as per the Van't Hoff's law with increase in temperature by 10°C.

(iv) Effect on Development:

The development of plants is influenced by temperature. Temperature requirement vary among plants for their development. Some of the plants prefer higher temperature, while some others prefer cold for their development.

(v) Effect on Growth:

When the temperature is slightly increased, the seedlings of several plants exhibit the elongation of the hypocotyle.

(vi) Effect on Transpiration in Plants:

Transpiration is the process of loss of water from the aerial surface of plants. The rate of transpiration increases with increase in atmospheric temperature and *vice- versa*.

2.2.3. Water and rainfall

Water is an indispensable part of land and soil productivity. The misuse of water leads to soil degradation and erosion. Proper management of water is highly necessary for better production. Water is also indispensable for human beings.

Thus, it goes without saying that water is the most important substance necessary for life. All the physiological processes take place in the medium of water. Protoplasm, the very basis of life, is made up mostly of water. Plants show considerable variation in their requirements of water.

On the basis of nature of soil, the water requirements of different plants are as follows:

(a) Hydrophytes:

Plants living in water and require large quantities of water for their sustenance.

(b) Xerophytes:

Terrestrial plants which can tolerate extremely dry conditions and pass through long periods without water.

(c) Mesophytes:

Terrestrial plants that require moderate quantity of water.

The main source of soil water is precipitation. The rainfall provides water to plants and animals. Rainfall occurs due to interchange of water between earth's surface and the atmosphere. This is known as the hydrologic cycle. In this cycle two important things are precipitation and evapo-transpiration. Penck has classified climate on the basis of precipitation- evaporation ratio into following types:

i. *Arid:* it is characterized by having evaporation greater than precipitation.

ii. *Arid-humid:* here evaporation is more or less equal to precipitation.

iii. *Humid:* here evaporation is lesser than precipitation.

Annual rainfall determines the types of vegetation in any region. We find evergreen forests in tropical regions due to heavy rainfall throughout the year. Grasslands are found in such regions where there is heavy rainfall during summer and low rainfall during winter.

In our country there are differences in the quantity of annual rainfall. Also, the distribution of rainfall in different seasons of the year is different. Therefore, we find that vegetation types in different parts of the country are much different from each other. We also notice different types of animals and birds in different geographical regions due to changes in vegetation and in turn, vegetation causes changes in the types of forests, animals and birds.

Different regions of the earth receive, different quantity of rainfall depending upon the geographical features and the availability of moisture laden winds. The quantity, duration and intensity of rainfall regulate plant life.

Only a part of the rain water is used by the plants, the rest is lost in many ways like evaporation and run-off. Thus, there is a difference between the actual rainfall and the effective rainfall.

The evaporation is governed by the moisture content and the temperature of the atmosphere, and hence, in effective rainfall the total rainfall in relation to temperature is taken into account.

The quantity of water that a soil holds or that infiltrates into the soil depends upon the properties of soil and type and density of vegetation covering it. In a bare area, the rain drops beat the compact surface of the soil and loosen the soil particles which are washed away.

In a clay soil, the clay particles are densely packed and these stick to each other. As the space is reduced, the water percolation is checked. This results in horizontal movement of water in the form of run-off, resulting in the loss of effective rainfall. Inverse is the case with a sandy soil, where in water infiltrates into the soil. The vegetation intercepts the beating effect of rainfall and thus, water is gradually soaked in soil from where plants use it over a long period.

The degree of slope is another factor for water loss. Therefore, on hill slopes, terrace cropping is practised.

Though most of the plants cannot make use of atmospheric humidity, several lichens, filmy ferns and epiphytic orchids can absorb humidity from the air.

2.3 Edaphic Factors

Edaphic factors deals with different aspects of soil, such as the structure and composition of soil including its physical and chemical features. A galaxy of complex factors constitutes the soil.

Soil is usually defined as "any part of earth's crust in which plants root". The soil is constituted as a result of long-term process of complex interaction leading to the production of a mineral matrix in close contact with interstitial organic matter consisting of both living and dead.

After a long time, the parent mineral matter takes the modified shape which forms soil. The interactions among climatic, topographic and biological factors pave the process of transformation and modification of mineral matter into the soil.

Thus, soil has mainly the following components:

(i) Mineral matter.

(ii) Soil organic matter or humus.

(iii) Soil water/soil solution.

(iv) Soil Atmosphere.

(v) Biological system (fauna of bacteria, fungi, algae, protozoa, ratifies, arthropods, etc.).

According to Dakuchayer (1889), "soil is a result of the actions and reciprocal influences of parent rocks, climate, topography, plants, animals and age of the land."

2.3.1 Formation of Soil

The soil development may be classified into two major phases:

1. Weathering of parent rock.
2. Maturation and profile development.

1. Weathering

The weathering is the process by which large rocks are broken down to small pieces and converted to a fine powder. This is a long term process occurring mostly under the influence of the climatic conditions of the area, and hence called weathering.

The mechanical or physical weathering takes places by the movement of rocks with running water or ice (as in rivers and glaciers) and by action of gravitational forces as landslide in mountainous regions. The freezing of water in small crevices in the rocks may also exert enough pressure to breakdown rocks into pieces.

In hot desert, large diurnal fluctuations in temperature also cause breaking down of rocks, especially exfoliation of sedimentary rocks. The chemical weathering includes hydrolysis, oxidation and carbonation of mineral compounds in the rocks by the action of weak acids like carbonic acid. Traces of sulphuric acid and nitric acid also occur in certain regions and influence weathering.

Biological weathering includes the action of various organisms, particularly lower plants (lichens and mosses) which secrete various organic acids, and produce humic acids after death and decay. These acids help in the weathering process.

2. Maturation

The maturation process determines the structure of the soil profile and the type of the soil. It is largely influenced by the prevalent climatic conditions, and indirectly by the type of vegetation found in that area.

There are four major maturation processes:

(a) **Melanization:** In the region of low humidity, the humus derived from the dead organic matter gets mixed in the upper layer of the soil which becomes dark coloured.

(b) **Podzolization:** In the regions of high humidity high rainfall and low temperature, the minerals in the humus get leached from the upper horizon (alluvial) and get precipitated in middle of B- horizon forming a hard pan. This leaves an ash coloured surface layer of the soil from which the soil derives its name podzol.

(c) **Qleization:** In very cold climates, the underground water lying above the rock layer continuously reacts with the partly weathered mineral matter. The hydrolysis and reduction of the minerals results in the formation of a hard gley horizon.

(d) **Laterisation:** In very hot and humid climate, the rapid decay of organic matter and release of bases from organic combination results in the solubilisation of silica and formation of oxides of Fe, Al, Mn, etc. This results in a red coloured soil, rich 'h iron and deficient in bases and organic matters.

Depending upon the organic content, soils are generally classified into following types:

i) Mineral soils (rich in mineral particles)

ii) Peat (rich in organic matter, found in wet areas)
iii) Mors (low in basic minerals)
iv) Mulls (rich in base content)

Muller (1879, 1884) has recognised two kinds of humus: mor and mull. Mor-humus is acidic, with fungal components and low in bacterial content. It is deficient in calcium and develops on sandy soil under conifers. Mull, on the other hand, is slightly alkaline or neutral, with high bacterial content. Intermediate between the two is moder which is rich in nutrient and has varied faunal components.

2.3.2 Soil Profile

Soil profile is the vertical section through the mature soil layers up to the parental material that reveal the different layers of soil. Generally there are three different horizons of soil, e.g.-

'A-horizon': upper horizon

'B- horizon': middle horizon below the A- horizon.

'C- horizon': lower most horizon below the B-horizon and above the bedrock.

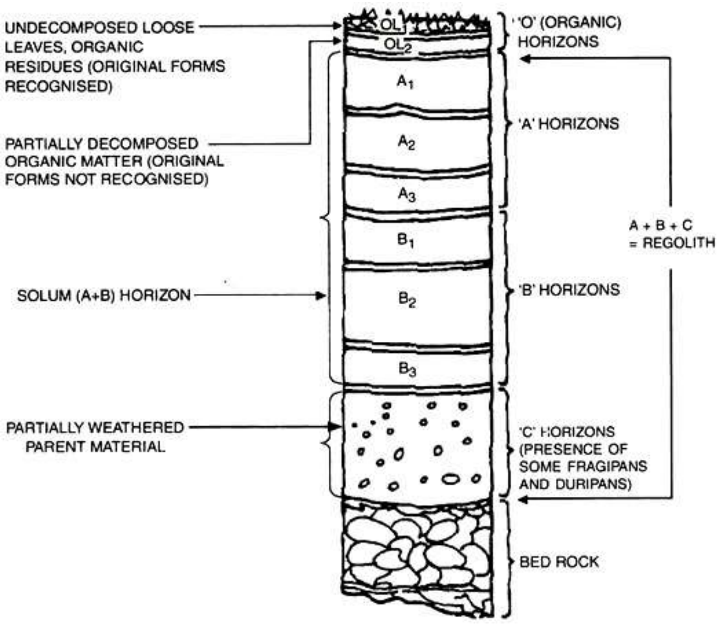


Fig. 2.1. Soil Profile.

Some workers recognize additional horizon- 'O- horizon', which is present above the A-horizon and represent the organic layer. The A- horizon represents the top stratum and is subjected to marked leaching. It is the most biologically significant layer with plant roots, small animals, microflora and fauna. It is provided with high organic matter and huge amount of nutrient.

The B- horizon or the subsoil is present just below the A- horizon with little organic matter, very few plant roots and sparse microflora and fauna. Iron and aluminium compounds are often accumulated in this region. A- and B- horizons collectively represents the true soil. C-horizon is present below the B-horizon and contains the parent materials of the soil. In this layer organic matter is present in very small amount and usually devoid of any life.

2.3.3 Effect of edaphic factors on plants

i. The soil may be acidic, alkaline or neutral in nature and hence affect the growth and distribution of plants. The growth and productivity of many species of plants are dependent on soil acidity, e.g. species of *Rhododendron*, *Rubus* are acid loving. Most of the field crops, such as barley, maize, soybeans, potato are slightly acid loving. Slightly alkaline soils are favoured by many other plants, ferns etc. Soil acidity also affects the availability of phosphate, iron, manganese and other ions. The accumulation of calcium, sodium and manganese salts results in alkalinity of the soil. Thus soil reaction affects the growth and development of plants in a particular soil.

ii. Nature and availability of soil nutrients also affect the plant growth. Usually inorganic solutes are absorbed by the plants in ionic form. The requirements of nutrients also vary among species. Some plants can grow in high salt concentrations called *halophytes*. There are plants which prefer alkalinity and calcium rich soil. These plants are known as *calcicoles* or *calciphytes*. On the other hand, some plants do not thrive well in calcium rich soil and are known as *calcifuges* or *oxylophytes*. Soil fertility is also correlated with humus content in the soil. Humus is the main source of nutrients for soil-microorganisms and green plants.

iii. Soil temperature along with other edaphic factors influences the properties of soil. Low temperature reduces the absorption of water and minerals by roots. Soil temperature is also important in determining the geographical distribution of plants.

iv. Soil air content present in between the soil particles which mainly contain lower amount of oxygen and high carbon dioxide content as compared to air. Soil air content affects the growth of the plants and microorganisms. Water logged soil usually are deficient of oxygen. Soil oxygen contents also help in respiration of underground parts of plants as well as germination of seeds.

v. The plants, animals and microorganisms living in the soil have a marked effect on the soil fertility. Decomposer, particularly fungi, bacteria, etc play a significant role in cycling of nutrients and thus a significant role in fertility of the soil. Some soil organisms secrete beneficial substances which markedly affect the growth of the plants. Some bacteria as well as blue green algae help in fixation of atmospheric nitrogen and thus increasing fertility. Some micorrhizal fungi help in the growth and development of plants by providing nutrients.

2.4 Hydrophytes

Hydrophytes are plants growing in water or soil covered with water. Plants of lakes, ponds, streams and other aquatic system as well as plants of marshy land also belong to this category. They are adapted to low oxygen content as oxygen dissolve less in water. They also have less amount of mechanical and water conducting tissues. The hydrophytes are classified into-

a) Free floating hydrophytes (e.g. *Pistia, Lemna, Spirodella*, etc.)

b) Rooted hydrophytes with floating leaves (e.g. *Nymphaea, Nuphar, Nelumbium*, etc.)

c) Rooted submerged hydrophytes (e.g. *Vallisneria, Hydrilla, Ceratophyllum*, etc.)

d) Rooted and immersed hydrophytes or helophytes or amphibious plants (*Typha, Scirpus, Sagittaria, Alisma*, etc.)

The adaptive features of hydrophytes are mentioned below:

2.4.1 Morphological adaptations

1. Root system is poorly developed.
2. Roots of floating hydrophytes show very poor development of root hairs, absence of true root caps, with root pockets to protect their tips from injuries. (e.g. *Eichhornia*)
3. Rooted hydrophytes like *Hydrilla, Vallisnera, Elodia* derive their nourishment through their body surfaces. More plants partly depend on their roots for the absorption of minerals from the soil. Roots are totally absent in *Ceratophyllum, Salvinia, Azolla, Utricularia*, etc.
4. In *Jussiaea repens* two types of roots develop. Some of them are normal, while others are negatively geotropic, floating roots, spongy in nature and keep the plants afloat.
5. In free floating hydrophytes, the stem is thick and short, floating on the surface of water (e.g.- *Eichhornia*).
6. In *Nymphaea and Nelumbium* the stem is a rhizome. These rhizomes live for many years and produce leaves every year.
7. In rooted plants with floating leaves, the leaves are large, flat and entire (e.g. *Nymphaea, Victoria*). Their upper surface is coated with wax. The wax coating protects the leaves from mechanical and physical injuries and also prevents clogging of stomata by water.

8. In floating plants of *Eichhornia, Trapa,* etc. the petioles become characteristically swollen and become spongy, providing buoyancy.
9. Plants such as *Limnophila heterophylla, Sagittaria, Ranunculus, Salvinia, Azolla*, etc. show heterophylly, with submerged dissected leaves offering little resistance against the water currents, and absorbing dissolved carbon di-oxide from water. The aerial leaves show typical mesophytic features. It acts as foliage leaf.
10. Pollination (e.g. *Vallisneria*) and dispersal of fruits and seeds are accomplished by the agency of water.

2.4.2 Anatomical adaptations

1. The root and shoot systems show common features such as cuticle which is very thin or absent.
2. Epidermis is usually a single layer of thin walled cells, not protective in function.
3. Cortex is well developed. It has numerous air chambers. It helps in buoyancy and rapid gaseous exchange.
4. Mechanical tissues are generally absent.
5. In the vascular tissue, xylem vessels are less common. Only tracheids are present in submerged forms.
6. In amphibious form, the xylem and phloem are well developed (e.g. *Limnophila heterophylla*) or vascular bundles may be aggregated towards the centre. (e.g. *Jussiaea*)
7. Epidermal cells of leaves contain chloroplasts and they can function as photosynthetic tissue, especially where the leaves and stems are very thin, e.g. *Hydrilla*
8. Stomata are totally absent in submerged, but in floating leaves, stomata are confined only to the upper surface. In amphibious plants stomata may be scattered on all the aerial parts.
9. In submerged leaves, air chambers are filled with respiratory and other gases and moisture.
10. In Water Lilly (*Nymphaea*) and some other plants special type of star shaped lignified cells called asterosclereids develop. It gives mechanical support to the plants.
11. The aquatic plants exhibit a low compensation point and low osmotic concentration of cell sap.
12. Mucilage cells and mucilage canals secrete mucilage to protect the plant body from decay under water.

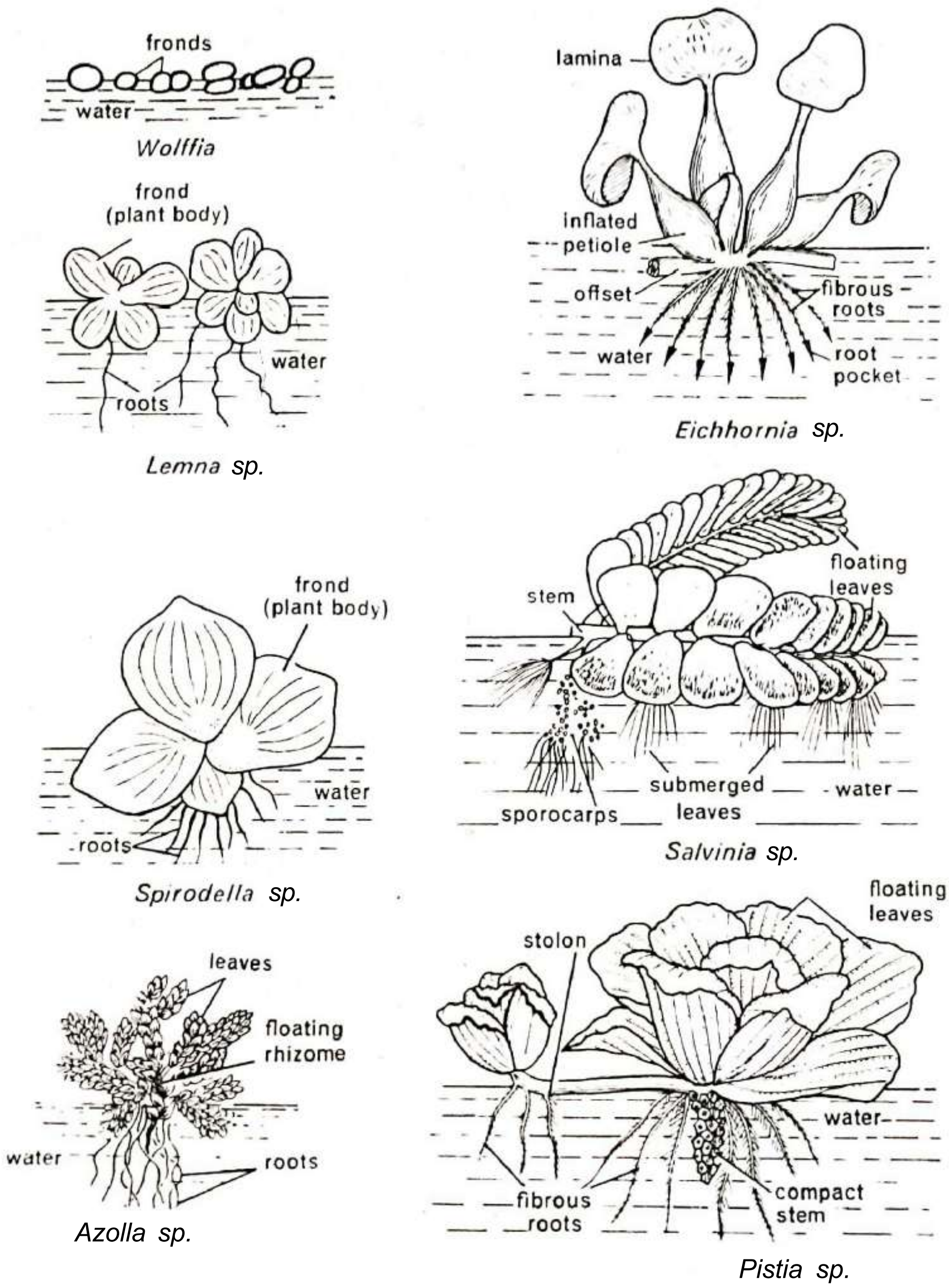


Fig. 2.2. Free-floating hydrophytes.

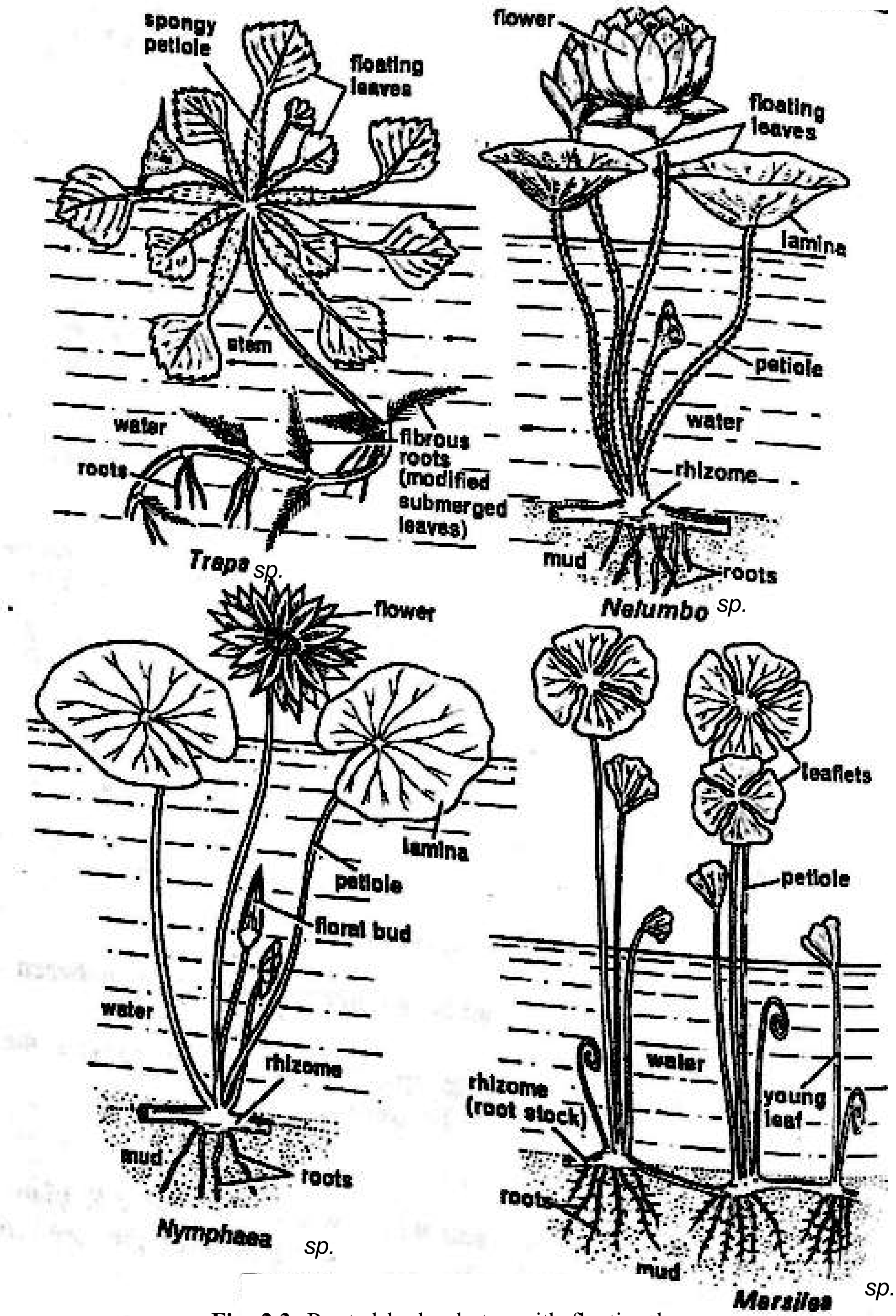


Fig. 2.3. Rooted hydrophytes with floating leaves.

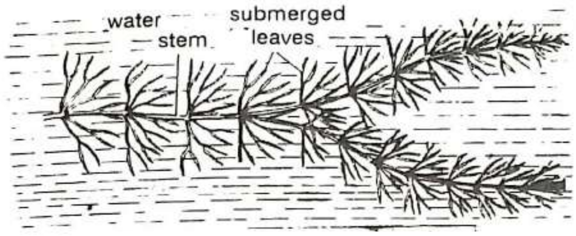


Fig. 2.4. Submerged floating hydrophyte.

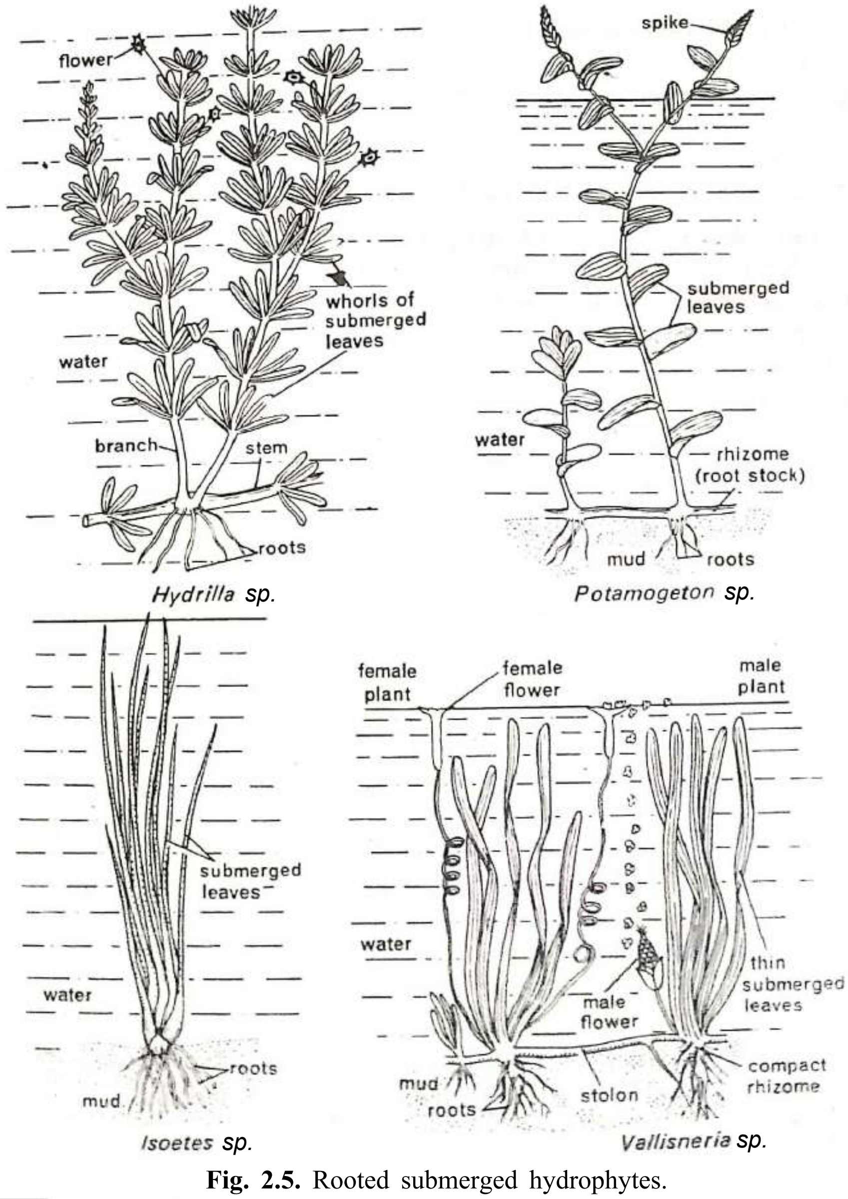


Fig. 2.5. Rooted submerged hydrophytes.

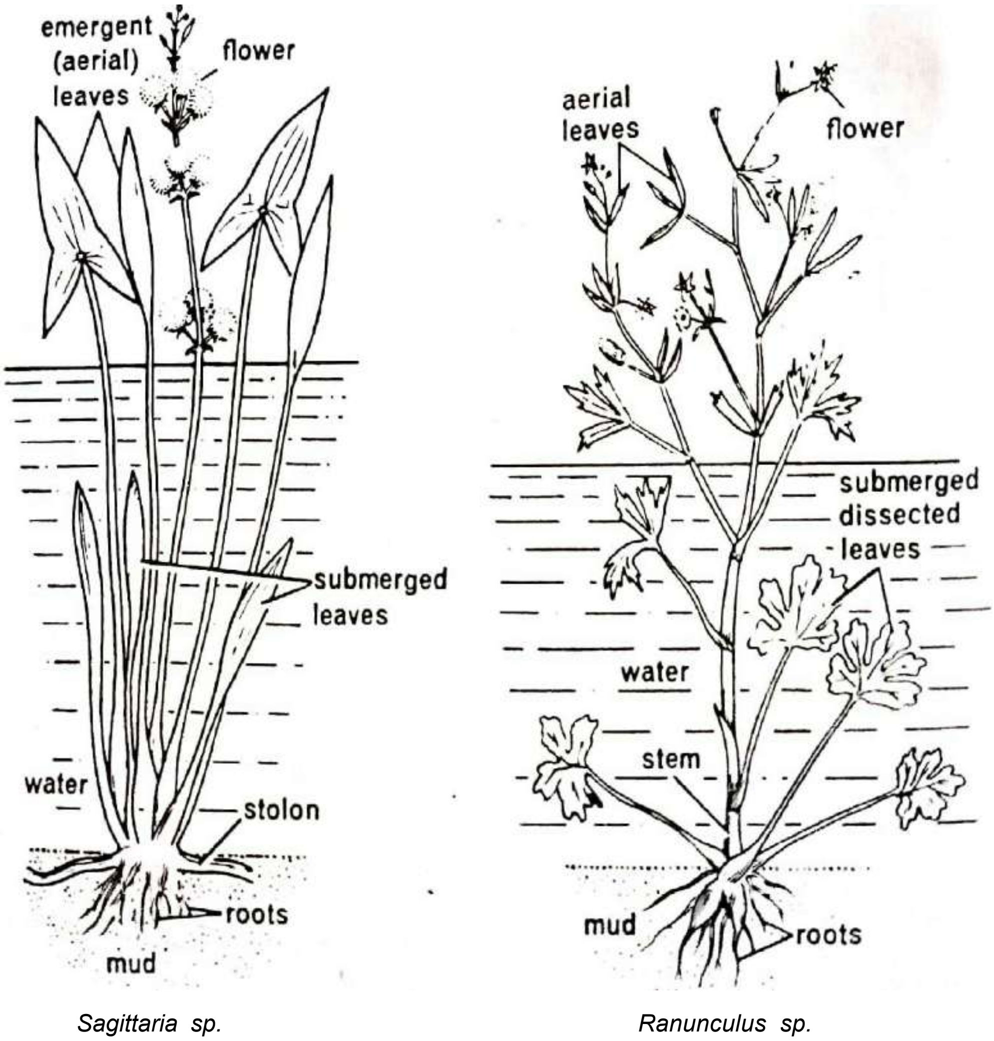


Fig. 2.6. Rooted emergent hydrophytes.

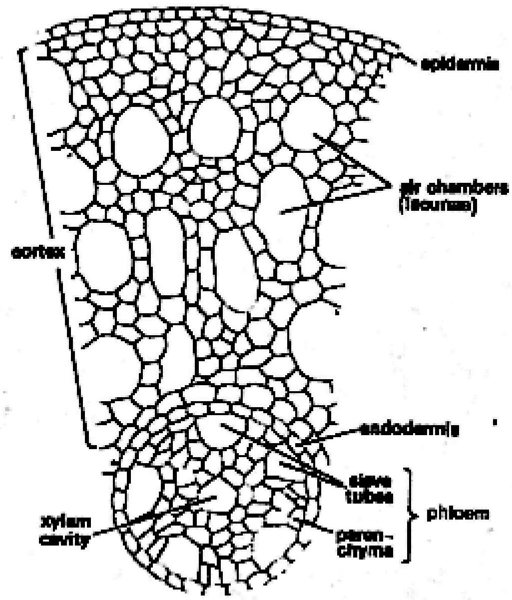


Fig. 2.7. T.S. root of *Potamogeton pectinatus* (submerged — hydrophyte). Note the absence of root hairs and cuticle; undifferentiated broad cortex with air chambers vascular tissues poorly developed, represented mainly by phloem; lack of mechanical tissues.

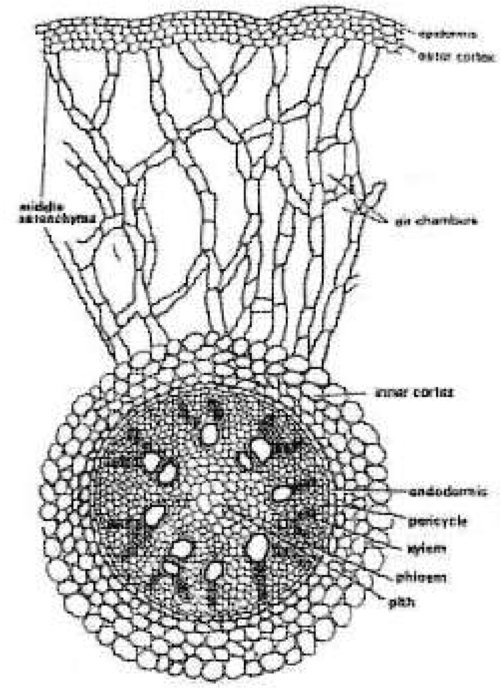


Fig. 2.8. T.S. root of *Eichhornia* (floating-leaved hydrophyte). Note, the absence of root hairs and cuticle; undifferentiated well developed cortex with abundance of aerenchyma; mechanical tissues represented only by xylem elements.

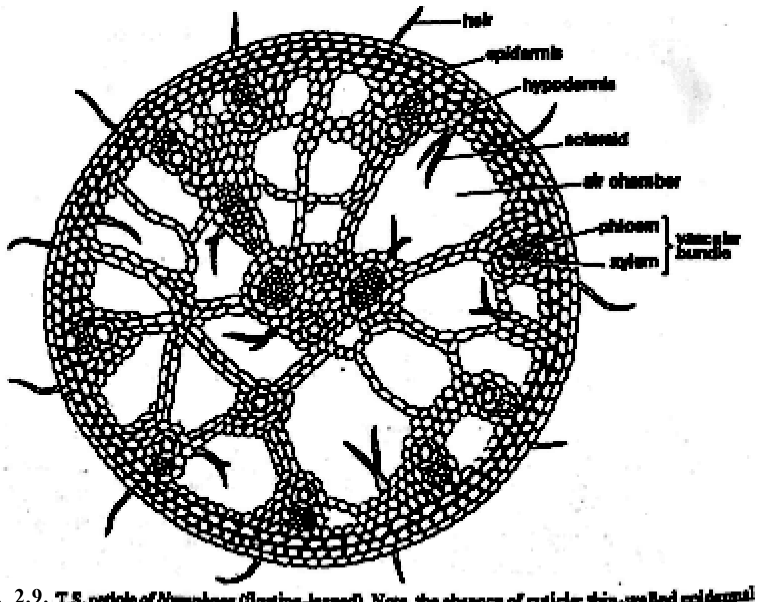


Fig. 2.9. T.S. petiole of *Nymphaea* (floating-leaved). Note, the absence of cuticle; thin-walled epidermal cells; reduced mechanical tissues represented only by a few layers of collenchymatous hypodermis; abundance of aerenchyma; vascular elements with abundance of phloem, xylem being represented by lacunae.

2.5 Xerophytes

Plants which grow in dry habitats or xeric conditions are called xerophytes. Xeric habitats are places with less amount of available water. Habitats may be physically dry (e.g. desert, rock surface, etc.) or may be physiologically dry (e.g.- saline habitats, acidic habitats, etc.) or may be both physically and physiologically dry (e.g.- slopes of mountain). These plants can withstand extreme dry conditions, but can also grow in mesophytic condition. The main adaptive feature of these plants is to reduce the water loss from their body, to develop mechanisms to store water within their body (succulence) or have a well developed root system to absorb water from the soil. The adaptive features of xerophytes are as follows:

2.5.1 Morphological Adaptations of Xerophytes

1. The root system is very well developed with root hairs and root caps, e.g. *Calotropis*.
2. The roots are fasciculated as in *Asparagus*.
3. Stems are stunted, woody, dry, hard, ridged, and covered with thick bark, may be underground, e.g. *Saccharum*. In *Opuntia* phylloclade (stem flattened leaf like structure) is covered with spines (modified leaves).
4. Stem is covered with thick coating of wax (e.g. *Opuntia*) or silica (e.g. *Equisetum*) or dense hairs (e.g. *Calotropis*).
5. Stems may be modified into a thorn (e.g. *Ulex*) or cladodes, i.e. small needle shaped leaf like structure (e.g. *Asparagus*).
6. Leaves are very much reduced, small scale-like, sometimes appearing only for a brief period (Caducous) or sometimes modified into spines or scales, e.g. *Casuarina*, *Ruscus*, etc.
7. Lamina may be narrow or needle like as in *Pinus* or divided into many leaflets as in *Acacia* or may be succulent as in *Aloe*, *Sedum*, etc.
8. In Euphorbia and *Zizyphus jujuba* stipules become modified into spines.
9. Xerophytes like *Calotropis* have hairy covering on the leaves and stems to check transpiration.

2.5.2 Anatomical Adaptations of Xerophytes

1. Root hairs and root caps are well developed to facilitate absorption of water as in *Opuntia* and many other cacti.
2. Roots may become fleshy to store water, e.g. *Asparagus*.
3. In succulent xerophytes, stems possess a water storage region (thin walled parenchyma cells)

4. Stems of non-succulent xerophytes show a very thick cuticle, well developed epidermis with thickened cell wall, several layered and sclerenchymatous hypodermis, e.g. *Casuarina*.
5. The stems have sunken stomata (e.g. *Equisetum, Nerium*, etc.) and well developed vascular and mechanical tissues.
6. Leaves usually show well developed cuticle. Sometime leaves develop succulence as in Aloe. Presence of multilayered epidermis (e.g. *Nerium*), sclerenchymatous and several layered hypodermis (e.g. *Pinus*), bulliform cells (e.g. *Saccharum*) are also xerophytic features.
7. Mesophyll is well differentiated and vascular tissues and mechanical tissues are well developed.

2.5.3 Physiological Adaptations of Xerophytes

1. In CAM plants (e.g. *Kalanchoe, Sedum*, etc.) the stomata remain open during night and remain closed during the day. This unusual feature is associated with metabolic activities of these plants.
2. In xerophytes, the chemical compounds of cell sap are converted into wall forming compounds (e.g. Cellulose, Suberin, etc.)
3. Some enzymes, such as catalases, perioxidases are more active in xerophytes than in mesophytes.
4. The capacity of xerophytes to survive in long period of drought is due to the resistance of the hardened protoplasm to heat and desiccation.
5. The Xerophytes have very high osmotic pressure, which increases the turgidity of the cell sap.

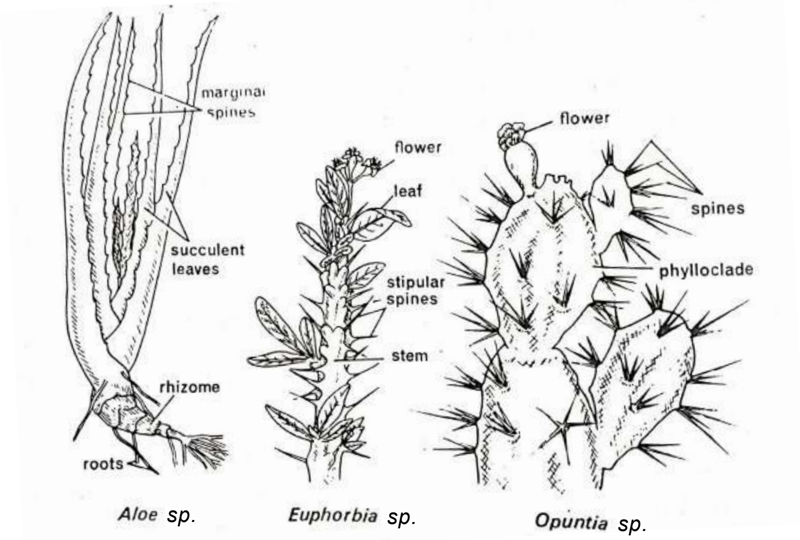


Fig. 2.10. Succulent xerophytes.

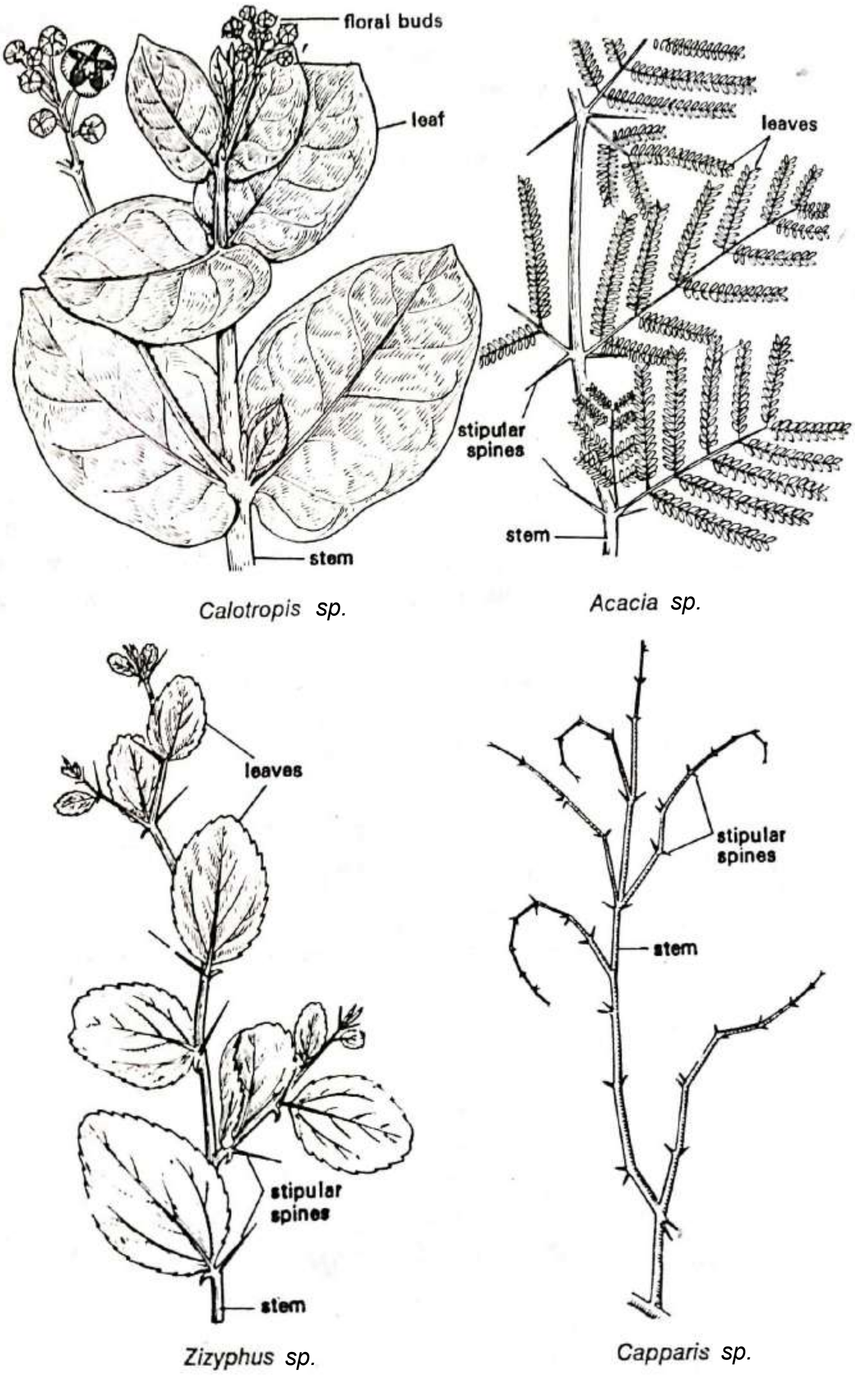


Fig. 2.11. Non-succulent perennials.

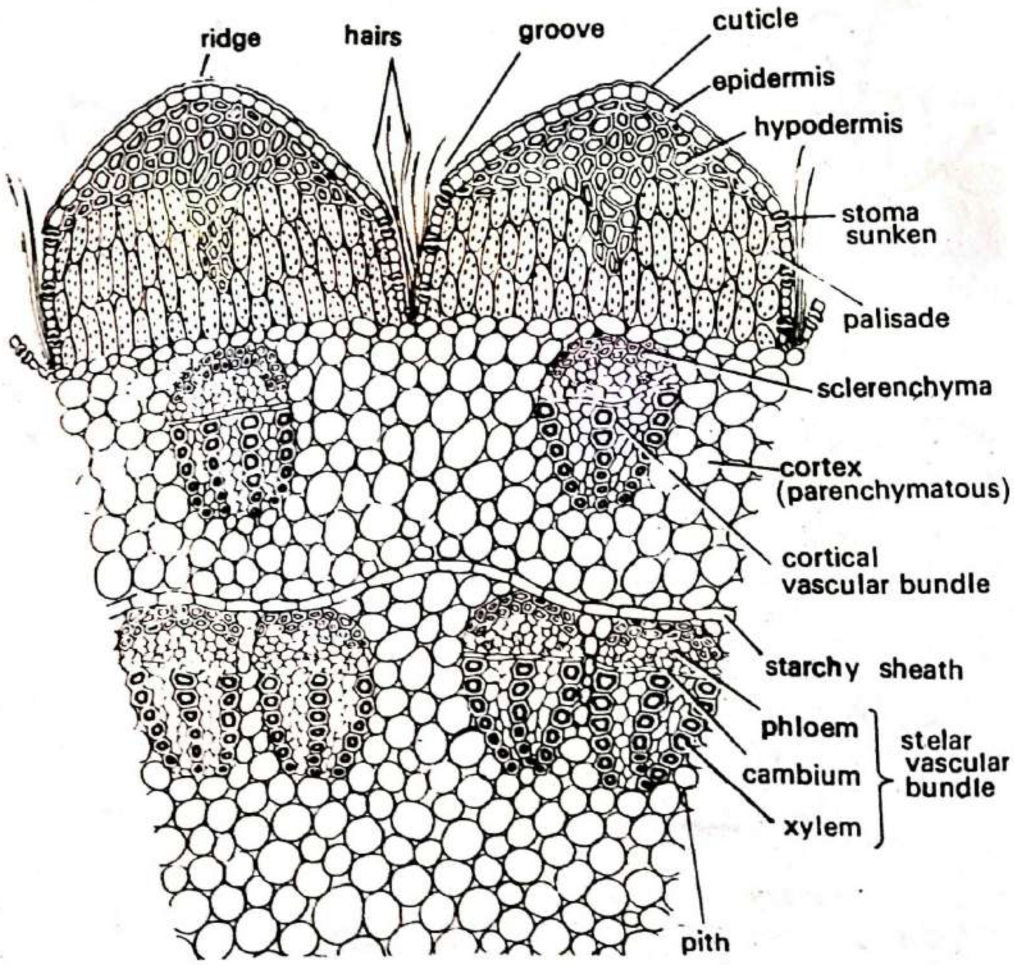


Fig. 2.12. T.S. stem (a part) of *Casuarina equisetifolia.* Note, the thick cuticl; sunken stomata, confined only to grooves; presence of hairs in grooves; sclerenchymatous hypodermis; green palisade region of subhypodermal cortex; well-developed vascular and mechanical tissues.

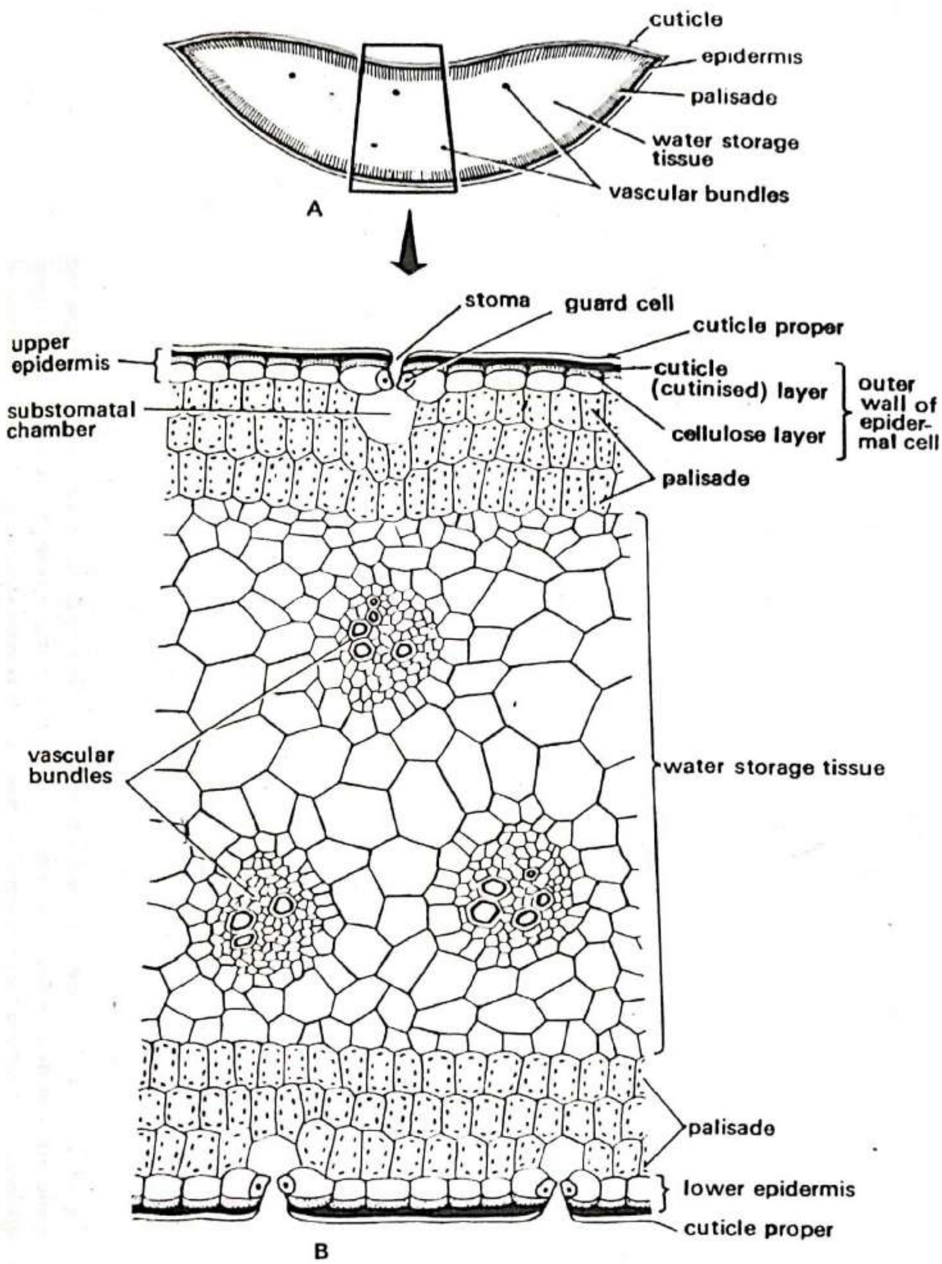


Fig. 2.13. T.S. leaf of *Aloe sp.* (succulent). A-diagrammatic B-central part of the same cellular and enlarged. Note, the well-developed centrally placed water-storage tissue made up of turgescent parenchymatous thin-walls cell located in between the upper and lower palisade layers; thick cuticle; sunken stomata; thickened outer walls of epidermal cells, well-developed palisade tissue.

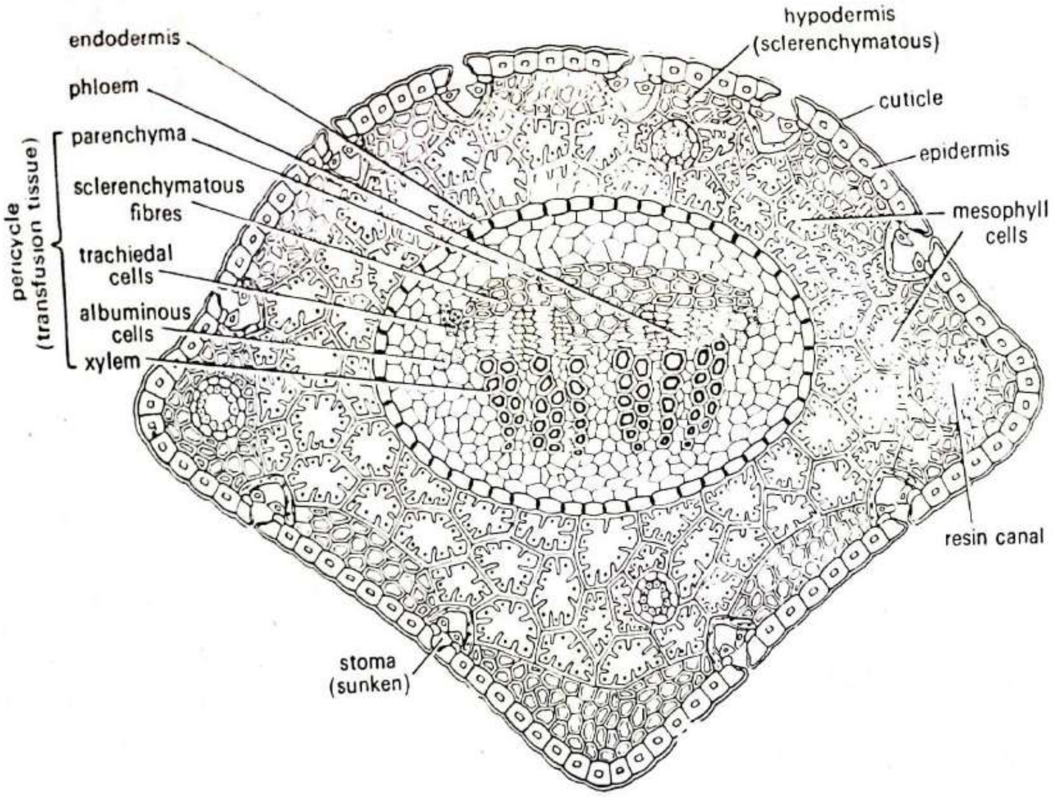


Fig. 2.14. T.S. needle of *Pinus roxburghii* (non-succulent perennial). Note, thick cuticle; thic-walled epidemis, sclerenchymatous hypodermis; sunken stomata; mesophyll cells with infoldings; complex transfusion tissue; well developed vascular tissues with abundance of xylem elements.

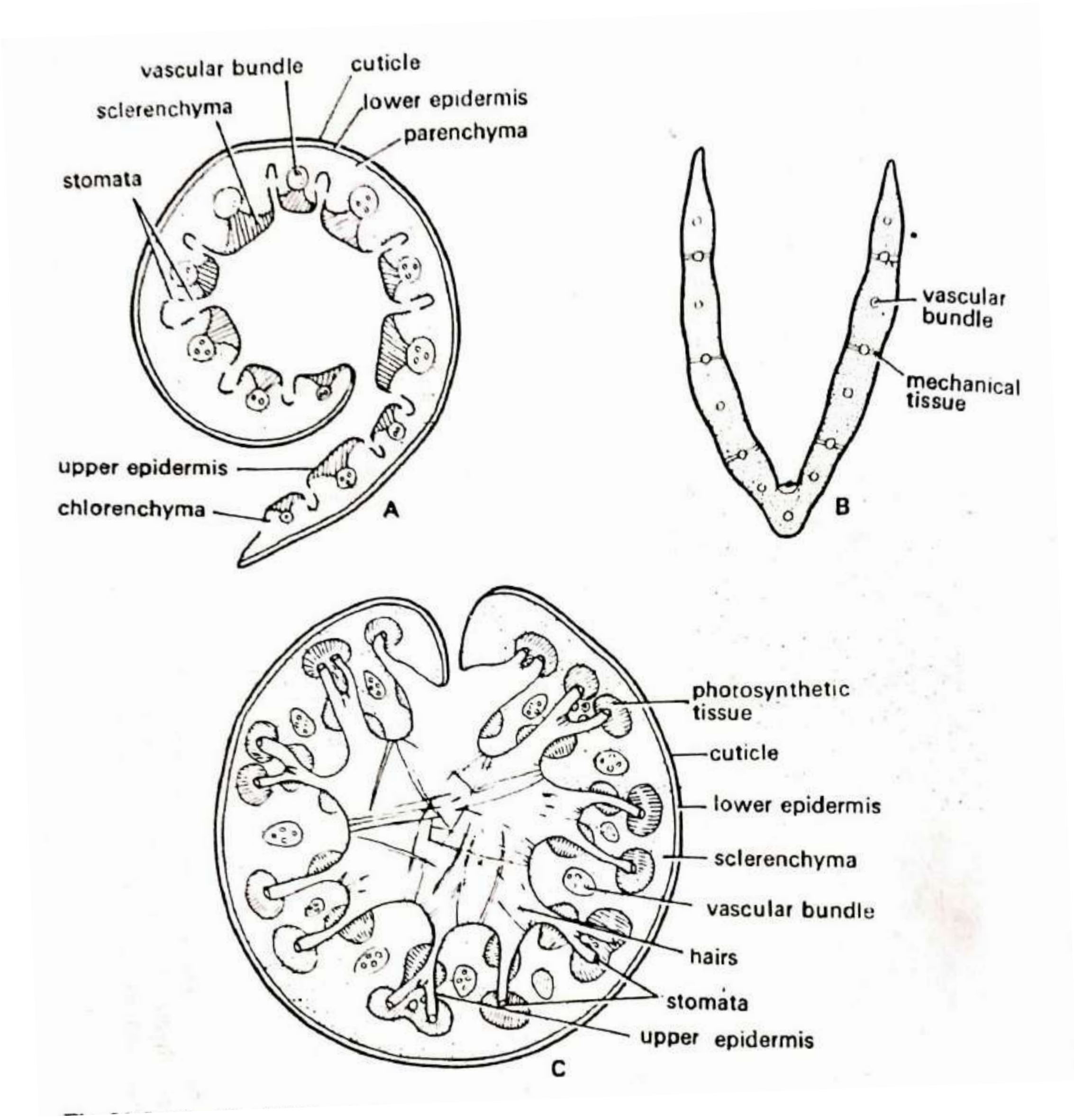


Fig. 2.15. Leaf rolling/folding devices in some non-succulent perennials. Cross sections (diagrammatic) of rolled/folded leaves of *Ammophila arenaria* (A). Note, that the leaf blade is rolled inwards with ridges and grooves on its adaxial side, thick cuticle; stomata confined to upper epidermis only, which came to lie in a hidden position due to leaf rolling; sclerenchymatous hypodermis. *Poa pratensis* (B), where the leaf is folded and *Agropyron sp* (C), Note the leaf rolling in the same manner as in (A) and the presence of thick cuticle, mechanical tissues, hairs, hidden stomata, etc.

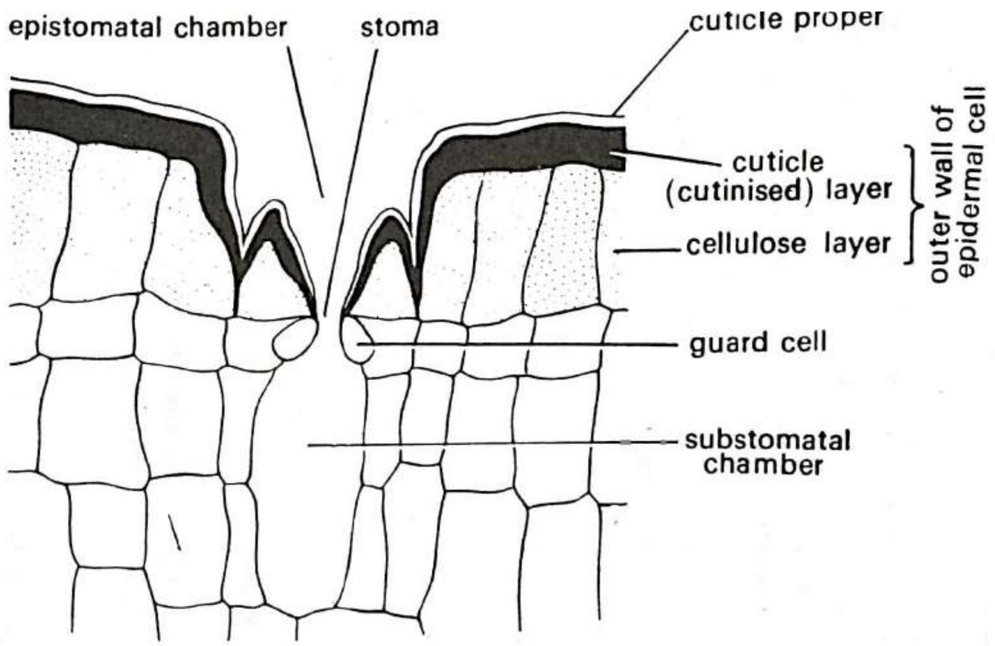


Fig. 2.16. A part (mainly epidermal) of T.S. leaf of a succulent xerophyte to show thick cuticle, heavy depositions of cutin and cellulose on outer walls of epidermal cells, and stomata.

2.6 Summary

From this chapter we are able to understand the different ecological factors, particularly the physical factors which affect the growth and development of a plant in a particular ecosystem. Light is one of the most important factors required for the growth and development of a plant, because it is essential for the process of photosynthesis. Light also affects the respiration, transpiration, production of hormone, development of flowers, fruits and vegetative organs, photoperiodism, seed germination and photomorphogenesis. Similarly, temperature also affect the growth and development of a plant. High or low temperature affects the protoplasm and protein function. So, it has direct effect on metabolism, respiration, development, growth and transpiration of plants, Water and rainfall is essential for plant survival and thus affect plant growth and different types of plants develop in different soil moisture conditions. They can be subdivided into hydrophytes, mesophytes and xerophytes based on water requirements of plants, Edaphic factors or soil characteristics are also very significant for plant development and growth. Soil moisture, temperature, pH, nutrient status, microbiota affect the plant development and growth and also their distribution. Hydrophytes are aquatic plants growing in water or soil covered with water. They have weakly developed root system, anisophyly is common, stem soft, sometimes spongy with weak mechanical tissue and vascular system, stomata are usually absent in submerged form or present on the dorsal side of the floating leaves and pollination usually takes place by water (hydrophily). Xerophytes are growing in soil with less amount of available water and thus possess characteristics opposite to hydrophytes. They are usually devoid of leaves, stems stunted, woody, sometimes succulent, covered with thick wax or silica or hairs, sometimes modified to cladode, root system is very well developed. Presence of thick cuticle, sunken stomata, well develooped vascular tissue and mechanical tissue are some of the important anatomical features of these plants.

2.7 Questions & Answers

Q1. Mention different types of ecological factors.

Ans.: **(i) Climatic or Aerial factors:**

(a) Light ;

(b) Temperature ;

(c) Water ;

(d) Rainfall ;

(e) Humidity ;

(f) Atmospheric gases (wind).

(ii) Topographic or Physiographic factors:

(a) Altitude;

(b) Direction of mountain chains and valleys;

(c) Steepness and exposure of slopes.

(iii) Edaphic factors:

These deal with formation of soil, its physical and chemical properties and details of related aspects.

(iv) Biotic factors:

These are all kinds of interactions between different forms of life. These are plants, animals, micro-organisms, etc.

(v) Limiting factors:

A limiting factor is that substance of quality in the environment, the supply of which is least abundant or over abundant in relation to the need of the living organism concerned.

Q2. Comment on the effect of light on plants.

Ans.: vide section 2.2.1

Q3. Classify plants based on their heat requirement.

Ans.: vide section 2.2.2

Q4. Comment on the effect of temperature on plants.

Ans.: vide section 2.2.2

Q5. What are hydrophytes? Give example.

Ans.: Plants living in water and require large quantities of water for their sustenance, e.g. *Nymphaea* sp., *Nelumbo* sp., *Pistia* sp., *Lemna* sp., etc.

Q6. What are xerophytes? Give example.

Ans.: Terrestrial plants which can tolerate extremely dry conditions and pass through long periods without water, e.g. *Opuntia* sp., *Agave* sp., *Acacia* sp., etc.

Q7. What are mesophytes?

Ans.: Terrestrial plants that require moderate quantity of water, e.g. *Mangifera* sp., *Syzygium* sp., *Artocarpus* sp., etc.

Q8. What are arid regions? Name one arid regions of India.

Ans.: Arid regions are characterized by having evaporation greater than precipitation, i.e. dried xeric habitat, e.g. Thar desert of India.

Q9. Comment on the effects of water in composition of vegetation.

Ans.: vide section 2.2.3

Q10. What do you mean by edaphic factors?

Ans.: these are factors that chiefly deals with the structure and composition of soil including its physical and chemical features.

Q11. Comment on the formation of soil.

Ans.: vide section 2.3.1

Q12. Write a short note on soil profile with suitable illustration.

Ans.: vide section 2.3.2

Q13. Comment on the effect of edaphic factors on plants.

Ans.: vide section 2.3.3

Q14. Describe the morphological adaptations of hydrophytes with suitable illustrations and examples.

Ans.: vide section 2.4.1

Q15. Describe the anatomical adaptations of hydrophytes with suitable illustrations and examples.

Ans.: vide section 2.4.2

Q16. Comment on different types of hydrophytes with examples.

Ans.: vide section 2.4

Q17. . Describe the morphological adaptations of xerophytes with suitable illustrations and examples.

Ans.: vide section 2.5.1

Q18. Enumerate briefly the anatomical adaptations of xerophytes with suitable illustrations and examples.

Ans.: vide section 2.5.2

Unit 3 ❒ Plant Communities

Structure

3.0 Objective

- In this unit we shall discuss the different types and processes of plant succession along with the succession in an aquatic (hydrosere) or xeric habitat (xerosere).
- You will have an idea about the plant communities and their changes in course of time from this unit.

3.1 Introduction and Objective

A group of similar form of organism in an ecosystem is known as community. It may include different types of organisms like plants, animals, microbes, etc. Different types of communities interact with each other directly or indirectly. Communities have different types of growth forms and structure and have their own developmentsl history known as succession. Plant succession is an orderly process of change in the plant community in a unit area.

❒ A collection of organisms interacting directly or indirectly is a community. Within the community some species carry out similar functions or exploit the same resources. These groups are called guilds. For example, plants growing on saline soils are halophytic guild. A community may be autotrophic when it includes photosynthetic plants and gains its energy from sun; or heterotrophic which depends upon the organic material from other organisms.

The community has attributes (features) the nature of the community is influenced by the interactions of species and their adaptations to the physical environment. These adaptations and interactions are reflected in such attributes of the community as structure, dominance, diversity and niches.

3.2 Characteristics of Plant Community

1. **Species diversity:** Each community is made up of different types of organisms- plants, animals, microbes, etc. which differ from each other. The number of species and population abundance also vary greatly within a community. The species diversity may be categorized into- a) regional diversity that include different communities of whole nations or parts of continents; & b) local diversity: which include the diversity of different communities within a nation in different latitudes.
2. **Growth Form and structure:** communities exist in different growth forms, e.g.- trees, shrubs, herbs, mosses, etc. again these growth forms include different types of organisms, e.g.- broad leaved trees, evergreen trees, etc. the different growth forms determines the structural patterns in a community.
3. **Dominance:** in a community not all the species are equally important. In fact, there are only a few species which determine the nature of community by exerting a major controlling effect on the community. Such species are known as **dominants**.
4. **Succession:** Every community has its own developmental history. It develops as a result of a directional change in it with time.
5. **Trophic structure:** Nutritionally each community exists as a self-sufficient, perfectly balanced organisms with autrophs as well as heterotrophic organisms.

3.2.1 Composition, structure and life forms of a community

i. Each community is characterized by certain characteristics such as species diversity, growth forms and structure, dominance, succession and trophic structure. The special field of **synecology** which is concerned with the structure and classification of plant community is called **phytosociology**. In order to describe and explain these characteristics certain characters are used. These characters can be broadly classified as: analytical characters and synthetic characters.

1). Analytical Characters

The features of the community which can be observed or measured directly in each stand are called analytical characters. They include kinds and number of species, distribution of individuals, species vigour, form, etc. The analytical characters can again be classified as:

1.1. Quantitative Characters: The characters that can be expressed in quantitative terms, i.e., can be measured. These include characters such as frequency, density, abundance, cover and basal area.

1.2. Qualitative Characters: The characters which can be expressed in qualitative way only, i.e., can be described only and not measured. These include physiognomy, phenology, stratification, abundance, sociability, vitality and vigour, and life or growth forms.

2). Synthetic Characters

The synthetic characters are those aspects of community which are based on analytical characteristics and utilize data obtained in the analysis of a number of stands. These describe the makeup of a community and include presence, constancy and fidelity.

ii. Biological and Physical Structure of Community:

Ecologists classify communities in different ways, however all communities have certain characteristics that define their biological and physical structure.

- **Biological Structure:**

  Biological structure of a community refers to number and relative abundance of species. A community can be composed of a few common species: or it can have a wide variety of species. When a single or few species predominate within a community, these organisms are called dominants.

- **Relative Abundance:** Relative abundance can be measured by counting all the individuals of each species in a number of sample plots and determining their percentage. For example, a sample taken from a forest community contains 24 species of trees having a diameter of more than 10 cm. Out of these two species, suppose A and B, make up almost 44 percent of the total stand density. These species are designated as most abundant. The next four species, C, D, E and F make up about 5 percent of stand. These would be classified as next most abundant species.

- **Species Diversity:** Species diversity refers to both the number of species and relative abundance of individuals among the species. A community that contains a few individuals of many species is said to have higher divers.

- **Physical Structure:** The physical structure of the community reflects abiotic factors as well as biotic factors. For example, in a forest the size and height of trees and the density and dispersion of their populations define the physical attributes of the community. These include growth forms and life forms, vertical layering, and horizontal structure.

iii. Growth Forms and Life Forms

Differences in terrestrial communities are defined by the form and structure of vegetation. General appearance of vegetation is referred to as physiognomy. Vegetation may be classified according to growth form or life form.

- **Growth Forms:** The plants may be tall or short, evergreen or deciduous, herbaceous or woody. On the basis of these characteristics growth forms such as herbs, shrubs and trees can be recognized. These can further be subdivided into needle-leaf evergreens, broadleaf evergreens, broadleaf deciduous trees, thorn trees, and shrubs, dwarf shrubs. ferns, grasses.
- **Life Forms:** A Danish botanist Christen Raunkiaer (1903) designed a more useful system. He classified the plant life by life forms. He defined these life forms in terms of height of plants perennating tissue (embryonic or meristematic tissue of buds, bulbs, tubers, roots and seeds that remain inactive over the winter) above ground. Raunkiaer classified all species within a community into six principal life form classes. These are:
- **Phanerophytes (Gr. phaneros = visible):** The plants in which perennial buds are carried well up in the air and are exposed to climatic conditions (present on stem). Trees and shrubs over 25 cm found in moist and warm environment are included in this class.
- **Chamaephytes (Gr. chamia = on the ground):** The plants species in which the perennial s hoots or buds are present on the surface of the ground or 25 cm above the surface are classified in this class. The buds receive organic food from fallen leaves. These include plants growing in cool and dry climates.
- **Hemicryptophytes (Cr. Hemi = half + kryptos = hidden):** This class includes plants whose perennials buds are present at the surface of the ground where they are protected by soil and leaves. Many such plants have rosette leaves and are found in cold, moist climates.
- **Cryptophytes (Gr. kryptos = hidden):** The class consists of species with their perennial buds buried in the ground on a bulb or rhizome, where they are protected from freezing and drying. Such life forms are found in cold, moist climates.
- **Therophytes (Gr. theros = summer):** The annuals, which complete their life cycle from seed to seed in one growing season, are included in this class. The plants survive unfavourable periods as seeds. These life forms are characteristics of desert and grasslands.
- **Epiphytes (Gr. upon):** The plants growing on other plants with roots up in the air are included in this class.

Such a system of classification provides a standard means of describing the structure of a community for the purpose of comparison.

iv. Vertical Structure

Each community has distinctive vertical structure. In terrestrial communities, the vertical structure is determined by their size, branching and leaves which influences and is influenced by the vertical gradient of light.

Stratification in a Terrestrial Ecosystem

In a Terrestrial ecosystem, for example a well-developed forest ecosystem, there are several layers of vegetation. From top to bottom, they are:

Canopy (Autotrophic Layer): It is the primary site of photosynthesis and has major influence on forest. If it is open, considerable sunlight and water will reach the lower layers, and if it is

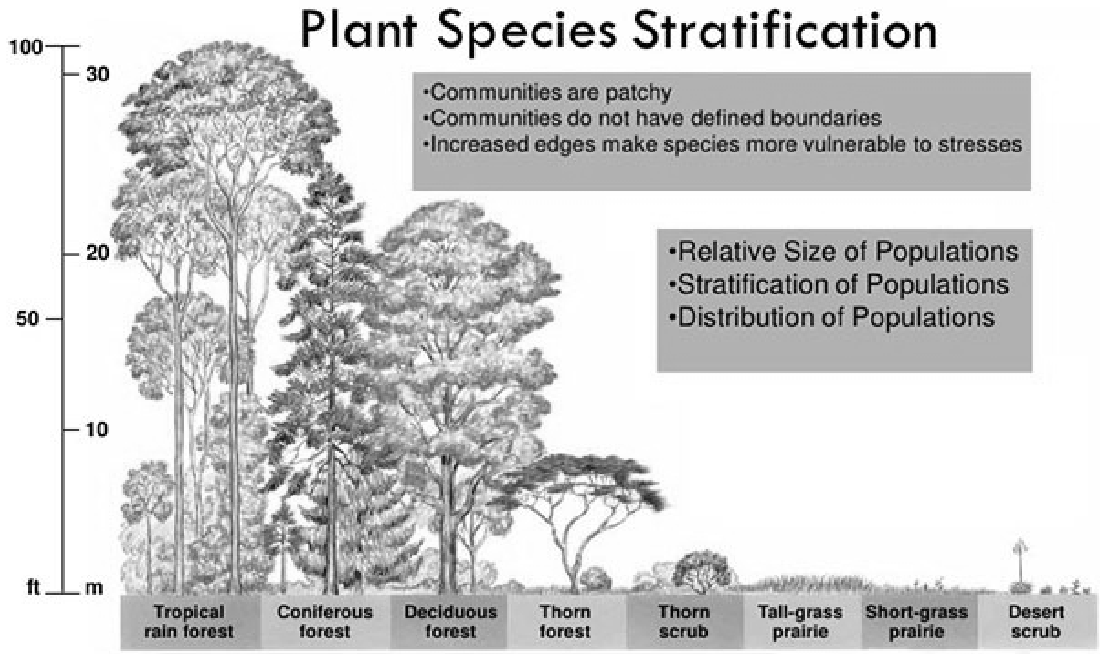


Fig. 3.1. Stratification in a forest ecosystem

dense the understory and shrub layers are poorly developed for want of light and water.

Understory: It consists of young trees and tall shrubs and their survival is subject to the density of canopy. Only shade tolerant species grow better in this layer. Understory species may replace the canopy trees after their death.

Shrub Layer: It is the layer, formed of shrubs and small, trees and is usually poorly developed.

Herb or Ground Layer: The nature of herb layer depends upon moisture, slope position, the density of the canopy. The species composition may vary from place to place throughout the forest.

Forest Floor: It is the site where important process of decomposition takes place and decaying organic matter releases nutrients for reuse of forest plants.

Stratification in Aquatic Ecosystems

Aquatic ecosystems such as lakes and oceans have both vertical and horizontal strata (layers) determined by light penetration, photosynthetic activity and in response to water depth. The horizontal zones are obvious to eye; and vertical zones being influenced by light penetration are not visible.

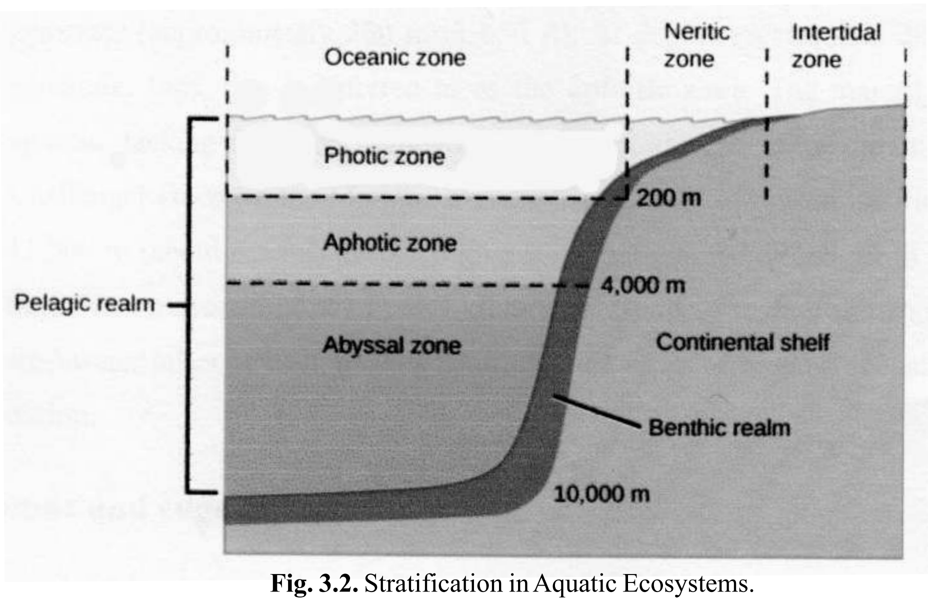


Fig. 3.2. Stratification in Aquatic Ecosystems.

In lakes and larger ponds three distinct profiles can be recognized on the basis of temperature and oxygen during midsummer. These are:

Epilimnion: It is layer of freely circulating water.

Metalimnion: It is layer of water characterized by a steep and rapid decline in temperature. This is an intermediate zone between epilimion and hypolimnion.

Hypolimnion : It is deep, cold layer of dense water about 4°C, often low in oxygen and a layer of-bottom mud.

Most lakes and ponds are surrounded by **littoral zone** or shallow water zone, in which light reaches the bottom, stimulating the growth of rooted plants. Beyond the littoral zone there is open water, the **limnetic zone**, which extends to the depth of light penetration. It is inhabited by plant and animal plankton and free-swimming organisms (nekton). Beyond the depth of effective penetration is the **profundal zone** that depends on a rain of organic material from the limnetic zone. Common to both the littoral zone and profundal zone is the third vertical stratum, the benthic zone or bottom region, which is the place of decomposition.

The horizontal zonation is characterized by presence of submerged, floating and emergent vegetation. These zones develop in response to water depth.

The ocean is categorized by several areas or zones. All of the ocean's open water is referred to as the **pelagic realm (or zone)**. The **benthic realm (or zone)** extends along the ocean bottom from the shoreline to the deepest parts of the ocean floor. Within the pelagic realm is the **photic zone**, which is the portion of the ocean that light can penetrate (approximately 200 m or 650 ft). At depths greater than 200 m, light cannot penetrate; thus, this is referred to as the **aphotic zone**. The majority of the ocean is aphotic, lacking sufficient light for photosynthesis. The deepest part of the ocean, the Challenger Deep (in the Mariana Trench, located in the western Pacific Ocean), is about 11,000 m (about 6.8 mi) deep. To give some perspective on the depth of this trench, the ocean is, on average, 4267 m or 14,000 ft deep. These realms and zones are relevant tro freshwater lakes as well, as they determine the types of organisms that will inhabit each region.

3.3 Ecotone and Edge Effect

An ecotone is an area that acts as a boundary or a transition between two ecosystems. A common example could be an area of marshland between a river and its riverbank. As the area is a transition between two ecosystems or biomes, it is natural that it contains a large

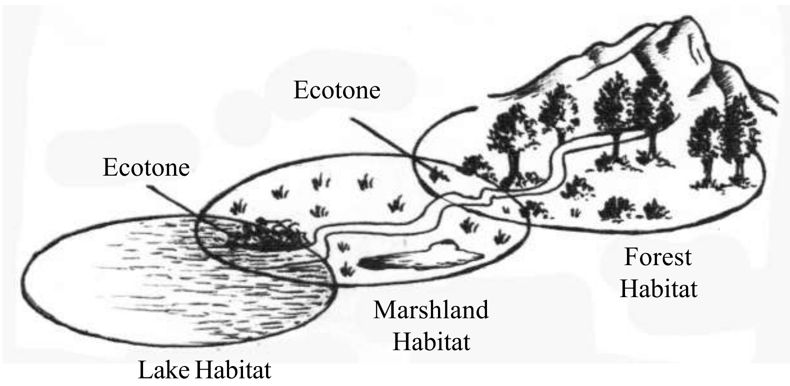


Fig. 3.3. Ecotones of different habitats.

variety of species of fauna and flora as the area is influenced by both the bordering ecosystems. An **ecotone** is not simply a boundary or an edge. The concept assumes the existence of actively interacting two or more ecosystems that result in the ecotone having the properties that do not exist in either of the adjacent ecosystems. In addition to external processes causing discontinuities ingredients, internal processes such as sediment tracks, root mats, special soil water condition, inhibitory chemicals or animal activity may maintain an ecotone as distinct from bordering communities. Examples of ecotones include marshlands (between dry and wet ecosystems), mangrove forests (between terrestrial and marine ecosystems), grasslands (between desert and forest), and estuaries (between saltwater and freshwater). Mountain ranges can also create ecotones due to the changes in the climatic conditions on the slopes.

3.2.1 Characteristics of Ecotones

- It may be wide or narrow.
- It is a zone of tension (as it has conditions intermediate to the bordering ecosystems).
- It could contain species that are entirely different from those found in the bordering systems.
- Ecotones can be natural or man-made. For example, the ecotone between an agricultural field and a forest is a man-made one.

3.3.2 Edge Effect

Sometimes ecotones are populated by more kinds and larger number of birds and game animals that can be found in the interior of the adjoining more homogeneous communities. Wild life managers called them as edge effect and often recommended special plantings between field and forest to increase the number of their animals. The species found here are called **edge species**.

3.3.3 Importance of Ecotone

1. They have a greater variety of organisms.
2. They also offer a good nesting place for animals coming in search of a nesting place or food.
3. They serve as a bridge of gene flow from one population to another because of the larger genetic diversity present.
4. They can act as buffer zones offering protection to the bordering ecosystems from possible damage. For example, a wetland can absorb pollutants and prevent them from seeping into the river.
5. Ecotones are also a sensitive indicator of global climate change. A shifting of boundaries between ecosystems is thought to be due to climate change. So, scientists and environmentalists are studying ecotones with greater interest now.

3.4 Plant Succession

Like an organism every plant community has a developmental history; this developmental history is called plant succession. A plant community first comes into existence with the colonization of a bare area by spore-bearing or seed-bearing plants. The bare area may be a rock, open soil surface or a shallow pool or lake; it is successively occupied by different plant communities. So, Plant succession is a natural process by which the same locality become successively colonised by different groups of communities of plants.

According to Odum, "plant succession may be defined as an orderly process of community change in a unit area".

According to Salisbury, "Plant succession is a competitive drift in which at each phase until the climax the constituent species render the habitat more favourable to their successors than to themselves."

Most plant associations are not static and constant in extent and character, but tend to expand their range to cover the entire environment to which they are well suited. Some particular species, on account to its size, abundance and ability to compete successfully with its associates, usually becomes dominant.

The presence of a particular dominant species, which is usually called as pioneer community, may in time change conditions so that a very different group of plants invade the community and eventually replace the original colonizers.

Climatic and topographic changes of various kinds may in time modify conditions so that there are marked changes in the distribution of plant associations. In a given locality one group of plants may thus encroach upon another. This kind of succession may be rapid, or it may extend over many years and it will continue until stability is attained through the establishment of vegetation which is essentially permanent. This is called as climax association for the region in question.

The great plant formations, such as forest, grassland, and tundra are climax formations. The process of succession may start at places like bare rocks, exposed soil surface, shallow water such as a small pool, silting up rivers and banks of a lake etc.

Plant succession may be of two kinds:

(i) Primary succession:

It begins in areas which have previously been unoccupied by plants, such as open water, bare rock, or sand.

(ii) Secondary succession:

This kind of succession begins wherever the existing vegetation has been destroyed without denuding the area of soil. It usually starts after forest fires, cutting of the trees, flood and erosions. It is also of common occurrence in abandoned agricultural lands. A single case of plant succession at a particular kind of habitat is usually referred to as a sere, and the various stages of a sere are called seral stages.

Succession may also be classified as autogenic and **allogenic succession**. Allogenic succession is the succession driven by the abiotic components of an ecosystem. In contrast, **autogenic succession** is driven by the biotic components of the ecosystem. An allogenic succession can be brought about in a number of ways which can include:

- Volcanic eruptions ;
- Meteor or comet strike ;
- Flooding ;
- Drought ;
- Earthquakes ;
- Non-anthropogenic climate change.

Allogenic succession can happen on a time scale that is proportionate with the disturbance. For example, allogenic succession that is the result of climate change can happen over thousands of years.

Depending upon the nature of the habitat on which the plant succession begins seven types of seres may be distinguished:

1. **Hydrosere:** When succession starts in aquatic habitat .
2. **Xerosere:** When succession initiates on a dry, bare land.
3. **Lithosere:** It starts on a bare rock surface.
4. **Psammosere:** Initiating on sandy habitats. Here the pioneer community comprises sand-binding grasses with runners, e.g. *Spinifex* sp. and *Ipomoea biloba*.
5. **Halosere:** It starts in saline soil or water. Here the pioneer plants usually have succulent leaves and stem e.g., *Suaeda maritima, Acanthus ilicifolius, Chenopodium, Basella* and some species of *Asclepias*.
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.

3.4.1 Process of Plant Succession

Major steps in an autotrophic succession are as follows:

1. **Nudation:** An area is exposed leading to the development of a bare area. The bare area develop either by emersion, submergence, erosion, deposits and climatic change or by biotic agencies.

2. **Migration:** The process of dispersal of seeds, spores and other structures of propagation of the species to bare area is known as migration. The movement of propagules between two places may complete in one or two steps. Several agencies help in migration of plants to new areas, e.g.- by wind, water, animals, etc.

3. **Germination:** It is the process of germination of propagules in the bare area when conditions are favourable. Thus, help in establishment of new species in the area.

4. **Ecesis:** Successful germination of propagules and their establishment in a bare area is known as ecesis. It is not necessary that all propagules reaching the new area must stabilize. The first plant community develop in the new area are known as *primary colonisers*. The germination may be affected by a number of external and internal factors.

5. **Colonisation and Aggregation:** After ecesis, the individuals of the species increase in number as the result of reproduction. In course of time, more and more migrules or propagules reach the area and become stabilized there. This ultimately results in the formation of group of colonising plants which is known as aggregation. Aggregation may be of two types- simple or mixed. In case of simple aggregation the aggregation results due to increase in number of a single species. In case of mixed aggregation individuals from different species or families aggregate in a particular area.

6. **Competition and Co-action:** Due to limited resources, species show both inter and intraspecific competition. This results into elimination of unsuitable and weaker plants. The relationship between species may be of three types- exploitation, mutualism and coexistence.

7. **Invasion:** Various other types of plants try to establish in the spaces left by the elimination of plants due to competition. The new aggressive and more adapted organisms are known as *invaders*. Invaders establish themselves in the new area either by partial invasion or permanent invasion. There may be several barriers which prevent invasion of new species to a particular area, like topographical barriers (mountains, valleys, sloes, etc), physical barriers (rivers, oceans, lakes, deserts, etc.) or biotic barriers (man, animals, insects, etc.).

8. **Reaction:** The newly arrived plants interrupt with the existing ones. As a result of reaction, environment is modified and becomes unsuitable for the existing community which sooner or later is replaced by another community. Plants usually modify their environments by two ways- by changing nature of soil and by modifying the climate. It is a continuous process which leads to the development of conditions which may become favourable for the newly invading species as compared to the previous colonising individuals.

9. **Stabilisation:** continuous competition and reaction bring about several marked changes in the environment and continuously promote gradual change in the structure of the vegetation. Ultimately the final vegetation is least affected by the introduction of new species in the area and thus forming dominant vegetation.

10. **Climax stage:** Finally, there occurs a stage in the process when the *climax community* becomes more or less stabilized for a longer period of time and it can maintain itself in equilibrium with the climate of the area. Climax stage is the final stage of vegetation development after the stabilisation phase. As compared to seral stage community, the climax community has larger size of individuals, complex organization, complex food chains and food webs, more efficient energy use and more nutrient conservation.

Major Trends during Succession:

1. There is an increase in structural complexity.
2. Diversity of species tends to increase.
3. Biomass and standing crop increase.
4. There is a decrease in net community production.
5. Increase in non-living matter.
6. Food chain relationship becomes complex.
7. Niche becomes special and narrower.
8. Energy use and nutrient conservation efficiency increases.
9. Stability increases.

3.4.2 Types of Seres

(A) Hydrosere:

A sere beginning on a wet area is often referred to as a hydrosere. It may proceed in open bodies of water, such as ponds, lakes, and marshes etc.

Hydrosere consists of following seven seral stages:

(1) Phytoplankton stage: In the initial stage of succession in an aquatic body of water algal spores, bacteria, some other phytoplanktons first come and established themselves there as the pioneer stage. It includes some blue- green algae like *Oscillatoria, Lyngbya, Nostoc, Anabaena, Microcystis*, etc; some green flagellates like *Chlorella, Volvox, Chlamydomonas, Ulothrix*, etc. they remain floating at or near the surface of the water body. These organisms add large amount of organic matter and nutrients by their life time activities and after their death they settle at the bottom of the water to form a layer of muck.

(2) **Submerged stage:** In this stage the depth of the water is more than 3-6m. A number of submerged aquatic plants, such as *Hydrilla, Potamogeton, Ceratophyllum, Najas, Vallisnaria, Utricularia*, and several algae occupy the shallow pond or lake. They get accumulated after death and decay and gradually raise the bottom of the pond or lake. Silting may also be associated with this accumulation. The inadequate oxidation of flora and fauna remains of the lake results in the formation of humus-which makes the bottom of the lake firmer.

(3) **Floating stage:** As the bottom of the lake is raised and the depth of the water is about 1.6 to 2.5 m floating stage appears which is characterized by plants like *Nymphaea, Nuphar, Nelumbo*, etc. These plants are rooted in the mud and their broad leaves float on the surface of the water, thus shading the submerged plants below. Besides these, the free floating plants like *Azolla, Eichhornia, Pistia, Spirodela, Lemna*, etc. may also appear. The death and decay of the submerged and free floating plants further raise the level of the lake bottom and contribute further to the soil-building process. This initiates the next reed-swamp stage.

(4) **Reed-Swamp stage:** This stage is initiated in extremely shallow waters (i.e., 03.-1 m). The area is invaded by amphibious plants like *Scirpus, Typha, Phragmites, Arundo*, etc. These plants remain only partly submerged in water. Their rhizomes are profusely branched and they are rooted in the bottom of the lake. These plants prevent light to reach submerged and floating plants which consequently die, and their dead remains settle down at the bottom of the lake or pond raising its level further.

Now a second group of plants, such as *Sagittaria, Alisma* and *Acorus*, etc. invades the area. Eventually the habitat is made unfit for the growth of the plants of reed-swamp stage. The soil becomes dry enough to afford a foothold for terrestrial species.

(5) **Sedge meadow stage:** Reed-swamp stage is followed by sedge-meadow stage when the depth of water body is about a few centimetres during rainy season, but it disappears during other season. It is characterized by plants like *Cyperus, Carex, Juncus, Elaeocharis*, etc. The soil level continues to rise and soil organic matter continues to increase. More competent and dominant plants, such as *Mentha, Caltha, Iris, Galium, Campanula* and *Teuricum*, etc. then invade the area. By excessive transpiration and soil binding, these species make the area too dry for any hydrophytic plant. This eventually leads to other-subclimax vegetation.

(6) **Woodland stage:** The sedge-meadow stage leads to the formation of wood land which remains saturated with water in spring and early summer. New sub-climax vegetation dominated by shrubs and small trees make their appearance in this area. Important among these plants are *Terminalia, Populus, Salix, Alnus*, etc. 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.

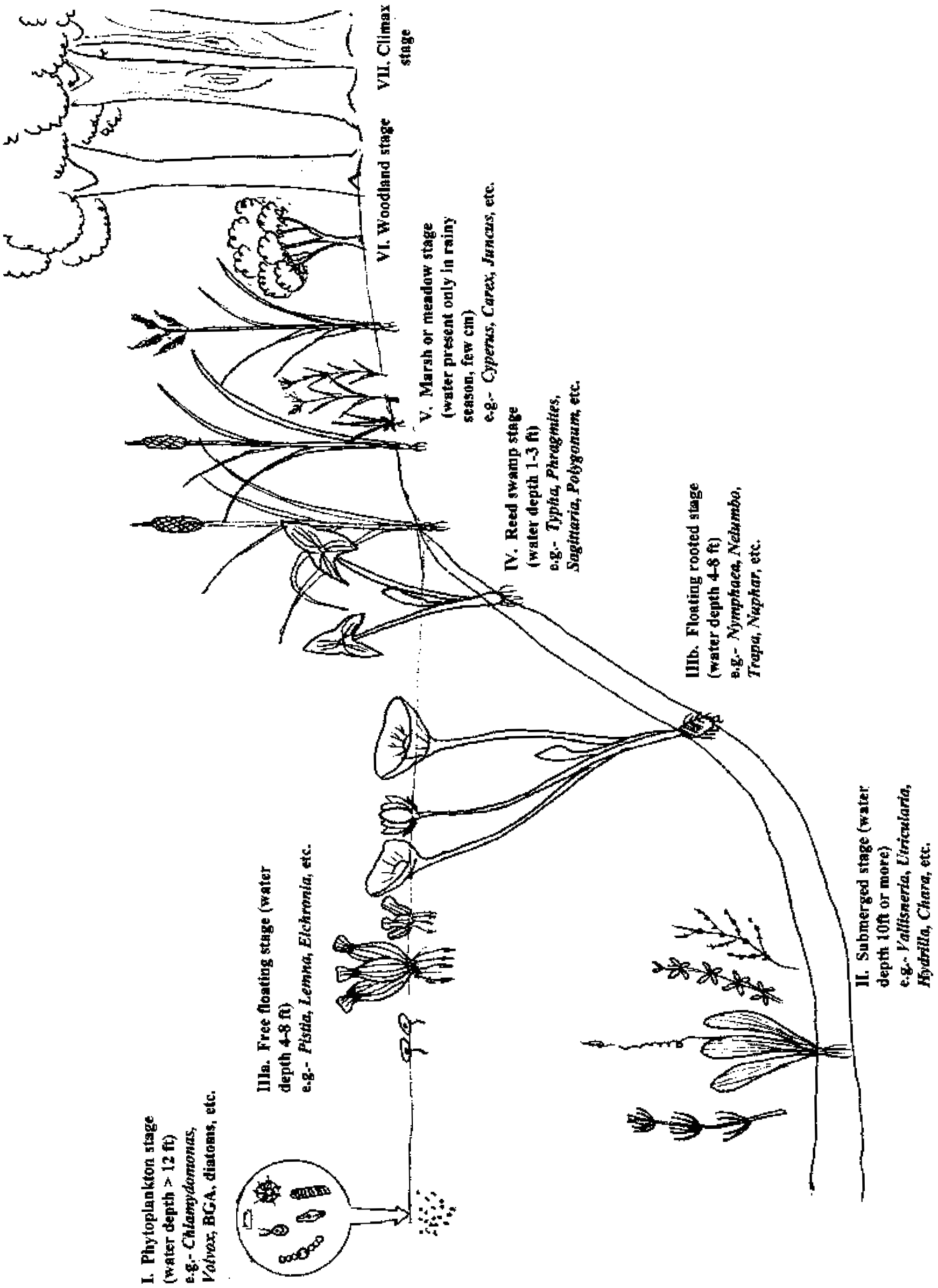


Fig. 3.4. Stages of hydrosere.

(7) Climax forest stage: As more and more plants appear in the area, competition among these plants also intensify and soil organic matter further increases, soil becomes more fertile and consequently the area is invaded by larger trees. Competition then becomes less intense as the community becomes stable and a climax state is reached. It may also be mentioned that succession in water always leads to land community. When succession starts in deep and large open water it may lead to stable aquatic vegetation.

(B) Xerosere:

When succession starts on a dry, bare area, it is usually referred to as xerosere. When the bare area is dry, the pioneers may be more or less xerophytic, the degree of xerophytism depend on local climate and physiographic factors.

A xerosere usually includes the following six seral stages:

(1) Crustose lichen stage: Succession on the bare rock surfaces begins with crustose lichens as pioneers. These lichens migrate to the rocks by means of wind-borne spores and soredia. The lichens grow only when enough moisture is available, but they can withstand drought conditions for long.

The mechanical and chemical action of the lichens on the underlying rock loosens particles which together with decaying lichen remains form a thin layer of soil on the rock surface. The requisite nitrogen is brought in by rain and wind-blown dust. These lichen form pioneer community.

(2) Foliose lichen stage: Simple crustose lichens may be followed by larger, leafy forms, such as *Parmelia, Dermatocarpon. Umbilicaria,* which grow on the slight accumulation of 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, which, like lichens, are able to survive in dry environment. These mosses are xerophytic in nature and important among these are the species of *Polytrichum, Fissidens, Bryum, Grimmia, Tortula*, etc. These mosses form an open community connected with a dense rhizoid system which passes through and binds together a few millimetres of soil particles. Within the shoots of these mosses wind and water borne soil particles continues to accumulate. The primary role of these mosses is to stabilize the soil surface and to increase its water-holding capacity.

(4) Herbaceous stage: The moss plants increase in number until a close carpet of moss is formed over the rocky substratum. The mosses shade the lichens and successfully compete with them for water and nutrients which eventually result in the death of the lichens. The death and decay of the lichens and old mosses add to the amount of organic matter in the soil and still further increases its water- holding capacity.

In his way the habitat is rendered suitable for the growth of higher plants and consequently a new community of herbaceous plants, such as *Festuca, Verbascum, Poa, Potentilla, Solidago*, etc. invade the area. The herbaceous plants over shadow the mosses, compete successfully with them for space, water and nutrients. The soil increases in thickness by disintegration of the rock and the decay of the various plant parts, more nutrients become available and next higher community, dominated by shrubs appear.

(5) Shrub stage: Shrubby plants, such as *Fragaria, Rubus, Capparis, Rhus*, etc. invade the area by means of seeds and underground rhizomes which was previously dominated by herbaceous plants. The herbaceous plants of the preceding stage now become shaded and tend to disappear. The death and decay of the herbaceous plants further enrich the soil. As the shrubs grow in size and number, they continue to modify the soil and make the habitat more and more suitable for the support of still higher plants i.e., trees.

(6) Climax forest stage: The first tree species to invade the area are usually xerophytic in character, but as the soil moisture increases, these are gradually replaced by mesophytic ones. The mesophytic species compete successfully and become dominant because their seedlings are much more shade-tolerant. Competition gradually becomes less intense as the community becomes stable and a climax state is reached.

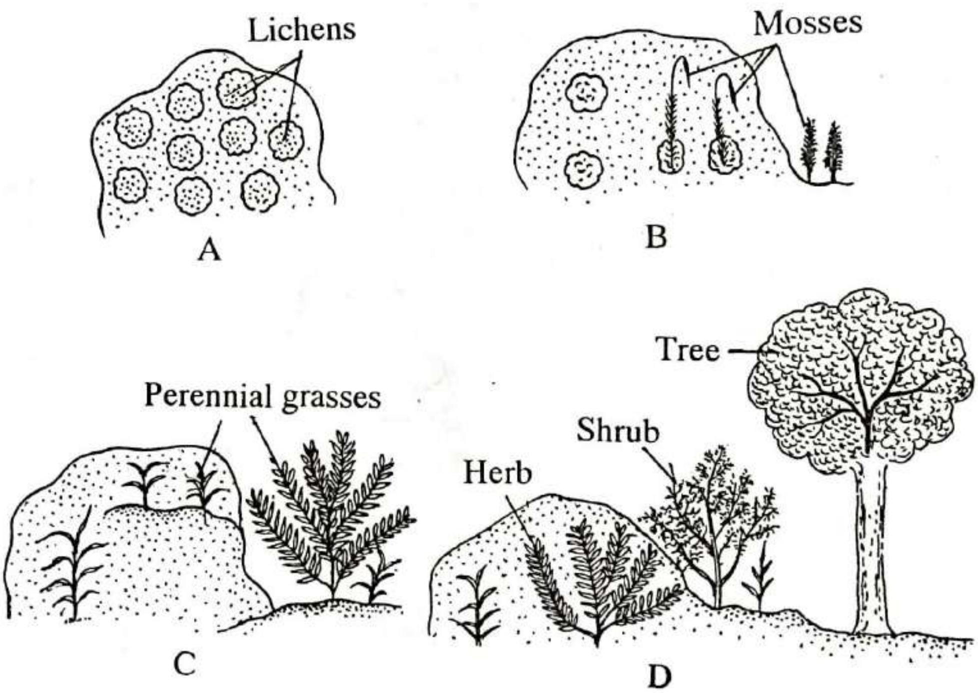


Fig. 3.5. Xerosere—stages of plant succession on a rock.

3.5 Summary

A group of interacting organisms or community is made up of different species, growth forms and structure, dominance, succession and trophic structure. The study of structure and classification of plant community is known as **phytosociology**. There are different growth forms and life forms of plant species. The different life forms include phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, therophytes and epiphytes. There is always stratification in a terrestrial and an aquatic ecosystem. An **ecotone** is an area a that acts as a boundary or a transition zone between two ecosystems and has the properties that do not exist in either of the interacting ecosystems. The ecotones are mostly populated by large number of birds and animals which is known as **edge effect**. The plant communities have a developmental history which is known as plant succession. Plant succession is basically an orderly process of community changes in a unit area. It may be primary or secondary in nature. Depending upon the nature of the habitat plant succession may be of different types — hydrosere, xerosere, lithosere, psammosere, halosere, geosere and senile. The major steps of plant succession include nudation, migration, ecesis, aggregation, competition and co-action, invasion, reaction, stabilisation and climax stage. Hydrosere is the plant succession in an aquatic body or wet area. Starting from the beginning the stages are-phytoplankton stage, submerged stage, floating stage, reed-swamp stage, sedge meadow stage, woodland stage and ultimately climax stage. On the other hand, xerosere is the plant succession in a dry, bare area. It usually has following six seral states-crustose lichen stage, foliose lichen stage, moss stage, herbaceous stage, shrub stage and climax forest stage.

3.6 Questions & Answers

Q1. What is plant community?

Ans.: A collection of organisms interacting directly or indirectly is a community. Within the community some species carry out similar functions or exploit the same resources. These groups are called guilds. For example, plants growing on saline soils are halophytic guild.

Q2. Comment on the characteristics of plant community.

Ans.: vide section 3.2

Q3. Describe the different life forms as proposed by Raunkiaer (1934).

Ans.: vide section 3.2 point iii.

Q4. Comment on the stratification in a terrestrial ecosystem.

Ans.: vide section 3.2 point iv.

Q5. Comment on the stratification in an aquatic ecosystem.

Ans.: vide section 3.2 point iv.

Q6. Write short notes on ecotone.

Ans.: vide section 3.3

Q7. What is edge effect?

Ans.: Sometimes ecotones are populated by more kinds and larger number of birds and game animals that can be found in the interior of the adjoining more homogeneous communities. Wild life managers called them as **edge effect** and often recommended special plantings between field and forest to increase the number of their animals. The species found here are called **edge species**.

Q8. What is plant succession?

Ans.: According to Odum, "plant succession may be defined as an orderly process of community change in a unit area".

Q9. What is primary succession?

Ans.: It begins in areas which have previously been unoccupied by plants, such as open water, bare rock, or sand.

Q10. What is secondary succession?

Ans.: This kind of succession begins wherever the existing vegetation has been destroyed without denuding the area of soil. It usually starts after forest fires, cutting of the trees, flood and erosions. It is also of common occurrence in abandoned agricultural lands.

Q11. What is autogenic succession?

Ans.: Autogenic succession is the succession which is driven by the biotic components of the ecosystem.

Q12. What is allogenic succession?

Ans.: Allogenic succession is the succession that is driven by the abiotic components of an ecosystem.

Q13. What is hydrosere?

Ans.: When succession starts in an aquatic habitat it is known as hydrosere.

Q14. What is xerosere?

Ans.: When succession initiates on a dry, bare land it is known as xerosere.

Q15. What is psammosere?

Ans.: It is the succession that initiate on sandy habitats. Here the pioneer community comprises sand-binding grasses with runners, e.g. *Spinifex* and *Ipomoea biloba*.

Q16. What is halosere?

Ans.: This succession starts in saline soil or water. Here the pioneer plants usually have succulent leaves and stem e.g., *Suaeda maritima*, *Acanthus ilicifolius*, *Chenopodium*, *Basella* and some species of *Asclepias*.

Q17. What is eosere?

Ans.: It is the development of vegetation in an area.

Q18. What is lithosere?

Ans.: It is the succession on a bare rock.

Q19. Describe the major steps of plant succession.

Ans.: vide section 3.4.1.

Q20. What do you mean by climax community?

Ans.: The final stage in the development of plant community when it becomes more or less stabilized for a longer period of time and can maintain itself in equilibrium with the climate of the area.

Q21. Describe the steps of hydrosere in a fresh water ecosystem.

Ans.: vide section 3.4.2 A.

Q22. Describe the steps of Xerosere in a fresh water ecosystem.

Ans.: vide section 3.4.2 B.

Q23. Name the pioneer colonisers in case of hydrosere and xerosere.

Ans.: In case of hydrosere - mainly the phytoplanktons (e.g.- *Volvox, Nostoc, Chlorella, Chlamydomonas*, etc).

In case of xerosere - mainly crustose lichens (e.g.- *Lepraria, Lecanora, Caloplaca*, etc).

Unit 4 ❒ Ecosystem

Structure

4.0 Objective

- From this unit you will have an insight to the ecoysystem as a whole.
- This will help you to understand the interrelationships between different living components as well as with abiotic components and thus have an idea about the stability of an ecosystem.

4.1 Introduction

Ecosystem is a dynamic complex of living and non-living components interacting with each other as a functional unit. So here we are going to have an idea about different components of an ecosystem, energy flow in an ecosystem, have a preliminary idea about food chain and food we, different ecological pyramids and biogeochemical cycling of minerals and gases.

❒ A biotic community lives in an environment which provides material and energy to it. Thus, there is an interaction between a biotic community and its environment, and the former cannot live isolated from the latter. A biotic community and its abiotic environment, called biotope (Gr. bios = life, topos = place), together form an ecological system, or ecosystem. The term ecosystem was introduced by Tansley in 1935, but the concept of ecology appeared much later. An ecosystem may be defined as a natural, functional ecological unit comprising of living organisms and their nonliving environment that interact to form a stable, self-supporting system. The relationship between a biotic community and the nonliving environment is always a mutual one, where the community not only get affected by the environment, but the community also modifies the environment.

Definition:

"The organisms and physical features of the habitat form an ecological complex or more briefly an ecosystem" (Clarke, 1954).

"The ecosystem is the basic functional unit of organisms and their environment interacting with each other and their own components" (E. P. Odum, 1963).

"Ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity, 1992).

An ecosystem is not an isolated unit as is often held. Instead, materials invariably move from one ecosystem to another - leaves are blown from a forest into a lake, birds migrate between their summer and winter homes.

Examples and Types:

Ecosystem may be natural or artificial. Common examples of natural ecosystems are a pond, a lake, a meadow, a desert, k grassland, a forest, a village, a field, a hill side, etc. Even a single log and edge of a pond are also instances of ecosystem. Instances of artificial ecosystems are a manned spaceship, an aquarium, and a pot of houseplants, etc. An ecosystem maybe temporary, such as a rain fed pond, laboratory culture of protozoans or permanent, such as a forest.

4.2 Components of Ecosystem

To sustain itself and last indefinitely, an ecosystem must have resources for supporting its resident organisms and for disposal of their wastes. The necessary components of an ecosystem are matter (water, minerals, carbon dioxide, oxygen) and several species of organisms. An ecosystem must also receive a continuous supply of energy. The components of an ecosystem may be divided into two main types: biotic and abiotic.

I. Biotic Components:

The living organisms present in an ecosystem form the biotic component. They are classified into three main categories: plants, animals and microorganisms (bacteria and fungi). These are respectively called producers, consumers and reducers or decomposers according to their role in keeping the ecosystem operating as a stable unit (Fig. 4.1).

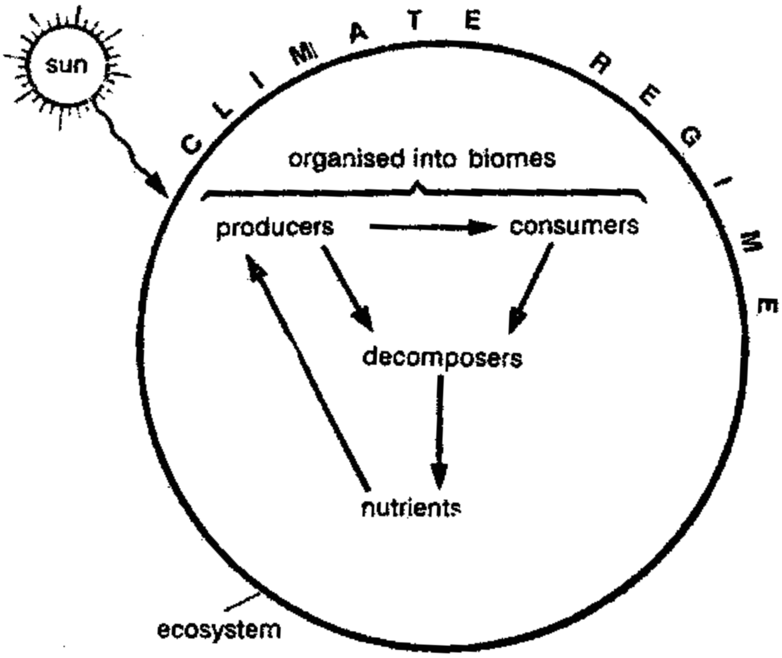


Fig. 4.1. Diagrammatic sketch showing the living (biotic) and non-living (aboitic) components of nature interacting with each other to form integrated ecosystem.

(i) Producers:

These are the green plants, some protists and certain bacteria. They are basically autotrophs. They, with the help of their chlorophyll, entrap the light energy of the sun and change it into the chemical energy of a simple carbohydrate glucose produced by them from simple inorganic compounds, namely, carbon dioxide and water. The process is called photosynthesis.

It may be briefly represented by the following equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

From the basic organic material (glucose), the plants then form complex organic compounds such as starches, proteins and lipids. Materials and energy stored by producers are utilized by consumers. As the green plants and other green organisms prepare their organic food themselves, they are known as the photoautotrophs (Gr. phot = light, autos = self, trophe = nourishment).

The producers dominate the terrestrial ecosystems, being the most abundant and massive of all groups of organisms there. Some bacteria capture energy released during certain inorganic chemical reactions and prepare organic food with it. They are called chemoautotrophs (Gr. chemeia = alchemy, autos = self, trophikos = nourishing), and the process is termed chemosynthesis.

(ii) Consumers:

These are mainly the animals. They are unable to synthesize their food. Therefore, they consume other organisms or parts of organisms. They are also known as the heterotrophs (Gr. heteros = other, trophe = nourishment) or phagotrophs (Gr. phagein = to eat, trophe = nourishment).

The consumers are of 3 or 4 types:

(a) Primary or First Order Consumers:

These are the animals which eat plants or plant products. They are called herbivores. Cattle, deer, goat, rabbit and hare belong to this category. Elton has used the term "key industry animals" for the primary consumers because they convert the plant material into animal material. Plants that are parasites on plants and bacteria and fungi which flourish on living plants are also primary consumers.

(b) Secondary or Second Order Consumers:

These are the animals which eat herbivores. They are called carnivores, cats, dogs, and foxes are examples.

(c) Tertiary or Third Order Consumers:

These are larger carnivores which feed on secondary consumers. For instance, wolves.

(d) Quaternary or fourth Order Consumers:

These are the largest carnivores which take tertiary consumers. They are not eaten by other animals. Tigers and lions are examples.

(iii) Reducers or Decomposers:

These are mainly **microorganisms** like bacteria and fungi. They obtain their food molecules from the organic materials of dead producers (plants) and consumers (animals) and their waste products. In the process of extracting nutrients and energy from these materials, they decompose the latter into:

(i) Small organic molecules which they utilize themselves, and

(ii) Into inorganic compounds that are released into the environment for reuse as raw materials by producers. The decomposers are known as the saprotrophs (Gr. sapros = rotton, trophe = nourishment). Some animals also feed on dead organisms. They are called scavengers or detrivores, e.g.- vulture.

Thus, there is a cyclic exchange of materials between a biotic community and its abiotic environment in an ecosystem. In other words, the nutrients are constantly recycled, i.e. used again and again in the same small area. If the ecosystem is a balanced one, no materials are ever exhausted. In contrast, energy is not cycled but is continuously lost from an ecosystem. Most organisms would soon die if the sun's energy is cut off for some time.

Role of Decomposers:

Sun is an endless source of energy, but the chemical materials of the environment are not inexhaustible. The decomposers return the chemical nutrients to the environment. They also make space available for new producers. Without this, all life will ultimately cease to exist. Thus, the decomposers have a crucial role in the ecosystem.

The decomposers are found in the soil and at the bottom of ponds, lakes and oceans. The basic requirements for a self-sustaining ecosystem are inorganic nutrients, producers, decomposers, and a continuous supply of energy. The consumers are not essential, but they do occur in most ecosystems (Figs.4.2, 4.3).

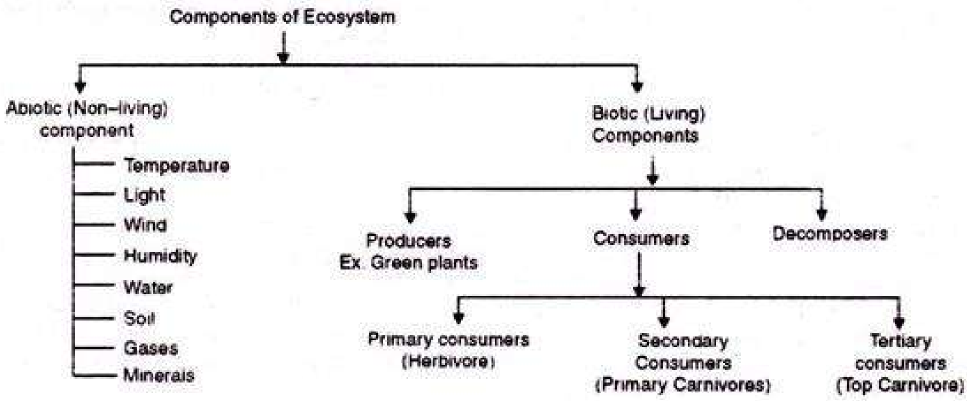


Fig. 4.2. Components of ecosystem

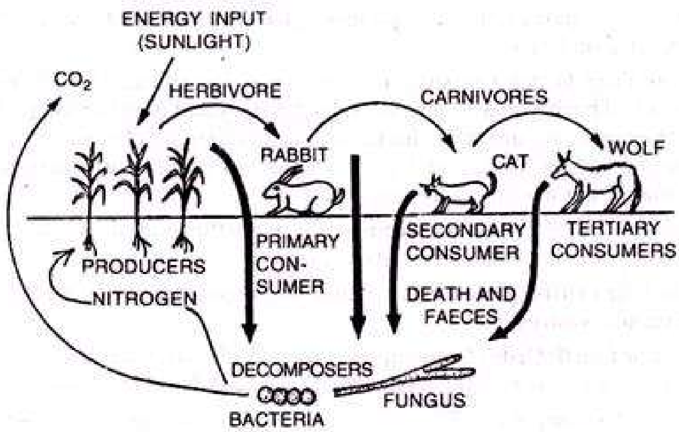


Fig. 4.3. Relationship among the Members of an ecosystem.

II. Abiotic Components:

Abiotic component of an ecosystem consists of non-living substances and factors. The important ones are as follows:

1. **Temperature:** Organisms generally live within a narrow range of temperature (5°C - 35°C) with the exception of spores, seeds, some prokaryotes and other lowly organized individuals. The latter can be found in hot springs (60°-90°C) or permafrost (- 30° to - 50°C). Temperature range varies in different parts of the earth.

   It has created different life zones - tropical, sub tropical, temperate, arctic or alpine. High or low temperature causes inactivity and death of organisms. It is immediate in case of poikilothermal (= ectothermal = cold blooded) animals and delayed in case of homoiothermal (= endothermal = warm blooded) animals. Therefore, organisms show adaptations to avoid extremes of temperature.

   Plants belonging to both hot and cold areas possess adaptations to reduce transpiration and retain water, e.g. tannins, hair, thick covering, mucilage, high solute content, thick leaves. Animals of cold areas possess thick coat of hair, scales, feathers and subcutaneous fat. In warm blooded animals, including humans, pigmentation is little in colder areas, yellow brown to red in arid climates and black in humid hot areas (Gloger's rule).

2. **Light:** It provides solar energy to the ecosystem for heating and photosynthesis. Maximum solar or light energy is available at equator. It decreases towards poles. In a tree more energy is available to upper leaves than the lower ones. Their rate of photosynthesis is accordingly higher. In a forest, trees have higher productivity than shrubs and herbs growing underneath.

   Floating hydrophytes have higher photosynthetic rate than the submerged hydrophytes. Besides photosynthesis, light controls morphogenesis (photo-morphogenesis). Photoperiods influence leaf fall, appearance of new leaves and flowering in plants. They control migration and breeding in several animals.

3. **Wind:** It controls weather, transpiration, pollination and dissemination of propagates. High speed winds inhibit free growth and flight animals. Unidirectional wind does not allow growth of branches on the wind-ward side.

4. **Humidity:** It is the amount of water vapours present in the atmosphere. Humidity controls formation of clouds, dew, fog, etc. Epiphytes grow only in humid areas. Evaporation of water from the body of land organisms in transpiration and perspiration is regulated by humidity. Both plants and animals develop modifications for reducing water loss from their body in arid areas.

5. **Precipitation:** It may occur as rainfall, snow, dew, hail, etc. Periodicity and amount of rainfall determines type of forest in an area - evergreen, deciduous, chaparral, grassland, savannah, desert, etc. Animals are also adopted accordingly.

6. **Water:** Land plants meet their water requirements from soil. Land animals obtain the same from pools, lakes, rivers, springs, etc. Plants and animals show modifications according to availability of water in the area and requirement of conserving the obtained water. Plants of dry areas are called xerophytes. They develop modifications to increase water absorption, reduce transpiration and at times store absorbed water.

   Certain animals of the dry areas do not drink water at all, e.g., Kangaroo, rat. They use water from food and its metabolism to run their body machinery. Animals of dry areas often reduce water loss by producing solid faeces and excreting solid urine.

   Water is abundant in aquatic habitats. Plants of aquatic habitats are called hydrophytes. Hydrophytes possess aerenchyma or air storing parenchyma to get support in water. Clarity of water, salt content, depth and water waves or speed determines the growth and distribution of plants and animals. In rivers and streams, animals obtain most of their food from organic materials coming from outside the water.

   In ponds and lakes producers grow in sufficient strength. Organisms found in fresh water have a problem of excess internal water because of endosmosis. Organisms found in ocean or saltish water has a problem of low internal water content due to exosmosis. Some have problem of excreting excess salts obtained from outside. In oceans at a depth of more than 200 m, producers do not occur. Only consumers are found there. Deep sea animals do not possess air sacs. Many of them are luminescent.

   Water currents restrict distribution of organisms in streams and intertidal areas of oceans. In streams only attached plants grow. They have dissected or ribbon shaped leaves. Animals found here is either strong swimmer, have attaching organs or live under stones, in burrows, crevices etc. Similarly in intertidal area of ocean attached plants (*Fucus, Laminaria*), sessile animals (Sea anemone and limpets), burrowing animals (e.g., Nereis, tube worms) or very strong swimmers are met with.

7. **Topography:** It is the surface behaviour of the earth like altitude, slope, exposure, mountain chains, valleys, plains, etc. Topography influences other environmental factors, atmospheric pressure, winds, rainfall, light intensity and light duration, temperature, water currents or wave action.

   It is also a causal agent for isolation, formation of new species and geographical distribution of organisms. North and south faces of hill possess different types of flora and fauna because they differ in their humidity, rainfall, light intensity, light duration and temperature regimes. It is because the two faces of the hill receive different amounts of solar radiations and wind action.

   Similarly, the centre and edge of a pond possess different depths of water and different wave action. Top side of a rock is exposed to wave action and light while the underside of the rock has little wave action and light. Therefore, different parts of the same area may possess different species of organisms.

8. **Gases:** Nitrogen is present in abundance (4/5th of atmosphere) but is itself chemically inert. It forms useful salts through electrochemical, photochemical and biological fixation. Carbon dioxide concentration of the atmosphere is always a limiting factor for photosynthesis.

   However, excess of carbon dioxide concentration is harmful to animals as well as climate. Its-concentration increases during night but decreases during day. In water it occurs as bicarbonate and carbonate ions. Oxygen concentration is supra-optimal for C3 plants, optimal for C4 plants and animals except at high altitudes.

   In water oxygen concentration determines distribution of organisms. In the middle or intermediate stratum photosynthesis increases oxygen concentration during day but it becomes little during night depending upon population, pollution and decomposition. In deep waters, animals are faced with very low oxygen concentration.

9. **Soil:** It determines vegetation growth and pattern, under-ground flora and fauna through its constitution, origin, temperature range, water retentively, aeration, minerals, etc. Soil present on the slopes, as well as the uncovered one, are liable to be eroded by water and air respectively.

10. **pH (Hydrogen ion Concentration):** There is very little change in pH in oceans. Terrestrial animals are also not much influenced by pH of the substratum. However, distribution of land plants and soil organisms is determined by pH of soil. A similar control on distribution is found in fresh water habitats. Snails and earthworms do not occur in acidic soils. At this pH, Euglena and other flagellates are quite abundant. Animals having calcareous shells live in media having neutral or alkaline pH.

11. **Mineral Elements:** A large number of minerals, also called biogenic or biogenetic nutrients, are required by organisms for their proper growth. Deficiency or absence of any one results in abnormal growth which may lead to death. Excess minerals are equally harmful. Abundance of some minerals favour the growth of some tolerant species.

    Soils deficient in nitrogen salts often possess nitrogen fixing bacteria and cyanobacteria. Plants having symbiotic relationship with these bacteria also abound in the soils. Carnivorous plants meet their requirement of nitrogen by catching small insects, worms, etc. Salinity of ocean is overcome by many animals through salt secreting glands. Similar glands occur in halophytes or plants growing in saline soils and marshes.

    Special adaptations are found in animals inhabiting estuaries where there are wide fluctuations in salt content. Areas having very high salt content are usually devoid of much vegetation, e.g., Dead Sea, Great Salt Lake.

4.3 Functions of an Ecosystem

The ecosystem is a dynamic unit. It shows continuous interactions, such as flow of energy, transfer of food etc. The biotic and abiotic components of an ecosystem are closely linked with one another to carry out these functions and such processes are called functions of an ecosystem.

4.4 Energy flow in an ecosystem

All the potential energy of plant material eaten is not converted into flesh of herbivores. A part of it is excreted as undigested food and another part is lost by respiration i.e., dissipates in the form of heat. Therefore, only a small part of energy is fixed in the form of potential chemical energy in the protoplasm.

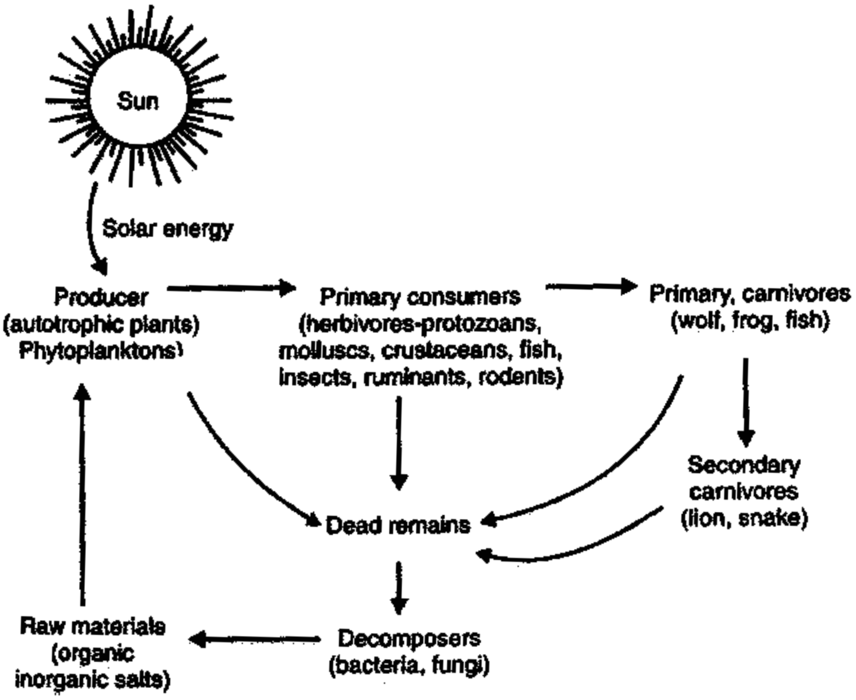


Fig. 4.4. Flow of energy at different levels of ecosystem.

The same process is repeated at the secondary consumer level and so on. Thus, at each step of transfer of energy, large amount is degraded and dissipates and never returns to ecosystem. The flow of energy from one to another trophic level takes place according to second law of thermodynamics which states that "whenever energy is transformed from one kind to another, there is an increase in entropy (relative disorder) and decrease in amount of useful energy."

The 10% Law:

If the net primary production is taken to be 100 units in producers, only 10 units of potential energy of plant material is actually assimilated by the herbivores. Similarly only 1 unit of potential energy of herbivores is assimilated in carnivores. Thus, during energy flow in ecosystem, the energy fixed in one level is only 10% of its previous level.

Thus, in an ecosystem, there is:

(i) A constant flow or transfer of energy from sunlight through plants and plant-eating animals to flesh-eating animals in the form of food.

(ii) A decrease in useful energy at each successive level of nutrition due to loss of some energy as heat at each transformation of energy, and

(iii) Return of entire solar energy that entered the living systems back to the nonliving world as heat but not as light.

Every food chain or web is essentially a system of energy transfer. In fact, energy transfer is the very basis of life. Food is the means of transfer of both matter and chemical energy in the living world.

4.5 Food Chains and Trophic Levels

The number of organisms of each species, or more precisely their total mass, is determined by the rate of flow of energy through the biological part of the ecosystem that includes them. The transfer of energy from its ultimate source in plants, through a series of organisms each of which eats the preceding and is eaten by the following, is known as food chain (Fig. 4.5).

The number of steps (i.e., trophic levels) in the series is limited to perhaps four or five because of the great decrease in available energy at each step. The percentage of food energy consumed that is converted to new cellular material, and thus is available as food energy for the next animal in the food chain, is known as the percentage efficiency of energy transfer.

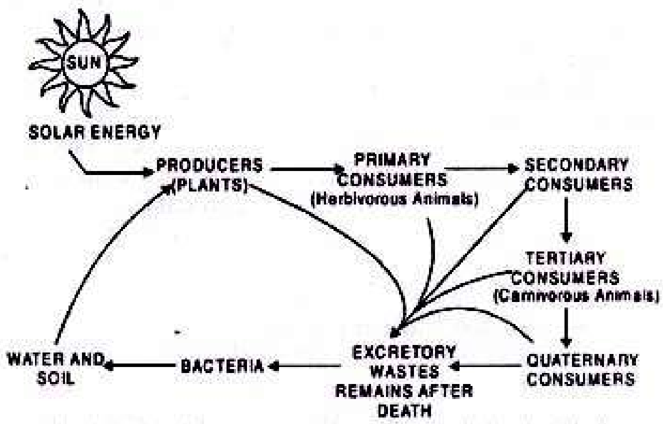


Fig. 4.5. Graphic representiation of a simple food chain in a typical ecosystem.

The flow of energy in ecosystems, from sunlight through photosynthesis in autotrophic producers, through the tissues of herbivorous primary consumers and the tissues of carnivorous secondary consumers, determines the number and total weight (biomass) of organisms at each level in the ecosystem. The flow of energy is greatly reduced at each successive level of nutrition because of the heat losses at each transformation of energy and this decreases the biomass in each level.

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

Humans are at the end of a number of food chains; for example, man eats a fish such as a black bass, which ate little fish, which ate small invertebrates, which ate algae. The ultimate size of the human population (or the population of any animal) is limited by the length of the food chain, the per cent efficiency of energy transfer at each step in the chain, and the amount of light energy falling on the earth.

Since humans can do nothing about increasing the amount of incident light energy and very little about the per cent efficiency of energy transfer, they can increase their food energy only by shortening their food chain, i.e., by eating the primary producers, plants, rather than animals. In overcrowded countries such as India and China, people are largely vegetarians because this food chain is shortest and a given area of land can in this way support the greatest number of people.

The aforementioned food chain which starts from a plant base, then goes to grazing or browsing herbivores and on to the predator carnivores is known as predator food chain or grazing & browsing food chain. In these food chains the size of the predators increases at each trophic level.

In addition to the predator food chains, there are parasitic food chains. For example, mammals and birds are parasitized by fleas; in the fleas live protozoa, which are in turn the hosts of bacteria. Since the bacteria might be parasitized by viruses, there could be a five-step parasite food chain. A parasite food chain also starts from a plant base and then goes to herbivores which may be the host of a large number of small animals (parasites).

4.6 Decay or detritus food chain

A third type of food chain is one in which plant material is converted into dead organic matter, detritus, before being eaten by animals such as millipedes and earthworms on land, by marine worms and molluscs, or by bacteria and fungi.

In a community of organisms in the shallow sea, about 30 per cent of the total energy flows via detritus chains, but in a forest community, with a large biomass of plants and relatively small biomass of animals, as much as 90 per cent of energy flow may be via detritus pathways. In an intertidal salt marsh, where most of the animals, i.e. shellfish, snails and crabs, are detritus eaters. 90 % or more of the energy flow is via detritus chains.

In a generalized form, a food chain may be represented as under:

Photosynthetic Organisms → Herbivores → Carnivores → Microorganisms for decay.

The energy originally derived from the sun by plants thus passes in material form through the various trophic levels of a food chain.

4.7 Examples

The food relations are very complex, even in a small community, but may be illustrated by two simplified examples.

(i) Food Chain in a Pond (Fig. 4.6):

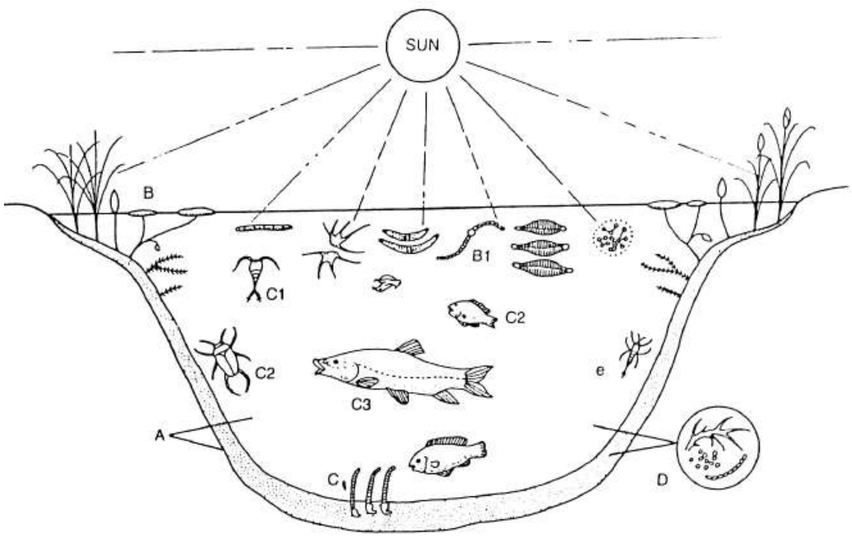


Fig. 4.6 A pond ecosystem.
A—Abiotic component; B and B1—Producers; C1—Primary consumers (herbivoers); C2—Secondary consumers; C3—Tertiary consumers; D—Decomposers—saprophytic bacteria and fungi.

In a pond, rooted or floating plants and floating algae synthesize food materials from dissolved nutrients. Unicellular algae are eaten by protozoans, which are in turn taken by small crustaceans. The latter are fed upon by water insects, which are devoured by small fishes. The small fishes are taken by large fishes. The large fishes, or any intermediate organisms, when dead, serve as food for the bacteria and fungi of decay. This completes the circuit.

(ii) Food Chain on Land (Figs. 4.7. & 4.8) :

On land, grass grows by synthesizing food from carbon dioxide of air and water and minerals of soil with the help of chlorophyll and sunlight. Grass is eaten by rabbits, which are preyed upon by cats. The latter may be taken by wolves, and the tigers may capture the wolves. The tigers as well as the other participants of the chain, on death, are reduced by bacteria and fungi of decay to simple inorganic materials. The latter are reused by grass.

Another land food chain is grass → grass shopper → frog ? snake → peacock → Hawk (Fig. 4.7).

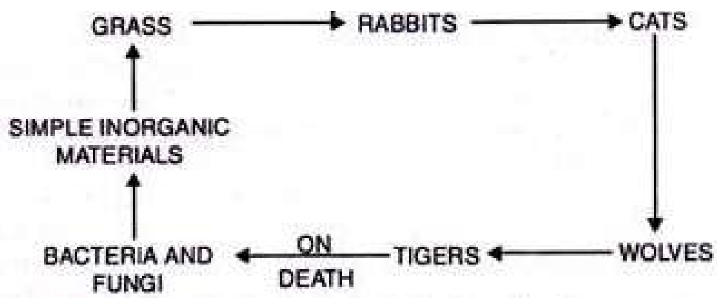


Fig. 4.7 A simple food chain on land.

There is perhaps no living thing that does not serve as a trophic level in some food chain. Some animals may form a link in more than one food chain. In any food chain, the successive members are larger in size but fewer in number.

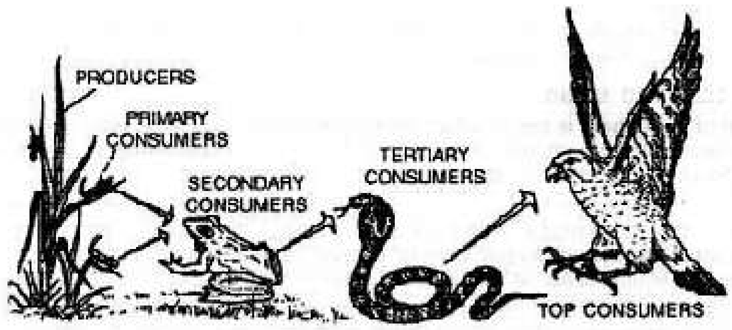


Fig. 4.8 A terrestrial food chain– 1. Producer-gfrass, 2. Primary consumer-grasshopper 3. Secondary consumer-Frog, 4. Tertiary consumer-Snake, 5. Quatemary Top consumer Hawk.

Food chains may be longer or shorter than those cited above, but usually there are only 4 or 5 successive trophic levels. An organism cannot always be assigned to just one trophic level. The insectivorous plants, such as Venus flytrap and pitcher plant, are producers as well as consumers. Frog is herbivorous in the larval and carnivorous in the adult stage. Many mammals, such as fox, bear and man, are omnivorous and belong to many trophic levels.

Three important ecological principles emerge from the study of food chains:

(i) To be complete and self-containing, a food chain must always begin with photosynthesis and end with decay. A food chain must get energy from outside to keep going,

(ii) The shorter a food chain, the more efficient it is. The more steps it has, the greater wastage of energy.

(iii) The size of any population is ultimately determined by the number of trophic levels in the food chain. With the decrease in useful energy at each step, very little energy is available for a population of quaternary consumers. The size of a population of quaternary consumers is less than that of tertiary consumers, a population of tertiary consumers is smaller than one of secondary consumers, and so on.

4.8 Food Web

Food chains are not strictly linear. They may have branches that may link one food chain with another. Thus, there may be several interlinked food chains in a community, and one animal may be a link in more than one food chain. The various interlinked food chains in a community constitute a food web, or food cycle. A food web includes all the feeding relationships in an ecosystem.

Composition: Normally a food web operates according to taste and food preferences of the organisms at each trophic level. However, availability of food source and other compulsions are equally important. In Sundarbans, the tigers eat fish and crab in the absence of their natural preys. Some organisms normally operate at more than one trophic level. Thus human beings are not only herbivores but also carnivores of various levels.

Jackals are both carnivores and scavengers. Snakes feed on mice (herbivores) as well as frogs (carnivores). Wild cats prey upon mice as well as birds and squirrels. A wolf eats not only fox but also rabbit and deer. Therefore, the concept of food web appears more real ecologically than the concept of a simple food chain.

The mechanism of operation of food web in maintaining stability of ecosystem is given below:

A herbivore, like rabbit, does not get starved if its preferred plant species is reduced in quantity due to some problems. It begins feeding on alternate plant species. The preferred gets chance to recover. It's same with the predators which also switch over to another alternative organisms if the prey of their first choice is not available.

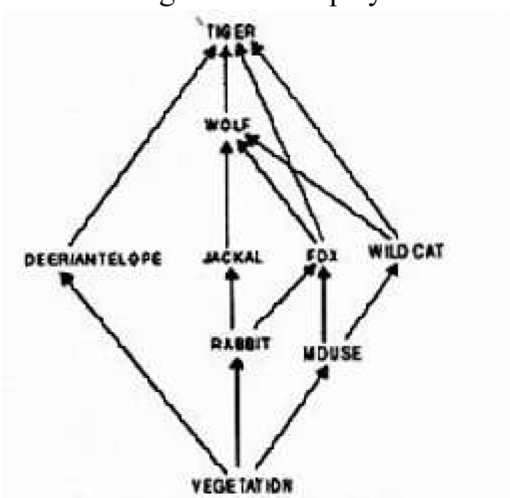


Fig. 4.9 A Terrestrial food web.

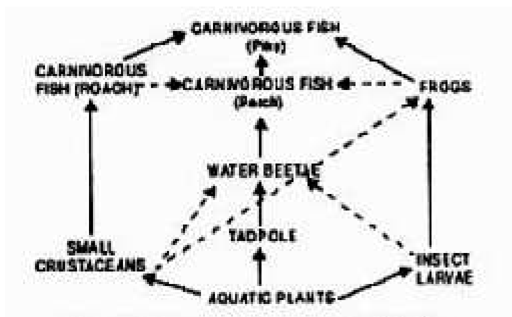


Fig. 4.10 An aquatic food web with the interconnected food chains.

In a food web there can be 3 types of food chains:

(i) Predator chains:

It begins with plants and proceeds from small to large animals.

(ii) Parasitic chains:

Which proceeds from large to small organisms.

(iii) Saprophytic chains:

That proceeds from dead animals to microorganisms.

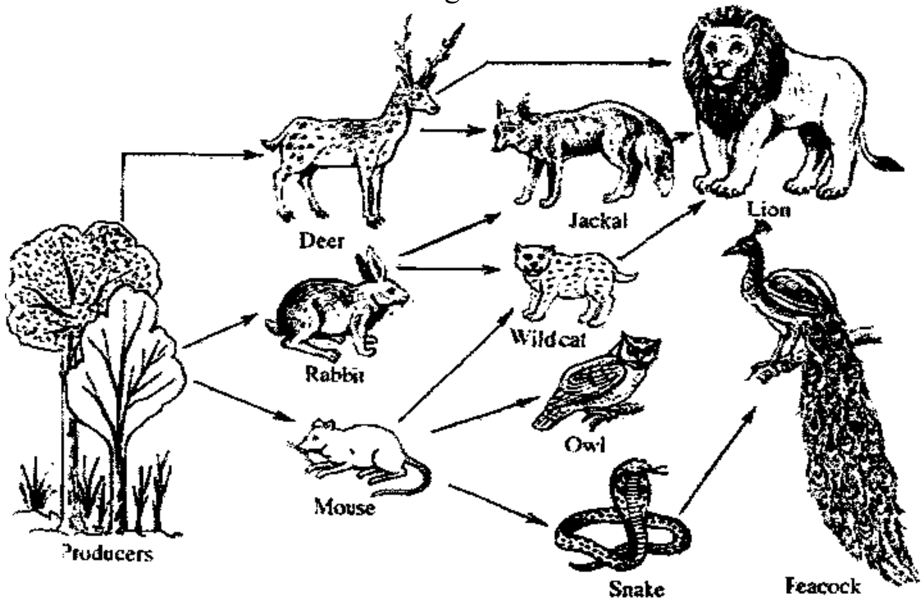


Fig. 4.11 Diagrammatic representation of food web in a forest ecosystem

4.9 Ecological Pyramids (Eltonian Pyramids)

An ecological pyramid is a graphic representation of a specific parameter (aspect) of a food chain developed by Charles Elton (1927). Since in any food chain there is a loss of energy at each step, it follows that there is a smaller biomass in each successive step.

A food chain may be visualized as a pyramid, each step in the pyramid is much smaller than the one on which it feeds. There are three important parameters of each trophic level in a food chain, namely, number of individuals, amount of biomass and amount of energy.

Accordingly, three types of ecological or food pyramids are recognized:

(1) Pyramid of numbers,
(2) Pyramid of biomass and
(3) Pyramid of energy.

In a food pyramid, the first trophic level forms the base and the last forms the apex.

1. Pyramid of Numbers:

The pyramid of numbers represents numerical relationship between different trophic levels of a food chain. Starting from the base of the pyramid and moving towards the apex, one finds a gradual decrease in the number of organisms and an increase in the body size (Fig. 4.12).

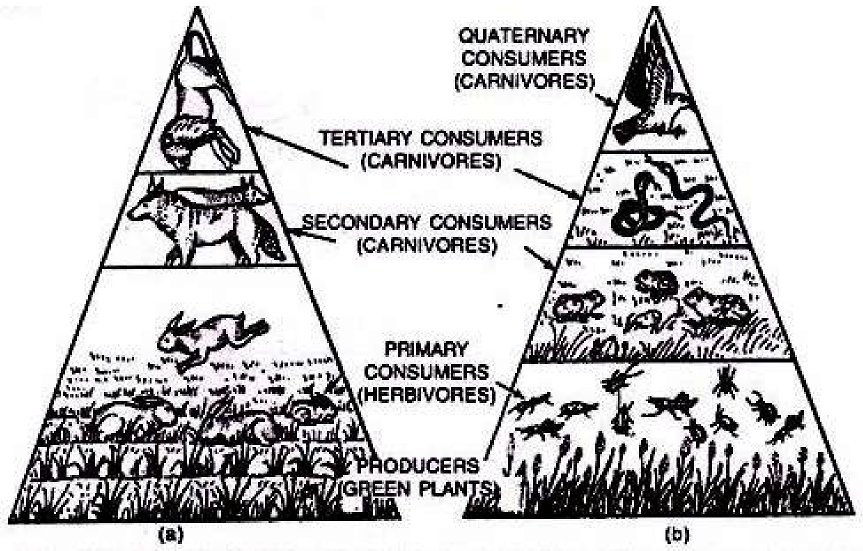


Fig. 4.12 •Upright pyramid of numbers showing decreasing number at successive stages (a) Grassiand ecosystem, (b) Crop ecosystem.

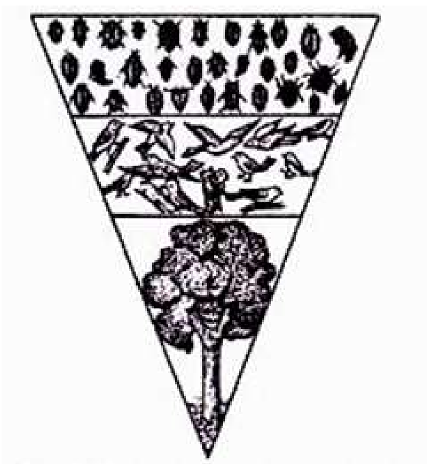


Fig. 4.13 An inverted pyramid of numbers of a tree ecosystem showing increase in a number of successive trophic levels.

In a lake ecosystem, the base of the pyramid is occupied by producers, such as diatoms and algae, whose number is maximum. The second trophic level is represented by zooplanktons, which are primary consumers and are less abundant than the producers. The third trophic level is represented by medium-sized fishes which feed upon primary consumers, these are still smaller in number. The apex or fourth trophic level is represented by large fishes which are very few in number.

Similarly in a grassland ecosystem, the base of the pyramid (i.e., first trophic level) is occupied by grasses (producers), and the apex by large carnivores, such as tigers (Fig. 4.12a). In parasitic food chains the pyramid of numbers is reversed (Fig. 4.13). For instance, a tree supports a large number of fruit or seed-eating birds, which in turn are infested by a large number of ecto- and endoparasites.

However, the pyramids of numbers is not an ideal device to illustrate the food chain because of its various drawbacks and limitations.

2. Pyramid of Biomass:

As the name itself indicates, the pyramid of biomass represents total weight of living matter present at each trophic level of the food chain. As one moves from base to apex, one finds gradual loss of biomass at each trophic level. For example, in a water ecosystem, the first trophic level (i.e. base) is occupied by a huge mass of phytoplankton; the second trophic level is occupied by zooplankton; the third trophic level is occupied by the primary carnivores, such as worms, mollusks and small fishes; the apex or fourth trophic level is occupied by large fishes.

Here also, in a parasitic food chain the pyramid of biomass is inverted (Fig. 4.15).

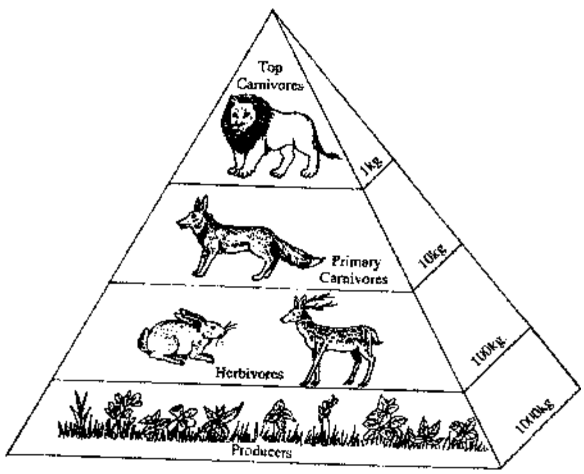


Fig. 4.14 Pyramid of biomass in a terrestrial ecosystem.

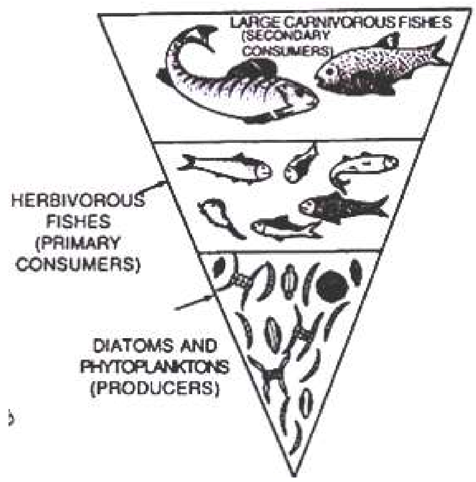


Fig. 4.15 An inverted pyramid of biomass of a pond ecosystem showing decrease innumber but increase in biomass.

The pyramid of biomass is relatively more illustrative than the pyramid of numbers because it represents quantitative relationship of the standing crop biomass.

3. Pyramid of Energy:

The pyramids of number and biomass do not take into consideration the rate of energy flow (i.e., rate of passage of food mass), while a pyramid of energy illustrates the total available energy at each trophic level of the food chain. Here also, as one moves from base to apex there is a gradual loss of energy (Fig. 4.16).

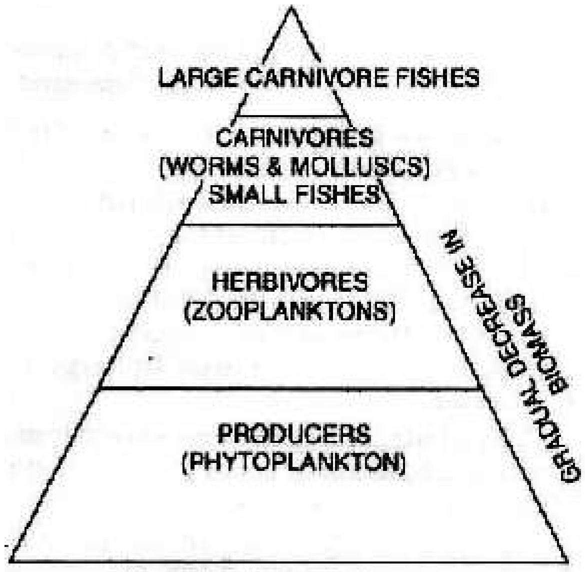


Fig. 4.16 Pyramid of energy.

It will be seen that the pyramid of energy is the best way to illustrate the functional nature of communities because:

(i) The number and weight of organisms at any trophic level depends on the rate at which food is being synthesized.

(ii) The shape of the pyramid of energy is not affected by variations in size and metabolic rate of individuals.

(iii) The number and biomass do not determine the role of decomposers in the dynamics of a community. Only measurements of actual energy utilization, as shown in the pyramid of energy, places the microorganisms in true relationship with the larger biotic components, and

(iv) It not only provides a means of comparing different ecosystems, it also helps in evaluating the relative importance of populations.

4.10 Cycling of Mineral Elements and Gases in an Ecosystem (Biogeochemical Cycles)

Life on the earth depends upon the availability of energy and circulation of essential elements needed for growth and development of plants and animals. These essential elements (nutrients) flow from nonliving to living world and back to nonliving in a more or less circular fashion and are called biogeochemical cycles.

These cycles are of three types such as:

(i) Hydrological cycles

(ii) Gaseous cycles, such as carbon, hydrogen, oxygen and nitrogen cycles and

(iii) Sedimentary cycles such as phosphorus, sulphur and calcium cycles.

4.10.1. Carbon Cycle

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the Earth. Carbon is one of the main component of all biological compounds and also a major component of many minerals such as limestone. Carbon cycle includes the movement of carbon as it is recycled and reused throughout the biosphere, as well as the long-term processes of sequestration of carbon to and release from the carbon sinks. The carbon cycle was discovered by Joseph Priestley and Antoine Lavoisier, and popularized by Humphry Davy.

a) Key features of Carbon cycle:

- Carbon is an essential element in the bodies of living organisms. It is also economically important in the form of fossil fuels.
- Carbon dioxide from the atmosphere is taken up by photosynthetic organisms and used to produce organic molecules, which travel through food chains. In the end, the carbon atoms are released as CO_2 in respiration of different organisms.
- Slow geological processes, including the formation of sedimentary rocks and fossil fuels, contribute to the carbon cycle over long timescales.
- Some human activities, such as burning of fossil fuels and deforestation, increase atmospheric CO_2 and affect Earth's climate and oceans.

b) Carbon: building block and fuel source :

About 18% of our body consists of carbon atoms, by mass. The plasma membranes of the cells, the sugar molecules in the cells as fuel and even the DNA that carries instructions to build and run our body is made up of carbon atoms.

Carbon is not only a part of our bodies, but it's also part of our modern-day industries. Carbon compounds formed long ago by plants and algae make up the fossil fuels, such as coal and natural gas that we use today as energy sources. When these fossil fuels are burned, carbon dioxide is released into the air, leading to the increase in atmospheric CO_2. This increase in CO_2 levels affects Earth's climate and is a major environmental concern worldwide.

c) The Carbon cycle

The carbon cycle is most easily studied as two interconnected subcycles:

- One dealing with rapid carbon exchange among living organisms
- One dealing with long-term cycling of carbon through geologic processes

Although the two cycles are separate, but actually these cycles are linked. For instance, the same pools of atmospheric and oceanic CO_2 that are utilized by organisms are also fed and depleted by geological processes.

Carbon exists in the air largely as carbon dioxide gas, which dissolves in water and reacts with water molecules to produce bicarbonate (HCO_3^-). Photosynthesis by land plants, bacteria, and algae converts carbon dioxide or bicarbonate into organic molecules. Organic molecules made by these autotrophs are passed through food chains and ultimately cellular respiration converts the organic carbon back into air or water in the form of carbon dioxide gas.

Long term storage of organic carbon occurs when the living organisms is buried deep underground or sinks to the bottom of the ocean and forms sedimentary rock. Volcanic activity and, more recently, burning of fossil fuels by human bring this stored carbon back into the carbon cycle. Although the formation of fossil fuels happens on a slow, geologic timescale, human release this carbon in the form of CO_2 on a very fast timescale.

The Biological Carbon cycle

Carbon enters all food webs, both terrestrial and aquatic, through **autotrophs**, or self-feeders. Almost all of these autotrophs are photosynthetic organisms, such as green plants, algae or photosynthetic bacteria.

Autotrophs capture carbon dioxide from the air or bicarbonate ions from the water and use them to produce organic compounds such as glucose. **Heterotrophs**, or other-feeders, such as animals, consume the organic molecules, and the organic carbon is passed through food chains and webs.

How does carbon cycle back to the atmosphere or ocean?

To release the energy stored in carbon-containing molecules, such as sugars, autotrophs and heterotrophs break these molecules down in a process called cellular respiration. In this process, the carbons of the molecule are released as carbon dioxide. Decomposers also release organic compounds and carbon dioxide when they break down dead organisms and waste products.

Carbon can cycle quickly through this biological pathway, especially in aquatic ecosystems. Overall an estimated 1,000 to 100,000 million metric tons of carbon move through the biological pathway each year. For context, a metric ton is about the weight of an elephant or a small car!

The Geological Carbon cycle

The geological pathway of the carbon cycle, on the other hand, takes much longer time than the biological pathway mentioned above. In fact, it usually takes millions of years for carbon to cycle through the geological pathway. Carbon may be stored for long periods of time in the atmosphere, bodies of liquid water (mostly oceans), ocean sediment, soil, rocks, fossil fuels, and Earth's interior.

The amount of carbon dioxide present in the atmosphere is influenced by the reservoir of carbon in the oceans and vice versa. Carbon dioxide from the atmosphere dissolves in water and reacts with water molecules in the following reactions:

$$CO_2 + H_2O \rightleftharpoons H_2CO^3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$$

The carbonate released in this process usually combines with Ca^{+2} ions to make calcium carbonate $CaCO_3^-$ a key component of the shells of marine organisms. When the organisms die, their remains may sink and eventually become part of the sediment on the ocean floor. Over geologic time, the sediment turns into limestone, which is the largest carbon reservoir on Earth.

On land, carbon is stored in soil as organic carbon by the decomposition of living organisms or as inorganic carbon formed by the weathering of terrestrial rock and minerals. Deeper under the ground fossil fuels such as oil, coal and natural gas, are the remains of plants decomposed under anaerobic oxygen-free conditions. Fossil fuels take millions of years to form. When humans burn these fossil fuels stored carbon is released into the atmosphere as carbon dioxide.

Another way for carbon to enter the atmosphere is by the eruption of volcanoes. Carbon containing sediments in the ocean floor are taken deep within the Earth in a process called subduction, in which one tectonic plate moves under another. This process forms carbon dioxide, which can be released into the atmosphere by volcanic eruptions or by hydrothermal vents.

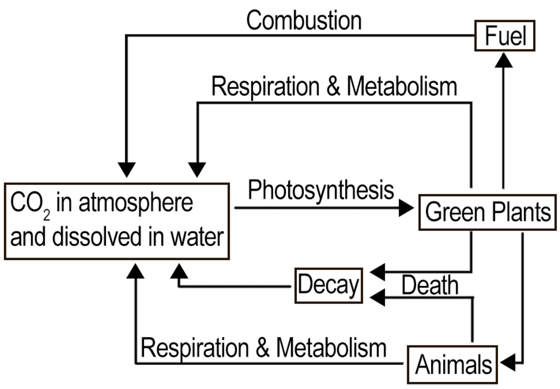


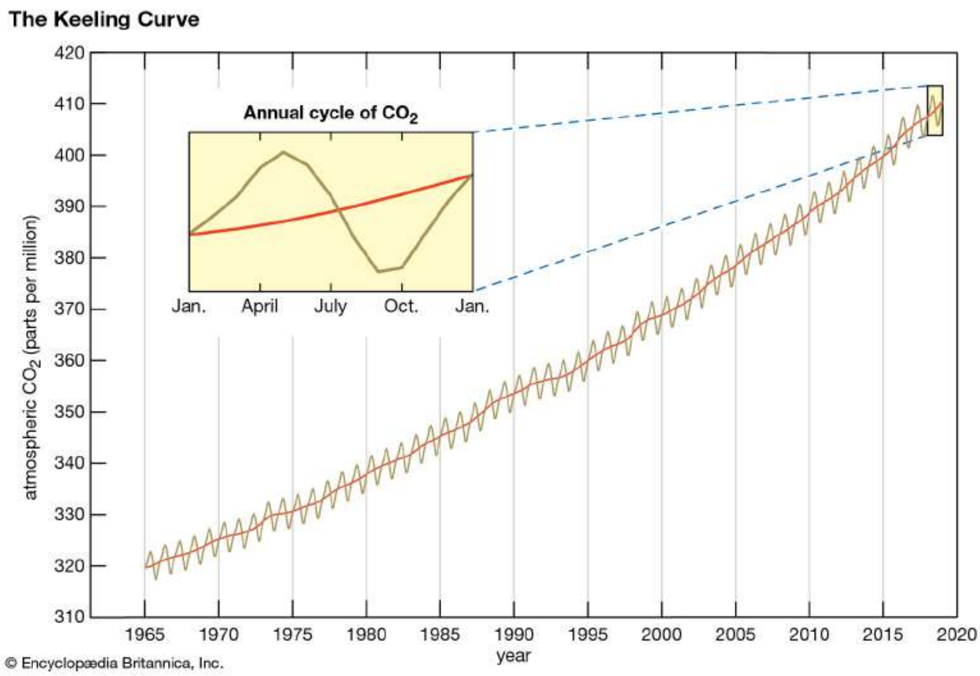
Fig. 4.17 Carbon Cycle.

d) Human impacts on the carbon cycle

Global demand for Earth's limited fossil fuel reserves has risen since the beginning of the Industrial Revolution. Fossil fuels are considered a non-renewable resource because they are being used up much faster than they can be produced by geological processes.

When fossil fuels are burned, carbon dioxide is released into the air. Increasing use of fossil fuels has led to elevated levels of atmospheric CO_2 is also a major contributor to increasing CO_2 levels. Trees and other parts of a forest ecosystem sequester carbon, and much of the carbon is released as CO_2 , if the forest is cleared.

Some of the CO_2 produced by human activities is taken up by plants or absorbed by the ocean, but these processes don't fully counteract the increase. So, atmospheric CO_2 levels have risen and continue to rise. CO_2 levels naturally rise and fall in cycles over long periods of time, but they are higher now than they have been in the past 400,000 years, as shown in the graph below:



CO_2 acts as a greenhouse gas. In the atmosphere, it traps heat and keeps it from radiating into space. Based on extensive evidences, scientists consider that elevated levels of CO_2 and other greenhouse gases are causing pronounced changes in Earth's climate. Without decisive changes to reduce emissions, Earth's temperature is projected to increase by 1 to 5ºC by the year 2100.

Also, while uptake of excess carbon dioxide by the oceans might seem good from a greenhouse gas perspective, it may not be good at all from the perspective of sea life. As we saw above, CO_2 dissolved in seawater can react with water molecules to release H^+ ions. So, dissolving more CO_2 in water causes the water to become more acidic. More acidic water can, in turn, reduce CO_3^- concentrations and make it harder for marine organisms to build and maintain their shells $CaCO_3$. Both increasing temperatures and higher acidity can harm sea life and have been linked to coral bleaching.

4.10.2. Nitrogen Cycle

Nitrogen is the fourth most prevalent element in living systems. It is a constituent of a number of organic compounds like amino acids, proteins, nucleotides, nucleic acid, hormones, chlorophyll, many vitamins, etc.

However, its availability from soil is limited and even for that plants have to compete with microbes both in natural and agricultural ecosystems. Nitrogen is available in the atmosphere in abundance (78% of atmosphere as di-nitrogen or N_2) but plants cannot directly absorb the same.

Therefore, nitrogen is the most critical element. A regular supply of nitrogen to the plants is maintained through nitrogen cycle. Nitrogen cycle is regular circulation of nitrogen amongst living organisms, reservoir pool in the atmosphere and cycling pool in the lithosphere. Nitrogen compounds are obtained from reservoir pool through nitrogen fixation.

a) Nitrogen fixation:

Conversion of free nitrogen of atmosphere into the biologically acceptable form or nitrogenous compounds is referred to as nitrogen fixation.

This process is of two types:

(i) Physico-chemical or non-biological nitrogen fixation and

(ii) Biological nitrogen fixation.

In physico-chemical process, the atmospheric nitrogen combines with oxygen (as ozone) during lightning or electrical discharges in the clouds and produces different nitrogen oxides.

The equations are as follows:

$$N_2 + 2(O) \xrightarrow[\text{discharge}]{\text{electric}} 2NO$$
$$2NO + 2(O) \longrightarrow 2NO_2$$
$$2NO_2 + (O) \longrightarrow N_2O_5$$

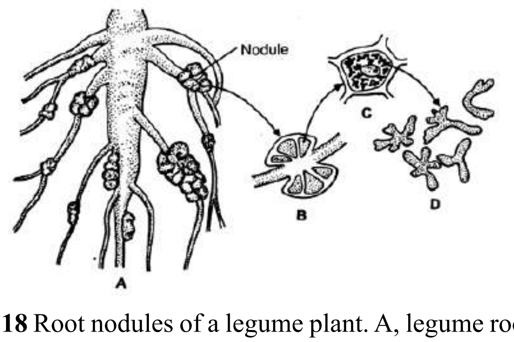


Fig. 4.18 Root nodules of a legume plant. A, legume root with nodules; B, T.S. of root nodule; C, single cell of nodule; D, nitrogen fixing bacterium, Rhizobium.

These nitrogen oxides get dissolved in rain water, and on reaching earth surface they react with mineral compounds to form nitrates and other nitrogenous compounds:

$$N_2O_5 + H_2O \longrightarrow 2HNO_2$$
$$2HNO_2 + CaCO_2 \longrightarrow Ca(NO_3)_2 + CO_2 + H_2O$$

During combustion of various types, some nitrogenous compounds are formed, which are washed down along with rain water.

Biological nitrogen fixation is carried out by certain prokaryotes. The cyanobacteria (blue-green algae) fix significant amounts of nitrogen in the oceans, lakes and soils.

Symbiotic bacteria (*Rhizobium*) inhabiting the root nodules of legumes and symbiotic cyanobacteria, such as *Nostoc, Anabaena*, etc., found in free state, or in thalli of *Anthoceros* (bryophyte), *Azolla* (water fern), coralloid roots of *Cycas* (gymnosperm) fix atmospheric nitrogen.

Certain free living nitrogen fixing bacteria, such as *Azotobacter*, *Clostridium, Beijerinckia*, etc., also fix free nitrogen of atmosphere in the soil. *Frankia*, an actinomycetous fungus found in the roots of higher plants, such as *Alnus* and *Casuarina*, also fix nitrogen.

Nitrogen fixing organisms combine the gaseous nitrogen of atmosphere with hydrogen obtained from respiratory pathway to form ammonia, which then reacts with organic acids to form amino acids.

Biological nitrogen fixation is the major source of fixed nitrogen up-to 140 - 700 mg/m^2 year as against 35 mg/m^2/year by electrical discharge and photochemical fixation.

Nitrogen Assimilation:

Inorganic nitrogen in the form of nitrates, nitrites and ammonia is absorbed by the green plants and converted into nitrogenous organic compounds. Nitrates are first converted into ammonia which combines to organic acids to form amino acids. Amino acids are used in the synthesis of proteins, enzymes, chlorophylls, nucleic acids, etc.

Animals derive their nitrogen requirement from the plant proteins. Plant proteins are not directly utilised by the animals. They are first broken down into amino-acids during digestion and then the amino-acids are absorbed and manipulated into animal proteins, nucleic acids, etc.

Ammonification:

The dead organic remains of plants and animals and excreta of animals are acted upon by a number of microorganisms, especially actinomycetes and bacilli, such as *Bacillus ramosus*, B. *vulgaris*, etc. These organisms utilise organic compounds in their metabolism and release ammonia. This process is called ammonification. After meeting their own metabolic requirement, these microbes release the excess ammonia in the soil.

Nitrification:

In next step of ammonia formation, ammonia is converted into nitrate by a group of chemo-autotrophic bacteria through a two-step process called nitrification.

Certain bacteria, such as *Nitrosomonas, Nitrococcus* and *Nitrospira* in oceans and soils convert ammonia into nitrites and then nitrites into nitrates. These bacteria primarily use the energy of dead organic matter in their metabolism. The equation is as follows:

$$2NH_4 + 2O_2 \longrightarrow NO_2^- + 2H_2O + \text{energy}$$

Conversion of nitrites to nitrates is brought about by several microbes, such as *Penicillium* (a fungus), *Nitrobacter*, etc.

$$2NO_2^- + O_2 \xrightarrow{Nitrobacter} 2NO_3^- + \text{energy}$$

Some nitrates are also made available through weathering of nitrate containing rocks.

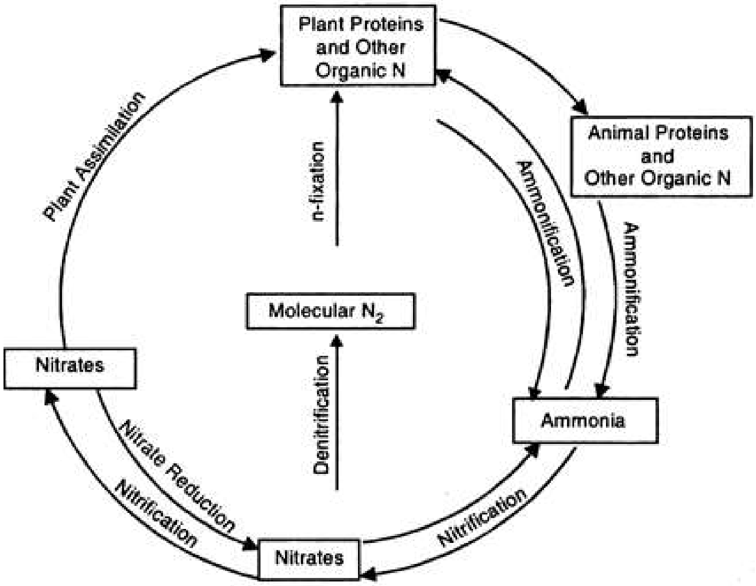


Fig. 4.19 Nitrogen Cycle.

Denitrification:

Ammonia and nitrates are converted into free nitrogen by certain microbes. This process is referred to as denitrification. *Pseudomonas denitrificans*, the most common denitrifying bacterium, thrives best under poorly aerated and detritus-rich conditions. Denitrifying bacteria transform nitrate nitrogen to nitrous and nitric oxides, and ultimately to gaseous nitrogen, which goes to atmosphere.

Denitrification by denitrifying bacteria.

$$2NO_3^- \longrightarrow 2NO_2^- \longrightarrow 2NO \longrightarrow N_2$$

Sedimentation:

Nitrates of the soil are washed away to the sea or leached deep into the earth along with percolating water. Nitrates thus lost from the soil surface are locked up in the rocks. This process is called sedimentation of nitrogen. Nitrogen of rock is released only when the rocks are exposed and weathered.

Thus a large part of nitrogen is fixed up and stored up in plants, animals and microbes. Higher plants absorb nitrate from the soil; the absorbed nitrate is ultimately converted to organic nitrogen. A fraction of nitrogen incorporated in plant tissues is used by consumers, and ultimately all dead remains convert into detritus and used by decomposers. Thus, complex nitrogen cycle completes.

4.10.3 Phosphorus cycle

The Phosphorus cycle, unlike those of Carbon and Nitrogen cycles lacks an atmospheric component. The global phosphorus cycle involves only aquatic and soil compartments. As a basic constituent of nucleic acids, phospholipids and numerous phosphorylated compounds, phosphorus is one of the nutrients of major importance to biological systems.

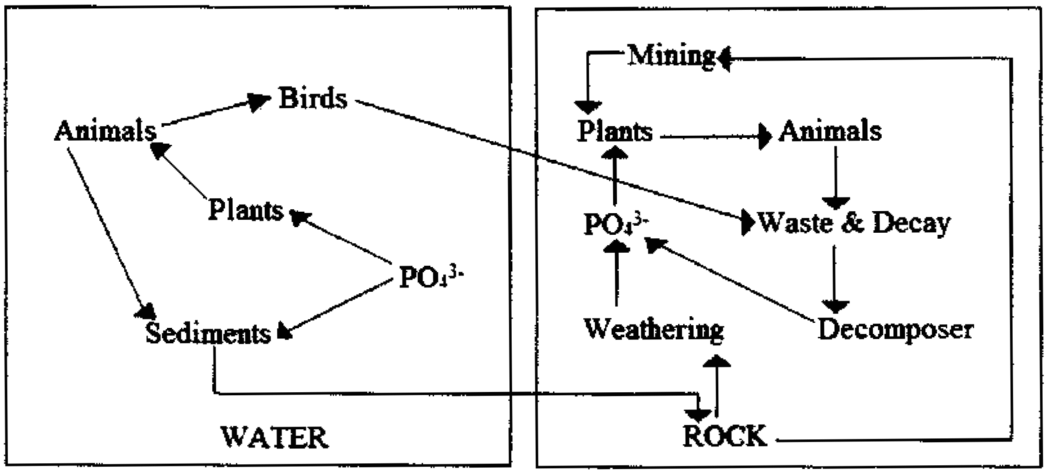


Fig. 4.20 Schematic representation of Phosphorus Cycle.

Further, as Hutchinson has noted, because the ratio of phosphorus to other elements in organisms tends to be considerably greater than the ratio of phosphorus in the available and primary sources, phosphorus becomes ecologically significant as the most likely limiting or regulating element in productivity.

Basic source and the great reservoir of phosphorus are the rocks or other deposits which have been formed in the past geological ages. These gradually erode and release phosphates to the ecosystems. Most of the phosphates escape into the sea where part of it is deposited in the shallow sediments and part of it is lost to the deep sediments.

However, the means of returning phosphorus to the cycle are inadequate to compensate for the loss. The principal global flux of phosphorus consists of the movement of about 21×10^{12} g P $yr.^{-1}$ from the terrestrial pool to the oceans through the rivers. Phosphate fertilizers, used in agriculture, are added to the soil at a rate of about 14×10^{12} g yr^{-1}, which is also carried into the oceans by runoff and rivers (Schlasinger 1991, Caraco 1993).

Much phosphates become lost to this central cycle by physical processes, such as sedimentation, which take it out of the reach of upwelling and major water circulation. Biological process, such as the formation of teeth and bone, and excretion also account for considerable losses from the major portion of cycle.

The fish and marine birds are also important in phosphorus cycle. The latter have apparently played an important role in returning phosphorus to the cycle. In this context we can consider the tremendous deposits of guano (the manure of sea birds) along the western coast of South America.

Although man harvests a lot of marine fish, according to Hutchsinson, only about 60,000 tons of elementary phosphorus per year is returned in this manner, compared with one to two million tons of phosphate rocks which are mined and most of which are washed away and lost.

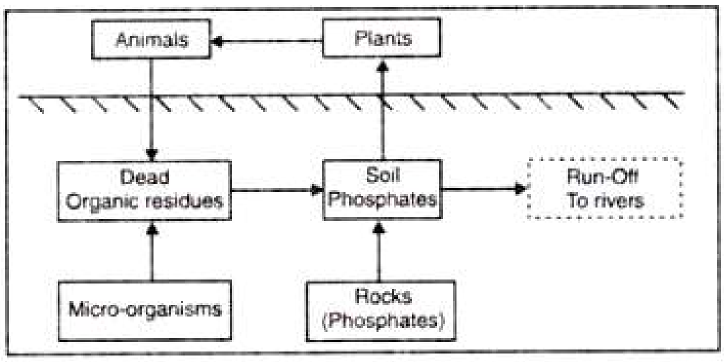


Fig. 4.21 The Phosphorus cycle on land.

For their nutrition plants absorb water dissolved inorganic phosphates from the soil either as di-hydrogen phosphate (H_2PO_4) or as hydrogen phosphate (HPO_4) and convert these into organic phosphate. The latter is transferred to animal consumers and decomposers.

Decomposers return phosphorus to the soil as the phosphate ion. Phosphate absorbed from the soil is thus returned back to soil in the form of dead plant and animal organic residues, which are converted to humus by the action of soil microorganisms. Much of the phosphate in the soil is fixed or adsorbed on to soil particles but some is lost through leaching out into watercourses.

In fresh water, the floating algae or phytoplankton rapidly absorb soluble inorganic phosphates and convert them into organophosphates. Algae provide food for zooplankton which in turn are consumed by other animals. All plants and animals eventually die and in due time their organic remains or debris decay through the action of microorganisms, and phosphates are released into the water for recycling. In aquatic plants, phosphorus, limits plant growth.

Certain specialized fungi play an important role in phosphorus cycle. In many cases plant species have mycorrhizae (fungus roots), a mutualistic relationship between a non-pathogenic fungus and living plant root cells (Salisbury and Ross, 1985). These mycorrhizae play an important role in soil nutrient cycling. The mycorrhizae help in solubilisation of inorganic phosphates and make them available for the plants and in turn they get nutrition from the plant.

Natural phosphate cycle can be very much affected by pollution. Agricultural fertilizers containing superphosphate or triple superphosphate are now frequently used in the fields; and sewage, even after treatment, contains phosphates derived from excreta and detergents. These phosphates can eventually reach freshwater streams and rivers through the land run-off and effluent discharge. Phosphate pollution of rivers and lakes has caused excessive growth of algae, which depletes the dissolved oxygen content of water and disrupts the natural food chains.

4.11 Summary

Ecosystem includes the interaction between biotic and abiotic components. The biotic componens include producers, consumers and decomposers. The consumers may be– primary, secondary, tertiary or quaternary in nature. The aboitic components include temperature, light, wind, humidity, precipitation, water topography, gases, soil, pH, minerals, etc. The energy flow in an ecosystem is always undirectional and the transfer of energy from one level to another follow 10% law. The transfer of energy from productsf to the consumers, through a series of organisms which eats the preceding and is eaten by the following is known as food chain. Food web includes various interlinked food chains in a community. An ecological pyramid is a graphic representation of a specific as pect of a food chain. It may be of different types-pyramid of numbers, pyramid of biomass and pyramid of energy. The cycling of nutrients from non-living to living world and again back to non-living form is known as biogeochemical cycles. In this chapter we have an idea of carbon cycle, nitrogen cycle and phosphorus cycle.

4.12 Questions & Answers

Q1. Define ecosystem.

Ans.: "The ecosystem is the basic functional unit of organisms and their environment interacting with each other and their own components" (E. P. Odum, 1963).

"Ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity, 1992).

Q2. Give a brief account of the different components of an ecosystem.

Ans.: vide section 4.2

Q3. What are producers?

Ans.: These are the autotrophic organisms including green plants, some protists and certain bacteria which can trap light energy and convert them into chemical energy by the process called photosynthesis.

Q4. What are primary consumers? Give example.

Ans.: Primary consumers are the animals which eat plants or plant products. They are called herbivores, e.g. - Cattle, deer, goat, rabbit, etc.

Q5. What are secondary consumers? Give example.

Ans.: These are the animals which eat herbivores. They are called carnivores, e.g. cats, dogs, foxes, etc.

Q6. What are tertiary consumers? Give example.

Ans.: These are larger carnivores which feed on secondary consumers. For example, wolves, tigers, lion, etc.

Q7. What are decomposers?

Ans.: These are mainly **microorganisms** like bacteria and fungi. They obtain their food molecules from the organic materials of dead producers (plants) and consumers (animals) and their waste products. In the process of extracting nutrients and energy from these materials, they decompose the latter into:

(i) Small organic molecules which they utilize themselves, and

(ii) Into inorganic compounds that are released into the environment for reuse as raw materials by producers.

For example, *Aspergillus, Rhizopus, Bacillus, Clostridium,* etc.

Q8. Comment on the role of the decomposers in an ecosystem.

Ans.: vide section 4.2 iii.

Q9. Comment on the different abiotic components of an ecosystem.

Ans.: vide section 4.2, pt II.

Q10. Describe the process of energy flow in an ecosystem.

Ans.: vide section 4.4

Q11. What is 10% law?

Ans.: If the net primary production is taken to be 100 units in producers, only 10 units of potential energy of plant material is actually assimilated by the herbivores. Similarly only 1 unit of potential energy of herbivores is assimilated in carnivores. Thus, during energy flow in ecosystem, the energy fixed in one level is only 10% of its previous level. It is known as 10% law.

Q12. Write a short note on Food chain.

Ans. Vide section 4.5

Q13. What is detritus food chain? Comment on this type of food chain.

Ans.: vide section 4.6

Q14. Describe the food chain in an aquatic system with suitable diagram.

Ans.: vide section 4.7

Q15. Describe the food chain in a terrestrial ecosystem with suitable diagram.

Ans.: vide section 4.7

Q16. Write a short note on food web.

Ans.: vide section 4.8

Q17. What is ecological pyramid?

Ans.: An ecological pyramid is a graphic representation of a specific parameter (aspect) of a food chain developed by Charles Elton (1927). Since in any food chain there is a loss of energy at each step, it follows that there is a smaller biomass in each successive step.

Q18. Comment on - pyramid of numbers, pyramid of biomass and pyramid of energy.

Ans.: vide section 4.9

Q19. What are biogeochemical cycles?

Ans.: Life on the earth depends upon the availability of energy and circulation of essential elements needed for growth and development of plants and animals. These essential elements (nutrients) flow from nonliving to living world and back to nonliving in a more or less circular fashion and are called biogeochemical cycles.

Q20. Describe the carbon cycle with suitable diagram.

Ans.: vide section 4.10.1 c.

Q21. What is nitrogen cycle?

Ans.: Nitrogen cycle is regular circulation of nitrogen amongst living organisms, reservoir pool in the atmosphere and cycling pool in the lithosphere. Nitrogen compounds are obtained from reservoir pool through nitrogen fixation.

Q22. Describe the nitrogen cycle with suitable diagram.

Ans.: vide section 4.10.2.

Q23. Name two bacteria that can symbiotically fix atmospheric nitrogen.

Ans.: *Rhizobium leguminosorum, Bradyrhizobium* sp.

Q24. Name two free living bacteria that can fix atmospheric nitrogen.

Ans.: *Azotobacter, Clostridium, Beijerinckia*, etc.

Q25. Name one fungus that can fix nitrogen.

Ans.: *Frankia.*sp.

Q26. What is ammonification?

Ans.: The dead organic remains of plants and animals and excreta of animals are acted upon by a number of microorganisms, especially actinomycetes and bacilli, such as *Bacillus ramosus, B. vulgaris*, etc. These organisms utilise organic compounds in their metabolism and release ammonia. This process is called ammonification.

Q27. What is nitrification?

Ans.: In nitrogen cycle ammonia is converted into nitrate by a group of chemo- autotrophic bacteria (*Nitrosomonas* and *Nitrobacter*) through a two-step process called nitrification.

Q28. What is denitrification?

Ans.: Ammonia and nitrates are converted into free nitrogen by certain microbes. This process is referred to as denitrification.

Q29. Name one denitrifying bacteria.

Ans.: *Pseudomonas denitrificans.*

Q30. Describe the phosphorus cycle with suitable diagram.

Ans.: vide section 4.10.3

Unit 5 ❐ Phytogeography

Structure

5.0 Objective

- In this unit we shall also have an insight of the endemism.
- You will get an idea about different types, theories and factors affecting endemism.

5.1 Introduction

Phytogeography deals with the spatial (*i.e.* relating to space) relationship of plants in present and the past. The distribution of plants on the surface of the earth is greatly influenced by two factors-inherent and geographic. The inherent factors are mainly genetical, while geographic factors are mainly ecological and topographical. In this chapter you will have an idea of phytogeographical regions of India and their characteristic vegetation types. Endemism is an importantcharacter of the vegetation of a particular area. It is the confinement of a particular species in an area.

5.2 Main Biogeographic Regions

Vegetation of any place is modified by the environmental factors— climate, geology and biotic factors.

The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation.

India has been divided into the following botanical zones by D. Chatterjee (1962):

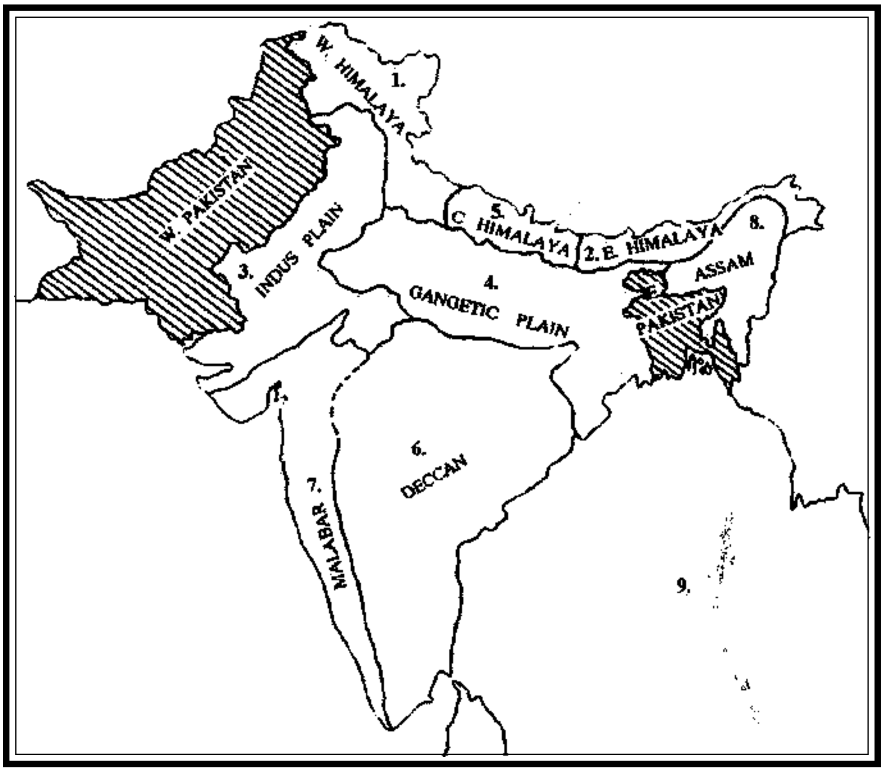


Fig. 5.1. Phytogeographical regions of India (according to D. Chatterjee, 1962)

(1) Western Himalayas,

(2) Eastern Himalayas,

(3) Indus plain,

(4) Gangetic plain,

(5) Central Himalayas,

(6) Deccan,
(7) Western coasts of Malabar,
(8) Assam, and
(9) Bay Islands of Andaman and Nicobar.

5.2.1. Western Himalayas

The northern part of our country is bounded by highest ranges of Himalayas and is one of the important botanical regions of the world with climate and vegetation ranging from truly tropical near the low altitudes to temperate arctic types at the high altitudes. The northern mountain division can phytogeographically be divided into western, central and eastern zones.

Western Himalayas consist of north Kashmir, south Kashmir, a part of Punjab, H.P., Garhwal and Kumaon. This zone is wet in outer southern ranges and slightly dry in inner northern zone. The average annual rainfall in this region is from 100 to 200 cm. Snowfall occurs in this region during winter season. The region may be divided into three subzones.

(i) Submontane zone or lower region or tropical and subtropical belts (up to about 1500 metres altitude from the sea level).

(ii) Temperate zone (from 1500 metres to 3500 metres altitude),

(iii) Alpine zone (above 3500 metres and up to the line of perpetual snow).

(i) Submontane or lower region or tropical and subtropical belts:

It includes outer Himalayas, particularly region of Siwaliks and adjoining areas where annual average rainfall is over 100 cm. This zone ranges between 300 and 1500 metres above sea level. In this zone, forests is dominated by timber trees of *Shorea robusta*. Other important tree species include *Salmalia malabaricum*, *Butea monosperma. Acacia catechu* and *Zizyphus* sp. At higher elevation (1000 to 1500 metre), cheer (pine) forests are also found at certain places. The common species of pine are *Pinus longifolia* and *Pinus roxburghii*.

(ii) Temperate zone:

It ranges at the altitudes from 1500 to 3500 metres above the sea level. *Quercus* are dominant along with *Populus, Rhododendron, Betula* and *Pyrus. Pinus excelsa, Cedrus deodara, Picea, Abies, Cupressus* and *Taxus baccata* are found in the heavy rainfall region (between 1600 and 1800 m). Herbs are also common in this region. Common herbs are *Ranunculus, Polygonum, Pedicularis, Potentilla. Primula, Delphinium, Clematis* and many members of Asteraceae.

In west Kashmir rice cultivation is common Sar or saffron (*Crocus sativus*), apples, peaches, walnut, almonds and other fruits are important economic plants of Kashmir region.

(iii) Alpine zone:

Above the altitude of 3500 metres and up to snowline (about 5000 m) is the alpine zone. The vegetation consists of evergreen conifers and some low and broad leaved trees. In lower alpine region, shrubby forests are common which may be (a) Birch-fir forest which is fairly dense and is mixed with evergreen shrubby Rhododendron at higher level and (b) Birch-*Rhododendron* forests in which silver fir, *Betula, Rhododendron* and *Juniperus* are common. In the upper alpine region, prominent herbaceous plants include the species of *Primula, Polygonum, Gentiana, Meconopsis, Saxifraga, Potentilla, Geranium, Aster, Astragalus*, etc. At about 5000 metre altitude and above snow perpetuates round the year and plant growth is almost nil. This altitude is called snow line or ice line.

5.2.2 Eastern Himalayas

Eastern Himalayas extend from Sikkim to upper Assam, Darjeeling and NEFA. Vegetation of this region differs from that of western Himalayas. The chief differences are due to changed environmental factors as heavy monsoon rainfall, less snowfall and high temperature and humidity.

This region can also be divided into:

(i) Tropical submontane zone

(ii) Temperate or Montane zone, and

(iii) Alpine zone

(i) Tropical or Submontane Zone:

The tropical subzone characterized by warm and humid conditions extends from plain up to the altitude of about 1800 m. In this zone mostly sal (*Shorea robusta*) forests, and mixed deciduous forests consisting of important plants, such as *Sterculia, Terminalia, Neolamarkia cadamba* and *Bauhinia* are common. In the savannah forests, common plants are *Albizia procera, Bischofia, Salmelia, Dendrocalamus*. In evergreen forests *Dillenia indica, Michelia champaca, Echnocarpus, Cinnamomum*, etc. are common.

(ii) Temperate or Montane Zone:

It may be further divided into upper and lower zones Lower temperate zone is the region between 1800 and 3000 metre altitudes. In the lower temperate zone, Oaks (*Quercus*), *Michelia, Pyrus, Cedrela, Eugenia*, etc. are common plants. In upper temperate zone (3000-4000 metre altitude), conifers and *Rhododendrons* are common. Important conifers of this region include *Picea, Abies, Larix, Juniperus, Tsuga*, etc.

(iii) Alpine Zone (from 4000 metres up to snow line):

Climate is humid and extremely cold. The vegetation in the alpine zone is characterised by complete absence of trees and predominance of shrubs and meadows. Important plants of this zone are Rhododendron and Juniperus.

5.2.3. Indus Plains

It includes part of Punjab, Rajasthan, Cutch, Delhi, a part of Gujarat. Some part of this plain is now in Pakistan. The climate of this zone is characterised by dry hot summer, and dry cold winter. Rainfall is usually less than 70 cms, but in certain regions it is as low as 10-15 cms. The soil of a wide area except cultivated land, is saline. Much of the land has become desert due to excessive dryness.

Vegetation is mainly bushy and thorny *Acacia arabica, Prosopis spicigera, Salvadora* sp., *Capparis decidua* are very common plants of this region. *Salsola phoetida* and Lunakh grass are found mostly in saline soils. Other plants of this botanic province are *Anageissus, Eugenia, Mango, Dalbergia sisso, Albizia lebbeck, Zizyphus nummularia*, etc.

Historical evidences indicate that the area was covered by dense forest some 2000 years ago, but gradual destruction of vegetation cover either by biotic agencies or by any other agency led to the development of desert in this plain. *Saccharum munjo, Cenchrus ciliaris, Prosopis spicigera, Acacia leucophloea, A. senegal* are the important plant species which are grown for checking the spread of desert.

5.2.4. Gangetic Plains

This is one of the richest vegetational zones in India. This zone covers flat land of a part of Delhi, whole of U.P., Bihar, and West Bengal and also a part of Orissa. Rainfall in this zone is from 50 cm to 150 cm. A great part of the land is under cultivation. The common crop plants are wheat, barley maize. jowar (*Sorghum* sp.), Bajra (*Pennisetum glaucum*), urad (*Vigna* sp), Moong (*Phaseolus mungo*), *Cajanus cajan*, til (*Sesamum indicum*), sugarcane. Pea (*Pisum* sp.), gram (*Cicer arietinum*), potato, *Brassica*, rice (*Oryza* sp.).

In western part of U.P. annual rainfall is from 50 cm to 110 cm. Dry deciduous and shrubby forests are common in this part. Important plants of south-western part of U.P. are *Capparis, Saccharum munja, Acacia arabica*. In the north-western part of U.P. near Himalayas foot-hills *Dalbergia sisso*. *Acacia arabica* are most common plants.

In eastern gangetic plain, the conditions are cold and wet (annual rainfall, 150 cm in West Bengal). In this part evergreen forests are common. In central part, the annual rainfall is about 100 cm to 150 cm. The vegetation consists mainly of deciduous trees. Sal trees are dominant. Other common trees are *Terminalia tomentosa*, *T. belerica*. *Acacia* sp., *Bauhinia* sp., *Diospyros* sp., *Eugenia* sp., neem trees (*Azadirachta indica*), *Madhuca indica* (Mahua), *Cordia myxa* (Lisora), *Tamarindus*, Mango (*Mangifera indica*), *Ficus* sp., etc.

In Bihar and Orissa hills, *Rubus, Potentilla, Fragaria* (Rosaceae), *Pyrus*, etc. are common. Mangrove vegetation is common in tidal regions in West Bengal near Sundarban, and Orissa.

Rhizophora mucronata, Sonneratia, Ceriops roxburghiana and *Acanthus ilicifolius, Kandelia rheedii, Bruguiera gymnorrhiza* are common mangrove plants in those regions.

5.2.5. Central Himalayas

Central Himalayas basically composed of parts of Kumaon including Garhwal, but most of the part belongs to Nepal. the different forest types of central Himalaya are composed mostly of evergreen broad leaf species and conifer species. A number of tree species found in the Himalaya showed varying patterns of distribution. Distributional ranges ofseveral species were segregated along the widened altitudinal ranges. Forests of this region are mainly dominated by *Pinus roxburghii* (Chir Pine) and *Quercus leucotrichophora*. (Banj oak). Chir pine often forms a pure crop in this area but, sometimes it also mixes with certain broad leaved species like *Q. leucotrichophora, Quercus glauca, Pyrus pashia, Myrica esculanta* and *Rhododendron arboretum*. The upper limit of tree species ranged between 4000-4600 m (*Rhododendron campanulatum* and *Betula utilis*). *Q. leucotrichophora* prefers cooler aspects below 1900m. The otehr species include *Michelia, Cedrela, Eugenia,* etc. in upper temperate zone conifers and *Rhododendrons* are common. Important conifers of this region include *picea, Abies, Larix, jumiperus, Tsuga,* etc.

5.2.6. Deccan

This region comprises whole of the southern peninsular India including Satpura and southern part of Godawari River. Average annual rainfall in this region is about 100 cm.

It may be divided into the following two subdivisions:

(i) Deccan plateau,

(ii) Coromandel coast.

In Deccan plateau teak forests containing *Diospyros, Acacia, Prosopis spicigera. Santalum album* (chandan tree) and *Cedrela toona* are common. On rocks, *Capparis, Euphorbia, Phyllanthus* are common. *Tectona, Pterocarpus*, *Borassus, Phoenix*, etc. are also common in this area In Chhota Nagpur plateau, important species are *Clematis natans, Berberis, Thallictrum* along with many members of Annonaceae, Rosaceae, Compositae, Araliaceae, Apocynaceae, Lauraceae, Amaranthaceae, Orchidaceae, etc.

In Coromandel Coast vegetation consists largely of some halophytic species.

5.2.7. Western Coast of Malabar

This is small botanical province covering Cape Comorin to Gujarat and Western Ghats .This is a region of heavy rainfall.

In this zone, four types of forests are common:

(i) Tropical forests (occur at 700 m altitude),

(ii) Mixed deciduous forests (found at the altitude up to 1600 m),

(iii) Temperate evergreen forests (occur above 1200 m altitude), and

(iv) Mangrove vegetation.

In tropical evergreen forest the trees are tall and they have root buttresses. Important species are *Cedrela toona, Dipterocarpus* spp., *Mangifera indica, Sterculia alata, Artocarpus hirsuta*. In the mixed deciduous forests, important plants are *Terminalia tomentosa, Terminalia paniculata, Tectona grandis, Dalbergia, Lagerstroemia lanceolata* and bamboo species, particularly *Dendrocalamus* and *Bambusa arundinacea*. On the Nilgiri hills sub-tropic and temperate conditions exist. Important plants of Nilgiri vegetation are *Rubus, Rhododendron arboreum, Berberis* sp, *Thallictrum* sp., *Ranunculus* sp., *Fragaria* sp., *Potentilla* sp. Many other herbs along with many grasses are also common.

Temperate forests commonly called as "sholas" contain *Gardenia obtusa, Michelia nilagirica, Eugenia* sp. are also common. In Malabar, plants belonging to family Dipterocarpaceae, TiliaWceae, Anacardiaceae, Meliaceae, Myrtaceae, Piperaceae, Orchidaceae and many ferns are common. The west coast of Malabar region receives very high rainfall. In the coastal region mangrove plants grow luxuriantly.

5.2.8. Assam

This botanical province is very rich in vegetation and covers valley of Brahmaputra, Naga hills and Manipur. Excessive rainfall and high temperature in this zone are responsible for the development of dense forests. Broad leaved, tall evergreen angiosperms and some conifers are very common in the forests.

Common plants occurring in this region are *Ficus, Artocarpus, Michelia champaca, Sterculia alata. Morus* sp., etc. Besides these bamboos canes, climbers, and green bushes are also common. Prominent plants in the northern forests of this zone are *Alnus nepalensis, Betula* sp., *Rhododendron arboreum. Magnolia* sp., *Michelia* sp. and *Prunus* sp. Sal also occurs at Garo hills. Orchids and fern species are very rich in this zone.

5.2.9. Bay Islands of Andaman and Nicobar

These are represented by the Andaman and Nicobar islands in the east and Lakshadweep islands in the west. The Andaman and Nicobar islands are a group of more than 300 islands, which support many characteristic plants and animals. The forests range from tropical evergreen to moist deciduous and even mangroves. The Lakshadweep group of islands comprise 36 major Islands, which together from an area of 32 sq km.

These bay islands represent elevated portions of submarine mountains. In Andaman, beech forests, evergreen forests, semi-evergreen forests deciduous forests and mangrove vegetation are of common occurrence. *Rhizophora, Bruguiera, Ceriops*, etc. are common plants in mangrove vegetation. In the interior evergreen forests tall trees are common. Important species of trees are *Calophyllum, Dipterocarpus, Lagerstroemia* and *Terminalia*, etc. The important crops are paddy and sugarcane.

5.3 Endemism

The word endemic is ascribed to any taxonomic unit or taxon which occurs in a restricted area usually isolated by geographical and temporal barriers. So, *endemism* is the phenomenon of confinement of species, genera or other groups to a small area beyond which their existence is not found. Thus, taxa with a confined distribution are referred to as *endemic taxa*.

e.g.- Degeneriaceae, a monotypic family is endemic to Fiji island. *Calcanthus*, a monotypic genus is endemic to Western Ghats, India.

5.3.1 Types

The endemic taxa can be recognised under the following types:

i. Paleoendemics: these are ancient endemics, which represent remnants of older floras, usually occurring in geologically old land masses. The chief characteristics of paleoendemics are-

a. Taxonomically isolated group having no closely related species or taxa.
b. Presence of woody life forms in isolated taxa occurring in islands and mountain massifs.
c. Low level of polyploidy.
d. Major disjunction in distribution of many of endemic taxa.
e. Possible fossil evidence.

Epibiotics or relict species are in a sense paleoendemics, e.g.- *Ginkgo biloba, Trapa natans*, etc.

ii. **Neoendemics:** these are newly evolved endemic taxa and are of relatively recent origin from an actively evolving genetic stalk occurring in a particular ecotone. The chief characteristics of neoendemics are-

a. Neoendemics developed through geographical spatial quantum speciation and sympatric speciation.
b. They have closely related taxa occurring in the same area.
c. They are usually herbaceous or shrubby forms showing high level of polyploidy.
d. They occur in areas of some kind of environmental stress.

e.g.- *Imaptiens* spp, *Primula* spp., *Rhododendron* spp., etc.

iii. **Holoendemics:** It includes phase of endemics between its origin, spread and eventually perhaps its loss. A neoendemic may behave as a holoendemic through the following steps:

(a) Origin,
(b) Expansion,
(c) Stabilization,
d) Diversification,
(e) Migration,
(f) Fragmentation,
(g) Contraction,
(h) Extinction.

5.3.2 Theories of endemism

The reasons behind endemism have been explained variously by different authors, which are as follows:

1. **Theory of epibiotics:** According to Ridley (1922), endemic species and genera are survivor of the larger group of past (relic type) which are now in course of gradual extinction. They are referred to as epibiotics, which do not spread but remain in an isolated area.

   This isolation is due to their inefficient dispersal, so that they are unable to cross the barrier and reach another area for their establishment. Hence they become confined to a limited area.

   e.g.- *Ginkgo biloba*, *Metasequia gigantea*, etc.

2. **Age and area hypothesis:** According to Willis (1922), the endemic species and genera new and recent forms of gradually extending plant groups and they represent juvenile forms in course of spread and expansion. According to this theory, the area of distribution of a species is directly proportional or related to the age of the species, i.e. a species which evolved a long ago has a larger area of distribution and a young or recently evolved species is distributed in a small area.

   Willis idea was based on the study of distribution of several species of Coleus in the plains and hills of Srilanka. With increasing age of any species the area of distribution is also increased. Thus a restricted area containing a definite plant groups where they are endemic exhibit their relatively recent origin and are regarded as younger species.

e.g.– species of *Impatiens, Primula, Rhododendron*, etc are endemic to a particular area.

Criticism:

i. Paleobotanical evidences clearly demonstrate that Ginkgo biloba with restricted distribution is not a young species, but existed in much wider areas several million years ago.

ii. Crop plants although relatively young in terms of their origin, occupy most of the land under cultivation in the World.

3. **Theory of D. Chatterjee:** From the above two theories proposed by two different authors, Chatterjee had opined that "both the schools are correct in their ideas, but from the evidence of large number of new forms, continually arising by natural crossing and mutation, it is quite likely that latter view has more supporters".

   According to D. Chatterjee (1960) the endemic species are new forms, originating from stalks capable of change. These newly evolved taxa become restricted to small areas, because of either due to competition with other taxa, or due to unfavourable condition they did not have the opportunity to migrate.

   He emphasizes that the frequency of species over an area varies directly with its age in evolution. E.g.- number of endemic species in Himalaya- 3165; number of endemic species in Central India- 2045; number of endemic species in Burma- 1071.

5.3.3 Endemism in India

Out of the 304 families of flowering plants recorded from India, there is not a single endemic family. In India there are about 142 genera that are endemic. The total estimated species that are endemic to India vary according to different authors, e.g.- according to D. Chatterjee (1962) it is 6700, while according to Nayer (1977) it is 4500. While the Peninsular India has about 33% endemics, while rest of the India has about 27% endemics. According to Sarkar (1990) of the 142 endemic genera 100 are dicots and rest from monocots. The largest numbers of endemic genera are in Acanthaceae among dicot (approximately 20) and in Gramineae among monocots (17). Orchidaceae is very poor in endemism. Out of the 142 endemic genera more than 100 are monotypic. The majority of endemic genera are found in Himalayas and in Peninsular India.

5.3.4 Factors controlling endemism

The different factor that contribute towards the development of endemic species are-

1. **Natural geographic barrier :** The chain of lofty mountains, extensive deserts, occurrence of marshes or saline or alkaline lands are some of the natural barriers which to-

gether with oceans in many parts of the continent are responsible for endemism. These barriers tend to prevent the transportation of seeds, fruits and other diasporas from one place to another. For example- there are many instances of oceanic islands where ocean played a vital role as geographical barrier-

Hawaii Island- 82% endemic species

New Zealand- 72% endemic species

Fiji Island- 50% endemic species

In India **-** the lofty Himalayan range contains the highest percentage of endemic species, flowed by south- India, while the Indo-gangetic plains are relatively poorer in endemism. The Himalayan range has the warm alluvial plains to the south and dry Tibetan plateau to the North. Thus the species comprising the temperate and alpine vegetation of Himalayas have higher number of endemic species as they are freely formed by natural crossing and cannot spread because of the natural barriers. South India also support good number of endemic species because of sea boundary on three sides. The endemic species of the above regions are unable to migrate freely either to the north or to the south due to the mountain barriers in the former and the ocean in the latter. Further the dry Tibetan plateau on the north and hot plain area to the south checked the spreading of species that evolved in Himalayas.

2. **Ecological conditions:** in course of evolution, the life of any taxa gets strongly conditioned by the ecological condition of its centre of origin. A change in such condition sometimes makes it difficult for the species to survive, except in some niches and corners. For instance, some are very rigidly fixed in their photoperiodic and thermoperiodic needs and fail to produce flowers and fruits at new places, in spite of vigorous vegetative growth.

   Metasequia and Ginkgo are endemic in China and Japan. Unfavourable conditions and unsuccessful competition with other species were responsible for their elimination from other parts of the globe.

3. **Natural crossing and mutation:** they are the most important genetical factors in the production of endemic species. The warm alluvial plains of India to the south and the dry Tibetan plateau to the north of the Himalayan region have significantly aided in this direction. Natural crossing and mutation rate is very low in endemic species, hence they are not able to adopt in a new area.

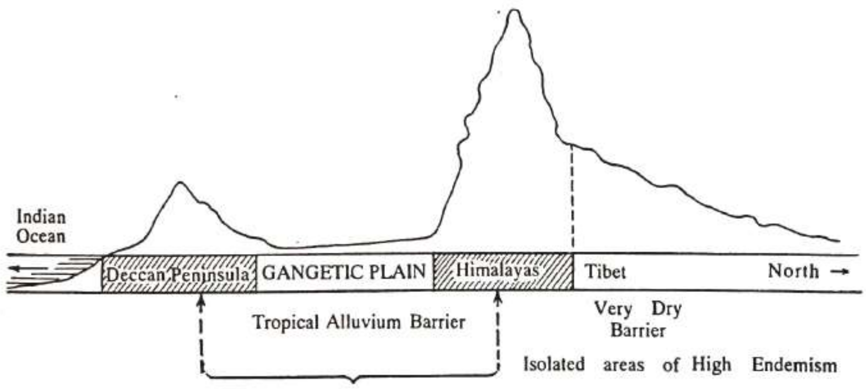


Fig. 5.2. Figure showing the influence of barriers in the induction of endemism in South India and the Himalayas (after D Chatterjee, 1939)

5.4 Summary

In this chapter we got an idea about the phytogeographical regions of India as proposed by D. Chatterjee (1962). The phytogeographical regions of India include-Western Himalayas, Eastern Himalayas, Indus Plain, Gangetic Plain, Central India, Deccan, Western Coast of Malabar, Assam and Bay Islands of Andaman and Nicobar. Each of the regions has their own characteristic floristic composition due to physiography, soil characters, altitude, temperature, rainfall, etc. Endemism is the confinement of the species to a particular region beyond which their existence is not found. Endemic plants may be of two types-neoendemics and paleoendemics depending on whether they are newly evolving taxa or ancient taxa respectively. Accordingly theories of endemism have two main opposite views : theory of epibiotics (relic endemics) and age and area hypothesis (neo-endemics). The factors that affect the endemicity include natural geographic barrier, ecological conditions, natural crossing and mutation.

5.5 Questions & Answers

Q1. Describe the phytogeographical regions of India with suitable diagram.

Ans.: vide section 5.2

Q2. Comment on the vegetation of Western Himalaya.

Ans. vide section 5.2.1

Q3. Comment on the vegetation of Eastern Himalaya.

Ans.: vide section 5.2.2

Q4. Comment on the vegetation of Indus plain.

Ans.: vide section 5.2.3

Q5. Comment on the vegetation of Gangetic plain.

Ans.: vide section 5.2.4

Q6. Comment on the vegetation of Deccan region.

Ans.: vide section 5.2.6

Q7. What is endemism? Give example.

Ans.: Endemism is the phenomenon of confinement of species, genera or other groups to a small area beyond which their existence is not found. Thus, taxa with a confined distribution are referred to as *endemic taxa.*

e.g. Degeneriaceae, a monotypic family is endemic to Fiji island. *Calcanthus*, a monotypic genus is endemic to Western Ghats, India.

Q8. What are neoendemics? Give example.

Ans.: These are newly evolved endemic taxa and are of relatively recent origin from an actively evolving genetic stalk occurring in a particular ecotone, e.g.- *Impatiens* spp, *Primula* spp., *Rhododendron* spp., etc.

Q9. What are paleoendemics? Give example.

Ans.: These are ancient endemics, which represent remnants of older floras, usually occurring in geologically old land masses, e.g. *Ginkgo biloba*.

Q10. Comment on the different types of endemics.

Ans.: vide section 5.3.1

Q11. Enumerate briefly different theories of endemism.

Ans.: vide section 5.3.2

Q12. Give a brief idea about the endemism in India.

Ans.: vide section 5.3.3

Q13. Describe the different factors affecting endemism.

Ans.: vide section 5.3.4

Unit 6 ❐ Introduction to Plant Taxonomy

Structure

6.0 Objective

- In this unit we shall also have an idea about the process of identification, basic idea of nomenclature and the types of classifications used in plant taxonomic studies.
- You will able to discuss the basic components of taxonomy.

6.1 Introduction

In this unit we shall discuss about the introduction to taxomomy and its components. Taxonomy is basically the science of identifying, naming and classification of plants. Its components also include identification, nomenclature and classification.

6.2 Taxonomy and Systematics

The word taxonomy derived from two Greek words- taxis (arrangement) and *nomos* (rules of laws). Plant taxonomy is a very rapidly growing branch of botany and also an invaluable tool for dealing with the problems of various branches. Taxonomy is as old as the language skill of mankind. It has always been essential to know the names of edible as well as poisonous plants in order to communicate acquired experiences to other members of the family and the tribe. Classifying plants in different categories has started since the advent of civilization, although taxonomy as a formal subject developed only after the famous work- *Theorie elementary de la botanique* by A. P. De Candolle in 1813.

The word **'taxon'** (taxa) was first used by a German Biologist Adolf Meyer in 1926 for animal groups. It was later proposed for the plant system in 1948 by Herman J. Lam. It is a taxonomic group of any rank, e.g. family, genus, species, subspecies, etc.

According to Lawrence (1951) taxonomy is the "science of identifying, naming and classifying plants". According to Davis and Heywood (1963), "taxonomy is the science dealing with the study of classification, including its bases, principles, rules and procedures". According to Heywood (1977), "one of the major roles of taxonomy is to produce a system of classification of organisms that best reflects the totality of their similarities and differences". So, taxonomy is the science that basically deals with the practise of naming and classifying organism (Davis and Heywood, 1963).

Another term systematics is commonly considered to be synonymous to taxonomy (Lawrence, 1951; Jones and Luschinger, 1979; Radford et al. 1986, etc.), although some authors do differ from them and prefer to draw a line of demarcation between them. According to recent and widely accepted views "systematics is the scientific study of the kinds and diversity of organisms, and of any or all possible relationships between them" (Simpson, 1961). It was recognized as a study which is concerned with the naming, classification and evolution among plants. According to Mason (1950), Camp (1951), Simpson (1961), etc. systematics mainly deals with the application and practice of taxonomy, while taxonomy is basically the theoretical and knowledge of classifying and identifying organisms. Blackwelder (1967) is of the opinion that systematic botany deals with the kinds of organismal diversity, their classification and evolution, while taxonomy is the practise dealing with the kinds of organism.

A more accepted definition of taxonomy proposed by Stace (1980) is "the study and description of variation in organisms, the investigation of causes and consequences of this variation, and the manipulation of the data obtained to produce a system of classification". This definition of taxonomy makes it to coincide with systematics. Although there are views which do not consider taxonomy and systematics as synonymous, but most of the present day authors believe that the terms are synonymous. According to them it deals mostly with the diversity of organisms, their relationships and to provide a mean of classification to reflect their evolution.

6.3 Basic components of Taxonomy

Taxonomy is often defined as a science dealing with the study of classification, including its bases, principles, rules and procedures. The general purpose of taxonomy is to arrange elements, components, objects or taxa in a way so that it can make the most effective use of information and leads to the acquisition of data, information and knowledge.

The three fundamental components of taxonomy are identification, nomenclature and classification. Its main aim is to provide a convenient method of identification and communication about taxa and provide a classification which is based on natural affinities of plants as far as possible.

(a) Identification: Identification of a taxon is a prerequisite for any study based on it. It is the determination of a taxon based on overall similarities and differences with other taxa. Identification is generally done by comparing representative specimen of a given taxon with the help of key descriptions, illustrations, etc. The reason for the development of an identification system is to provide a means of easy, accurate, positive identification for each taxon.

The most widely used system of identification is mainly done with the help of herbarium specimens. Another important system is the use of keys (mainly dichotomous, sometimes polychotomous) present in different Floras (like Bengal Plants by David Prain) or e-Floras (like Flora of China). Polychotomous keys are mostly used in computer based systems or software. Some pictorial guide books are also available for the easy identification of some taxa of a particular region (like Trees of Delhi by P. Kishen).

Sometimes, the specimen may not match with the existing predetermined specimen and also can not be identified with the help of standard literature. In such a case it is taken to be new to science. Identification is thus also the assignment of additional unidentified plants to a correct rank once a classification has been established. It is the determination of a name for a specimen. This also implies its rank.

(b) Nomenclature: Once the taxon has been identified, it becomes necessary to give it a scientific name. Thus, nomenclature is the naming of a taxon correctly. It is a precise and universal system of rules used by all botanists of the world for naming the plants. Nomenclature of plants is governed by the Rules and Regulations of ICBN (International Code of Botanical Nomenclature), presently ICN (International Code of Nomenclature for algae, fungi and plants). It is regularly updated (usually at an interval of six years) in International Botanical Congress organized by IAPT (International Association of Plant Taxonomy). To avoid disadvantageous nomenclatural changes of certain taxa, there is provision for conserved names (*nomina conservanda*). Nomenclature of cultivated plants is governed by International Code of Nomenclature for Cultivated Plants (ICNCP).

With the revolution of electronic media there is an attempt to communicate a common uniform code for all living organism - called Draft BioCode which was first proposed in 1995. The successive reviews were made in 1997 by Greuter et al. Another version of draft BioCode was proposed on January 1, 2000, but agreement to replace the existing Codes was not accepted unanimously. In 2011, a revised *BioCode* was proposed which instead of replacing the existing Codes, would provide a unified context for them, referring to them when necessary.

Some authors encountered problems in using the Linnean system in phylogenetic classification. So another *Code* was proposed in 1998, i.e. the *PhyloCode*, which would regulate phylogenetic nomenclature instead of the traditional Linnaean nomenclature. It omits all the ranks except species and "clades" and is based on the recognition of monophyletic groups.

(c) Classification: Classification is the arrangement of groups of plants with particular circumscription by rank and position according to artificial criteria, phenetic similarities or phylogenetic relationships. It includes the determination of position or rank for new as well as old taxa. Generally classification provides a system of named, circumscribed reference bases (taxa) for informational storage, retrieval and use.

The classification may be categorized into three basic types:

a) Artificial classification: based on few arbitrary, easily available characters, such as habit, flower colour, number of stamen, etc.

e.g. Sexual system of Linnaeus (1753)

b) Natural classification: uses characters from all possible sources and based upon overall resemblances and based upon overall resemblances, mostly gross morphology. It does not consider any evolution among group.

e.g. Bentahm and Hooker's system of classification (1862-83).

c) Phylogenetic classification: is based on the evolutionary descent of a group of organisms, the relationships depicted either through a phylogram, phylogenetic tree or Cladogram. The classification is constructed with the purpose that all the descent of a common ancestor should be placed in the same group, i.e. the group should be monophyletic.

e.g. Cronquist's system of classification (1988).

6.4 Summary

Taxonomy is the science that deals with the study of classification, including its bases, principles, rules and procedures. Another term systematics is commonly considered to be synonymous to taxonomy. Systematics is denied as thescientific study of the kinds and diversity of organisms, and of any or all possible relationships betwen them. There are three basic components of taxonomy-identification, nomenclature and classification. **Identification** is the determination of a taxon based on overall similarities and differences with other taxa. It is generally done by comparing representative specimen of a given taxon with the help of key descriptions, illustrations, etc. **Nomenclature** is the naming of a taxon correctly. It is a precise and universal system of rules used by all botanists of the world for naming the plant. **Classification** is the arrangement of groups

of plants with particular circumscription by rank and position according to artificial criteria, phenetic similarities or phylogenetic relationships. It may be of three types artificial, natural and phylogenetic.

6.5 Questions & Answers

Q1. Define taxonomy.

Ans: Taxonomy is the study and description of variation in organisms, the investigation of causes and consequences of this variation, and the manipulation of the data obtained to produce a system of classification (Stace, 1980).

Q2. What do you mean by taxon?

Ans: Taxon is taxonomic group of any rank. It may be a species, genera, family, order and so on.

Q3. Who did first introduce the term 'taxon'?

Ans: The word 'taxon' (taxa) was first used by a German Biologist Adolf Meyer in 1926 for animal groups.

Q4. Define systematics.

Ans: Systematics is the scientific study of the kinds and diversity of organisms, and of any or all possible relationships between them (Simpson, 1961).

Q5. "Taxonomy and systematics are synonymous"- justify your statement.

Ans. Vide section 6.2

Q6. What are the basic components of taxonomy?

Ans.: The three fundamental components of taxonomy are identification, nomenclature and classification.

Q7. What do you mean by identification?

Ans: Identification of a taxon is a prerequisite for any study based on it. It is the determination of a taxon based on overall similarities and differences with other taxa. Identification is generally done by comparing representative specimen of a given taxon with the help of key, descriptions, illustrations, etc.

Q8. Mention different methods of identification.

Ans: The most widely used system of identification is mainly done with the help of herbarium specimens. Another important system is the use of keys (mainly dichotomous, sometimes polychotomous) present in different Floras (like Bengal Plants by David Prain) or e-Floras (like Flora of China). Polychotomous keys are mostly used in computer based systems or software. Some pictorial guide books are also available for the easy identification of some taxa of a particular region (like Trees of Delhi by P. Kishen).

Q9. What do you mean by plant nomenclature?

Ans: Nomenclature is a precise and universal system of rules used by all botanists of the world for naming the plants. Nomenclature of plants is governed by the Rules and Regulations of ICBN (International Code of Botanical Nomenclature), presently ICN (International Code of Nomenclature for algae, fungi and plants).

Q10. What is IAPT?

Ans: IAPT is International Association of Plant Taxonomy which organizes International Botanical Congress to regularly update (usually at an interval of six years) the ICBN or ICN.

Q11. What is ICNCP?

Ans: ICNCP is International Code of Nomenclature for Cultivated Plants which actually governs the Nomenclature of cultivated plants.

Q12. What is BioCode?

Ans: With the revolution of electronic media there is an attempt to communicate a common uniform code for all living organism - called Draft BioCode which was first proposed in 1995. In 2011, a revised BioCode was proposed which instead of replacing the existing Codes, would provide a unified context for them, referring to them when necessary.

Q13. What is PhyloCode?

Ans: Some authors encountered problems in using the Linnean system in phylogenetic classification. So another Code was proposed in 1998, i.e. the *PhyloCode*, which would regulate phylogenetic nomenclature instead of the traditional Linnaean nomenclature. It omits all the ranks except species and "clades" and is based on the recognition of monophyletic groups.

Q14. What do you mean by classification?

Ans.: Classification is the arrangement of groups of plants with particular circumscription by rank and position according to artificial criteria, phenetic similarities or phylogenetic relationships.

Q15. What is artificial system of classification? Give example.

Ans: Artificial system is based on few arbitrary, easily available characters, such as habit, flower colour, number of stamen, etc.
e.g. Sexual system of Linnaeus (1753)

Q16. What is natural system of classification? Give example.

Ans.: Natural system of classification uses characters from all possible sources and based upon overall resemblances and based upon overall resemblances, mostly gross morphology. It does not consider any evolution among group.

e.g. Bentahm and Hooker's system of classification (1862-83).

Q17. What is Phylogenetic system of classification? Give example.

Ans: Phylogenetic system is based on the evolutionary descent of a group of organisms, the relationships depicted either through a phylogram, phylogenetic tree or Cladogram. The classification is constructed with the purpose that all the descent of a common ancestor should be placed in the same group, i.e. the group should be monophyletic.

e.g. Cronquist's system of classification (1988).

Unit 7 ❒ Identification

Structure

7.0 Objective

In this unit,

- You will get an overview of identification process of a specimen.
- You will learn what is herbarium & its significance.
- You will be able to use the taxonomic keys to identify the taxon.

7.1 Introduction and Objective

Identification is a process of determination of the group to which a specimen belongs. In this chapter we shall discuss about the herbarium and its significance in the process of identification as well as about the taxonomic keys used to identify a taxa. A herbarium is a repository of dried, preserved plant speciments that are arranged according to an accepted system of classification. A specimen can be identified by matching with the preserved herbarium specimens. On the other hand, taxonomic key is an artificial arrangement of where a choice is given between two or more contra-dictory statements of which one is accepted while toehr(s) is rejected. By following this process of choice making between statments the taxa can be identified. The taxonomic keys are mostly used in the Flora.

❒ Identification in biological sense is the determination of the group to which a specimen belongs, which assumes that organisms have been distinguished from one another, classified and circumscribed, as well as named by professional taxonomists. Identification usually includes a direct comparison of the unknown specimen with classified, circumscribed, and named taxa or the use of some device such as key (Radford, 1986). An identification system is composed of named taxa having differentiating characters. The traditional methods of identification include expert determination, recognition, comparison (with the preserved specimens, i.e. herbarium) and the use of key and similar devices. The specimens also can be identified with the help of illustrations, photographs or descriptions.

7.2 Herbarium

A herbarium is a store-house containing collection of plants, which have dried, pressed, mounted specimens on herbarium sheets, identified and classified according to some approved system of classification.

A herbarium is a *"Hortus siccus"* or "dry garden" and is used for study by botanists and students; they want as good material as possible to study. Plants are often collected in far-off places to be studied and correctly named.

7.2.1 Historical background

Sometime in the 1530's Luca Ghini, who was at that time Professor of Botany in the University of Bologna, Italy, discovered that plants dried under pressure and pasted on sheets of paper could be preserved almost indefinitely - and could be transported easily. It is on record that he had a collection of some 300 sheets so prepared. Unfortunately, it appears that this collection no longer exists.

Several Ghini's students and colleagues recognized the value of this technique and the collections of at least two of them survive. Andrea Cesalpini in 1563 had made a collection of some 768 specimens of Italian plants. This collection is still preserved at the Instituto Botanico of the University of Florence.

Ulisse Aldrovandi, who succeeded Ghini as Professor of Botany at Bologna and who taught a number of the most prominent botanists of the next generation, attempted to form an herbarium that was world-wide in scope. About 4,368 specimens of this collection are preserved at the Instituto Orto Botanico in Bologna.

The herbarium technique proved so useful that it was quickly adopted by botanists throughout Europe. Arber (10) records that more than 20 collections formed or begun before 1600 are still extant in various European herbaria.

Originally, the individual sheets with plants mounted on them were bound and treated as books. Aldrovandi's herbarium, for example, is preserved as 17 bound volumes.

This was the general technique until about 1700. Linnaeus (1707-1778) did not use this technique, preferring to keep the sheets separate and storing them (probably in cases) horizontally. Stearn thinks that Linnaeus' example and teaching led to the spread of this technique - which is the one generally used today.

Binding the single sheets into books had the disadvantage of making any changes or additions to that part of the collection difficult if not practically impossible.

This led to the use of portfolios, in which several unattached single sheets could be kept in a book-like fashion, a compromise between bound volumes and single sheets filed in cases. The advantage of portfolios was that they could be stored on shelves like books. The disadvantages were that the specimens were joggled every time the portfolios were moved and could be severely damaged by crushing if shelved too tightly. There was also always the risk of insect infestation, unless the specimens were poisoned - a messy and unpleasant, if not risky, business.

However, as late as 1833, Asa Gray was selling bound volumes of mounted grass and sedge specimens entitled North American Graminae and Cyperaceae. And even today biological supply houses sell portfolios in which to keep herbarium specimens. Old techniques die slowly.

7.2.2 Significance of Herbarium

- It is repository of dried plant specimens that are protected against the destruction by fungi and insects. It thus also contains specimens having historical significance.
- Identification of plant specimens by simple matching with the preserved specimens of the herbaria.
- It is also a store house of type specimens, which are kept with restricted access. The type specimens are of immense value in the precise identification of the specimens and also in determining the application of names of a taxonomic group.
- It also provides help in compilation of Floras, Manuals and Monographs.
- Herbaria are essential for the study of plant taxonomy, the study of geographic distributions, and the stabilizing of nomenclature. Thus, it is desirable to include in a specimen as much of the plant as possible (e.g., flowers, stems, leaves, seed, and fruit).
- Herbaria also preserve a historical record of change in vegetation over time. In some cases, plants become extinct in one area or may become extinct altogether.

In such cases, specimens preserved in a herbarium can represent the only record of the plant's original distribution. Environmental scientists make use of such data to track changes in climate and human impact.

- Many kinds of scientists use herbaria to preserve voucher specimens, representative samples of plants used in a particular study to demonstrate precisely the source of their data.
- Repository of voucher specimens: for any form of scientific research based on plants and publication of data in scientific journals require accession number of the preserved specimen for future documentation purposes.
- Provide help in teaching and research- training students in herbarium practices; loaning herbarium specimens for taxonomic work and exchange of specimens between herbaria. It also acts as useful sources for plant DNA for molecular systematic studies and phylogenetics.
- They may also be a repository of viable seeds for rare species.

7.2.3 Important Herbaria of the World

1. Muséum National d'Histoire Naturelle (P) (Paris, France)
2. New York Botanical Garden (NY) (Bronx, New York, USA)
3. Komarov Botanical Institute (LE) (St. Petersburg, Russia)
4. Royal Botanic Gardens (K) (Kew, England, UK)
5. Conservatoire et Jardin botaniques de la Ville de Genève (G) (Geneva, Switzerland)
6. Missouri Botanical Garden (MO) (St. Louis, Missouri, USA)
7. British Museum of Natural History (BM) (London, England, UK)
8. Harvard University (HUH) (Cambridge, Massachusetts, USA
9. Museum of Natural History of Vienna (W) (Vienna, Austria)
10. Swedish Museum of Natural History (S) (Stockholm, Sweden)
11. United States National Herbarium (Smithsonian Institution) (US) (Washington, DC, USA)
12. National Herbarium Nederland (L) (Leiden, Netherlands)
13. Université Montpellier (MPU) (Montpellier, France)
14. Université Claude Bernard (LY) (Villeurbane Cedex, France)

15. Herbarium Universitatis Florentinae (FI) (Florence, Italy)
16. National Botanic Garden of Belgium (BR) (Meise, Belgium)
17. University of Helsinki (H) (Helsinki, Finland)
18. Botanischer Garten und Botanisches Museum Berlin-Dahlem, Zentraleinrichtung der Freien Universität Berlin (B) (Berlin, Germany)
19. The Field Museum (F) (Chicago, Illinois, USA)
20. University of Copenhagen (C) (Copenhagen, Denmark)
21. Chinese National Herbarium, (Chinese Academy of Sciences) (PE) (Beijing, People's Republic of China)

7.2.4 Important Herbaria of India

1. The Central National Herbarium, Kolkata
2. Herbarium of Forest Research Institute, Dehradun
3. BSI, Eastern Circle, Shillong
4. BSI, Southern Circle, Coimbatore
5. BSI, Western Circle, Pune
6. BSI, Northern Circle, Dehradun
7. BSI, Central Circle, Allahabad
8. Blatter Herbarium, Mumbai
9. National Botanical Garden Herbarium, Lucknow
10. Herbarium of Industrial Section, Indian Museum, Kolkata

7.3 Taxonomic Keys

A taxonomic key is an artificial arrangement or analytical device where a choice is given between two contradictory statements of which one is acceptable and the other is rejected. Carrying on the process ultimately leads to the identification of a taxon under study. Usually 'Flora' is provided with a key for identification of the taxa.

A single pair of contradictory statements of a key is known as ***couplet***. Each statement of a couplet is known as ***lead***. So, leads are the contrasting characters of a couplet. Characters following the lead are called secondary key characters.

There are two types of keys used for identification of plants:

a) Single access key or dichotomous key &

b) Multi-access key or multi -entry key or polyclaves.

a) **Dichotomous key:** These keys basically composed of pair of contrasting characters or couplets. Each couplet is composed of two leads or contrasting statements. It is most common form of taxonomic key used in the literature. This type of key was first introduced by J.P. Lamarck (1778) in his 3 volume work Flore Francoise. The contrasting statements or leads should start with the same word as far as possible.

Dichotomous key may be of three different types:

i) Indented or Hoked Key: Here the statements or leads are indented at affixed distance from the left margin of the page and additionally the subordinate couplets are indented below the primary one with an increasing distance from the margin. The distance from margin increase with each subordinate couplet. This is one of the most common form of key used in Floras and Manuals like - Bengal Plants by David Prain (1903), Flora of British India by J.D. Hooker (1872-1897), etc.

e.g.-

Fruit a group of achenes; unspurred flowers:

Petals absent:

Sepals usually 4; involucres absent .... *Clematis*

Sepals usually 5; involucres present... *Anemone*

Petals present .... *Ranunculus*

Fruit a group of follicles; spurred flowers:

Spurs 5; flowers regular .... *Aquilegia*

Spur 1; Flowers irregular .... *Delphinium*

ii) **Bracketed or Parallel Key:** here the two leads of a couplet are always together and the distance from the margin is always the same. The arrangement of couplet in this type of key is useful for longer keys because finding the alternate key is not problematic here and also there is less wastage of page space. This type of key is mainly followed in the Flora of USSR, Plants of Central Asia, Flora of British Isles, etc.

e.g.-

1. Fruit a group of achenes; unspurred flowers 2
1. Fruit a group of follicles; spurred flowers... 4
2. Petals absent 3
2. Petals present .... *Ranunculus*
3. Sepals usually 4; involucres absent. .... *Clematis*
3. Sepals usually 5; involucres present..*Anemone*
4. Spurs 5; flowers regular. .... *Aquilegia*
4. Spur 1; Flowers irregular. .... *Delphinium*

iii) **Serial or Numbered key:** this key retains the arrangement of yolked or indented key, but with no indentation so that distance from the margin remains the same. The location of alternate lead is possible by serial numbering couplets (or leads when separated) and indicating the serial number of the alternate lead within parentheses. Such a key has been used for identification of animals, but also adopted in some botanical works.

e.g.-

1 (5). Fruit a group of achenes; unspurred flowers
2 (4). Petals absent
3. Sepals usually 4; involucres absent .... *Clematis*
3. Sepals usually 5; involucres present. ....*Anemone*
4 (2). Petals present .... *Ranunculus*
5 (1). Fruit a group of follicles; spurred flowers.
6. Spurs 5; flowers regular. .... *Aquilegia*
6. Spur 1; Flowers irregular. .... *Delphinium*

This type of key retains the visual groups of statements and taxa. Alternate leads, even though separated can easily be located and there is no wastage of page space.

A major drawback of all form of dichotomous keys is that the user has a single fixed choice of the separated characters decided by the person who construct the key.

b) **Polyclave or Multi-access keys:** here a choice of several characteristics can be used. A polyclave is actually a multi-entry, order-free key implemented in several different formats. In a polyclave method the user is free to choose any character, in any order of sequence, and thus avoid any rigid format of traditional dichotomous keys.

One form of polyclave is a diagnostic key in which cards are utilized. The cards are placed on top of one another to eliminate the taxa which disagree with the plant to be identified.

The second form of polyclave is a computer aided multi-entry key and the third form is a printed table which gives the status of different taxa and characters useful for separating the taxa.

7.4 Summary

In this chapter we have discussed about the process of identification including herbarium and taxonomic keys. Herbarium is a repository of mostly dried, preserved plant specimens (herbarium specimens) that are arranged according to an accepted system of classfication. Luca Ghini in 1530 initiated the process of preserving plkant specimens in a dried manner. Herbaria are not only useful for identification only, but also are significant in terms of historical perspective, collection of original type specimens, in compilation of Floras and Monographs, to study the geographic distribution, ethnobotanical significance and also many other reserch works, etc. Central National herbarium is the largest herbarium of India, A taxonomic key is basically an artificial arrangements or analytical device where a choice is given between two or more contradictory characters (leads) and any one of them is chosen as correct. The process si followed to identify the plant specimens by matching with the correct statements. The key may be of two types-dichotomous key and polyclaves. Dichotomous key again may be of three different types-indented, bracketed and numbered keys.

7.5 Questions & Answers

Q1. Define herbarium.

Ans: A **herbarium** is a collection of plants, which have dried, pressed, mounted on herbarium sheets, identified and classified according to some approved system of classification.

Q2. Comment on the significance of herbarium.

Ans.: Vide section 7.2.2

Q3. Name the largest herbarium of the World.

Ans: Muséum National d'Histoire Naturelle (P) (Paris, France).

Q4. Name the largest herbarium of India.

Ans: Central National Herbarium, Kolkata (CAL).

Q5. What is acronym? Give example.

Ans: An acronym is an abbreviated name of any internationally reputed herbarium of the World. It is always written in capital letter, e.g. CAL for Central National

Herbarium, Kolkata, K for Royal Botanic Gardens (Kew, England, UK), etc.

Q6. What is taxonomic key?

Ans.: A taxonomic key is an artificial arrangement or analytical device where a choice is given between two contradictory statements of which one is acceptable and the other is rejected. Carrying on the process ultimately leads to the identification of a taxon under study.

Q7. What do you mean by ***couplet*** and lead?

Ans.: A single pair of contradictory statements of a key is known as couplet. Each statement of a couplet is known as ***lead***. So, leads are the contrasting characters of a couplet. Characters following the lead are called secondary key characters.

Q8. What do you mean by dichotomous key? Give example.

Ans.: vide section 7.3 a.

Q9. What is indented key? Give example.

Ans.: vide section 7.3.a.i.

Q10. What is bracketed or parallel key? Give example.

Ans.: vide Section 7.3.a.ii.

Q11. What do you mean by serial or numbered key? Give example.

Ans.: vide section 7.3.a.iii.

Q12. What is multi access or polyclave key?

Ans.: vide section 7.3.b.

Unit 8 : Taxonomic Evidences

Structure

8.0 Objective

In this unit,

- You will get an idea about taxonomic evidences.
- You will able to discuss how particularly cytological and palynological evidences that are helpful in taxonomic elucidation.

8.1 Introduction

Taxonomy is basically a synthetic science that does not have a data of its own. i.e. it is dependent on the other branches of plant science for its data e.g. morphology, anatomy, palynology, cytology, genetics, ecology, embryology, molecular level data, etc. these data basically help in precise identification of the taxa as well as determination of the correct position and placement of the taxa.

8.2 Cytological Evidence

Contribution made by cytology in taxonomy form an outstanding feature over the past few decades and "cytotaxonomy" has emerged as a distinct discipline. Chromosome number, size and shape often have a taxonomic value in the same manner as the morphological character and also a direct source of evidence for the nature and origin of variation. The following aspects are of importance in considering cytology in plant taxonomy:

1. **Chromosome number:** it is an important taxonomic character, the individuals within a species usually had a same chromosome number, e.g. - the chromosome number in angiosperm is lowest in *Haplopappus* (n=2) to n=154 in *Morus nigra*, n= 250 in *Kalanchoe*, while in *Poa literosa* n= 263-265. Sometimes there may not be any variation in chromosome number throughout the group, e.g.- *Quercus* (2n= 24, n = 12) and the members of Fagaceae.
2. **Basic Chromosome Number:** it is the ancestral chromosome number, symbolically represented as 'X'. It is not always easy to determine the basic chromosome number, because aneuploidy or polyploidy may confuse the picture. For example, in the genus *Carex* the haploid set of chromosome may vary from n= 6 to n= 56, but the basic chromosome number in X= 6. In Centrospermae, the family Chenopodiaceae has the basic chromosome number X= 9, whereas in Caryophyllaceae the basic chromosome number may vary from X= 6 -17.
3. **Polyploidy and Aneuploidy:** the occurrence of change in chromosome number is very common in almost all groups of angiospems. Such taxa may involve autoplyploidy, alloploidy, aneuploidy or amphidiploidy. For example, *Solanum nigrum* complex has all three forms of plants- diploid (2n= 24), tetraploid (2n= 48) and hexaploid (2n= 72).
4. **Amphidiploidy:** formation of intergeneric or interspecific hybrids and subsequent polyplodization result in the formation of amphidiploids. For example, Raphanobrassica is produced by crossing *Raphanus sativus* (2n= 18) and *Brassica oleracea* (2n= 18). In this process new species may be formed.

5. **Segmental Polyploidy:** one of the best examples of segmental allopolyploidy is *Primula kewensis* (*P. floribunda X P. verticillata*). It has two distinct properties- ability for genetic segregation both with respect to morphological differences of parents and chromosomal difference; to form fertile hybrids through back crossing.
6. **Cryptic Polyploidy:** this involves cases where morphological markers are absent and nature of ploidy is difficult to detect, e.g.- *Narcissus* ployploid complex.
7. Karyotype and chromosome morphology: the karyotype study is very useful in taxonomic studies. A particular karyotype may represent a single species or even a genus.

Evidence I. In two principal systems of classifications, those of Hutchinson (1959) and Engler and Diels (1936), the position of Pandanales and of Alismatales and Butomales of Helobieae are significant. Engler and Prantle considered Pandanales to include three principal genera- *Pandanus, Typha* and *Sparganium* and form the ancient stalk from which monocot have evolved. Hutchinson, on the other hand, suggested that the entire monocot had evolved from Alismatales and Butomales. In this system Pandanales, from which Typhales was separated, is regarded as related to Arecales.

The application of principles of Karyotype evolution in Pandanales has yielded interesting result. In both *Typha* and *Sperganium* the basic chromosome number is X=15, whereas in *Pandanus*, it is multiple of 15. The similarity in chromosome number of three genus is indeed remarkable. Even in the morphology of the chromosome, homogeneity is evident, all being characterised by very small chromosomes with nearly identical constrictions. It is very difficult to distinguish them on the basis of their Karyotypes as they look very similar to each other. So from the cytotaxonomic evidence it is evident that *Typha*, *Sperganium* and *Pandanus* should be retained in Pandanales as proposed by Engler and Prantle.

Alismatales, specially the genus *Alisma*, has characteristic features of an ancient genus. *Alisma plantago-aquatica* has basic chromosome no X = 5, long chromosome and a symmetrical karyotype. It is assumed that it gave rise to the other groups of monocots, but it is not true for all families of Alismatales and Butomales. For example, members of Hydrocharitaceae, *Limnocharis* of Butomaceae and even *Limnophyton* and *Sagittaria* of Alismataceae show asymmetry of chromosome arms. So, although *Alisma* show primitiveness in terms of cytological features, but the homogeneity of the group alismatales and Butomales is debatable. But *Alisma* with is morphological and cytological characteristics may in association with other primitive genera of Helobieae be the starting point of all other monocotyledons.

Evidence II. Another important and debated issue is the position of the two families like Liliaceae and Amaryllidaceae, which differ significantly in two systems of classification. Engler and Prantle included these two families under Liliflorae, a very advanced group in the system. The distinguishing character is the ovary character, being superior in Liliaceae and inferior in Amaryllidaceae. Hutchinson, however, considered the inflorescence character to be more important and transferred the tribe Agapantheae , Gillesieae and Alloineae to his Amaryllidaceae. More important in this system of classification is the creation of a new order Agavales, to which several genera from Liliales, such as *Agave, Funkia, Yucca, Dracaena*, etc has been transferred with *Polyanthes* of Amaryllidaceae, specially on the basis of the arborescent habit, non-bulbous root stock and spike inflorescence.

Hutchison's idea of creation of the order Agavales finds full support from cytological observations. It is remarkable that *Yucca* and *Agave* of Liliaceae and *Polyanthes* of Amaryllidaceae possess very similar karyotype, all of them show a basic chromosome number of X= 30 and an extreme size differences within the complement, with ten long long and fifty very short chromosomes. The morphology of short chromosomes too is nearly identical in all these taxa. Most of the chromosomes possess constrictions near the tip and metacentric chromosomes are very rare. However, *Funkia*, earlier retained by Hutchinson under Liliaceae should be transferred from this group on the basis of its extremely asymmetrical karyotype.

8.3 Palynological evidence

Palynology is the study of pollen grains, spores, etc of different groups of plants.

- Pollen characters useful for the study:
  - i. Aperture type,
  - ii. Pollen wall architecture,
  - iii. Shape,
  - iv. Pollen unit,
  - v. Polarity,
  - vi. Symmetry,
  - vii. Grain size.

8.3.1 Pollen aperture

- Apertures are spatially delimited, generally thin walled areas in the outer pollen wall or exine through which the pollen tube usually (but not always) emerges at the time of germination.

  Although most apertures represent thinner areas in the exine or aperture membrane, in some pollen grains it may be thick areas or thicker than the exine on inaperturate pollen grains.

- Pollen aperture may be categorized largely on the basis of their-
  a) Number,
  b) Position,
  c) Shape.

8.3.1.1 Aperture number

i. Inaperturate (without any aperture),
ii. Monoaperturate (with one aperture),
iii. Diaperturate (with two apertures),
iv. Triaperturate (with three apertures),
v. Polyaperturate (with more than three apertures) .

Fig. 8.1 Number of aperture.

8.3.1.2. Aperture shape

- There are three different types of shapes of apertures:
  a. Elongate, furrow like apertures (Colpate),
  b. Round, pore like apertures (Porate),
  c. Encircling, ring or band like apertures (Zonate).

* Weakly defined apertures may be indicated by syllable '-oid' into the term, e. g.- colpoidate (weakly defined furrow like apertures).

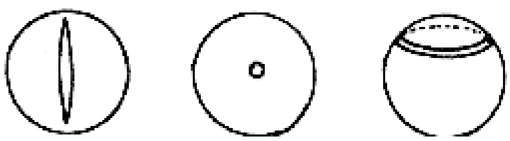


Fig. 8.2 Types of aperture.

8.3.1.3. Aperture position

- **Polar axis-** line passing through the centre of the pollen grain from outside to the centre of the pollen tetrad.
- **Equatorial axes-** are the lines that perpendicularly bisect the polar axis and forms a boundary (equator) between the outer distal and inner proximal faces of the grain.
- There are three basic types of apertures:
  - i. Polar apertures (located at or towards the pole),
  - ii. Equatorial apertures (located at or near equator),
  - iii. Global apertures (more or less uniformly scattered over the surface of the pollen grain.).

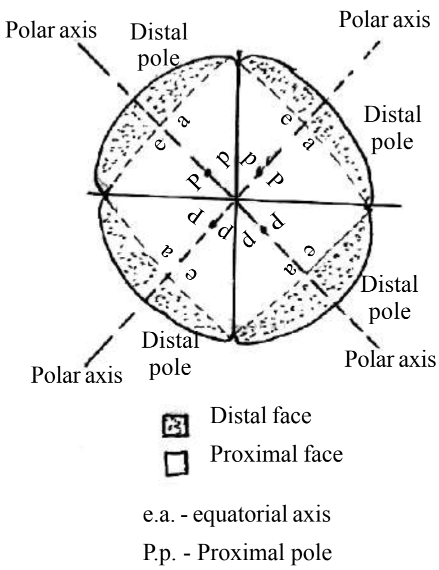


Fig. 8.3 Pollen Tetrad showing positions of apertures.

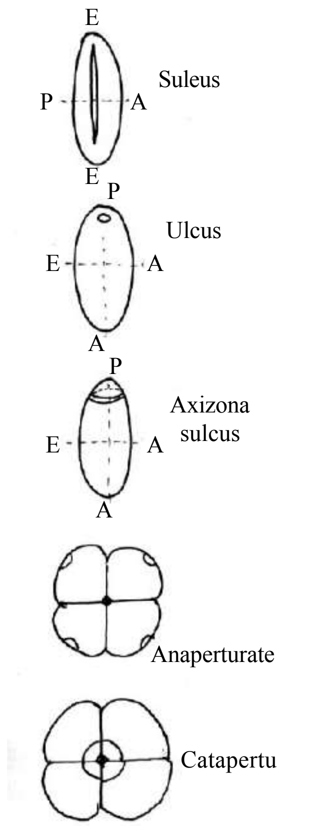


Fig. 8.4 Polar apertures types.

8.3.1.4. Polar apertures

- Sulcus- single, polar elongate, furrow-like apertures (pl.-sulci). Sulacate pollen grain.
- Ulcus- single, polar, rounded, pore like apertures (pl.-ulci). Ulcerate pollen grain.
- Axizonasulcus- single, latitudinal, ring or band like aperture encircling one of the poles (pl.-axiizonasulculi). Axizonasulcate pollen grains.

- Ana-aperturate (distal apertures)
- Cata-aperturate (proximal apertures)

8.3.1.5. Equatorial apertures

- Colpus (pl.-colpi)- elongate, furrow like apertures located equidistantly at the equator and normally bisected by the equatorial plane.
- Pore (pl.-pores)- round, pore-like apertures located equidistantly on the equator.
- Sulcus (pl.- sulculi)- elongate, furrow -like apertureslocated equidistantly on the equator, longitudinal apertures.
- Zonizonasulculate (pl.-zonizonasulculi)- longitudinal ring or band like encircling apertures.
- Ulculate pollen or ulculus (pl.-ulculi)- pore like apertures that are longitudinally derived.

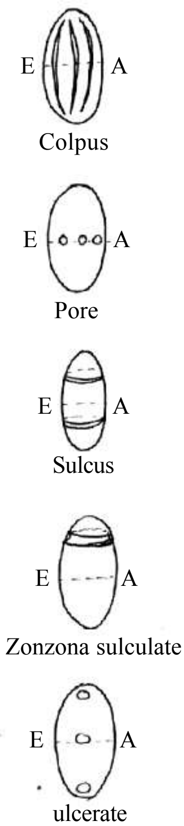


Fig. 8.5 Equatorial aperture types.

8.3.1.6. Global apertures

- Rugae (sing.- ruga)- elongate, furrow- like apertures distributed throughout the pollen grain. Rugate pollen grains.
- Foramina (sing.- foramen)- pore like global apertures. Forate pollen grains.

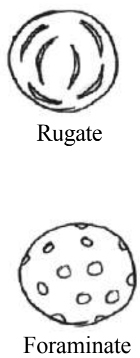


Fig. 8.6 Global aperture types.

8.3.1.7. Aperture structure

- Simple apertures- have more or less uniform aperture membranes.
- Compound apertures or orate apertures- possess specially delimited areas of the aperture membrane known as ora (sing.- os).
- Most compound apertures are monoorate with one os per structure.
- Diorate apertures are with two ora per aperture (infrequent).
- Ora are usually more or less rounded in nature. Extended or elongated ora may either be transversely elongated- longate or latitudinally elongated- lolongate.
- Compound apertures are designated by the syllable '-or-' into the term describing the corresponding simple apertures, eg.- colporate, pororate, rugorate, fororate, etc.
- Some apertures do have weakly defined ora/pore in case of compound apertures, e.g.- colporoidate pollens (well developed colpi with weakly developed ora), while colpoidorate pollens have weakly developed colpi with well developed ora.

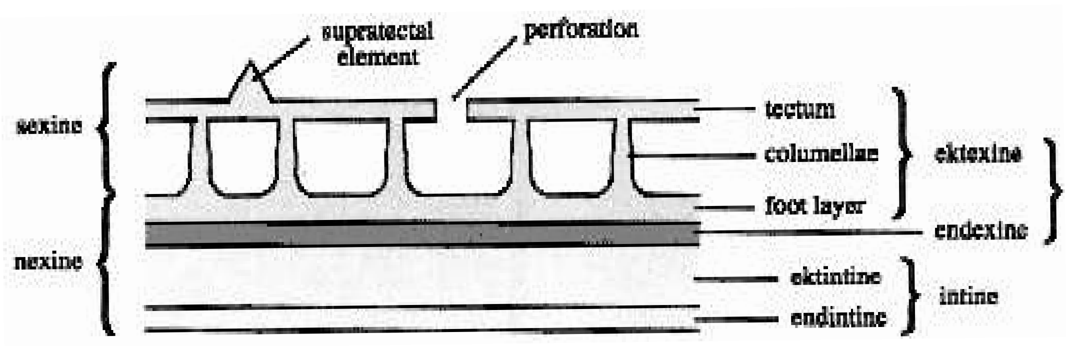


Fig. 8.7 Pollen wall structure.

8.3.2 Exine sculpturing

i. **Psilate/ levigate (smooth),**

ii. **Granulate (covered with small grains),**

iii. **Foveolate (pitted),**

iv. **Fossulate (grooved),**

v. **Reticulate (with mesh like sculpture),**

vi. **Striate (with parallel grooves),**

vii. **Verrucate (warty),**

viii. **Baculate (with rod like projections),**

ix. **Echinate (with pointed projections),**

x. **Clavate (with club shaped projections).**

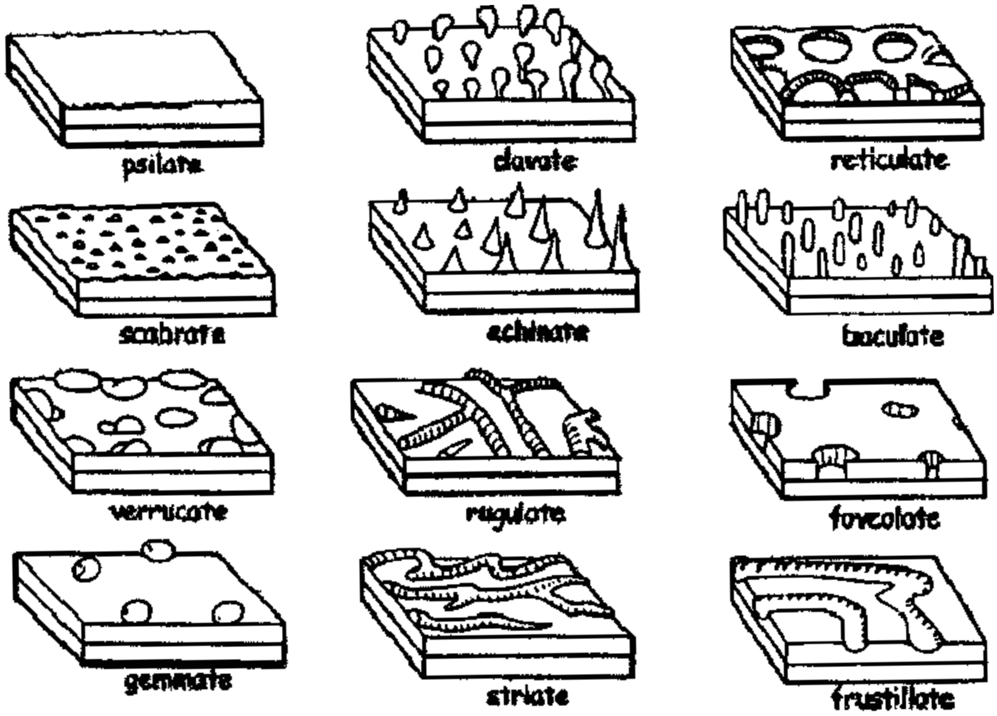


Fig. 8.8 Pollen exine sculpturing types.

8.3.3 Shape:

- Non fixiform (without definite shape),
- Fixiform (with definite shape),
- Fixiform pollens may be -

a) Boat shaped (boat-shaped with large equatorial axis and short polar axis).

   i) Boat-shaped elliptic (EA/PA = 1 -1.5),

   ii) Boat shaped elongate (EA/PA>2).

b) Globose (equatorial axis and polar axis are of same in length).

   i) Spheroidal (EA= PA),

   ii) Oblate (PA is shorter than EA),

   iii) Prolate (PA is longer than EA).

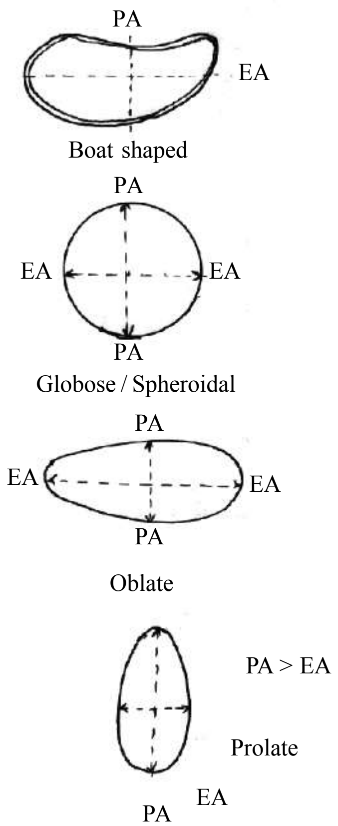


Fig. 8.9 Shape of pollen grains.

8.3.4 Pollen Unit

- Monad (solitary grains),
- Dyad (2 pollen grains held together) e.g.- Podostemaceae, Scheeuzeriaceae, etc.
- Tetrad (4 pollen grains resulting from meiosis of PMC held together as a unit).

Five different types of tetrads are found in angiosperms:

1. Tetrahedral tetrads: four pollen grains form a tetrahedron which is compact and spherical. It is characteristics of Ericaceae.
2. Linear tetrad: four pollen grains arranged in a straight line, e.g. *Typha* sp.
3. Rhomboidal tetrad: four pollen grains in a single plane, with two separated from one another by close contact of the other two.
4. Tetragonal tetrad: four pollen grains in one plane and equally spaced, e.g. *Philydrum* sp.
5. Decussate tetrad: four pollen grains in two pairs, arranged at right angles with one another, e.g. *Lachnanthes* sp.

- Polyad (pollen grains of definite number, usually >4 are held together).

  In some genera, such as Calliandra of Mimosoideae, the pollen grains are connate in a group of more than four. In Orchidaceae (e.g. *Piperia* sp.) large number of pollen grains are aggregated in groups. So there are more than one groups in a theca. These are known

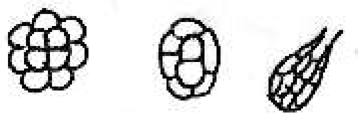

Polyad

Fig. 8.10 Polyad pollen grains.

as massulae. In Asclepiadaceae the pollen grains are aggregated in a single mass called pollinium.

8.3.5 Pollen Polarity

- Pollen polarity refers to the position of one or more apertures relative to a spatial reference. This spatial reference defines a polar axis as the extended pollen grain diameter that passes through the centre of the original pollen tetrad- proximal pole and distal pole.
- There are 3 general types-

1) Isopolar- two polar hemispheres are same but can be distinguished from the equatorial region.
2) Heteropolar- two polar hemispheres are different, because of differential displacement of one or more apertures.
3) Apolar- polar and equatorial regions cannot be distinguished after pollen separation from the tetrad.

8.3.6 Pollen Grain Symmetry

- Symmetry is the quality inherent in a body which is capable of division into similar or equal halves. Pollen grain symmetry is based on planes of symmetry that exist in a particular grain as seen from polar view.

Pollen type	Polar axes	Polar plane	Equatorial axes	Equatorial plane
Heteropolar monosulcate pollen	1	2	2	0
Apolar inaperturate pollen	1	α	α	1
Isopolar with 2- many distinct equatorial apertures	1	2 -α	2-α	1

8.3.7 Palynology in solving Taxonomic problems

- In case of *Sesamum* the number of colpi is species specific, e.g. 11 in *S. indicum*, 9 in *S. prostratum* and 8 in *S. laciniatum*.
- *Butomposis umbellata* can be recognised from the related *B. lanceolata* by the nature of aperture, the former having monocolpate and the latter with pantoporate pollen grains.

- The family Pedaliaceae (s.l.) are composed of *Pedalium*, *Sesamum*, *Martynia*, etc. Based on morphological characters like raceme inflorescence and parietal placentation the genus *Martynia* has been separated from the Pedaliaceae and included under Martyniaceae. Palynological study shows that *Martynia* represent inaperturate, spheroidal pollen grains with reticulate ornamentation. In sharp contrast the pollen grains of *Pedalium* and *Sesamum* are aperturate, oblate or prolate in shape without reticulate ornamentation (psilate). So it is evident that pollen morphological characters of *Martynia* are quite distinct and deserve separation in the form of a family Martyniaceae.
- Anasulcate pollen grains are undoubtedly the primitive aperture type in the angiosperms. It is commonly found in extant and extinct gymnosperms. Anasulcate pollens are restricted to most primitive subclass Magnoliidae and to the monocots. Anasulcate pollen has given rise to the following aperture types-anatrichotomosulcate, zonasulcate, anasulcate, catasulcate and inaperturate. Inaperturate pollen grains gave rise to uniquely angiospermous colpate pollen apertures. From the basic tricolpate form the diversity of non-magnoliid aperture types such as 5-colpate, 6-colpate, porate, colpate, pororate, rugate, forate, etc appear to have evolved.
- On the basis of pollen morphology, it was confirmed that the genus Coriaria to be retained in Coriariaceae.
- Occurrence of similar type of pollen grains in unrelated taxa have also been reported, e.g.- the pollen grains of *Citrus medica*, *Hiptage madhablata* and *Pavetta tomentosa* have conspicuous cap-like bodies at the polar regions.
- On the other hand, more than one type of pollen grains is found in certain genera, e.g.- dimorphic pollen grains of *Berberis umbellata*, pollen heteromorphism in *Nicotiana tabacum* and polymorphism in pollens of *Salvia leucantha*.
- Basic palynology also has usefulness in systematics, e.g.- *Daphniphyllum* shows closer resemblance with Hamamelidaceae rather than with Magnoliaceae, Euphorbiaceae, Pittosporales, or Geraniales.
- Eudicots are large monophyletic assemblage of angiosperms, comprising about 75% of all angiosperms. The monophyly of eudicots is well supported by molecular data and pollens are usually of tricolpate type which is derived from monosulcate type. Many eudicots have more than three apertures which are considered to be derived from tricolpate type.

8.4 Summary

Cytotaxonomic data includes mainly the study of chromosome characteristics including chromosome number, basic chromosome number, polyploidy and aneuploidy, amphidiploidy, segmental polypolidy, cryptic polyploidy and most significantly karyotype analysis. In this chapter we have discussed the cytological evidences that are useful taxonomic judgement and determining the placement of the taxa. Palynological data on the other hand, include the study of pollen grains, spores, etc of different groups of plants. Pollen characters that are useful as taxonomic data are aperture types, wall architecture, shape, pollen unit, polarity, summetry and grain size. Of these characters pollen aperture is the most significant one. Oollen aperture may further be categorized on the basis of the number, position and shape. In this chapter we have got an idea of the evidences that utilizes pollen characters in solving taxonomic problems.

8.5 Questions & Answers

Q1. What is cytotaxonomy?

Ans.: Chromosome number, size and shape often have a taxonomic value in the same manner as the morphological character and also act as a direct source of evidence for the nature and origin of variation. These characters when used for taxonomic study, it is known as cytotaxonomic evidence.

Q2. Name the cytotaxonomic characters useful for taxonomic study.

Ans: vide section 8.2

Q3. What is basic chromosome number?

Ans.: It is the ancestral chromosome number, symbolically represented as 'X'. For example, in the genus *Carex* the haploid set of chromosome may vary from n= 6 to n= 56, but the basic chromosome number in X= 6.

Q4. What is amphidiploidy? Give example.

Ans.: Amphidiploids are formed from intergeneric or interspecific hybrids and subsequent polyplodization. For example, *Raphanobrassica* is produced by crossing *Raphanus sativus* (2n= 18) and *Brassica oleracea* (2n= 18). In this process new species may be formed.

Q5. What is crypticpolyploidy?

Ans.: This involves cases where morphological markers are absent and nature of ploidy is difficult to detect, e.g. *Narcissus* ployploid complex.

Q6. Give two evidences where cytology helped in taxonomic study.

Ans.: Vide section 8.2

Q7. What is palynology?

Ans.: Palynology is the study of pollen grains, spores, etc of different groups of plants.

Q8. Mention the pollen characters useful for taxonomic studies.

Ans.: Aperture type, Pollen wall architecture, Shape, Pollen unit, Polarity, Symmetry and Grain size.

Q9. What is inaperturate pollen grain?

Ans.: vide section 8.3.1.1

Q10. What is colpate pollen grain?

Ans: vide section 8.3.1.2

Q11. What is zonate pollen grain?

Ans: vide section 8.3.1.2

Q12. What is colpoidate aperture?

Ans: Colpoidate is weakly defined furrow like aperture.

Q13. What are cata -aperturate and ana-aperturate pollen grains?

Ans.: Pollen grains with proximal apertures are known as cata-aperturate pollen grains, whereas pollen grains with distal apertures are known as ana-aperturate pollen grains, e.g.- ana-aperturate pollen grains are very common in angiosperms. Cata-aperturate pollen grains are found in Annonaceae.

Q14. Name the different types of polar apertures.

Ans.: vide section 8.3.1.4.

Q15. Name the different types of equatorial apertures.

Ans: vide section 8.3.1.5.

Q16. Name the different types of global apertures.

Ans: vide section 8.3.1.6

Q17. What are compound apertures? Give example.

Ans.: Compound apertures or orate apertures- possess specially delimited areas of the aperture membrane known as ora, e.g.- colporate, pororate, fororate, etc.

Q18. Distinguish between prolate and oblate pollen grains.

Ans.: vide section 8.3.3

Q19. What are polyads?

Ans.: When pollen grains of definite number, usually >4 are held together- they are known as polyads.

Q20. What are heteropolar and isopolar pollen grains?

Ans.: vide section 8.3.5.

Q21. Mention two palynological evedences that are useful in solving taxonomic problems.

Ans.: vide section 8.3.7.

Unit 9 ❒ Taxonomic Hierarchy

Structure

9.0 Objective

- In this unit we shall discuss about the taxonomic hierarchy as mentioned in the Botanical Code, ICBN (International Code of Botanical Nomenclature) or presently ICN (International Code of Nomenclature for algae, fungi and plants).

9.1 Introduction

Taxonomic hierarchy is the classification of living organisms in successive level of complexity and taxonomic rank is the relative level of a group of organisms in a taxonomic hierarchy. Taxa are taxonomic groups of any rank.

i. Taxonomic groups of any rank will be referred to as taxa (sing.- taxon) in the Code. The term 'taxon' is not a category in the classification system but a general term used to denote taxonomic group of any rank within the system.

ii. The rank of species is basic; one or more species make up a family (*familia*); one or more families are included under an order (*ordo*); one or more orders make up a class (classis); one or more class make up a division (*divisio*); several divisions make up the kingdom (*regnum*).

iii. In present ICN there are 24 ranks of Taxa including 7 major ranks and 5 infraspecific ranks, which are as follows:

  1. **Plant Kingdom**
  2. Subkingdom

3. **Division** (-phyta), eg.- Magnoliophyta
4. Subdivision
5. **Class** (-opsida), eg.- Magnoliopsida
6. Subclass (-ideae) e.g.- Magnoliidae
7. **Order** (-ales) eg.- Magnoliales
8. Suborder (ineae) eg.- Geraniineae
9. **Family** (-aceae) eg.- Magnoliaceae
10. Subfamily (- oideae) eg.- Magnolioideae
11. Tribe (-eae), eg- Rosieae
12. Subtribe (- inae) eg.- Rosinae
13. **Genus**
14. Subgenus
15. Section
16. Subsection
17. Series
18. Subseries
19. Species
20. Subspecies
21. Variety
22. Subvariety
23. Forma
24. Subforma

iv. All are mononomial Latin names except the name of the species.

v. Up to family all the names are noun and plural form .Names of taxa above the rank of family are automatically typified and are based on generic names, e.g.- the order based on the family Magnoliaceae should end in 'ales', i.e. Magnoliales; the class based on the order Magnoliales is Magnoliaopsida.

vi. The name of a family is a plural adjective and the name of the family based on a genus should end with '-aceae', i.e. Magnoliaceae. Although for eight families the ending is irregular and not '-aceae', but for long usage these names are also accepted by ICN.

vii. The name of a subfamily should end with '-oideae' to the stem of a genus, e.g.- Amaranthoideae, Rosoideae, etc. The tribes should end with '- eae', e.g.- Rosae, Amarantheae, etc. the subtribes should end with '-ineae, e.g. Amaranthinae, Rosinae, etc.

viii. All mononomials having proper endings after the name of the type Genus. The name of a genus is a substantive in the singular number, or a word treated as such. It may be taken from any source and be composed in an absolutely arbitrary manner, e.g. *Impatiens, Rosa*, etc. the generic name may not consist of two words, unless they are joined by a hyphen.

ix. The names of a intergeneric hybrid are formed by combining the names of the two parent genera connected by the 'X' sign, eg.- X *Agropogon* (= *Andropogon* X *Polypogon*).

x. For the name of a species it is always a binomial. First one is the generic name or generic epithet started with capital initial letters followed by the specific name or specific epithet started with small letter or initial. Both form the name of a species.

xi. For genus and species no ending is specified, but grammatically both are same.

xii. Generic epithet cannot be repeated with specific epithet (which will be a tautonym). It is rejected by ICN, eg.- *Malus malus*, *Linaria linaria, Berberia berberia*, etc.

xiii. In case of infraspecific rank the epithet is written after the name of the plant prefixing the rank in short, eg.- *Urena lobata* L. ssp. *sinuata*; *Rosa damascana* f. alba.

9.2 Summary

In this chapter we have discussed about the taxonomic hierarchy which include 7 major ranks, i.e. Plant Kingdom, Division, Class, Order, Family, Genus and Species. Here Species is the basic rank. There 5 infranspecific ranks below tha speciews level, viz.- Subspecies, Vartiety, Subveriety, Forma and Subforma. The major ranks are again subdivided into sub ranks, e.g., Subgenera, Sborder, subclass, etc. the ending of each of the major and sub ranks are also specified by the ICN, e.g.- '-opsida in case of Class, '-ales' in case of Order, etc. all names are mononomials except the name of the species which is binomial. For Genus and Speciews no ending is specified, but grammatically both are same. Tuatonynms where generic name and specific epithet are same is not allowed by the Code.

9.3 Questions & Answers

Q1. How many ranks are there in ICN?

Ans.: There are 24 ranks of Taxa including 7 major ranks and 5 infraspecific ranks in present ICN.

Q2. Mention the different ranks under ICN.

Ans.: Vide section 9.1

Q3. What should be the ending for a Sub-family according to ICN? Give example.

Ans.: The name of a subfamily should end with '-oideae' to the stem of a genus, e.g. Amaranthoideae, Rosoideae, etc.

Q4. How the name of a intergeneric hybrids are written? Give example.

Ans.: The names of a intergeneric hybrids are formed by combining the names of the two parent genera connected by the 'X' sign, eg.- X *Agropogon* (= *Andropogon* X *Polypogon*).

Q5. What is tautonym? Give example.

Ans.: When the specific epithet exactly repeats the generic name, it is known as tautonym, e.g. *Malus malus*. Tautonyms are subsequently rejected in ICN.

Unit 10 ❒ Botanical Nomenclature

Structure

10.0 Objective

- In this unit we shall discuss about different rules and regulations of nomenclature including Principles, Typification, Author citations, Effective and Valid Publications, Rejection of names and Rules of Priority.

10.1 Introduction

Nomenclature is basically the process of naming a taxon. The Rules and regulations regarding naming of a taxon are governmed by ICBN (International Code of Botanical Nomenclature) or presently ICN (International Code of Nomenclature for algae, fungi and plants).

❒ Nomenclature deals with the application of a correct name to a plant or taxonomic group. Nomenclature is often associated with identification of the taxa. The rules and regulations regarding nomenclature is governed by International Code of Nomenclature for algae, fungi and plants (ICN), formerly known as ICBN (International Code of Botanical Nomenclature). This is published by International Association of Plant Taxonomy (IAPT). The Code is revised after International Botanical Congress which usually held at an interval of 5 years. Naming of animals is governed by International Code of Zoological Nomenclature (ICZN), while the nomenclature of bacteria and viruses are governed by International Code for the Nomenclature of Bacteria (ICNB, presently Bacteriological Code- BC) and International Code of Virus Classification and Nomenclature (ICVCN) respectively. Naming of cultivated plants is accordingly based on International Code of Nomenclature for Cultivated Plants (ICNCP) which is mostly based on ICN with few additional provisions.

Presently there have been attempts in developing unified Code for all living organism. Draft BioCode and PhyloCode are developed to fulfil the purpose of unified Code System, but yet these are not adopted universally.

10.2 Division I. Principles

Principle I

The nomenclature of algae, fungi, and plants is independent of zoological and bacteriological nomenclature. This *Code* applies equally to names of taxonomic groups treated as algae, fungi, or plants, whether or not these groups were originally so treated.

Principle II

The application of names of taxonomic groups is determined by means of nomenclatural types.

Principle III

The nomenclature of a taxonomic group is based upon priority of publication.

Principle IV

Each taxonomic group with a particular circumscription, position, and rank can bear only one correct name, the earliest that is in accordance with the rules, except in specified cases.

Principle V

Scientific names of taxonomic groups are treated as Latin regardless of their derivation.

Principle VI

The rules of nomenclature are retroactive unless expressly limited.

10.3 Typification

The application of names of taxa of the rank of family or below is determined by means of nomenclatural types (types of names of taxa). The application of names of taxa in the higher ranks is also determined by means of types when the names are ultimately based on generic names.

A nomenclatural type (typus) is that element to which the name of a taxon is permanently attached, whether as the correct name or as a synonym. The nomenclatural type is not necessarily the most typical or representative element of a taxon.

10.3.1 Nomenclatural Type

- It is a specimen.
- It is based on first description.
- Name is attached to that specimen.
- Along with that name the specimen is permanently preserved in a herbarium.
- Name along with the description should appear in the printed form.
- Providing details of the specimen.
- Preferably citing the acronym (i.e. short or abbreviated form of any internationally accepted herbarium. Acronym is written in capital letter).

** Automatic typification above the rank of family.

10.3.2 Typification

a) **A holotype** of a name of a species or infraspecific taxon is the one specimen or illustration used by the author, or designated by the author as the nomenclatural type. As long as the holotype is extant, it fixes the application of the name concerned.

   For the purposes of this Code, original material comprises the following elements: (a) those specimens and illustrations (both unpublished and published either prior to or together with the protologue) upon which it can be shown that the description or diagnosis validating the name was based; (b) the holotype and those specimens which, even if not seen by the author of the description or diagnosis validating the name, were indicated as types (syntypes or paratypes) of the name at its valid publication; and (c) the isotypes or isosyntypes of the name irrespective of whether such specimens were seen by either the author of the validating description or diagnosis or the author of the name.

b) **A lectotype** is a specimen or illustration designated from the original material as the nomenclatural type, if no holotype was indicated at the time of publication, or if the holotype is missing, or if a type is found to belong to more than one taxon.

In lectotype designation, an isotype must be chosen if such exists, or otherwise a syntype if such exists. If no isotype, syntype or isosyntype (duplicate of syntype) is extant, the lectotype must be chosen from among the paratypes if such exist. If no cited specimens exist, the lectotype must be chosen from among the uncited specimens and cited and uncited illustrations that comprise the remaining original material, if such exist. If no original material is extant or as long as it is missing, a neotype may be selected. A lectotype always takes precedence over a neotype.

c) **An isotype** is any duplicate of the holotype; it is always a specimen.

d) **A syntype** is any specimen cited in the protologue when there is no holotype, or any one of two or more specimens simultaneously designated in the protologue as types.

e) **A paratype** is any specimen cited in the protologue that is neither the holotype nor an isotype, nor one of the syntypes if in the protologue two or more specimens were simultaneously designated as types.

f) **A neotype** is a specimen or illustration selected to serve as nomenclatural type if no original material is extant, or as long as it is missing.

When a holotype or a previously designated lectotype has been lost or destroyed and it can be shown that all the other original material differs taxonomically from the lost or destroyed type, a neotype may be selected to preserve the usage established by the previous typification. A neotype may be superseded if it can be shown to differ taxonomically from the holotype or lectotype that it replaced.

The author who first designates a lectotype or a neotype must be followed, but that choice is superseded if (a) the holotype or, in the case of a neotype, any of the original material is rediscovered; the choice may also be superseded if one can show that (b) it is in serious conflict with the protologue and another element is available that is not in conflict with the protologue, or that (c) it is contrary to Art. 9.14.

g) **An epitype** is a specimen or illustration selected to serve as an interpretative type when the holotype, lectotype, or previously designated neotype, or all original material associated with a validly published name, is demonstrably ambiguous and cannot be critically identified for purposes of the precise application of the name to a taxon. Designation of an epitype is not effected unless the holotype, lectotype, or neotype that the epitype supports is explicitly cited.

The author who first designates an epitype must be followed; a different epitype may be designated only if the original epitype is lost or destroyed.

- ❖ Designation of an epitype is not effected unless the herbarium or institution in which the epitype is conserved is specified or, if the epitype is a published illustration, a full and direct bibliographic reference to it is provided.
- ❖ On or after 1 January 1990, lectotypification or neotypification of a name of a species or infraspecific taxon by a specimen or unpublished illustration is not effected unless the herbarium or institution in which the type is conserved is specified.
- ❖ On or after 1 January 2001, lectotypification or neotypification of a name of a species or infraspecific taxon is not effected unless indicated by use of the term "lectotypus" or "neotypus", its abbreviation, or its equivalent in a modern language.

10.4 Author citation

1. **Single author:** When a name is published by a single author, e.g.

    Annona L.

    Annona squamosa L.

2. **Use of et and et al.:**

    When a name is published by two authors, the names of both the authors are connected by *et* or *&*.

    e.g. *Zenkeria sebastinei* Henry *et* Chandrab. (or Henry & Chandrab.)

    When a name is published jointly by more than two authors, it will be published by the name of the first author followed by *et al.*

    e.g. *Indotristicha tirunelveliana* Sharma *et al.*

3. **Use of ex:**

    When an author who first validly published a name ascribes to another person who earlier proposed, but not validly published the name.

    e.g.- *Hoppea wightiana* Wall. ex Wight & Arn.

Use of in: when a name with a description supplied by one author is published in another authors work.

e.g. *Osbeckia wynaadensis* C. B. Clarke in Hook.f.

5. **Use of emend:** if an original description of a taxon is incomplete and subsequently corrected or altered retaining the same type, the original author is retained, followed by word emend and the name of the author responsible for change.

   e.g. *Phyllanthus* L. emend. Muell- Arg.

6. **Use of pro parte or p.p.:**

   It means partly or in part.

   e.g. *Maba neilgerrensis* Wight, Illust. 2:t.148. 1850

   M. buxifolia sensu Clarke in Hook.f. FBI 3:551. 1882 p.p. non Pers. 1807

   M. buxifolia Pers. 1807

7. **Use of *sensu amplo* (s.a.) and *sensu stricto* (s.s.):**

   Sensu amplo or *sensu lato* means in wide sense

   Sensu stricto means in strict sense.

   e.g. *Eugenia* L. *sensu amplo* includes species of *Syzygium, Cleistocalyx* and *Eugenia* proper. On the other hand *Eugenia sensu stricto* excludes other genera.

8. **Double citation or use of parentheses:**

   When a genus or taxon of lower rank is altered in rank and retained its name, the author of the basionym must be cited in parentheses followed by the name of the author who effected alteration.

   e.g. *Sida retusa* L.

   Sida rhombifolia L. subsp. *retusa* (L.) Bross.

9. **Use of pro syn: Pro syn means synonym.**

   e.g. *Hedyotes evaluata* Bedd. ex Gamble in Kew Bull. 1919: 405, pro syn.

   Oldenlandia evaluata Gamble

10. **Use of nomen nudum or nom. nud.:**

    Means naked name or a name without any description.

    e.g. *Convolvulus adpressus* Wall Cat no. 1424. 1828, *nom nud*.

11. **Use of auct. non:**

    A misapplied name is indicated by the words '*auct.non*.' followed by the name of original author and the bibliographical reference to the misidentification.

e.g. *Phyllanthus fraternus* Webster, Contr. Gray Herb. 176:53.1955.

P. niruri auct.non L. 1753; Hook.f. FBI 5:298.1887

12. **Use of nom. cos.:**

If a taxon is conserved the word nom.cos. should be added to the citation.

e.g.- *Tectona* L.f. Suppl. 20, 151.1781. *nom.cons*.

10.5 Effective Publication (Article-29-31)

It chiefly deals with the mechanism of publication

- ❖ It is the publication of the name of a taxon that appear in the printed form.
- ❖ In the scientific books and journals.
- ❖ Available through loan, sale and gift.
- ❖ Available in the library which is accessible to the botanists.
- ❖ Accessible to the public.
- ❖ It can be published in indelible ink before 01.01.1953, in Trademen's catalogue or non-scientific newspaper before 01.01.1953, in the seed exchange list before 01.01.1973.
- ❖ The date of effective publication is the date on which the printed matter become available.

The names that are not considered as effective publication-

- ❖ a name which is placed in the garden growing in there open to public.
- ❖ Name announced in the meeting along with the description.
- ❖ Any printing matter (leaflet, form etc) distributed to the public.
- ❖ Along with the herbarium specimen description can not be distributed.
- ❖ Online publication through internet is accepted if done in PDF with ISSN, ISBN no.

10.6 Valid Publication (Article-32-45)

Separated from author citation (46-50) in Melbourne Code

- ❖ It has 4 sections-

  I. General Rules.

II. Rules for new taxon.

III. Rules for new combination

IV. Rules for new status and replaced name

V. Names provided for particular groups like fungi, fossils, algae, etc.

Conditions of valid publication:

1. It must be effectively published.
2. Name should be Latin or Latin derivative.
3. Names are mononomial, for species it is binomial.
4. Names should provide the Rules that given in Article No.- 16-27.
5. After the name of the taxon **author citation** must be given.
6. After author, **Rank** should be mentioned in the first printed form, e.g. *fam. nov.* (new family), *sp. nov.* (new species), etc.
7. Description or diagnosis should be provided (in English from Melbourne Code).
8. Nomenclatural type must be cited.
9. If a new genus and a species is described, combined description should be provided. * if a name of genus appear in printed form without any diagnosis providing an illustration showing the analysis of the characters appear prior to 01.01.0908 considered as valid publication. It is same for species and below rank.
10. For new taxon creation (*nom. nov.*) description with diagnosis must be provided or a reference to a previously and effectively published description or diagnosis of the taxon. For nom. Nov. Here the replaced synonym should be clearly indicated and a full and direct reference given to its author and original publication with page or plate reference and date.
11. For new combination (*comb. nov.*) or new status (*stat. nov.*)- basionym should be clearly indicated and a full and direct reference given to its author and original publication with page or plate reference and date.
12. The proposal of provisional name in anticipation of future acceptance of the group concerned is not valid.
13. Publication of the new taxon of the rank of family or below on or after 01.01.1958 is valid only when the nomenclatural type is indicated.

10.7 Rejection of names (*nomina rejicienda* or *nom.rej*)

1. A legitimate name must not be rejected merely because it is inappropriate, or disagreeable or because another is preferable or better known, or because it has lost its original meaning or because the generic name does not accord with the morph represented by its type.
2. A name, unless conserved or sanctioned, is illegitimate and is to be rejected if it was **nomenclaturally superfluous** when published.
3. The name of a family, genus or species, unless conserved or sanctioned, is illegitimate if it is **a later homonym.**
4. Consideration of homonymy does not extend to the names of taxa treated as plants, except as stated below:
   a) later homonym of the names of taxa once treated as plants are illegitimate, even though the taxa have been reassigned to a different group of organisms to which this Code does not apply.
   b) a name is illegitimate if it becomes a homonym of a plant name when the taxon to which it applies is first treated as plant.
5. The name of the species or infraspecific taxon or subdivision of a genus may be illegitimate even if its epithet was originally **placed under an illegitimate generic or specific name.**
6. Any name that would cause a **disadvantageous nomenclatural changes.**
7. A name that has been widely and persistently used for a taxon or taxa **not including its type must be rejected.**

10.8 Rules of Priority

❖ The nomenclature of a taxonomic group is based upon priority of publication.

❖ Each family or taxon of lower rank with a particular circumscription, position, and rank can bear only one correct name, special exceptions being made for nine families and one subfamily for which alternative names are permitted, *viz*.-Palmae/ Arecaceae, Gramineae/ Poaceae, Cruciferae/ Brassicaceae, Leguminosae/ Fabaceae, Guttiferae/ Clussiaceae, Umbelliferae/ Apiaceae, Labiatae/ Lamiaceae, Compositae/ Asteraceae.

❖ However, the use of separate names is allowed for fossil-taxa that represent different parts, life-history stages, or preservational states of what may have been a single organismal taxon or even a single individual.

- A name has no priority outside the rank in which it is published.
- For any taxon from family to genus, inclusive, the correct name is the earliest legitimate one with the same rank, except in cases of limitation of priority by conservation .
- An autonym is treated as having priority over the name or names of the same date and rank that established it.
- e.g.- *Heracleum sibiricum* L. (1753) includes *H. sibiricum* subsp. *lecokii* (Godr. & Gren.) Nyman and *H. sibiricum* subsp. *sibiricum* automatically established at the same time. When *H. sibiricum*, so circumscribed, is included in *H. sphondylium* L. (1753) as a subspecies, the correct name of that subspecies is *H. sphondylium* subsp. *sibiricum* (L.) *Simonk.*, not *"H. sphondylium* subsp. *lecokii*".
- For purposes of priority, names of fossil-taxa (diatom taxa excepted) compete only with names based on a fossil type.

  e.g.- A common Jurassic leaf-compression fossil is referred to as either Ginkgo *huttonii* (Sternb.) Heer or *Ginkgoites huttonii* (Sternb.) M. Black. Both names are in accordance with the Code, and either name can be correct, depending on whether this Jurassic fossil-species is regarded as rightly assigned to the non-fossil genus *Ginkgo* L. or whether it is more appropriate to assign it to the fossil-genus *Ginkgoites* Seward (type, G. obovata (Nath.) Seward, a Triassic leaf compression).
- Names of organisms (diatoms excepted) based on a non-fossil type are treated as having priority over names of the same rank based on a fossil type.

  e.g.-The generic name *Metasequoia* Miki (1941) was based on the fossil type of *M. disticha* (Heer) Miki. After discovery of the non-fossil species *M. glyptostroboides* Hu & W. C. Cheng, conservation of *Metasequoia* Hu & W. C. Cheng (1948) as based on the non-fossil type was approved. Otherwise, any new generic name based on M. glyptostroboides would have had to be treated as having priority over *Metasequoia* Miki.
- For purposes of priority, names given to hybrids are subject to the same rules as are those of non-hybrid taxa of equivalent rank.

  e.g.- The name ×*Solidaster* H. R. Wehrh. (1932) has priority over ×*Asterago* Everett (1937) for the hybrids between *Aster* L. and *Solidago* L.

Limitations of Rules of Priority:

1. Not applicable for invalid publications- names which are not validly published can not be considered for priority.
2. Principle of priority is not mandatory for names of taxa above the rank of family.
3. Priority Rule is limited to within the rank concerned.

4. Priority Rule does not apply to name which is sanctioned or conserved over earlier names (i.e. *nomina conservanda*).
5. Priority Rule does not apply to names puiblished before the starting point date of different groups of plants.

10.9 Summary

From this chapter we got an idea about the Rules and Regulations of Plant Nomenclature as mentioned in the ICN. The basic aim of plant nomenclature is to provide a single name to each of the taxon and also to provide a stable method for naming of a taxon. There are six principles of the Code on which the entire nomenclature is based. A nomenclatural type is the main specimen used by the author or designated by the main author. It is again of many types-Holotype, Isotype, Lectotype, Syntype, Paratype, Neotype and Epitype. In the citation of authors name we also have learned the use of et. ex. in, emend, parentheses, nom.nud., etc. Publication is mandatory for each of the taxon. The publication that chiefly deals with the mechanism of publication is known as effective publication while the publication that deals with the nomenclature of the taxon is known as valid publication. For being considered as a valid publication it should be effectively published. There is no provision for nvalid publication in the Code. *Nomina rejicienda* or *nom. rej.* basically deals with the rejection of names. Later Homonym, Invalid Publication, Superfluous name or a name without any type specimen are usually rejected by the Code. The Ruloes of Priority basically deals with the priority of publication. Principle no. III and IV basically govern the Rules of Priority. It has some limitations.

10.10 Questions & Answers

Q1. Write the full form of ICBN.

Ans. The full form of ICBN is International Code of Botanical Nomenclature.

Q2. What is the full form of ICN?

Ans: International Code of Nomenclature for algae, fungi and plants.

Q3. What is the full form of ICZN?

Ans.: International Code of Zoological Nomenclature (ICZN).

Q4. What is the full form of ICVCN?

Ans.: International Code of Virus Classification and Nomenclature.

Q5. What is the full form of ICNB?

Ans.: International Code for the Nomenclature of Bacteria (ICNB, presently Bacteriological Code- BC).

Q6. Write the 6 Principles of ICN.

Ans. Vide section 10.2

Q7. Define nomenclatural type.

Ans.: A nomenclatural type (typus) is that element to which the name of a taxon is permanently attached, whether as the correct name or as a synonym.

Q8. Write the characters of a nomenclatural type.

Ans.: vide section 10.3.1.

Q9. Define Holotype.

Ans. Vide section 10.3.2 a.

Q10. Define isotype.

Ans.: Vide section 10.3.2 c.

Q11. Define syntype.

Ans.: Vide section 10.3.2 d

Q12. Define paratype.

Ans.: Vide section 10.3.2 e.

Q13. Define neotype.

Ans.: Vide section 10.3.2 f.

Q14. Define epitype.

Ans.: Vide section 10.3.2 g

Q15. Define lectotype.

Ans.: Vide section 10.3.2 b.

Q16. Distinguish between syntype and paratype.

Syntype	**Paratype**
A syntype is any specimen cited in the protologue when there is no holotype, or any one of two or more specimens simultaneously designated in the protologue as types.	A paratype is any specimen cited in the protologue that is neither the holotype nor an isotype, nor one of the syntypes if in the protologue two or more specimens were simultaneously designated as types.
No holotype is present.	Holotype is present.
Lectotype is selected to serve the purpose of holotype.	Lectotype selection is not needed as holotype is extant.
Author simultaneously designates more than one specimen as type.	Selected to study the seasonal variation.

Q17. Distinguish between epitype and neotype.

Epitype	**Neotype**
An epitype is a specimen or illustration selected to serve as an interpretative type when the holotype, lectotype, or previously designated neotype, or all original material associated with a validly published name, is demonstrably ambiguous and cannot be critically identified for purposes of the precise application of the name to a taxon.	A neotype is a specimen or illustration selected to serve as nomenclatural type if no original material is extant, or as long as it is missing.
An epitype is selected even when all the original materials, i.e. holotype, isotypes, etc present.	Neotype is selected when no original materials are present.
Author has to select the epitype as the original materials, although present, create ambiguity.	In selecting a neotype the author doesn't have any available reference material for selecting the type

Q18. What do you mean by author citations?

Ans.: the name of the original author who published a name is given after the binomials in an abbreviated form with or without any

Q19. Explain the author citation- *Hoppea wightiana* Wall. ex Wight & Arn.

Ans.: *Hoppea wightiana* - the name of the plant was proposed by Wallich without any description which was subsequently described and validly published by Wight and Arnott. Hence the word 'ex' is used between the name of the author who proposed the name without any description (*nomen nudum*) and the author(s) who validly published the name.

Q20. Explain the use of **'in'** in author citation with example.

Ans.: When a name with a description supplied by one author is published in another authors work.

e.g. *Osbeckia wynaadensis* C. B. Clarke in Hook.f. Here the name was published by C. B. Clarke in the book- flora of British India edited by Sir J.D. Hooker.

Q21. What do you mean by 'auct.non.' in author citation? Give example.

Ans.: A misapplied name is indicated by the words 'auct.non.' followed by the name of original author and the bibliographical reference to the misidentification.

e.g. *Phyllanthus fraturnus* Webster, Contr. Gray Herb. 176:53. 1955.

P. niruri auct.non. L. 1753; Hook.f. FBI 5:298. 1887- because *P. niruri* is not found in India. It should be treated as *P. fratarnus.*

Q22. What do you mean by *sensu amplo* and *sensu stricto* in author citation?

Ans.: *sensu amplo* - means in wide sense and *sensu stricto* - means in strict sense.

e.g. *Eugenia* L. sensu amplo includes species of *Syzygium*, *Cleistocalyx* and *Eugenia* proper. On the other hand Eugenia sensu stricto excludes other genera.

Q23. What do you mean by '*nom. cos*.'?

Ans.: 'nom. cos.' Refers to the conserved names which are conserved against earlier names,

e.g. *Tectona nom*. cos., i.e. the genus *Tectona* is a conserved genus.

Q24. What do you mean by *nomen nudum* or *nom. nud*.?

Ans.: *nomen nudum* refers to the names without any description or naked names, e.g.- *Convolvulus adpressus* Wall Cat no. 1424. 1828, *nom nud.*

Q25. What is double citation?

Ans.: When a genus or taxon of lower rank is altered in rank and retained its name, the author of the basionym must be cited in parentheses followed by the name of the author who effected alteration.

e.g. *Sida retusa* L.

Sida rhombifolia L. *subsp. retusa* (L.) Bross.

Q26. What is basionym?

Ans.: Basionym is the name from which the new combination is derived, e.g.-

Basionym: *Sida retusa* L.

New combination: *Sida rhombifolia* L. subsp. *retusa* (L.) Bross.

Q27. What is effective publication?

Ans.: it is the primary step of publication which chiefly deals with the mechanism of publication.

Q28. Mention the conditions of effective publication.

Ans.: vide section 10.5

Q29. Mention the conditions which are not considered as effective publication.

Ans.: vide section 10.5

Q30. What do you mean by valid publication?

Ans.: it is an effective publication that mainly deals with the nomenclature of a taxon. In case of valid publication all the conditions of effective publications must be fulfilled. A validly published name is considered as legitimate name.

Q31. Mention the conditions of a valid publication.

Ans.: vide section 10.6

Q32. What do you mean by *nom. rej*.?

Ans.: It is *nomina rejicienda*, i.e. rejected names.

Q33. Mention the conditions of rejection of names (nomina rejicienda) or write a short notes on rejection of names.

Ans.: vide section 10.7

Q34. Mention the Rules of Priority.

Ans.: vide section 10.8

Q35. Comment on the limitations of Rules of Priority.

Ans.: vide section 10.8

Unit 11 ❒ Types of Classification

Structure

11.0 Objective

In this unit,

- You will learn about different types of classification.
- You will able to distinguish among three basic types of classification.

11.1 Introduction

Classification is basically the grouping of taxa based on their similarity. From the beginning of taxonomy many people tried to classify the plants based on their knowledge and perception. Initially the classification was artificial, i.e. based onone or few charadters. In course of time the classifications were changed to natural system where characters from all possible sources are taken into considerations to study the relationship and grouping of taxa. After the discovery of Darwin's 'Origin of Species'' (1867) the concept of evolution came into existence and the classifications were changed to phylogenetic one showing the relationships and evolution among the taxa. In this chapter we are going to discuss in detail Bentham and Hooker's System of Classification (1862-1883) which is a natural system of classification and one of the most accepted system followed in different herbaria of the World.

❒ Keeping in view, the enormously high number of plant species, it is impossible for anyone to study all plants individually. To overcome this problem, the plants can be placed into small or large groups based on their similarities and differences, and then arranged in a sequential manner into categories according to their levels, and each category is given a name following the rules of nomenclature. Classification is thus, *the arrangement of groups* *of plants with particular circumscription, rank and position according to artificial criteria, phenetic similarities or phylogenetic relationships*. It includes the determination of position or rank for new taxa as well as old taxa, which have been remodelled, divided, united, transferred or altered in rank. Generally classification provides a system of named, circumscribed reference bases (taxa) for informational storage, retrieval and use.

In sequence of increasing inclusiveness, the groups are assigned to a fixed hierarchy of categories such as species, genus, family, order, class and division. So the final arrangement constitutes the system of classification. The process of classification includes the appropriate assignment of position and rank to a new taxon; dividing a taxon into smaller units; uniting two or more taxa; transfer of a taxa from one group to another one and alter its rank. The classification may be categorized into three basic types:

a) **Artificial classification:** based on few arbitrary, easily available characters, such as habit, flower colour, number of stamen, etc.

   e.g.- Sexual system of Linnaeus (1753)

b) **Natural classification:** uses characters from all possible sources and based upon overall resemblances and based upon overall resemblances, mostly gross morphology. It does not consider any evolution among the groups.

   e.g.- Bentahm and Hooker's system of classification (1862-83).

c) **Phylogenetic classification:** is based on the evolutionary descent of a group of organisms, the relationships depicted either through a phylogram, phylogenetic tree or Cladogram. The classification is constructed with the purpose that all the descent of a common ancestor should be placed in the same group, i.e. the group should be monophyletic.

   e.g.- Cronquist's system of classification (1988).

   There are two more forms of classification:

A phenetic system of classification includes relationship between taxonomic units based on their overall similarities based on data from all available sources. The overall similarity is measured by mathematical calculations (similarity index, coefficient of correlation, etc) and is considered to represent the relationships between the taxa. This system was primarily proposed by Michel Adanson (1763), but later strongly advocated by Sneath and Sokal (1973).

Evolutionary taxonomic classification differs from a phylogenetic classification in that the gaps between two related groups are very significant in recognizing the groups. It also accepts origin of more than two descendent from a common ancestor (and thus paraphyletic groupings). The approach is known as eclecticism and is practised by eclecticists. E.g.- Simpson (1961), Ashlock (1979), Mayr and Ashlock (1991), etc.

11.2 Bentham and Hooker's System of Classification

It is one of the most well developed natural systems of classification adopted in different herbaria throughout the World. The system of classification was proposed by two English Botanists- **George Bentham** and **Sir Joseph Dalton Hooker** in three volume work- *Genera Plantarum* (1862-1883). It is the only Post Darwinian natural system of classification as its last volume published after Charles Darwin's "Origin of Species" (1867), but it was not based on any evolutionary concept, so it was Pre Darwinian in concept. This system was a refinement of the system proposed by A. P. De Candolle and Lindley, which in turn were based on the system of de Jussieu.

George Bentham (1800-1884) was an eminent botanist and was the author of many important monographs including Labiatae, Ericaceae, Scrophulariaceae and Polygonaceae. Hand book of British Flora (1858) and Flora Australensis (1863-78) are some of the other important works published by him.

Sir Joseph Dalton Hooker was a very well known botanist who succeeded his father, William Jackson hooker, as the Director of Royal Botanic Garden, Kew. He published many important books like Flora of British India in seven volumes (1872- 97), Student's Flora of the British Isles (1870) and also revised the later editions of Handbook of British Flora. He also supervised the publication of Index Kewensis (2 volumes, 1893). This famous person had explored many parts of the World and had published many floristic works that are inevitable till date.

They classified the flowering plants or seeded plants describing 202 Natural Orders (families), 7569 Genera and 97205 Species. They broadly classified the seeded plants into Dicotyledons a, Gymnospermae and Monocotyledons. The Dicots were further classified into three subclasses- Polypetalae, Gmaopetale and Monochlamydeae with a total of 14 Series, 25 Cohorts (Orders) and 165 Natural Orders (families). Monocotyledons were subdivided into 7 Series directly with 34 Natural Orders (families). Gymnospermae was subdivided directly into three Natural Orders (families)- Cycadaceae, Coniferae and Gnetaceae.

The system of classification is as follows :

Class — Spermatophyta

- I. Distyledons (14 sries, 25 cohort, 165 families)
- II. G y m n o s p e r m a e (Cycadaceae, Coniferae, Genetaceae)
- III. Monocoty ledons (7 series, 34 families)

Subclass — Class-I. Dicotyleders

1. Polypetalae (Petals free)
2. Gamopetalae (Petals united)
3. Monochlamydeae (Petals absent; perianth present)

Series — Subclass-1 Polypetalae

- I. Thalamiflorae (stamens many, hypegynous, Disc absent
  - COHORT
    1. Ranales. (Ranunculaceae) Magnoliaceae, etc.
    2. Parietales (Cruciferae, Capparideae, etc.)
    3. Polygalineae (Polygaleae, etc)
    4. Caryophyllineae (Caryophyllaceae, etc.) Portulacaceae,
    5. Guttiferales (Guttiferae, Dipterocarpeae, etc.)
    6. Malvales (Malvaceae, Sterculiaceae, Tiliaceae)
- II. Disciflorae (stamens hypogynous, Disc present)
  - COHORT
    1. Geraniales (Geraniaceae, Rutaceae, etc.
    2. Olacales (Olacineae, etc.) Illicineae,
    3. Celastrales (Celastraceae, Rhamnaceae, etc.
    4. Sapindales (Sapindaceae, Anacardiaceae, etc.
- III. Calyciflorae (stamens e p i g y n o u s) perigynous; ovary interior)
  - COHORT
    1. Rosales (R o s a c e a e , Leguminosae, etc.
    2. Myrtales (Myrtaceae, Lythraceae, etc.
    3. P a s s i f l o r a l e s (Passifloraceae; Cucurbitaceae, etc.
    4. F i c o i d a l e s (F i c o i d e a e , Cactaceae, etc.)
    5. U m b e l l a l e s (Umbelliferae, etc.)

Subclass-2. Gamopetalae

Series

- I. Inferae (ovary interior)
  - COHORT
    - 1. Rubiales (Rubiaceae, Caprifoliaceae, etc.
    - 2. Asterales (Compositae, etc) Dipsaceae,
    - 3. Companales, (Campanulaceae, etc.) Stylideae,
- II. Heteromerae (ovary superior, androecium 1-2 series, carpels more than 2)
  - COHORT
    - 1. Ericales (Ericaceae, etc.) Monotropeae,
    - 2. Primulales (Primulaceae, etc.) Plumbagineae,
    - 3. Ebenales. (Ebenaceae, Sapotaceae, etc.)
- III. Bicarpellatae (ovary superior, androecium of 1 series, carpels 2
  - COHORT
    - 1. Gentianales (Gentianaceae, Apocynaceae, etc.)
    - 2. Polemoniales (Convolvulaceae, Solanaceae, etc.
    - 3. Personales (Scrphulariaceae, Acanthaceae etc.
    - 4. Lamiales, (Labiatae, Verbenaceae, etc.

Subclass-3. Monochlamydeae

SERIES

- I. Curvembryeae (embryo coiled, ovule 1) (Polygonaceae, Amaranthaceae, etc.)
- II. Multiovulate aquaticae (ovules many, immersed aquatics) [Podostemaceae]
- III. Multiovulate terrestris (ovules many, terrestrial) [Nepenthaceae, Aristolochiaceae, etc.]
- IV. Microembryeae (embryo very minute) [Piperaceae, etc.]
- V. Daphnales, (ovary with 1 carpel & 1 ovule) [Proteaceae, Laurineae, etc.]
- VI. Achlamydosporae. (ovary inferior, 1 locule, 1-3 ovules) [Loranthaceae, Santalaceae, etc.]
- VII. Unisexualis. (flowers unisexual) [Euphor biaceae. Urticaceae, etc.
- VIII. Ordines anomali. (uncertain relationships). [Ceratophyllaceae, etc.]

Class-III Monocotyledons

→ 1. Microspermae (ovary inferior, seeds minute)
e.g.- Orchidaceae & 2 more families.

→ 2. Epigynae (ovary inferior, seeds large)
[Irideae, Amaryllidaceae & 5 more]

→ 3. Coronarieae (ovary superior, coloured perianth)
[Liliaceae, Commelinaceae & 6 more

→ 4. Calycineae (ovary superior, perianth green)
[Juncaceae, Palmae, Flagellariaceae]

→ 5. Nudiflorae (Periarth usually absent, ovary superior)
[Typhaceae, Araceae & 3 more]

→ 6. Apocarpae (carpels free)
[Alismaceae & 2 more]

→ 7. Glumaceae. (Reduced Perianth, bracts large, scaly)
[Cyperaceae, Gramineae & 3 more]

Dicotyledons– 3 Sub-classes, 14 Series, 25 Cohorts & 165 Natural Orders
Gymonospermae - 3 natural orders
Monocotyledons- 7 series, 34 Natural Orders
Total -3 Classes, 3 Sub-Classes, 21 Series,
202 Natural Orders (families)
7569 Genera
97, 205 Species.

Merits of the system:

1. It has a great practical value for the identification of plants.
2. It is very easy to follow for routine identification.
3. It is widely followed by different herbaria of the World, e.g.- Central National Herbarium, India; Herbarium of Kew Botanic Garden, London.
4. Creation of Gymnosperm as an independent group.
5. Placement of Ranales at the beginning of Dicot is justified as it is regarded as the most primitive members of dicot by many authors.
6. Placement of Dicots before Monocots is also justified in terms of phylogeny.
7. Here the natural affinities of the taxa are concerned that can be visualized easily and mostly dependent on morphological features.
8. The grouping is based on a combination of characters rather being single character and

thus position of many groups are highly justified in the system, e.g.- placement of Cucurbitaceae in Polypetalae with Passifloraceae.

9. Placement of Heteromerae before Bicarpellate is also justified.

Demerits of the System:

1. Although the system is Post-Darwinian in publication, but it is pre-Darwinian in concept, i.e. it does not consider any phylogeny among the groups.
2. Placement of Gymnospermae between dicots and monocots is not justified.
3. Monochlamydeae is actually an unnatural assemblage of taxa. The creation of this group has resulted in the separation of many closely related families, e.g.- Podostemaceae is more closely allied to Rosales than Monochlamydeae; placement of Caryophyllaceae in Polypetalae and Illeciberaceae and Chenopodiaceae in Monochlamydeae is not justified as they are very closely allied.
4. Placement of Liliaceae and Amaryllidaceae in different Series is not justified as they are considered to be very much closely allied to each other based on phylogeny.
5. Series Unisexualis in Monochlamydeae Series is a loose assemblage of diverse families.
6. Creation of Ordines Anomali is also not supported by many authors. Cronquist and Takhtajan placed Ceratophyllaceae under Subclass Magnoliidae and the other under Dilleniidae.
7. Placement of Orchidaceae at the beginning of Monocots and Alismataceae at the end part of the Monocot are also not justified as they are the most advanced and most primitive members of Monocots respectively.
8. Placement of Inferae at the beginning of Gamopetalae is also not supported.

11.3 Summary

So from this chapter we got an idea about and the different system of calssification and also have gone through in detail about a Natural system of Classification by Bentham and Hooker (1862-1883). The classification was published in *Genera Plantarum* book-a three volume work. They classified of seed plants into three Classes-Dicotyledons, Gymnospermae and Monocotyledons. The Dicotyledons were further subdivided into three Sub-Classes-polypetalae, Gamopetaae and Monochlamydeae. Polypetalae was further subdivided into three Series-Thalamiflorae (6 Cohorts), Disciflorae (4 Cohorts(and Calyciflorae (5 Cohorts). Gamopetalae was subdivided into three Series-Inferae (3 Cohorts), Heteomerae (3 Cohorts and Bicarpellatae (4 Cohorts). Monochlamydeae had only 8 Series and without any Cohorts. Monocotyledons were subdivided into 7 Series directly without any Sub-classes and Cohorts. The system of classification is preferred throughout the World for its ease of identification and followed in different herbaria, although placements of some taxa are not justified.

11.4 Questions & Answers

Q1. What is classification?

Ans.: Classification is thus, the arrangement of groups of plants with particular circumscription, rank and position according to artificial criteria, phenetic similarities or phylogenetic relationships.

Q2. What is artificial classification?

Ans.: Artificial system of classification is based on few arbitrary, easily available characters, such as habit, flower colour, number of stamen, etc.

e.g.- Sexual system of Linnaeus (1753).

Q3. What do you mean by natural system of classification?

Ans.: Natural system uses characters from all possible sources and based upon overall resemblances and based upon overall resemblances, mostly gross morphology. It does not consider any evolution among the groups.

e.g.- Bentahm and Hooker's system of classification (1862-83).

Q4. What do you mean by Phylogenetic system of classification?

Ans.: Phylogenetic system of classification is based on the evolutionary descent of a group of organisms, the relationships depicted either through a phylogram, phylogenetic tree or Cladogram. The classification is constructed with the purpose that all the descent of a common ancestor should be placed in the same group, i.e. the group should be monophyletic.

e.g.- Cronquist's system of classification (1988).

Q5. What do you mean by phenetic system of classification?

Ans.: A phenetic system of classification includes relationship between taxonomic units based on their overall similarities based on data from all available sources. The overall similarity is measured by mathematical calculations (similarity index, coefficient of correlation, etc) and is considered to represent the relationships between the taxa. This system was primarily proposed by Michel Adanson (1763), but later strongly advocated by Sneath and Sokal (1973).

Q6. Write the name the authors of a natural system of classification that you have studied.

Ans.: George Bentham and Sir Joseph Dalton Hooker's system of classification (1862-83).

Q7. Name the book in which Bentham and Hooker's system was published.

Ans.: Genera Plantarum (1862-83)- a three volume work by Bentham and Hooker.

Q8. Briefly describe the system of classification by Bentham and Hooker up to Subclass. Comment on its merits and Demerits.

Ans.: vide section 11.2.

Suggested Readings

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