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(B.Sc. CBZ)

Plant Ecology and Taxonomy
(DBSZCO202T24)

Self-Learning Material
(SEM II)

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Course Code: DBSZCO202T24
Plant Ecology and Taxonomy

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COURSE INTRODUCTION

The course has 3 credits and 14 units. This course surveys the 500-million year evolutionary history of terrestrial plants, from the earliest spore-producing land plants to Darwin's "abominable mystery" of flowering plant evolution. It introduces phylogenetic principles and methods for identifying, naming, and classifying plant diversity. A total evidence approach to phylogenetic systematics is presented where genetic, morphological, and paleontological data are used to reconstruct the evolutionary relationships of extant and extinct taxa. Students will gain knowledge on plant classification and identification and relationship.

Course Outcomes: After the completion of the course, the students will be able to:

1. Describe the major clades of plant diversity and their evolutionary relationships
2. Describe the phylogenetic characters that define these clades
3. Explain the principles of phylogenetic systematics and apply these to the categorization of plant diversity
4. Apply the scientific method and philosophy of hypothesis testing to plant systematics
5. Use plant scientific names correctly, including the names of infraspecific taxa, interspecific hybrids, and cultivated varieties
6. Apply knowledge of floral, fruit and vegetative features and use dichotomous keys to identify unknown plants to family, genus, and species
7. Explain the significance of plant systematics and taxonomy to other areas of biological research, including evolutionary biology, ecology, and conservation

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UNIT-1

INTRODUCTION, HISTORICAL BACKGROUND & EVOLUTION OF ANGIOSPERMS

1.1 OBJECTIVES

The main goal of this chapter is to broaden your understanding about the following issues:-

- Introdution of Systematics
- History of Systematics
- Objectives of Taxonomy

1.2 INTRODUCTION

Plant taxonomy is one of the earliest branches of Botany. It was began as ―Folk Taxonomy‖ in early 15th century but it has expanded and gone very long way in the previous 500 years. The breadth and idea of taxonomy have evolved significantly. Even though the earth's flora was created during the previous three centuries, contemporary taxonomists nevertheless face difficulties. Threats exist to the richly flora tropical nations. There are now 4,000,000 plant species known, of which 2,866,000 are angiosperms. About 70% of the plants that have been discovered are from tropical climates.

Currently, most individuals are interested in applied sciences like cytology, genetics, ecology, molecular biology, and experimental biology; however, very few are considering the more fundamental or basic areas of botany like taxonomy and morphology. It's now considered outdated. Without correctly identifying the plant material they are dealing with, no applied branch can be tackled, which is why taxonomists are crucial.

According to Simpson (1961), systematics is the scientific study of the many forms and diversity of organisms as well as any and all relationships among them. It encompasses identification, taxonomy, categorization, and nomenclature. It was de Candolle who first used the word taxonomy in 1813.

Classification is the process of placing a single plant or a collection of plants into a certain category according to a predetermined plan and a system of nomenclature. Species, which are classified into genus and then suborders of families, orders, subclasses, classes, and divisions, are the fundamental units of categorization.

The classification of organisms started in the distant past by primitive humans who used it for their own purposes and language. As language developed, the differences between predators and herbivores, as well as between deadly and edible plants, became evident. They perceive the need for various flora and fauna to serve them. For their festivities, they chose particular flora and fauna. In this sense, the categorization in its most basic form entered society.

Among pre-civilized men, folk systematics is becoming more and more common. They used gross morphology to identify groupings of plants. This marks the start of the artificial categorization scheme. Their classification schemes are based on pragmatic reasons. Classification's history dates back to the oldest Indian civilizations. Philosophers such as Sushruta, Charak, and the early Greeks Aristotle, Plato, and Pliny, among others, attempted to categorize plants based on their own perspectives, which were inevitably more philosophical than scientific.

1.3 HISTORY OF PLANT TAXONOMY

Folk taxonomy's classification of valuable plants marks the beginning of taxonomy history. They distinguished as economic plants by people. The path for herbal taxonomy was thus paved. The following stages of the history can be studied:

I. The First Phase –

- Theophrastus, a Greek naturalist who is regarded as the Father of Botany, wrote "Enquiry into Plants" between 370 and 285 BC. In his writings, he suggested Crataegus, Daucus (daukan), Asparagus (aspargos), and Narcissus, among other plants. He categorized plants as herbs, undershrubs, shrubs, and trees based on their habits. In HistoriaPlantarum, the oldest known botanical book, he provides the names and descriptions of five hundred plants. He highlighted the distinctions between monocots and dicots

- Pliny (c. 23–29 AD) produced a lengthy Natural History; there are currently 37 volumes available.
- PedanionDioscorides, an Asian physician who lived from 62 to 128 AD, wrote around 600 therapeutic plants. The Greek title of his work was MateriaMedica.
  The Italian physician Andrea Caesalpino (1519–1603 AD) identified 1500 woody and herbaceous species in his work De Plantis (1583).
- Plants from Italy, France, and Switzerland were collected by Gaspard Bauhin (1560-1624 AD). His books, ProdromusTheatiBotanici (1620) and PenaxTheatiBotanici (1623), detail his collection. He tried using the binomial method of naming for the first time.
- John Ray (1628 – 1705 AD). Three volumes of HistoriaPlantarum were produced by British botanists (1686 - 1704). He was the first to separate the plants and trees into dicotyledous and monocotyledous groups based on the presence or absence of one or two cotyledons.
- J. P. de Tournefort (1656–1708) examined corolla and identified plants and trees.
- In Padua, Italy, the first herbarium was founded in 1553. During the mid-17th century, herbaria were founded in many regions across the globe.
- The Swedish naturalist Carolus Linnaeus (1707–1778) is regarded as the founder of modern botany and taxonomy. His works include Species Plantarum (1753), PhilosophiaBotanica (1751), Classes Plantarum (1738), and Genera Plantarum (1737). A sexual system was used to describe and order 7300 species. It was a made-up system with a limited character set. He introduced binomial systems, such as the arboreum rhododendron. (1) Monandria (one stamen), (2) Diandria (two stamen), and (24) Cryptogamia (no blossom) are the 24 classifications of Linnaeus.
- Initially, taxonomy was only used for species name and exploration.

II. **Natural System phase-**

- In his 1758 publication Genera Plantarum, Antoine L. de Jussieu categorized plants into fifteen groups.
- A French botanist named AugustinPyrame de Candolle (1778–1841) created the morphological technique to categorization and published Theorieelementaire de la botanique in 1813. Vasculares and Cellulares, Monumental works - ProdromusSystematisNaturalisRegniVegetabilis, were the classifications he gave to plants. Alphonse de Candolle, A. P. de Candolle's son, eventually finished the task that his father was unable to finish.
- In Origin of Species, published in 1859, Charles Darwin proposed the theory of natural selection and the evolution of species.
- Genera Plantarum (1862–1883), written by Bentham and Hooker (1800–1884), provided a practical application of categorization and has served as an inspiration to subsequent generations of Kew Botanists.

III. **Phylogenetic Stage –**

- Evolutionary concepts served as the foundation for phylogenetic categorization. With Endlichler (1804–1849) and Eichler (1837–1887), it all began.
- Segle and Prantl (1887–1915) proposed a semi-phylogenetic categorization scheme.
- Syllabus der Pflanzenfamilien (1964) and Die NatiirlichenPflanzenfamilien (1887–1899). He ranked monocots ahead of dicots and thought orchids to be more advanced than grasses.
- Class 1: Eleven orders of monocotyledons
- Class 2: Phytoplankton
- Subclass 1: Archichlamydeae, which include 29 orders.
- Subclass 2. Nine orders of Metachlamydeae (Sympetalae)

- Classification of flowering plants by A. B. Rendle (1865–1938). He considered amentiferae and apetalous to be primitive dicots, and monocots as primitive to dicots.
- Charles Edwin Bessey (1845–1915) presented the first completely phylogenetic approach based on Dictas of Phylogeny, which HansHallier (1868–1938) modified.
- In Families of Flowering Plants (1959), British scientist John Hutchinson (1884–1972) proposed a phylogenetic classification of value based on his 24 principles of phylogeny. He was categorized using the same criteria as Bentham, Hooker, and Bessey. The first book, released in 1928, covers dicots; the second, with monocots; and the third, British Flowering Plants (1940)

IV. Current Phase-

- Modern botanists such as Takhtajan (1969), Cronquist (1981), Stebbins (1974), Robert Thorne (1976), and others improved the system.
- The classifications based on factors such as distribution, ecology, anatomy, paleontology, cytology, and biochemistry in addition to morphology.
- Methods for preparing and presenting herbarium specimens were created and refined.

V. Biosystematic Phase

- The development of biosystematics over the past fifty years has led to a qualitative improvement in the field of taxonomic idea and application.
- The objective of holotaxonomy‖ is the purpose of ‟new systematics‖.
- In 1940, Huxley coined the phrase "New systematics."
- The name "Biosystematics" was introduced to new systematics by Camp and Gilly (1943).
- Cytotaxonomists regarded the quantity, dimensions, and configuration of chromosomes as highly dependable factors for

cytotaxonomic categorization. Chemotaxonomy was developed as a result of the advancement of methods such as two-dimensional paper chromatography and the discovery of chemicals in plants as secondary metabolites.

- The novel methods, such as amino acid sequencing and nucleotide sequence identification in DNA and RNA, can provide specifics.
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VI. Phase of Holotaxonomic-

To comprehend phylogeny, data is obtained, examined, and a significant conclusion is reached-

- Data collection, analysis, and synthesis are within the purview of Numerical Taxonomy, a separate taxonomy discipline.
- The foundation of numerical taxonomy, also known as quantitative taxonomy, is the numerical assessment of the similarity between groups of organisms and the subsequent classification of these groups into higher ranked taxa.
- The Alpha Taxonomy comprises the Exploration and Consolidation phases, whereas the Omega Taxonomy comprises the Biosystematic and Encyclopaedic phases.

1.4 BASIC COMPONENTS OF TAXONOMY

Taxonomy is a fundamental science with the increase in knowledge of various components developed.

i. **Alpha Taxonomy** (Descriptive Taxonomy)**:** This branch of taxonomy deals with species designation and description. It evolved in the 19th century, usually on the basis of physical characteristics. The work of Tournefort, de Jussieu, and Linnaeus served as its foundation.

ii. **Beta Taxonomy** (Macrotaxonomy)- The classification of species according to a hierarchical structure of higher taxa. It evolved throughout the twentieth century.

iii. **Gamma Taxonomy**: This taxonomy includes aspects related to evolutionary patterns and intraspecific populations. An effort is made to explain the emergence and evolution of species. A taxonomist must rely on paleobotany, which covers all taxa of extinct plant groupings, to ascertain the origin of a species.

iv. **Omega taxonomy**: Based on all characters that are accessible, it is the most ideal system.

The Alpha-Omega Taxonomy idea is the best. While alphataxonomy serves as a basis for biology, omega taxonomy is eventually formed by a collection of all available fact

1.5 AIMS AND OBJECTIVES OF TAXONOMY

Plant Taxonomy' operations constitute the basis for all other biological disciplines, which in turn depend on them for any more data that might be helpful in creating a classification. The following objectives are the focus of these activities:

1. To provide people an easy way to identify and communicate. Detailed and diagnostic descriptions, together with a functional taxonomy with the taxa grouped in a hierarchy, are needed for identification. Polyclaves, dichotomous keys, computer-aided identification, and correctly labeled and placed herbarium specimens are crucial identification aids. By working with the International Association of Plant Taxonomy (IAPT), the Code (ICBN) was created and recorded to assist in determining the one accurate name that is recognized by the whole botanical community.

2. To provide an inventory of the world's flora. Floristic records of continents (Continental Floras; see also Flora Europaea by Tutin et al.), regions or countries (Regional Floras; see also Flora of British India by J. D. Hooker), and even states or counties (Local Floras; see also Flora of Delhi by J. K. Maheshwari) are well documented, despite the difficulty of establishing a single world Flora. Furthermore, there are World Monographs available for a few families (such as Das pflanzenreich ed. by A. Engler) and few genera (such as the genus *Crepis* by Babcock).

3. To identify evolution in action; to piece together the history of evolution within the kingdom of plants, ascertaining the order in which changes in evolution have occurred and how characters have changed.

4. To provide a system of classification which depicts the evolution within the group. A phylogram is sometimes used to illustrate the evolutionary connection between the groups; the longer branches indicate more evolved groupings, while the shorter, closer to the base, reflect more primitive ones. Furthermore, balloons of varying sizes that correspond to the number of species within each group are used to symbolize the groupings. A bubble diagram is the common term for this type of phylogram.

5. To provide an integration of all available information. To collect data from every area of study, analyze it using computer-assisted statistical techniques, provide a summary of the data, and create a categorization system based on general resemblance. But as science will never stop, fresh data will keep coming in and creating new problems for taxonomists, this synthesis will never finish..

6. To provide the process for storing, retrieving, exchanging, and using information in order to serve as a reference. To supply extremely useful information on genetic and ecological variety, unique elements, and endangered species.

7. To provide fresh ideas, reframe the classics, and create new methods for accurately determining taxonomic affinities using phenetics and phylogeny.

8. To provide comprehensive databases encompassing every plant species (and maybe every life) on the planet. Together, a number of sizable organizations have created searchable online databases containing molecular data, synonyms, pictures, descriptions, and taxon names.

There are three main objectives of taxonomy:

1. **IDENTIFICATION**
2. **CLASSIFICATION**
3. **NOMENCLATURE**

1. **IDENTIFICATION-** The process of identifying or determining a specimen's identity involves matching it to an existing taxon and allocating the appropriate rank and location within the existing classification. In real life, it means giving a name to a specimen that is unknown. One way to accomplish this is to visit a herbarium and compare specimens that are unknown with well recognized specimens that are kept there. An identification specialist in the field may also get the specimen as an alternative.

   Identification can also be accomplished by consulting a variety of literary sources, including manuals, monographs, and floras, and employing the identification keys these sources of information give. Once the unidentified specimen has been tentatively recognized using a key, the identification may be verified by cross-referencing it with the comprehensive taxonomic description found in the relevant literature source.

2. **CLASSIFICATION-** Organisms are classified when they are arranged into groups according to common characteristics. Until every organism is gathered into a single, most inclusive group, the groupings are subsequently put together into more inclusive groups. The groupings are placed into a predefined hierarchy of categories, such as species, genus, family, order, class, and division, in increasing order of inclusivity. This final arrangement creates a categorization system.

   A new taxon (a taxonomic group given to any rank; pl. taxa) can be classified by assigning its proper location and rank. It can also be classified by splitting a taxon into smaller units, combining two or more taxa into one, shifting its rank, and shifting its position within a group. Once created, a categorization offers a crucial method for storing, retrieving, and using information. The Linnaean system is the common name for this ordered categorization scheme. Different approaches are used to classify taxonomic entities:

1\. **Artificial classification**, based on arbitrary, readily visible traits like habit, color, quantity, form, or similar features, is utilitarian in nature. The number of stamens was used by Linnaeus, whose sexual system falls under this category, to classify blooming plants in the first place.

2. Natural classification, first proposed by M. Adanson and culminating in the widely used classification of Bentham and Hooker, groups taxa based on their general resemblance. Morphology was adopted by natural systems in the eighteenth and nineteenth centuries to restrict their general resemblance. The notion of general similarity has experienced significant enhancements in the past several years. Rather of relying just on morphological characteristics to determine similarities between natural systems, traits taken from all relevant taxonomic domains are now used to assess overall similarity (phenetic connection).

3. Phenetic Classification, All available data from morphology, anatomy, embryology, phytochemistry, ultrastructure, and really all other disciplines of research are used to determine overall similarity in terms of a phenetic connection. Sneath and Sokal (1973) vigorously defended phenetic classifications, although the major higher plant categorization systems did not share their views. However, in contemporary phylogenetic systems, phenotypic relationship has been heavily utilized to determine realignments within the categorization scheme.

4. Phylogenetic classification phylogram, phylogenetic tree, or cladogram is used to illustrate the evolutionary connection between a set of species, which forms the basis of phylogenetic categorization. The idea behind classification is that all offspring of a shared ancestor belong to the same group (i.e., the group should be monophyletic). In order to make a group monophyletic, those descendants that have been excluded and become paraphyletic are reintroduced (as in the case of the merging of Brassicaceae and Capparaceae in recent classifications, and the union of Asclepiadaceae with Apocynaceae). The group is divided into monophyletic taxa if it is polyphyletic, meaning that its individuals come from many phyletic lines. For example, the genus Arenaria separated into Arenaria and Minuartia.

3. **NOMENCLATURE-** Nomenclature deals with the determination of a correct name for a taxon. For many categories of living things, there exist distinct sets of regulations. The International Code of Botanical Nomenclature (ICBN) regulates the nomenclature of plants, including fungus, through its guidelines and recommendations. The Botanical Code, which is updated approximately every six years, assists in selecting the appropriate scientific name for a taxon based on its specific characteristics, including location, rank, and

circumscription, among many others. The Code includes a list of preserved names to prevent awkward name changes for certain taxa. The International Code of Nomenclature for Cultivated Plants (ICNCP), which is mostly based on the Botanical Code with minor modifications, governs plants that are grown under cultivation.

The International Code of Zoological Nomenclature (ICZN) governs animal names, whereas the International Code for the Nomenclature of Bacteria (ICNB), presently known as the Bacteriological Code (BC), governs names of bacteria. The International Code of Virus Classification and Nomenclature (ICVCN) is a distinct code that is specifically designed for viruses.

SUMMARY

- Plant taxonomy aids in the preparation of a far from comprehensive inventory of the world's flora, particularly that of the tropics.
- To create a logical and comprehensive system of plant classification, one must have a thorough understanding of and familiarity with plant taxonomy.
- An essential tool for researching the evolutionary effects of plant variety is plant taxonomy.
- Every plant species, whether extinct or currently living, has a single "Latin" scientific name according to the concepts and regulations of plant taxonomy.
- One can categorize the study of plant taxonomy into pre- and post-evolutionary periods. The pre-evolutionary time is further subdivided into four periods: the Transition period, the Post-Herbal Era, the Greek and Roman era, and the Herbalist period.
- In ancient India, plant taxonomy also thrived. Among the well-known ancient Indian taxonomy writings are the Aryurveda, Charak-Samhita, and Shushruta-Samhita.

Key words

Classification: Arrangement of a single plant or a collection of plants in a certain category according to a naming system with a specific and well-established plan.

Taxonomy: Includes identification, taxonomy, classification and nomenclature.

Artificial: System with the use of a small number of characters in order to facilitate identificatio

Nature:system based on form relationships.

Phylogenetic: System based on genetic relationship and evolution.

Q.1 Multiple Choice Questions

i) Natural system of classification was proposed by:

(a) Bentham & Hooker

(b) Hutchinson

(c) Theophrastus

(d) Cronquist

Ans. (a)

ii) Phylogenetic classification was proposed by……..

(a) Bentham & Hooker

(b) Hutchinson

(c) Lawrence

(d) All of the above

Ans. (b)

iii) Artificial system of classification was proposed by:

(a) Linnaeus

(b) De Candolle

(c) Engler and prantl

(d) Cronquist

Ans. (a)

iv) **What is the sequence of taxonomic hierarchy:**

(a) division-class-order-family-tribe-genus-species

(b) division-class-family-order-tribe-genus-species

(c) division-class-family-tribe-order-genus-species

(d) division-order-class-family-genus-tribe-species

Ans. (a)

v) **Taxonomy' term was coined by:**

(a) Linnaeus

(b) Bentham and Hooker

(c) A.P. de Candolle

(d) Juliane Huxley

Ans. (C)

UNIT 2

CLASSIFICATION OF ANGIOSPERMS

2.1 OBJECTIVES

The main goal of this chapter is to broaden your understanding about the following issues:-

- Introdution
- Natural System of classification
- Phylogenetic system of classification

2.2 INTRODUCTION:

The hundreds of living things on Earth are given some order by way of classifications based on similarities. Classification is the process of placing a single plant or a collection of plants into a certain category according to a predetermined plan and a system of nomenclature. Species, which are classified into genus and then suborders of families, orders, subclasses, classes, and divisions, are the fundamental units of classification.

The categorization of organisms dates back to ancient times, when primitive humans used their own language for practical purposes. As language evolved, the differences between plants that are deadly or edible, carnivorous, and herbivorous became evident. They sense that certain flora and animals are essential to their needs. They chose certain flora and fauna for celebrations. In this sense, the classification gained traction in society. Among pre-civilized men, folk systematics is becoming more and more common. They used gross morphology to identify groups of plants. This marks the start of the artificial classification scheme. Their classification schemes are based on pragmatic reasons. Classification's history dates back to the oldest Indian civilizations. Philosophers such as Sushruta, Charak, and the early Greeks Aristotle, Plato, and Pliny, among others, attempted to categorize plants based on their own perspectives, which were inevitably more philosophical than scientific. The different plant classifications that have been suggested thus far fall into one of three categories:

(a) Artificial : Banhin, Tournefort, John Ray, Carl Linnaeus, and other systems use one or a few features to categorize plants, mainly to make the organism easy to identify.

(b) Natural : The system primarily relies on relationships to realize all of the information that is accessible at any given moment. For example, de Candolle, Robert Brown, Lamarck, Bentham, and Hooker's categorization.

(c) Phylogenetic : This system attempts to categorize plants by their evolutionary sequences and genetic links. such as Bessey, Hutchinsm, and Eichler.

According to C. Jeffrey (1982), there are four primary categories into which the classification system can be split:

(a) Artificial: Up until 1830, the classification was based on habit.

(b) Pre-evolutionary Natural Systems: These systems, such as those described by Bentham & Hooker, A. P. de Candolle, and de Jussieu, were generally far more natural between plants.

(c) Phylogenetic Systems: Naturally occurring groups with commendable or shared traits are connected to one another by a common ancestor, such as Eichler and Engler.

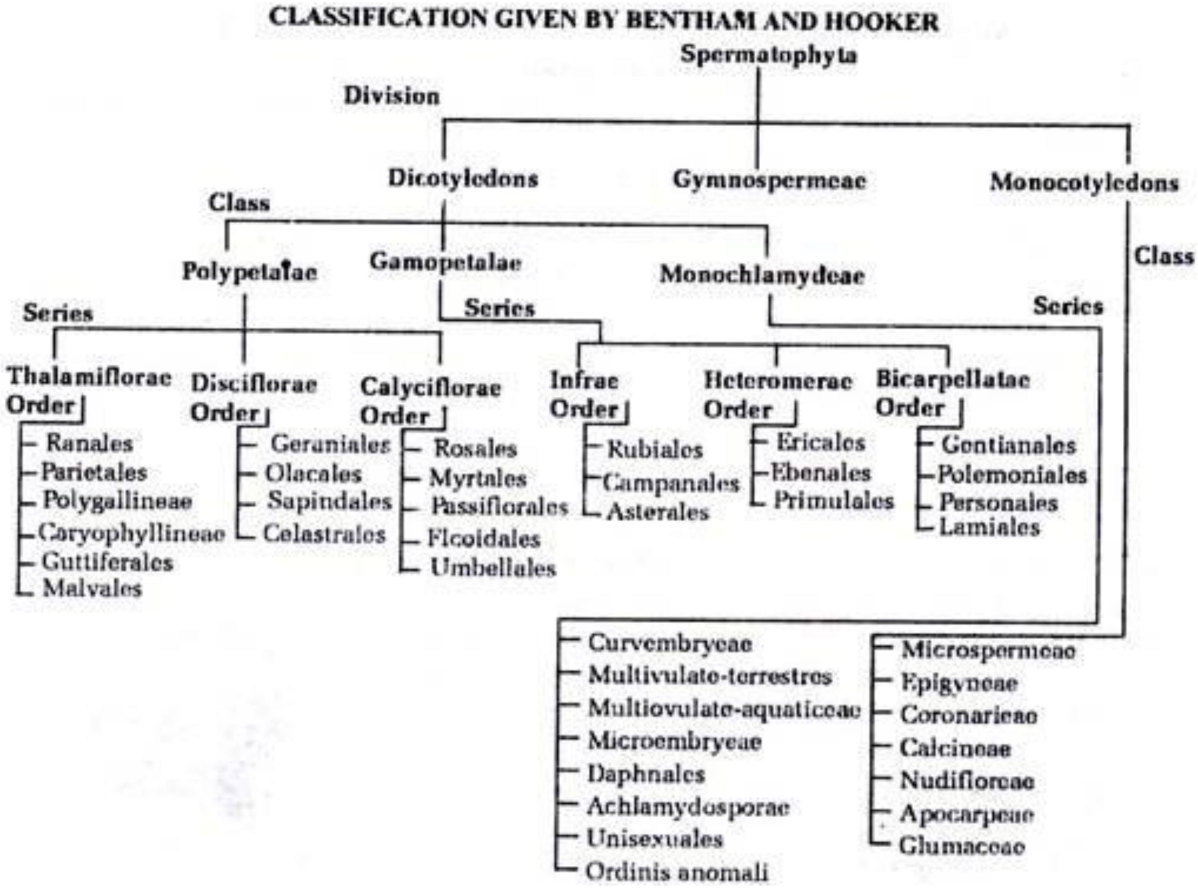
(d) Phenetic System: Optimal generalizations of all phenotypes' combined traits, such as Hutchinson.

2.3 Bentham's & Hooker's System

Throughout the British Empire, the renowned English systematists who jointly published "Genera Plantarum" (1862–1883) are still cited for their classification. This approach is used in our nation to preserve the Central National Herbarium in Sibpur (Howrah), West Bengal.

The classification scheme is based on de Candolle's, although it places more emphasis on the difference between fused and free petals. The Polypetalae, Gamopetalae, and Monochlamydeae are the three divisions of the dicots. Gymnosperms' placement between dicots and monocots is merely a matter of convenience and does not signify any affinities.

The categorization flow chart for Bentham and Hooker's system (1862–1883) is shown below:



Merits and Demerits of Bentham's and Hooker's Classification

One merit is that it offers simple methods for identifying plants.

The demerits are:

- Preservation of Monochamydeae, which normally biseriate perianth.
- Chenopodiaceae are apetalous friends of Caryophyllaceae; family Salicineae and Cupuliferae are related to now extinct.
- Simple flower to Paronychieae as elaborate primitive.

  Monocots place more importance on the relative position of the ovary; so, Iridaceae and Amayllidaceae have a larger affinity to Liliaceae than do Scitamineae and Bromelliaceae due to a shared epigyuous trait.
- Position of Monochlamydeae and delimitation owing to their affinities (Rendle).

Essential for recognizing the Families:

(a) The majority of flowers are penta or tetramerous, and

(b) the calyx and corolla are largely different.

(c) Most flowers are trimerous;

(d) The calyx and corolla are largely combined into one whorl; perianth is present; and monocotyledons

2.4 Hutchinson's Classification

John Hutchinson proposed the phylogenetic classification system in his book "The Families of Flowering Plants." He was an English botanist who lived from 1884 until 1972. In line with Bessey's Dicta of Phylogeny, he put out 24 principles of phylogeny. He released a book titled "Evolution and Phylogeny of Flowering Plants" in 1969. Genera of Flowering Plants (1964–1967) are his other work. His classification underwent several revisions (1955, 1969), before making a definitive appearance in 1973.

According to the categorization, angiosperms have a monophyletic origin, deriving from hypothetical proangiosperms. Angiosperm evolution was first thought to have occurred along two paths.

(a) Herbaceae (28 orders, comprising the herbaceous families Ranales through Lamiales)

(b) Lignosae (woody or arborescent plants; 54 orders; Magnoliales to Verbenales)

He did, however, believe that monocots descended from Ranales. Within all 29 orders and 69 families, monocots were categorized into three groups according to the nature of the perianth: Calciferae, Corolliferae, and Glumiflorae.

Little changes were made to the 1973 revised taxonomy, which moved Lytherales from Herbaceae to Myrtales in Lignosae. Currently, there are 342 families and 82 orders for diptons, compared to 29 orders and 69 families for monocots.The crucial details are as follows:

1. The system is built upon Bessey's architecture. Its foundation is the idea that flowering plants with petals and sepals, together with other floral and anatomical characteristics, are more phylogenetically primitive than non-petalled plants.
2. This approach is predicated on extensive Phylogenetic knowledge.

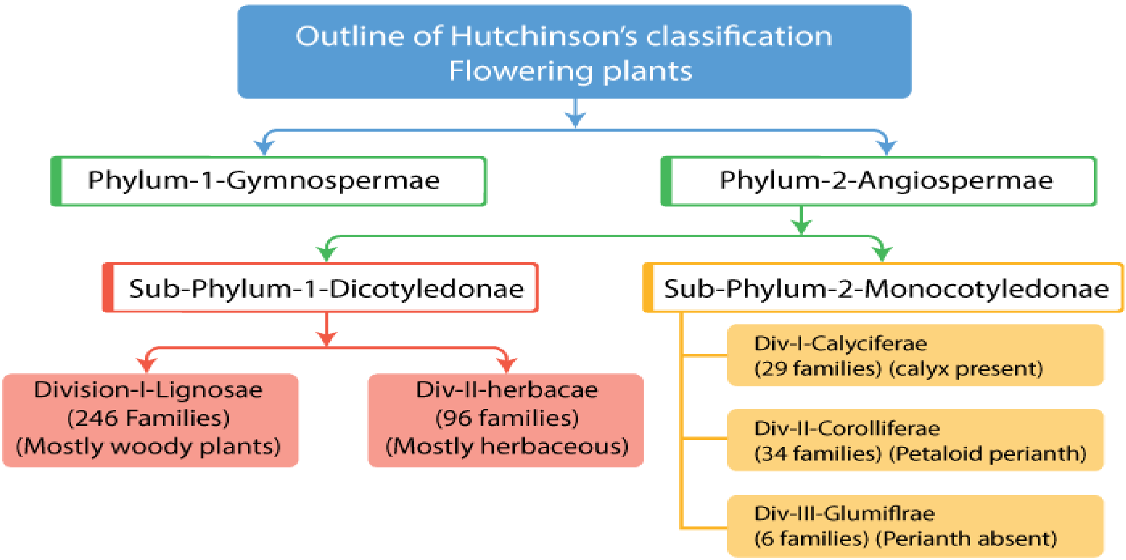
3. The Monocotyledons are arranged following the Dicotyledons, from which they were thought to have originated early on.
4. The Magnoliales and Ranales are regarded as the most primordial orders of the Dicotyledons; they have spirally formed carpels and bisexual blooms with lots of free stamens.
5. Based on their relationships, the Gamopetalae and Monochlamydeae are placed throughout the Polypetalae, emphasizing similarities rather than differences.
6. Based on a combination of characteristics, the flowering plants are grouped into smaller groups, with closely related families grouped together.
7. The gymnosperms are regarded as a separate class.
8. He offered new theories for a number of the 29 orders in which the families of monocotyledons are grouped, leading to more logical groupings.
9. The alismatales and butomales are at the beginning of the monocotyledons. They resemble the Ranales androecium in having an apocarpous gynoecium, folicular and achenial fruits,
and a great number of stamens.
10. The belief that the Gramineae is the most evolved family of monocotyledons is at odds
with what is now known about the group.
11. He identified 411 Angiosperm families.

Classification Principles

The evolutionary organization of plants was highly valued by Hutchinson, who based plant categorization on 24 principles, which are summarized below:

1. There are two types of evolution: upward and downward, with degradation and degeneration in the latter.
2. Not every plant organ evolves at the same time; certain organs or groups of organs may be progressing while others remain stable or regressing.
3. In general, evolution has been steady, and once a certain retrogression or progression begins, it continues until the end of the phylum.
4. It's likely that trees and shrubs are more primature than herbs in some groups.
5. Shrubs and trees are more ancient than vines.
6. Annuals are descended from perennials, which are older than biennials.

7. Similar to terrestrial flowering plants, aquatic epiphytes, saprophytes, and parasites are generally more recent.
8. Although it is not a given that plants with scattered vascular bundles, or monocotyledons, are directly descended from those with ordered collateral vascular bundles in a cylinder, the former are more primitive in origin.
9. The spiral arrangement of floral leaves, such as petals and sepals, and leaves on stems came before the opposite and whorled forms.
10. The umbel and capitulum belong to the latter.
11. Compared to whorled and valvate, spirally imbricate floral portions are more premature.
12. The type of flowers with few parts (oligomerous) comes after the type with many parts (polymerous), and both types are accompanied by a gradual sterilization of the reproductive organs.
13. Petaliferous flowers bloom before apetalous ones, with the latter coming from a decrease.
14. Compared to sympetaly, polypetaly is more archaic.
15. Compared to zygomorphic flowers, actinomorphic blooms are more primitive.
16. The initial state is hypogyny, from which epigyny and perigyny eventually developed.
17. Syncarpy is the outcome of apocarpy, which is more basic.
18. A few carpels follow a lot of carpels.
19. Non-endospermic seeds are more modern, while endospermic seeds with tiny embryos are more archaic.
20. A lot of carpels come before a few.
21. Compared to zygomorphic flowers, actinomorphic flowers are more primitive.
22. A more sophisticated flower has fewer stamens than a primitive flower, which had numerous stamens.
23. Connate stamens come after separate stamens.
24. The capsule usually appears before the drupe or berry, and aggregate fruits are more recent than solitary.



Advantages of the Hutchinson System

1. It is a phylogenetic system that only uses phylogenetic principles.
2. The phylogenetic systems of Oswald Tippo, Cronquist, Takhtajan, Dahlgren, and others were built upon this foundation.
3. According to the concept, Magnoliales are primitive lignoceous dicots, whereas Ranales are primitive herbaceous dicots.
4. Only closely related taxa make up very small families and orders.
5. Families in monocots are generally recognized to be arranged that way.
6. It is thought that monocots are more evolved than diploids.

Disadvantages of the Hutchinson System

1. Dicots were separated into two main groupings, Lignosae and Herbaceae, based on habit. Among the Lignosae are woody plants. Many did not accept this because, in any other case, closely related plants were kept separate, making it impossible to distinguish between the two evolutionary lines.
2. Based on floral structure, the two related families were divided; for example, closely related Ranales families like Ranunculaceae and Magnoliaceae were kept apart.
3. There are a number of herbaceous groups that are closely related to or even descended from woody families. For example, the herbaceous Apiaceae family is thought to have originated from the Cornaceae family,

whereas the woody Araliaceae family or the herbaceous Brassicaceae family are descended from the woody Capparidaceae family via the Cleomaceae family.

4. This approach is not particularly useful for classifying plants.

SUMMARY

Plant classifications were covered in this unit. One of the oldest fields of botany is plant taxonomy. According to Simpson (1961), nomenclature, taxonomy, classification, and identification are all part of systematics. Classification is the process of placing an individual plant or a collection of plants into a certain category according to a predetermined plan and a system of nomenclature. Species are the fundamental unit of classification. The different plant classification schemes that have been put forth thus far are either a part of natural, artificial, or phylogenetic systems. Plants were first classified according to their own principles. This unit covers the basic elements of taxonomy as well as its goals and terminology. The natural system, based on free and fused petals, that Bentham and Hooker suggested in Genera Plantarums (1862–1883) was covered in depth. There are also benefits and drawbacks to Bentham & Hooker's classification. Dienaturlichen Pflanzen Familien published Engler and Prantl's plant categorization in 1909. In this hierarchy, monocots come before dicots. Hutchinson suggested classifying plants in Families of Flowering Plants according to their phylogenetic relationships. Also covered were the 24 fundamental ideas that Hutchinson presented to 411 families.

Key Words : Systematics, Phylognetic, Artificial, Polypetalae, Gamopetalae

Q.1 Multiple Choice Questions

(i) The sexual system of classification was given by:

(a) John Ray (b) Carolus Linnaeus
(c) Bentham and Hooker (d) Hutchinson

(ii) Die Naturlichen Pflanzen Familien‖ was written by:

(a) Engler and Prantl, (b) Carolus Linnaeus
(c) Bentham and Hooker (d) Hutchinson

(iii) Natural system of classification was proposed by:

(a) Engler and Prantl (b) Carolus Linnaeus

(c) Bentham and Hooker (d) Hutchinson

(iv) Systema naturae was written by:

(a) Engler and Prantl (b) Carolus Linnaeus

(c) Bentham and Hooker (d) Hutchinson

(v) Phylogenetic classification was proposed by:

(a) Engler and Prantl (b) Carolus Linnaeus

(c) Bentham and Hooker (d) Hutchinson

Answers: (i) b (ii) a (iii) c (iv) b (v) d

Q.2 Answer in 3-4 lines:

(i) Evolution and classification of flowering plants

(ii) Priority Principles

(iii) Genera Plantarum

(iv) Historia Plantarum

(v) Charaka Samhita

UNIT-3

BASIC PRINCIPLES, PLANT NOMENCLATURE AND ICBN

3.1 OBJECTIVES

Students will comprehend the following after reading this chapter:

- Introduction
- Bionomial Nomenclature
- ICBN (Principles and Rules)

3.2 INTRODUCTION

The term "name" refers to both living and non-living entities. Every known item to humans has a name, which serves to both characterize and convey concepts about it. In certain languages and locations, the name could be different. Nomenclature is the art of naming objects; botanical nomenclature is the term used to refer to the naming of plants. Botanical nomenclature is the practice of naming plants according to worldwide guidelines put forward by botanists to provide a consistent, stable system that is applicable to all countries.

Common Names

The term "common name" refers to the name that locals give to a particular plant in that location. These names differ from one language and one area to another. Names in India vary depending on the dialect.

Scientific Name

Scientists proposed a name that is widely recognized and used across national boundaries. However, the issue still exists—that is, the language is not universal. Thus, the botanists decided to establish certain guidelines and requirements. The primary recommendation was for the name to be written in Latin. Worldwide, botanists utilize Botanical Latin as a universal language for identifying and characterizing plants. It comes from the Latin of the Roman authors of botanical literature, most notably Pliny the Elder (c. 23–79 AD). The custom that all plants should have Latin names (or names of Latin form) and that all literature on them should be written in Latin was formally established by the Swedish botanist Carolus Linnaeus (1707–1799). It is because:

1. Word meanings in Latin do not change over time in the same way that they do in living languages since Latin is a dead language.
2. Latin used in botany is very descriptive, having several adjectives for color, texture, and form.
3. Political resentment that may arise if botanists converted to another language, such Spanish or English, is not sparked by the Latin language.

3.3 BINOMIAL NOMENCLATURE

For the first time, Linnaeus suggested that each living thing had a binomial name, or a name that
consists of two epithets. One is a generic epithet, whereas the other is a specific one. An organism's name becomes trinomial if it also has a variety. In his books Critica Botanica (1737) and Fundamental Botanica (1736), Linnaeus provided some guidelines for plant genus names. First laid out by A.P. de Candolle, the standards for plant nomenclature were adopted at the International Botanical Congress in Paris in 1867. The Swedish naturalist Carolus Linnaeus first using binomial nomenclature for plant names in 1753. It was released in the edition of Species Plantarum.‖.

The generic name, such as *Sarracenia,* which bears the name of the scientist Michel Sarracin, is always a word that expresses color, name, or adjective. A species is always followed by an adjective, such as alba for white flowers, sativa for edible flowers, nigrum for black flowers, etc.Not every time are these names utilized. A pronoun such as "species" (americana, indica, benghalensis, etc.) may be used. It might be the name of another scientist to whom the plant is dedicated, like Sahnii, or the form of a leaf (a characteristic of the plant), like sagittifolia.

3.4 INTERNATIONAL CODE FOR NOMENCLATUE OF ALGAE, FUNGI AND PLANTS (ICN)

By the middle of the eighteenth century, plant names were often polynomial, made up of many words arranged in a sequence. The fundamental guidelines were put forward by Linnaeus in Philosophia Botanica in 1751. A.P. de Candolle published The orieelementaire de la botanique in 1813, outlining the guidelines for plant nomenclature. A.P. de Candolle's son Alphonse de Candolle called a meeting of botanists worldwide to propose new regulations. In 1867, Candolle called the inaugural International Botanical Congress to be held in Paris. Prior to being adopted by the Melbourne Congress, the International Code for Nomenclature of Algae, Fungi, and Plants (ICN) was known as the International Code Botanical Nomenclature (ICBN).

1. Paris Code (1867)

The first International Botanical Congress was held at Paris in August 1861. About 150 American and European Botanists were invited to make laws for Botanical Nomenclature (*Lois delanomenclaturebotanique*).The laws called Paris code, as they were adopted at French capital. This code established Linnaeus as the initial source for all naming. Author citation was crucial, and the Priority rule was seen to be fundamental to a legitimate publishing. The Paris code is flawed in numerous ways. The Kew Rule was a new regulation that American and British botanists began adhering to after a few years of breaking from the original guidelines.

2. Rochester Code(1892)

In 1892, N.L. Britton presided over the United States Botanical Congress in Rochester, New York. After modifications and additional recommendations, the Paris code was renamed as the Rochester Code. Among the crucial suggestions were (

1. Adhering strictly to the Principles of Priority.
2. The publication name and date to determine priority.
3. Acceptance of alternative bionomials that arise from the application of priority rules, even when tautonyms are involved.

3. ViennaCode(1905)

In June 1905, Vienna held the third International Botanical Congress. The basis for identifying vascular plants is Linnaeus Species Plantarum (1753), as decided upon at this convention. A nomenclature called as nomenclature genericaconservenda favors widely used generic names over older, less well-known ones. Latin diagnosis must be included with the names of new taxa, and tautonyms are prohibited.

4. AmericanCode(1907*)*

In 1907, the botanists who developed the Rochester Code declined to adopt the Vienna Code because they were not happy with it. American Code was substituted for the

Rochester Code. Latin diagnosis is not required, nor does American code follow the Nominagenericaconservenda concept. It acknowledges the idea of type. According to American Code, a binomial that has been used for one plant cannot be used in any fashion for that same species again.

5. BrusselsCode(1912)

In 1910, the Fourth International Botanical Congress was place in Brussels. Different beginning points for the priority of non-vascular plant names are accepted under this code. It acknowledges the Vienna rules' type idea and categorization.

6. CambridgeCode(1935)

The fifth Botanical Congress, held in Cambridge in 1930, eliminated the distinction between the Vienna code and the American code. The following are the recommended provisions in this code:

a. It is best to explore the type notion

b. It is necessary to include a list of Nominagenericaconservanda.

c. The use of tautonymsneed to end.

d. After January1,1932, plants must be diagnosed in Latin.

7. AmsterdamCode(1947)

The Sixth International Congress of Botany took place in Amsterdam in 1935. A significant modification to the regulations was implemented in this regard, meaning that beginning of January 1, 1935, names of newly discovered plant groups—aside from bacteria—must only be deemed legitimately published if they bear a Latin diagnosis.

8. Stockholm Code(1952)

In 1952, Stockholm held the 7th International Botanical Congress. When referring to any taxonomic group or entity, the term "Taxon" was originally used.

9. Paris Code(1956)

In July 1954, the 8th International Botanical Congress was held in Paris once more. In this case, the requirement for a Latin diagnosis was dropped, and it was determined that it should be released in German, French, and English. The Code's Preamble and

Principles were kept apart from its Rules and Recommendations. A supplement and amendment were made to NominaGenericaConservendaetrejecienda.

10. Montreal Code(1961)

In August 1959, during the 9th International Botanical Congress in Montreal, a committee was formed to look into the matter of family name protection. Nominafamiliarumconservanda was introduced for the Angiospermae. The guideline also said that names of plants from prehistoric times should correspond with those of plants from more recent times.

11. Edinburgh Code(1966)

In August 1964, during the 10th Botanical Congress in Edinburgh, the committee's report was delivered. As per its recommendation, A.L.de Jussieu's Genera Plantarum (1789) should be the initial source for family names. In the list of NominafamiliarumConservenda, a few family names were renamed, such as Capparaceae for Capparidaceae and Cannabaceae for Cannabinaceae. An Annotated Glossary of Botanical Nomenclature, a glossary of technical words, was to be prepared by a newly established committee.

12. Seattle Code(1972)

August 1969 noted the 11th International Botanical Congress convene in Seattle. F.A. Stafleu released the code in 1972. The tautonymous taxonomic designations between genus and species and below it are included in the Seattle Code. Code created the term "autonym," which refers to mechanically generated names.

3.5 PRINCIPLES

There are six principles-

I. Botanical nomenclature is independent of zoological nomenclature. The code applies equally to names of taxonomic groups treated as plants whether or not these groups were originally so treated (Plants do not include Bacteria).

II. Application of names of taxonomic groups is determined by means of nomenclature types.

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

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 specific cases.
V. Scientific names of taxonomic groups are treated as Latin regardless of their derivation.
VI. The rules of nomenclature are retroactive unless expressly limited.

A taxon or group of plants may only have one correct name, and a name may be used to a single group of plants, per the code. The guidelines or articles provide thorough instructions on every topic related to plant naming. The suggestions are how the guidelines should be used in practice.

3.6 FOCAL POINTS OF ICN (2011)

1. To properly describe plants, botanists worldwide use a clear and straightforward nomenclature system that deals with terms that indicate the ranks of taxonomic groups or units as well as scientific names that correspond to specific taxonomic groups of plants. A taxonomic group's name serves as a means of reference and an indicator of its taxonomic rank, not to highlight its characteristics or history. The goal of the code is to provide a consistent system for naming taxonomic groupings while avoiding and rejecting names that might lead to confusion, ambiguity, or mistakes in research. It saves time and effort from needless name construction.
2. The Botanical Nomenclature system is based on the Principles.
3. Rules and Recommendations comprise the detailed provisions. To better demonstrate the guidelines and recommendations, examples have been provided.
4. Names that violate a rule cannot be kept; the purpose of the Rules is to organize historical nomenclature and make provisions for the future.
5. The recommendations address ancillary issues and aim to increase uniformity and clarity, particularly in future nomenclature. Names that conflict with recommendations should not be disregarded for this reason, but they should not be used as models.
6. The clauses govern how this code may be changed in light of its most recent rulings.

7. Both fossil and non-fossil species that are classified as plants are subject to the Rules and Recommendations (with the exception of bacteria). Certain plant groupings require special considerations. Established in 1980, the International Commission for the Nomenclature of Cultivated Plants developed the International Code of Nomenclature of Cultivated Plants.
8. The only valid justifications for renaming something are when one has sufficient taxonomic research to have a deeper understanding of the facts or when one must abandon terminology that defies established conventions.\
9. hen there is no pertinent rule or when the application of a rule is questionable, established custom is followed.
10. All earlier iterations of the code are superseded by this one.

The Code

Principle (Basicpoint | Rules (Articlefornamе) | Recomendations (Practical)

Some Important Rules and Recommendations

1. The source generic name must be used to identify all plants that are members of the same genus (Rule 213)
2. Distinct generic names must be used to identify all plants that belong to distinct genera (Rule 214)
3. The person who creates a new genus is responsible for naming it (Rule 218)
4. The finest generic names are those that accurately describe a plant's key characteristics or appearance (Rule 240).
5. Avoid using generic names that are longer than one and a half feet, hard to say, or offensive (Rule 249)
6. A plant's unique name has to set it apart from all of its relatives (Rule 257)
7. Size is not a factor in identifying species (Rule 260)
8. There is no discernible change based on the plant's initial location (Rule 264)
9. Requires that each species be given a generic name. (Rule 284)
10. The particular name must always come after the generic name. (Rule 285)

3.7 PHYLOCODE

Clade and species name is increasingly moving away from the Linnaean system of binomial nomenclature. Agroup known as a "clade" is made up of all the members which consist a single common ancestor. Any group that consists of all the offspring of its members' last common ancestor is referred to as a clade.

Whenever a species is assigned to a different genus due to phylogenetic or phenetic evaluation, its name in the pre-existing code changes. Because they are operationally defined in terms of ranks and kinds, the supraspecific names in this case are linked to the phylogeny.

The phylogenetic code, or phylocode, for botanical nomenclature is designed to facilitate effective biological knowledge storage and retrieval as well as clear communication. The first day of 2000 saw the code being cited. Currently, only clade names are governed by phylocode.

Following the American Institute of Biological Sciences conference in San Diego, California, USA (1995), phylogenetic terminology was developed. The first symposium, titled "Translating Phylogenetic Analysis into Classification," was arranged by Richard G. Olmstead. The second symposium, named "The Linnean Hierarchy: Past, Present, and Future," was arranged by J. Mark Porter in 1996 at Ranchosanta Ana Botanic Garden in Claremont, California, USA. The third symposium was held in 1999 in St. Louis, Missouri, USA, during the XVI International Botanical Congress. The title of the article was "Overview and Practical."

Implications of phylogenetic Nomenclature

F. Pleijel, A. Minelli, and K. Kron drafted the first draft of Article 21, which M. Donoghue and P. Cartino revised. I. Eriksson wrote the majority of the first versions of Recommendations 10 D and 11.8 B, while W. M. Owens supplied the Latin terminology used in Article 9.3.

Properties of Phylocode

The following are the properties of Phylogenetic system:

1. The system lacks hierarchy as the naming procedure does not include rank assignment.
2. The name of clades is governed by rules.

3. There is no ranking between the categories "species" and "clade". A clade is a monophyletic group of related species, while a population lineage is composed of species.A supraspecific term in Phylocode is assigned a phylogenetic meaning and is used to refer to the clade that meets that definition, regardless of the clade's estimated makeup. The species specimens and synapomorphies that are mentioned in these definitions are referred to as specifiers since they identify the clade to which the name belongs and perform a role akin to that of types.
4. The use of names is limited based on the frame of the clade.

Regardless of past affiliation with specific clades, the pre-existing system proposes that synonyms are names of the same rank depending on types within the group of interest. Synonyms, as defined by the phylogenetic system, are terms that, independent of previous affiliation with specific ranks, indicate the same clade.

Advantages of Phylogenetic Nomenclature (Phylocode)

1. Super family and other intermediary levels can be named using Phylocode.
2. It enhances the stability of nomenclature. It is simple to determine a species' phylogenetic position by linking its name to the names of one or more clades that it belongs to.
3. Phylocode's rejection of ranks also removes the inaccuracy that arises from many taxonomists treating the same taxa at the same rank.

Hierarchy of Classification

Kingdom - Division - Class - Subclass - Order - Suborder - Family - Subfamily - Genus - Subgenus - Section - Species - Categories - Subspecies (ssp) - Varieties (var.) - Sub varieties (sub var.) - Forma (f.) - Clone (cl.)

3.8 THE RULES

Rank of Taxa

When classification of individual plants, the species is the fundamental unit of categorization. Every species is a member of a group of taxa with progressively higher ranks. The primary levels of taxa in Article 3 are species, genus, family, order, class, division, and kingdom, listed in increasing order. The only way this code defines the categories is by enumerating their order. For minor orders, families, or genuses, this might not hold true, but the sequence must remain unchanged.

One may utilize categories like family (ending with aceae, Polygonaceae), suborder (ending with ineae, Chenopodineae), order (ending with ales, Malvales), and so on. the code gives the categories—from division to subtribe—standardized grammatical ends. It is appropriate to modify the name of any taxonomic group that does not adhere to these endings. After this process, the family name ends in aceae, and the alternative names of the families whose endings are not confirmed are altered to those that do.

Graminae into Poaceae Palmae- Arecaceae Cruciferae-Brassicaceae Leguminosae-Fabaceae Umbelliferae- Apiaceae Labiatae- Lamiaceae Compositae- Asteraceae

Aster, Asteraceae, Poa, Poaceae, and other generic names provide the basis for the usage of the ending with- aceae. the subfamily Oideae, the tribe Oae, and the subtribeInae.

The term Leguminosae is authorized under article 52 of the code, but only if it encompasses the three subfamilies Papilionoideae, Caesalpinoideae, and Mimosoideae. This is a singular exception to the rule. The subfamilies of Papilionaceae will become the Fabaceae if they are elevated to family status.

Types of Taxon

The type approach is used to determine the names of various taxonomic groupings. According to the ICBN's articles and guiding principles, all taxonomic categories shall be founded on nomenclatural types,which means that all names will always be associated with a taxon or specimen that has been recognized as a type. In the case of species (and intraspecific taxa), the type is a specimen, or in other cases, only an example. Attached should be the name of the first author.The names of the taxa above the species level, such as Section, Subgenus, Genus, Tribe, and Family, are derived from the name of the next lowest taxon that the group was initially founded on; for example, the genus Lamium served as the basis for the Lamiaceae family. On the genera Orchis, etc., Orchidaceae was established. When a new species is reported, the author often possesses one or more specimens with characteristics that allow the species to be distinguished from existing ones.

A taxon's type is the component element to which the taxon's name is attached permanently. Principle II states that nomenclatural types are used to decide how taxonomic group names are applied. This implies that the author of a description of a new species must specify the kind of specimen that served as the basis for the new species. When it comes to species or infra-specific designations, the type refers to a single specimen that serves as the foundation for the new species. One herbarium sheet may have little herbaceous plants put on it; the sheet as a whole may be designated as the type.

Holotype: A single specimen—a plant as a whole or a portion of it—to which the taxonomic name is attached permanently is referred to as a holotype.

Isotype or Cotype: A biological specimen that is identical to the holotype and was obtained at the same location and time is called an isotype (at the type locality).

Paratype: Any biological specimen—other than the holotype—that is designated as representative and utilized in the creation of the initial description of a species or subspecies is referred to as a paratype.

Syntype: Syntypes are specimens that serve as a basis for new taxa when the author has not chosen a holotype. All of these specimens become syntypes if the author decides to create a new species after studying collections made by various collectors and from various locations.

Lectotype: A specimen is selected by a specialist to serve as the type from the isotype, paratype, or syntype in cases when an earlier designated holotype has been lost, destroyed, or was never designated.

Neotype: A Neotype is selected from additional specimens to act as the Type in the event that the Holotype, Isotype, Paratype, or Syntype are lost or unavailable. It is known as Standard Specimen by certain taxonomists.

Topotype: Topotype refers to a specimen that is selected to serve as a type when no original type material is available and it is obtained from the type locality.

It is also believed that a species may be going through certain natural changes in space and time. Type has been a useful tool for accurately identifying specimens. It is also generally acknowledged that an image or description of any taxonomic group is never as accurate as a preserved specimen.

Principle of Priority

Principle of Priority refers to the process of choosing a single accurate taxonomic group name. Illegitimate names ought to be discarded, and only legitimate names ought to be kept. The following are the priority rules, per Article 11–12:

(i) There can only be one right name for each family or taxon of lower rank with a certain circumscription, location, and rank (Art 11).

(ii) The right name for any taxon, ranging from family to genus, is the first accepted name with the same rank that has been legally published (Art -11).

(iii) Unless a taxon's name is legitimately published, it has no legal standing under this law (Art-12)

(iv) Nomenclatural type determines the application of both rejected and preserved names (Art-14).

(v) Botanists are permitted to keep a name that has been suggested for conservation once it has been temporarily accepted by the general committee, pending the outcome of a subsequent international Botanical Congress.

Valid Publication of names is usually considered beginning inMay1753,the date of publication of *Species **P**lantarum*vol. I by Linnaeus.

With many names of a taxon, the valid will be the earliest name which is regardedeas correct name. Rule of Priority provides stability to this name.

The principle that seniority isfixed by the date ofvalid publication is known as Principle of Priority.

Limitations of the Principle of Priority

1. **Starting dates :** PrincipleofPrioritystartswiththeSpeciesPlantarumofLinnaeus published on 1-5-1753.
2. **Limited only upto family ranks:** This principle does not apply over family rank.
3. The correct name should not be outside the rank. Only when a correct name in the taxon is not available, a combination with other rank is allowed.
4. The application of Principle of Priority resulted in numerous name changes. To avoid it a list of conserved generic and family names has been prepared and published in the code with some changes. Such Nominaconservanda(nom.

Cons.) are to be used as correct name replacing earlier legitimate names, e.g., Sesbaniascop, 1777 is the conserved genus as against Sesbanadam1763 and Agatiadam1763.

Effective and Valid Publication

From the discussion of the principles of priority, it seems that publication is the most important step in nomenclatural procedures. The name is effectively published when the published name should appear in printed and distributed to the botanical institutions. The name is valid when the name is published in accordance with the provisions of the code.

The code's "conditions and dates of valid publication of names" is the heading found in section 6. Effective publication in this context refers to the need that the names be published with a legitimate and effective publication.

Distribution of the publication in printed form, whether by sale, trade, or gift to the general public, or at the very least to botanical institutes that have libraries open to all botanists, is how it becomes effective. It is unaffected by the announcement of new names at public gatherings, by the placement of names in public collections or gardens, by the issuance of microfilm derived from unpublished manuscripts, typescripts, or other materials, by online publication, or by the distribution of distributable electronic media.

Publications in newspapers, catalogs, and seed exchange lists started on January 1, 1953, and completed on January 1, 1977, are ineffective. Theses submitted for a higher degree on or after January 1, 1953, are only deemed successfully published if they include an internal proof of publishing (such as an ISBN or a commercial publisher) or a statement of publication. Publication of handwritten content before January 1, 1953, that has been replicated by a mechanical or graphic method (indelible signature), such as metallic etching, offset printing, or lithography, is enforceable.

The date is the one on which the final requirement was met in the event that all of the requirements for a legal publication are not met concurrently. But in the site of its validation, the name must always be properly acknowledged. If a name is published on or after January 1, 1973, and all requirements for valid publication are not met at the same time, it cannot be considered properly published. Instead, a complete and explicit reference to the locations where these prerequisites were previously met must be provided.

A Latin or English description or diagnosis, or a reference to a previously published and successfully published Latin or English description or diagnosis, must accompany the given names of a new taxon of fossil plants in order for it to be approved. This publication date must be on or after January 1, 1996.

Groups that were not previously covered by the ICBN are now recognized as organisms covered under the botanical Code, and the Code recognizes them as validly published if they fit with the relevant non-botanical Code standards. This clause originally applied to organisms that were later identified as algae, but the Vienna Code expanded its scope to include organisms that were later identified as fungus. The inclusion has aided in the identification of Microsporidia, which were formerly thought to be protozoa but are now identified as fungus. Similar to this, the Pneumocystis species, which were first classified as mammalian diseases but are now classified as fungi, are now considered to properly published despite lack a Latin diagnosis or description. This is because the Zoological Code does not need Latin to be used.

Tokyo Code stipulated that new names of plants and fungi were to be registered in order for them to be legally published from January 1, 2000. This regulation was subject to confirmation by the XVI International Botanical Congress (St Louis, 1999). An optional two-year trial registration had already started on January 1, 1998, and would last for two years. But in St. Louis, the plan was rejected by a vote, and the Code no longer contains any mention of the registration. A name's date of valid publication is unaffected by a spelling modification made to it.

Publication of Names

ThenameofaTaxonshouldfulfillcertainrequirementsbeforeitseffective publication as:

(i) **Formulation:**Itshouldindicate

(a) sp.nov.(species novum) foranew species

(b) Comb. nov.(combinationnovum) forchangein the epithet ofbasionym. Thename of the original author should be kept in Parantheses.

(c) nom.nov.(Nomennovum) whentheoriginal nameiscompletelyreplaced.

(ii) **EnglishorLatin diagnosis: -**Asper ICN**(**TheMelbourneCode)therequirementof Latin diagnosis for Names of New Taxa has been changed. As per this code the description of new names should be in English or Latin.

(iii) **Typification: -** Holotype should be designated. The name of new Taxon is valid onlywhen the type of the name is mentioned after January 1, 1990. The name of the taxon whose type is a specimen or unpublished illustration; the herbarium or institution in which the type is conserved must be specified.

(iv) After January 1, 1996 the name of new taxon of fossil should be accompanied by a Latinor English description of character.

Article 32,1-2 of Tokyo Code (ICBN) is amended as new names of plants and fungi will have to be registered in order to be validly published after January 1, 2000.

Citation of Author's Name

A name must be accompanied with the identity of the author or writers who first published the name legally in order for it to be comprehensive, accurate, and easily verifiable. The names of the authors are commonly abbreviated, e.g. L. for Carolus Linnaeus, Benth. for G. Bentham, Hook. for William Hooker, Hook.f. for Sir J. D. Hooker (f. stands for filius, the son; J. D. Hooker was son of William Hooker), R.Br. for Robert Brown, Lam. for J. P. Lamarck, DC. for A. P. de Candolle, Wall. for Wallich, A. DC. for Alphonse de Candolle, Scop. for G. A. Scopoli and Pers. for C. H. Persoon.

Single author- The name of a single author follows the name of a species (or any other taxon) when a single author proposed a new name, e.g. Solanum nigrum L.

Multiple authors –when the name has more than two or more authors may be associated with a name for a variety of reasons. These different situations are exhibited by citing the name of the authors differently:

1. Use of et: When more than two authors publish propose a new name of species, their names are connected by et, e.g. Delphinium viscosum Hook.f. et Thomson.

2. Use of parentheses: According to the conventions of botanical naming, the original epithet of a taxon should always be used, even if the taxon is being transferred from one genus to another or its level is being upgraded or downgraded. A basionym is the name of the taxon that provides the epithet. Parentheses surround the name of the original author or authors whose epithet appears in the changed name, and the name of the author or authors who changed the name outside of them, e.g., *Cynodon dactylon* (Linn.) Pers., based on the species' original basionym, *Panicum dactylon* Linn.

3. Use of ex: When a first author proposes a name but it is only legitimately published by the second author, or when the first author fails to satisfy all or some of the requirements of the Code, then the names of the two authors are connected by ex e.g. Cerasus cornuta Wall. ex Royle.

4. Use of in: When an author publishes a new species or a name in another author's publication, their names are connected using e.g. Carex kashmirensis Clarke in Hook.f. Clarke published this new species in the Flora of British India whose author was Sir J. D. Hooker.

5. Use of emend: The names of two authors are connected using emend. (emendavit: person making the correction) when the second author modifies a taxon's circumscription or diagnostic without changing the type, e.g. *Phyllanthus* Linn. emend. Mull.

6. Use of square brackets: The prestarting point author is indicated by square brackets. Since Tournefort effectively established the generic name *Lupinus* in 1719—prior to 1753, when Linnaeus's Species plantarum became the basis for botanical nomenclature—the genus should properly be cited as *Lupinus* [Tourne.

Retention, Choice and Rejection of Names

The identification of illegitimate names—those that do not conform to the rules of botanical nomenclature—is an essential stage in the process of choose the proper name for a taxon. A legal name cannot be disregarded only because it is unsuitable or offensive, because it has lost its original meaning, or because another is more popular or preferred. It is not appropriate to disregard the name Scilla peruviana L. (1753) just because the species is not found in Peru. Any one or more of the following circumstances can result in a name being rejected:

1. **Nomen nudum (abbreviated nom. nud.):** A name without any explanation attached. Numerous names included in Wallich's 1812 Catalogue (abbreviated Wall. Cat.) were nomen nudum. A new name must be found because the nomen nudum, even if validated, is rejected (e.g., Quercus dilatata Wall., a nom. nud.

rejected and replaced by Q. himalayana Bahadur, 1972). Alternatively, these were validated later on by another author by providing a description (e.g., Cerasus cornuta Wall. ex Royle).

2. Absence of typification, improper formulation, not effective publication, or absence of a Latin diagnostic in the name.
3. **Tautonym**: While binomials with the same generic name and specific epithet are permitted under the Zoological Code (e.g., *Bison bison*), they are prohibited in Botanical nomenclature as tautonyms (e.g., *Malus malus*). Since the tautonym's words are precisely the same, names like Cajanus cajan or Sesbania sesban are obviously not tautonyms and are therefore acceptable. Repetition of a certain epithet inside an infraspecific epithet (e.g. *Acacia nilotica ssp. nilotica*) is a valid autonym rather than a tautonym.
4. **Later homonym**: The Code prohibits the use of the same name for two distinct species (or taxa), just as a taxon should only have one valid name. If they exist, they are homophones. The one that was published first is referred to as the earlier homonym, and the one that was published later as the later homonym. Even in cases when the earlier homonym is invalid, the Code prohibits subsequent homonyms. *Ziziphus jujuba Lam*., 1789 had long been used as the correct name for the cultivated fruit jujube. This, however, was ascertained to be a later homonym of a related species *Z. jujuba Mill*., 1768. The binomial *Z. jujuba Lam*., 1789 is thus rejected and jujube correctly named as *Z. mauritiana* Lam., 1789. Similar to this, although the first known term for almonds is *Amygdalus communis L*., 1753, *Prunus communis* (L.) Archangeli 1882, which was later used to refer to a species of plum, *Prunus communis Huds*., 1762, acquired the later name for almonds. Almonds' original name, *P. communis (L.)* Archangeli, was therefore superseded by P. dulcis (Mill.) Webb, 1967. It is necessary to treat two or more general or specialized names based on separate kinds as homophones when they are so close that there is a possibility that people may misunderstand them (either because they are applied to related taxa or for some other reason). Some names that are handled as homophones are Asterostemma Decne. Astrostemma Benth. (1880) and Eschweilera DC. (1828) and Eschweileria Boerl. (1887); Pleuropetalum Hook. f. (1846) and Pleuripetalum T. Durand (1888); Skytanthus Meyen (1834) and Scytanthus

Hook. (1844). Three genus names honoring Richard Bradley are recognized as homonyms: Bradlea Adans. (1763), Bradlea Banks ex Gaertn. (1790), and Braddleya Vell. (1827). Only one of the names can be used without a significant danger of misunderstanding. The specific epithets chinensis and sinensis, ceylanica and zeylanica, napaulensis, nepalensis, and nipalensis, which belong to the same genus, would also create homonyms.

5. **Later isonym**: If numerous authors independently publish the same name, based on the same type, at various dates, only the oldest of these so-called "isonyms" has nomenclatural significance. All references to the name must come from their initial, legitimate publication; subsequent "isonyms" are acceptable. Another name for A. podophylla Baker (1891) non Hook. (1857) was Alsophila kalbreyeri, which was independently published by Baker (1892) and Christensen (1905). A later "isonym" of A. kalbreyeri Baker, Alsophila kalbreyeri is not recognized by any classification system, according to Christensen's publication.
6. **Nomen superfluum (abbreviated as nom. superfl.):** A name is not follow the ICBN principles and rules and must be rejected, i.e., if the taxon to which it was applied—as circumscribed by its author—included the type of a name or epithet which ought to have been adopted under the rules. Physkium natans Lour., 1790 thus when transferred to the genus Vallisneria, the epithet natans should have been retained but de Jussieu used the name Vallisneria physkium Juss., 1826 a name which becomes superfluous. The species has accordingly been named correctly as Vallisneria natans (Lour.) Hara, 1974. A combination based on a superfluous name is also illegitimate. Picea excelsa (Lam.) Link is illegitimate since it is based on a superfluous name Pinus excelsa Lam., 1778 for Pinus abies Linn., 1753. The legitimate combination under Picea is thus Picea abies (Linn.) Karst., 1880.
7. **Nomen ambiguum (abbreviated as nom. ambig.):** A name is rejected if it is used in a different sense by different authors and has become a source of persistent error. The name Rosa villosa L. is rejected because it has been applied to several different species and has become a source of error.
8. **Nomen confusum (abbreviated as nom. confus.):** Selecting a good lectotype is challenging since a name that is based on a type that consists of two or more fully discordant parts is rejected. For example, the genus Actinotinus received its

features from two genera, Viburnum and Aesculus, when a collector had inserted the Viburnum inflorescence into the terminal bud of an Aesculus. It is consequently necessary to drop the term Actinotinus.

SUMMARY

The method of plant nomenclature was covered in this chapter. Botanical nomenclature is the system of plant name based on worldwide guidelines developed by botanists to provide a consistent and global standard. Common names, scientific names, binomial nomenclature, and various ICBN codes (such as Paris code 1067 to Vienna code 2005) were also covered in this lesson. The principles (6), focal points of ICBN 1983, phylocode, The rules, rank of taxa, principle of priority, effective and valid publication, publications of names, citation of authors names, retention,choice and rejection of names,rejectionofname,nameofcultivatedplantsandnames of hybrids in cultivation were discussed in detail.

Key Words—

Scientific name: Name of the globally recognized and applied plan.

Binomial: A name consisting of two epithels (one specific and one generic)

ICBN: International Code of Botanical Nomenclature.

Species: A unit of classification.

Type: Name of the taxon is based on type.

ICNCP: International Code for Nomenclature of Cultivated Plants

UNIT-4

TECHNIQUES AND TOOLS 0F COLLECTION& PRESERVATION OF SPECIMENS

4.1 Objectives

4.2 Herbarium Introduction

4.3 Tools for Herbarium

4.4 Techniques in Collection

- Collection
- Field note
- Taking images
- Pressing
- Drying
- Poisoning
- Mounting
- Label
- Preservation of specimens
- Problems in Management
- Index Herbarium (IH)
- Important Herbarium of India
- Steps for Herbarium
- Functions of Herbarium

4.5 Summary

4.1 Objectives

After reading this chapter students will be able to understand-

- Definition of Herbarium
- Various types of plant collection
- Preservation of plant specimen
- Tools of Herbarium

4.2 Herbarium

A herbarium is a collection of dried and compressed plant specimens mounted on suitable sheets, sorted in accordance with a recognized classification system, and stored in wooden or steel cabinets with pigeon holes that are often expressly made for this use. There are thousands of different types of plants in the universe, and identifying them all without using a specific system is impossible. This marked the start of systematic botany, and one of the processes involved was the arrangement of plants in a certain manner. Plants must be gathered using a specific system before being arranged. The plant specimen that has been obtained serves as the main source of information for floristic investigations**.** Plant materials need to be chosen, gathered, and stored with care so that they can be precisely arranged for classification and serve as a clue for identification. The conserved specimen serves as an enduring documentation for future research. This specimen comes from the herbarium.

Luca Ghini (1490–1556) created the first herbarium, which marked the beginning of the science behind herbarium development in the sixteenth century. Subsequently, there has been a noteworthy advancement in the fields of plant specimen collection and the methods employed by researchers over time to prolong the preservation of herbarium specimens. It has been known for 450 years that plant specimens can be preserved in dried form. The naturalist Gherardo Cibo, a student of Luca Ghini, gathered the oldest intact herbarium specimen, which is housed in Rome (1532). In Italy, Luca Ghini traveled extensively in search of plants. He displayed the plants in this manner, and the University of Padua in Italy founded the world's first herbarium in 1545. In that same year, the first Botanic Garden was founded. The term "herbarium" was first used to refer to a book about therapeutic herbs rather than a collection of plants. Two words were employed by Tourneforte in 1700 as an equal to Hartussiccus, which was eventually taken up by Linnaeus. Three of Ghini's students—Aldrovondi, Cesalpino, and Turner—made their herbaria in the middle of the 16th century. Cesalpino was from Italy, while Turner was from England. A scientific method to the study and classification of plants is introduced in Cesalpino's work "De Plantis libri XVI," which is comparable to the significance of Cesalpino's herbarium in Florence. Herbarium was created by John Falconer in 1553.About a hundred different plants are described as having medical uses in Dioscorides' Materia Medica. Italy's Renaissance saw the establishment of the first botanical garden as well as the teaching of botany. They created a book of mounted, dried plant specimens, which they dubbed "dry gardens" or "Harti Sicci."

4.3 Herbarium Tools

The following lists the equipment used to create herbarium:

Pruning sheets, Newspaper, Plastic bags or vasculum (metal box), Plant press (Plywood / Iron), Digging Tool, Field note book, Lead pencil, Lox hand lens, String tags, Collecting vials & jars, Fixing solution, Field note book

Field Equipment & Tools--All-Pro Trowel, Clippers, Field Bags, Forceps, Hori-Hori, Manual Cover, Blotting, Mounting, Mounting Papers, Adhesives, Bryophyte Packets,Seed Envelope, Bond Pape, Humidity Indicators

Methods of Collection

Collecting, drying, poisoning, mounting, stitching, labeling, depositing, and other processes are involved in creating a herbarium.

Collection

It is necessary to select angiospermic material with features such as leaves, a fully developed inflorescence, flowers, and fruit. One must return to the location multiple times if necessary. The material's size is determined by availability and requirement. For herbaceous tiny plants, two to four twigs are adequate; for woody plants, however, one to two roots should also be harvested. Plant material that is unhealthy, contaminated, or improper should not be collected. Field numbers ought to be assigned to the collection. At least four to six specimens of the same field number should exist for the species. Notes on habits, habitat, flower color, notable aspects of the locality, etc., should be made in the field notebook. When collecting plants for a herbarium, the following equipment are very crucial: It could be very helpful to have a tiny knife, scissors, gloves resistant to thorns, and a small, useful shovel. The purpose of these containers is to shield plants from harm during your collection visit, thus the specimens you have collected should be placed inside a sturdy bag made of fabric or polythene. It is advisable to pack a folder that is at least 45x30 cm if your trip is taking place during the summer or lasts for two or more days. The folder needs to be sturdy, like cardboard or aluminum, and it needs to have some old newspapers in it—the more plants you collect, the more newspapers you will require. The folder should have a handle or shoulder belt attached for convenient carrying. It can also be covered with cloth and fastened with straps or belts.

Field note

A field record is kept in a tiny, pocket-sized notebook following specimen collection. The location (name of place or distance from specific point), date of collection, collection number, and, if available, the specimen's name and description—which may vary after drying—are all recorded. In addition, high-quality specimens can deteriorate if their field performance is subpar. GPS (Global Positioning System) and visual perception are required to record the plant's range, latitude, longitude, and ecology. The microhabitat of the specimen should also be mentioned, i.e., at least five related species. Lastly, it is important to note the plant's distribution status: is the species that was collected uncommon, common, frequent, local common, or sporadic? If two specimens of the same species are taken in the same location and on the same day, they ought to be assigned the same collection number.

Taking Images

Capturing color images of every plant in its natural habitat is another way to significantly improve the herbarium's quality. This allows the dried specimen to be arranged with one or more photos, which are especially useful for large plants like trees or bushes that are obviously too big to fit in a herbarium completely. A photograph can also effectively depict a plant's habitat, provided that it is taken with due consideration for the proximity of surrounding shrubs or trees.

A 35 mm single lens reflex camera with a regular lens and a macro lens—the latter of which is highly helpful for close-ups of flowers and other particular features—is the recommended equipment. If numerous close-ups are required, a tripod can also be quite helpful in keeping the camera stable. Moreover, a tripod can eliminate the need for a flash, which is useful in low light situations but has the drawback of producing somewhat unnatural-looking photos. Print film speeds might vary from 64 to 100 ISO to 200 or 400 if planned images in the forest are to be taken.

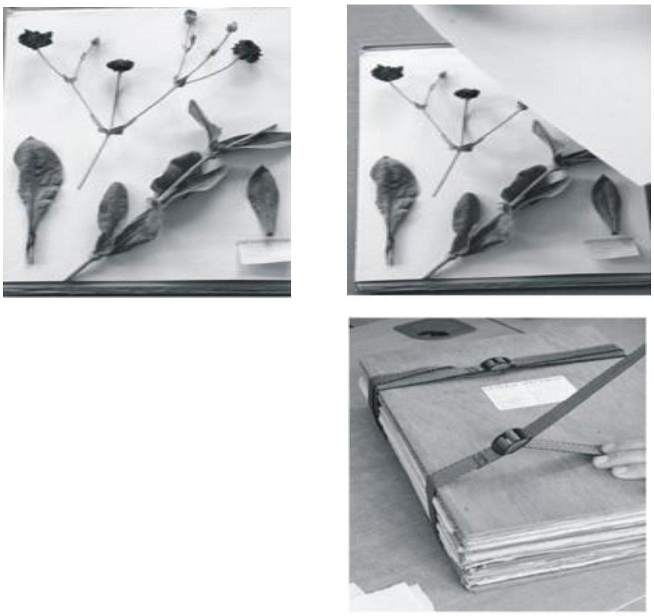
It is advisable to document every shot you take in a notebook to supplement the information used for categorization and to add to the herbarium. Take care to prevent water damage and harm from hard handling to your camera and films.

Pressing

Newspaper is used to gently hold the specimens. The flower's parts are very carefully dispersed, keeping their original shape without overlapping. The specimens must be folded into a V, N, or Z shape if they are lengthy.

If the specimen is a gymnosperm, it must be dipped in glycerine before being pressed. When dealing with flowers that have gamopetalous corollas, it is recommended to crush a few of the blooms individually and to divide and disperse some of them. Larger flowers can frequently be helped to dry faster by using cotton cushioning. The specimens are thereafter stored inside flimsies, covered by blotters on both sides, and placed in a herbarium press. The plant press is closed and pressure is exerted by tightening the straps once the press is filled or all of the specimens have been placed inside. Dried and hard fruits and cones must be stored in specific boxes rather than being preserved or crushed.

pressing of specimen in press board



Steps of pressing

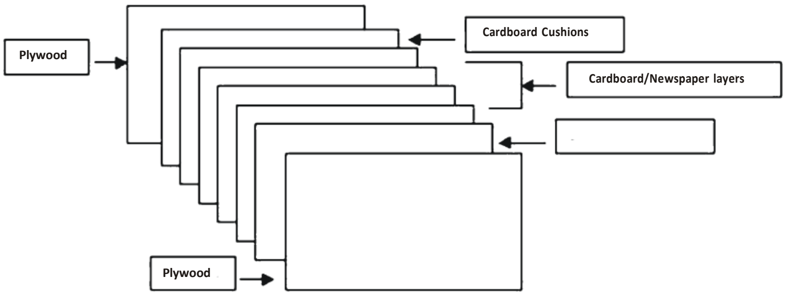


Fig. Basic Structure of press

Drying

There are two kinds of drying methods: those that are carried out in the absence of heat and those that make use of artificial heat. Artificial heating is the most common method of drying. Heat-treated, dry air is forced up and through the corrugate's canal to achieve this. In presses, corrugates—also called ventilators—are utilized to dry plants using artificial heat. It is a thin aluminum metal sheet or pasteboard with fluted ducts. It allows warm, dry air to travel through the press's air passageways. The most popular way to dry is without using any heat. In the plant press, plants are arranged in pressing sheets in between blotters. Corrugates are not utilized. There is a 24-hour lockdown on the press. This is referred to as the sweating phase. It is then opened, and each pressing sheet is flipped back as blotters are removed, specimens are inspected, and pieces are rearranged as necessary.

The folder sheet is rearranged, then placed on a clean dry blotter and topped with another dry blotter. After another 24 to 36 hours, the fresh stack of blotters and specimens is secured inside the press, and the process of swapping out wet blotters for dry ones is repeated. After two or three days, there is typically a third replacement of blotters. Three to four changes of blotters are required; each wet blotter removed must be dried, usually by sun exposure, before being repurposed. It takes around one week for the drying process to be finished. Care is used when packing dried specimens. If sufficient attention is not provided until the permanent storage, fungi and insects will cause harm.

Poisoning

It is important to take precautions against insect pest damage to herbarium specimens. The most destructive insects are silverfish, booklice, cigarette beetles, and herbarium beetles. Sometimes, little amounts of insect repellents like para dichlorobenzene or naphthalene balls are kept in herbarium cabinets. Mercuric chloride is thought to be helpful despite being harmful and potentially harmful to health since it offers long-term defense against insect attack. In addition to insects, materials stored in moist conditions or in high humidity environments are constantly at risk from mold and mildew. It is thought that LPCP and naphthalene have fungicidal qualities. Still, thymol works rather well as a fungicide.

Mounting

The technique of mounting involves securing a specimen to a herbarium sheet and placing a label in the lower right corner. Specimens are affixed onto herbarium paper sheets that are standard size, measuring 29 by 43 cm.

The majority of herbaria adhere the specimens to the sheets using paste or glue. There are several ways to attach the specimen. A typical procedure is to apply a water-soluble paste to a glass plate, set the specimen on the paste, and then move the glued plant to the mounting sheet. Fragment packets are little paper envelopes that are affixed to the sheet for the purpose of containing seeds, additional blossoms, or any portion of the specimen.

Label

An integral and crucial component of permanent plant specimens is the herbarium label. Though they might differ significantly, labels are typically rectangular in shape and size, measuring between 10 and 15 cm (4 and 6 in.). The bottom right location is often considered to be the ideal for the main label; this makes the label easier to see when stored in protective covers that open on the right side. In an ideal world, there would be room above the label for determination slips to be attached in the future. In general, a herbarium label ought to have the following details:

1. Heading- name of the institution in which the specimens originated /deposited.
2. Scientific name- Genus, specific epithet, author, or authors
3. Family-
4. Locality-
5. Range, latitude and longitude-
6. Habitat-
7. Date of collection-
8. Name of collector(s)-
9. Determined by-
10. Remarks-

Preservation of the specimens

Fumigants and heating repellents are utilized to stop the attack of these harmful substances. The specimens can be heated for six hours at 60 degrees Celsius in a specially designed cabinet to kill larvae, eggs, and other materials. One typical and efficient method for fumigation in a closed chamber is to combine one part ethylene dichloride with one part carbon tetrachloride (CCl_4). DDT, or dichlorodiphenyl trichloroethane, is a widely used insecticide.

Problems in Management

In the contemporary epoch of molecular biology and biotechnology, traditional disciplines such as taxonomy and herbarium have undergone considerable turmoil. Herbaria support the advancement of all fields related to biology. The so-called modern biologists of today, who are least aware of the value of a herbarium disregard herbaria.

Some herbaria, which have been built over many years by taxonomists, are currently in danger of collapsing because of the false belief held by the ruling biologists that herbaria are just repositories of collections of dead plants that cannot advance national development or generate funding for research. In reality, herbaria are simply a resource of plant databases from which biologists obtain basic knowledge, either directly or indirectly, about the plant species that they study in depth.

Due to a shortage of skilled labor, national herbariums such as the Central National Herbarium (CAL), the Herbarium of the Forest Research Institute in Dehradun, and the Herbarium of the National Botanical Research Institute in Lucknow are in grave risk of closing.

A sizable structure, curators, a collection, researcher tables, and funding are needed for an ongoing herbarium. These days, funding for this topic is scarce, making maintenance extremely challenging. Policymakers need to be aware of this and take action to preserve the significant herbaria. Taxonomists should also be contacted to assist with herbarium care and exploration.

Index Hebariorum (IH)

For the past three centuries, herbaria—collections of dried reference specimens—have been used by scientists to catalog the diversity of plants and fungi on Earth. Currently, there are about 3,990 herbaria worldwide, and about 10,000 curators and experts in biodiversity work with them. An estimated 350,000,000 specimens total from all of the world's herbaria record the vegetation of the planet over the previous 400 years. An overview of this essential tool for biodiversity research and conservation is provided by Index Herbariorum.

An herbarium's physical location, Web URL, contents (such as the quantity and kind of specimens), history, and the names, contact details, and areas of specialty of related staff are all included in the Index Herbariorum (IH) entry for that herbarium. IH includes only those collections that are permanent scientific repositories. In order to be accepted, new registrants must show that their collection is sizable—5,000 specimens at the very least—actively managed, and available to scientists. Since the establishment of IH in 1935, every institution has been given a permanent, unique identification in the form of a four- to eight-letter code.

The International Association for Plant Taxonomy in the Netherlands produced the first six editions of Index Herbariorum (1952–1974). As co-editor of edition 6, Dr. Patricia Holmgren, who was the director of the New York Botanical Garden (NYBG) at the time, went on to become the senior editor of IH. She was in charge of compiling the hard copy volumes 7 and 8, while Dr. Noel Holmgren, a scientist employed by the NYBG, was in charge of developing the IH database, which went online in 1997.

Important Herbaria of India

S. No.	Name of Herbarium Places	No. of plants	Year of Specimens founding	Abbreviation
1	Central National Herbarium,Calcutta	2,500,00	1793	CAL
2	Forest Research Institute,Dehradun	3,000,00	1816	DD
3	Herbarium of the NationalBotanic Garden, Lucknow	1,00,000	1984	NBG
4	Botanical Survey of India, Dehradun Northerncircle	60,000	1956	BSD

Important World's Herbaria

2	New York Botanical Garden	7,200,000	USA
4	Royal Botanic Gardens Kew	7,000,000	UK; Kew, England
6	Missouri Botanical Garden	5,870,000	USA; St. Louis, Missouri
7	British Museum of Natural History	5,200,000	UK; London, England

Steps for Herbarium Preparation

– Preparation of specimen

– Drying of specimen

– Preservation of specimen

– Mounting of the specimen

– Labeling of the specimen

– Filing of the specimen

Collection - Drying - Preservation - Mounting - Labeling – Filing

Functions of Herbarium

A contemporary herbarium has useful purposes or functionality. A herbarium serves the key purposes listed below:

1. It offers the data required to confirm and identify recently obtained plants.
2. It is a priceless repository for plant information and material.
3. It is a collection storage facility that houses priceless type specimens. Research on taxonomy is considerably aided by the herbaria.
4 Acts as a vital source for identifying every plant on the planet.
5. It provides a source for biodiversity gathering. Today, the majority of estimates of biodiversity worldwide are based only on herbarium collections.
6. It supports biodiversity monitoring by executing secure herbarium collection, which is necessary for all monitoring programs in order to get quantitative baseline data on the distribution and abundance of keystone species.
7. It acts as a repository for voucher specimens used in different botanical studies.

8. Supports the evaluation of a taxon's conservation status.
9. A herbarium's extensive collection of a certain species helps with population biology research by evaluating the diversity or variability exhibited by a species throughout its distributional range.
10. It provides a source for the hunt for novel genetic material to enhance domesticated stock.

4.5 SUMMARY

This unit included the topics of herbarium, museum, and herbarium techniques. An assortment of dried and compressed plant specimens mounted on suitable sheets and stored in pigeon holes according to a recognized classification system is called a herbarium. Luca Ghini is credited with founding the science of herbarium. The purpose of a herbarium, its classification, its instruments, its methods of collecting, its index, and the significant Indian herbarium were all covered. A museum is an organization that does botany-related scientific and instructional activities in addition to gathering, conserving, and displaying botanical collections.

Key words: DDT, Museum, Taxon, Ethnobotany, Systematics.

Q.1 Multiple Choice Questions

(i) The standard size of a herbarium sheet is:

(a) 28.75x41.25 cm. (b) 25.15x40.25 cm.

(c) 18.75x41.25 cm. (d) 28.75x35.25 cm.

(ii) The largest Herbaria in the world located at:

(a) Royal Botanical Garden, England

(b) National Botanical Garden, India

(c) New York Botanical Garden, New York

(d) Komarov Botanical Institute, Russia

(iii) What is the primary purpose of a herbarium?

(a) To grow plants for research

(b) To store dried plant specimens

(c) To cultivate rare plant species

(d) To study live plants in controlled environments

(iv) Which scientist is often credited with pioneering the use of herbaria in botanical research?

(a) Charles Darwin (b) Gregor Mendel

(c) Carl Linnaeus (d) Albert Einstein

(v) What is the term for a person who specializes in the collection and study of plant specimens for a herbarium?

(a) Botanist (b) Herbariologist (c) Horticulturist (d) Taxonomist

Answers: (i) a (ii) a (iii) b (iv) c (v) a

Q.2 Answer in 3-4 lines:

(i) Field note book

(ii) Plant press

(iii) Pruning shears

(iv) Endangered species

(v) Digger

UNIT-5
BOTANICAL GARDENS AND HERBARIA

5.1 Objectives

This chapter's primary objectives are to increase your knowledge of the following topics:

The definitions of a herbarium and a botanic garden, as well as what it means to be familiar with both.

5.2 Introduction

A herbarium is a collection of dried and compressed plant specimens mounted on suitable sheets, sorted in accordance with a recognized classification system, and stored in wooden or steel cabinets with pigeon holes that are often expressly made for this use. There are thousands of different types of plants in the universe, and identifying them all without using a specific system is impossible. This marked the start of systematic botany, and one of the processes involved was the arrangement of plants in a certain manner. Plants must be gathered using a specific system before being arranged. The plant specimen that has been obtained serves as the main source of information for floristic investigations. Plant materials need to be chosen, gathered, and stored with care so that they can be precisely arranged for classification and serve as a clue for identification. The conserved specimen serves as an enduring documentation for future research. This specimen comes from the herbarium.

Luca Ghini (1490–1556) created the first herbarium, which marked the beginning of the science behind herbarium development in the sixteenth century. Subsequently, there has been a noteworthy advancement in the fields of plant specimen collection and the methods employed by researchers over time to prolong the preservation of herbarium specimens. It has been known for 450 years that plant specimens can be preserved in dried form. The naturalist Gherardo Cibo, a student of Luca Ghini, gathered the oldest intact herbarium specimen, which is housed in Rome (1532). In Italy, Luca Ghini traveled extensively in search of plants. He displayed the plants in this manner, and the University of Padua in Italy founded the world's first herbarium in 1545. In that same year, the first Botanic Garden was founded. The term "herbarium" was first used to refer to a book about therapeutic herbs rather than a collection of plants. About 1700, Tourneforte employed two words to replace Hartussiccus, a term that Linnaeus eventually embraced. Three of Ghini's students, Aldrovondi, Cesalpino, and Turner (all from Italy) also created herbariums around the middle of the 16th century. The importance of Cesalpino's herbarium in Florence is comparable to his book "De plantislibri XVI," which established a scientific method for the study and classification of plants. In 1553, John Falcener created the Herbarium.About a hundred plants' medical uses are described in Dioscorides' Materia Medica. Italy's Renaissance saw the establishment of the first botanical garden as well as the teaching of botany. They created a "Book" of mounted, dried plant specimens, which they dubbed "Dry gardens" or "HartiSicci."

The categories for the herbaria are:

(a) Major or National Herbaria, which cover the entire world's flora and are used for both identification and study.

(b) Minor Herbaria: These comprise scaled-down versions of regional, local, and College/University herbaria.

Figure 5.1: Pressing the specimen into the press board

5.2.1 Important Herbaria of India/World

S. N	Name of Herbarium	Places	No. of plants specimens	Year of foundng	Abbreviation
1.	Central National Herbarium	Kolkata	2,500,00	1793	Kol
2.	Forest Research Institute	Dehradun	3,000,00	1816	DD
3.	Botanical Survey of India, Northern circle	Dehradun	60,000	1956	BSD
4.	Herbarium of the National Botanic Gardens, Lucknow	Lucknow	1,00,000	1984	NBG
5.	Botanical Survey of IndiaCentral Circle	Allahabad	40,000	1955	BSA
6.	Madras Herbarium	Coimbatore	1,50,000	1874	NH

Significant Herbaria in the World

S. No.	Name	No. of Specimens	Location
1.	Muséum National d'Histoire Naturelle	9,500,000	France; Paris
2.	New York Botanical Garden	7,200,000	USA
3.	Komarov Botanical Institute	7,160,000	Russia; St. Petersburg
4.	Royal Botanic Gardens Kew	7,000,000	UK; Kew, England
5.	Conservatoire et Jardinbotaniquesde la Ville de Genève	6,000,000	Switzerland; Geneva
6.	Missouri Botanical Garden	5,870,000	USA; St. Louis, Missouri
7.	British Museum of Natural History	5,200,000	UK; London, England
8.	Harvard University Herbaria	5,005,000	USA; Cambridge
9.	Swedish Museum of Natural History	4,400,000	Sweden; Stockholm
10.	United States National Herbarium, Smithsonian Institution	4,340,000	USA
11.	National Herbarium of the Netherlands	4,000,000	Netherlands; Leiden
12.	National Botanic Garden of Belgium	3,500,000	Belgium, Meise
13.	Zentraleinrichtung der Freien Universität Berlin	3,000,000	Germany, Berlin

14.	Botanische Staatssammlung München	3,000,000	Germany, Munich
15.	Chinese National Herbarium	2,470,000	China
16.	Royal Botanic Garden, Edinburgh	2,000,000	UK; Edinburgh, Scotland
17.	Herbarium Bogoriense	2,000,000	Indonesia
18.	Royal Botanic Gardens, National Herbarium of Victoria	1,200,000	Australia
19.	National Herbarium of New South Wales	1,000,000	Australia
20.	National Herbarium Nederland, Utrecht University branch	800,000	Netherlands; Utrecht
21.	Institute Botànic de Barcelona	700,000	Spain; Barcelona
22.	National Botanic Gardens, Ireland	600,000	Ireland; Dublin
23.	Zimbabwe National Herbarium	513,700	Zimbabwe; Harare
24.	Bolus Herbarium	373,000	South Africa

5.3. Taxonomic literature

There are vast literatures on taxonomic botany is available and the literatures are in various forms:

General Taxonomic indexes

World floras and manuals

Monographs and revisions

Bibliographic, catalogues and review series

Periodicals

References

Maps and Catalogues
Biographic reference
Data of Publication
Location of type specimen
Directories, addresses and Colour Charts
Outstanding botanical libraries

Flora: The term "flora" describes both the plants that grow in a certain area and the publications that provide scientific descriptions of those plants. Anything from a basic list of the plants that grow in a region to an in-depth description of those species can be found in a flora. Unlike popular handbooks, floras make an effort to include every plant, not just the most prevalent or noticeable ones. Scientific names are nearly usually included in a flora; additional information that may be included is common names, habitats, literature references, flowering periods, blossoming distribution, images, and notes. Depending on the situation, the plants may be arranged alphabetically or they may be shown in a classification scheme that shows which plants are most similar to one another or are believed to be related. Additionally, floras frequently contain identifiers, or "keys," that allow the user to recognize an unfamiliar plant.

5.3.1 Flora writing

1. First, the location for the flora study must be determined.
2. The defined geography of the designated area must be provided, together with a map.
3. Give a thorough description of the area's ecology, including the highest and lowest temperatures, rainfall, water bodies, main habitats, soil conditions, physiographic regions, etc.
4. Determine the area's floristic zones or biological ecosystems.
5. Thorough field research to examine the vegetation and periodically gather every plant.
6. A field book must be kept up to date with information on the plants that were collected, such as the local name, frequency, phenology, and field number and description.

7. Other local and regional flora will be used to help identify plant specimens that have been collected. The specimen needs to be verified by comparing it to genuine sheets in any Botanical Survey of India regional herbarium.

8. The ICBN should verify the species' nomenclature.

9. For a new species, the author reference needs to be verified.

10. Provide botanical keys so that all families, genera, and species may be identified.

11. The species description ought to match the real specimen that was taken from the location.

12. If any new species are discovered, they should be described and made public in accordance with ICBN guidelines.

13. Families in flora are often grouped in accordance with a recognized categorization. For the most part, it was Bentham and Hooker's approach; however some plants have recently started using Cronquist's classification scheme.

A species is must have the following: (a) a correct name; (b) a vernacular name; (c) a clear description with variation; (d) distributional data; and (e) Environmental state Utilizations (g) Status of conservation (h). Origin: native or exotic (i) specimens from the region that were analyzed.

Flora should contain

- (a) Title
- (b) Geography
- (c) Environmental condition
- (d) Taxonomic treatment
    - (i) Nomenclature
    - (ii) Vernacular name
    - (iii) Description
    - (iv) Cultivar, if any
    - (v) Phenology
    - (vi) Distribution
    - (vii) Ecological data
    - (viii) Use
    - (ix) Conservation status
    - (x) Origin
    - (xi) List of voucher specimens

(e) Summary statistics
(f) Bibliography
(g) Illustration
(h) Index

A two to three page synopsis of the work should be provided, and it should include a visual or tabular representation of the total number of families, genera, species, and both native and invasive species, as well as rare and endemic species. Modern computers are employed to solve it.

Palmer and associates (1995) An abundance scale is provided.

Density	Score	Description
(1) Abundant	5	Dominant in one or more common habitats
(2) Frequent	4	Easily found but not dominant in common habitats.
(3) Occassional	3	Widely scattered but not very difficult to find.
(4) Infrequent	2	Difficult to find with few individuals or colonies but found in several locations
(5) Rare	1	Very difficult to find only few specimens is found in the area.
(6) Absent	0	Not found in the area presently But it might be present in the previous survey.

The use of plants

Flora is an important source for academic research, lecturers at universities, and students studying agriculture and botany. It's employed for plant identification. It is helpful for managing and assessing biodiversity. Flora is helpful in managing ecosystems, forests, and land. It offers a general overview of the local plant life. The development of botanical gardens and parks benefits from flora. Plants that are specifically cultivated for medicinal or drug purposes can be used by pharmaceutical, Ayurvedic, and seed firms, among others. Planning a city, hamlet, or town is aided by the flora. It is helpful for studying vegetation, assessing rare and endangered species, and other related tasks. The assessment of phytogeography patterns is aided by flora.

5.3.2 Monograph- It is the study of a taxon, or genus, or family, independent of its place of occurrence. Keys, descriptions, accurate nomenclature, and even the taxon's evolutionary history are provided by monograph.
The monograph is written following a thorough examination and study of the subject. It also includes studies on seed dispersal, pollination behavior, and physiological adaptability.

Difference between monograph and flora

Monograph	Flora
Broad account of the taxonomic data	Taxonomically less critical and superficial
Provide the whole range of a taxon	Excludes all taxonomic variations.
Infraspecific variation and biosystematics data are carefully analyzed.	Not found in the flora
It provides an organized synthesis of all Taxonomic data that is presently accessible.	It is a method of data identification.

5.4 BOTANICAL GARDEN

Botanical gardens, often called botanic gardens, are typically well-kept parks that feature a variety of plants labeled with their scientific names. They could have collections of rare plants like succulents, cactus, and orchids. Essentially, botanic gardens and arboretums are outdoor collections of identified live plants, with a carefully planned environment that serves as a passive component of the communities in which they are located. For those who have chosen gardening as their pastime, they are the primary source of plants and plant-related information. They serve as the primary source of newly discovered knowledge about a wide variety of plants.

They display the indigenous flora of the area and occasionally serve as ―outdoor laboratories‖ for researchers and students. Some botanic gardens are large enough to provide for a pleasant drive through them during the blossoming season and serve as a tranquil place of leisure. They add beauty to the institution to which they belong. We may learn what plants to use in our little home gardens and in what combinations to create eye-catching designs from these unique exhibits, which include hedge displays and smaller gardens that are part of larger gardens.

Regular public lectures are held in a number of public or government gardens, where anyone may learn about gardens in general, and in particular about houseplants, home landscaping, and Christmas flower arrangements, both conceptually and practically.

The following should be on exhibit in a contemporary botanical or botanic garden:

(1) Groups of various kinds of domesticated plants, particularly decorative ones as dahlias, poppies, cannas, lilies, primulas, violas, crotons, coleus, ferns, palms, orchids, etc.

(2) Special interest, medicinal, and economically valuable plants.

(3) Particular geographic plant forms, such as aquatic, marsh, alpine, desert, and so on.

(4) Weeds and how they are controlled.

(5) Plants that have been referenced in ancient and holy literature, as well as state flowers, national flowers, and local favorites

5.4.1 HISTORY

According to a number of accounts, gardens of all kinds were seen within and surrounding the temples prior to the arrival of Christianity. The cultivation of edible, medicinal, and beautiful plants is a fantastic practice that the Romans, Chinese, and Persians had. This marked the start of gardens being established. Following the arrival of Christianity, the usage of medicinal plants multiplied and their cultivation was pursued as a means of treating illness. The fact that the herbalists knew so many different plants made them respected. Subsequently, the value of study plants drew a large audience, and the need to create learning gardens was recognized. This resulted in the establishment of academic institutions and gardens. Gardens began to contribute to the knowledge of botany from 300–200 BC. Long before recorded history began, people grew plants in their gardens. In ancient India, food and medicinal plants were cultivated and kept between 4000 and 2000 BC. Gardens were common elements of temple and religious site grounds throughout the Mediterranean culture. An outstanding illustration of this construction is the Hanging Garden of Babylon. Plants from the conquered territories were collected by the Romans, who grew them mostly in Italy. Later, Persians, Aztecs, and Chinese began cultivating flowers for fragrance and decoration. Plants received little attention throughout the middle ages, between 600 and 1600 AD. The look Garcia d'Orta's on medicinal plants in 1565 was translated into Latin in the seventeenth century. This brought a lot of tourists from Europe to India, and in the sixteenth century, many nations began to cultivate medical herbs; many plants were produced in the garden. The 16th and 17th centuries saw a shift in the uses of botanic gardens after then.

It was also the era of discovery and the start of global trade. To attempt and develop new species that were being brought back from trips to the tropics, gardens like the Real Jardín Botánico de Madrid and the Royal Botanic Gardens, Kew, were established. In addition to fostering and supporting botanical research in the tropics, these gardens assisted in the establishment of new botanical gardens there to aid in the cultivation of these recently discovered plant species. The Botanic Gardens of Calcutta founded by the British in 1787, whilst the Botanic Gardens of Pamplemousse in Mauritius were developed by the French in 1735, and the Botanic Gardens of La Oroava in Tenerife were constructed by the Real Jardín Botánico de Madrid. Almost entirely, the purpose of these tropical gardens was to accept and grow commercial products including cloves, tea, coffee, breadfruit, cinchona, palm oil, and chocolate.

During this period, teak and tea were brought to India, star fruit, pepper, and breadfruit were brought to the Caribbean, and para rubber was brought to Singapore. Since there was no true scientific foundation for these tropical gardens, they could not be properly referred to as "Botanic Gardens," which nearly caused them to fail. The development of independent organizations and agricultural colleges rendered these "cultivational" gardens essentially obsolete. In Europe and the British Commonwealth, municipal and civic gardens were established in the 19th and 20th centuries.

Very few of these gardens had any scientific programming; the majority of them were only designed for enjoyment. The first botanic garden to be established in the United States of America was the Missouri Botanic Garden, which opened its doors in 1859.

The only true scientific endeavors carried out by gardens during this period of botanic garden history were the accurate labeling of collections and the global seed exchange. Because of the rise of the conservation movement, botanic gardens have seen a renaissance as academic institutions throughout the past 30 years. Because of their current collections and the significance they presently hold, scientific expertise in the propagation of plant species that they possess. Nowadays, many gardens view conservation as their raison d'être. This started when the IUCN started promoting the ex situ conservation of vulnerable plants in the 1970s. Currently there are 1775 botanic gardens and arboreta in 148 countries, and there are many more planned or under development, including the first botanic garden in Oman, which will be among the When completed, it will be the largest gardens in the world and have the first inside fog forest on a significant scale, housed inside a massive glasshouse.

5.4.2 FUNCTIONS OF BOTANIC GARDEN

1. Provide a basis for contemporary taxonomic research, such as morphological character comparisons between preserved and live individuals.
2. Provide suitable conditions for the introduction and acclimation of plants, making them a crucial instrument for the development of profitable plants.
3. The collections of germplasm found in botanical gardens serve as the foundation for improvement and hybridization.
4. Various rare and endangered plant species of the globe that are in risk of becoming extinct in their native habitat are housed in botanical gardens thanks to their intricate glass homes, green houses, and in some cases even phytotrons. Thus, gardens contribute to the preservation of the global plant life.
5. Materials for those plants that are not normally available in that area or location for study and research.
6. Offers training facilities for horticulture, gardening, landscape, and other related fields.
7. Well-established botanic gardens sustain ties of exchange with other gardens worldwide, therefore dispersing seeds, saplings, and other propagules to remote locations. Moreover, some botanic gardens periodically publish lists of plants that are available for exchange and distribution. Such catalogs of available seeds are sometimes referred to as "Index Seminum."

8. The archives of regional flora that botanic gardens provide are nevertheless valuable for ongoing monographic research. It is a fundamental foundation for all other plant research, according to Holttum (1970). In order to gather live plant material for biosystematic research, the gardens also offer facilities. For botanical research, several of these gardens provide materials and seeds. Haywood (1964) includes a list of the seed supply. The research laboratory, library, herbaria, and green houses. The year 1962 saw the founding of the International Association of Botanic Gardens. Such recorded collections are currently found in over 125 botanic gardens. The 1963 International Directory of Botanic Gardens was issued by this organization.

9. Botanical gardens are peaceful havens with stunning scenery.

5.4.3 SPECIAL KINDS OR SECTIONS OF GARDENS

a. Arboretum (Arboreta): Arboreta are botanical gardens or sections of botanic gardens with a predominately woody plant collection. Arboreta duties can be fulfilled by small portions of woods reserved for the conservation of arborescent species.

b. Pinetum (Pineta): Consists primarily of conifers. The Indian Botanical Garden in Calcutta looks after one such pinetum.

c. Orchidarium (Orchidaria): An orchidarium is a garden filled with collections of orchids. BSI founded in Coimbatore and Shillong..

d. Bambusetum (Bambuseta Bamboos are the main plant groups. An excellent bambusetum is kept up in the Indian Botanic Garden in Kolkata.

5.4.4 IMPORTANT BOTANIC GARDENS OF THE INDIA

Australia	Botanic Gardens of the New South Wales, Sydney.
India	Indian botanic garden, Howrah; Lloyd botanic garden, Darjeeling; National botanic gardens, Lucknow.
Scotland	Royal botanic garden, Edinburgh.
England	Royal botanic gardens, Kew; Oxford, Cambridge.
United States	Arnold Arboratum of Harvard University, Brooklyn, Cambridge, Washington New York, Long Wood, Missouri, Strybing Arboratum, Huntington, Fairchild botanic gardens.

Royal Botanic Gardens, Kew, England-- Sir Henry Capel, an enthusiastic gardener who passed away in 1696, first planted his own garden at Kew, the site of the famous Royal Botanic Gardens in England.

Directors of Kew Gardens included Sir Geoffrey Evans, Edward James Salisbury (knighted in 1946), and Arthur William Hill (knighted in 1931). The current director of Kew is George Taylor. The Royal Botanic Gardens, Kew, now span over 300 acres and are governed by the Ministry of Agriculture, Fisheries, and Food, but with some autonomy for the Director.

Kew Bulletin and Index Kewensis are two of the more significant publications of botanical study conducted at Kew. In addition to papers in various scientific journals and official publications, there are publications such as Hooker's Leaves Plantarum (which has black and white drawings and full descriptions of the plants conserved at Kew), Botanical Magazine (which has colored plants of living plants with descriptions), etc. Books in their whole on a wide range of botanical topics are also written and published.

BOTANICAL GARDENS IN INDIA

There are several botanical gardens with a wide variety of plants and trees in India. Both native plant species and exotic floral specimens are preserved in the Botanical Gardens. Research on fruit and flower quality and quantity, as well as plantation and culture, is conducted in the Botanical Gardens. Regular flower shows are also organized by it.

State	Name of the garden
Rajasthan	University of Rajasthan Botanic Garden, Jaipur Desert Botanic Garden, Cazri, Jodhpur BSI Arid Zone Botanic Garden, Jodhpur Ganga Niwas Garden, Jodhpur Mandore Garden, Jodhpur Nehru Park and Umaid Garden, Jodhpur
Assam	Guwahati University Botanic Garden
Bihar	Bhagalpur University Botanical Garden, Post Graduate, Magadh University Botanical Garden, Jubilee Park Telco Garden and Nursery
Delhi	National Bureau of Plant Genetic Resources Botanical Garden Delhi University Botanical Garden

National Botanic Gardens, Lucknow, India-- The public of Lucknow know the site of the National Botanic Gardens as Sikander Bagh. In the southeast corner of the current National Botanic Gardens lies a historic garden. Nawab Saadat Ali Khan (1789–1814) constructed it. Situated on the Gomti River's southern bank, the National Botanic Gardens, now headed by K.N. Kaul, span around 75 acres.

Indian Botanic Garden, Howrah-- The Lieutenant Colonel Robert Kyd founded the Indian Botanic Garden in 1787. It is located on the Hooghly River's west bank (Ganga). Spanning 273 acres, the garden is vast.

Initiated by Sir George King in 1872, its distinctive landscape design—which has undulating land surfaces, man-made lakes and moats connected by subterranean pipelines that draw water from the Hooghly River—is regarded as one of the greatest in the world's botanic gardens.

The garden was originally called the East India Company's Garden, the Company Bagan, or the Calcutta Garden. Later, it was called the Royal Botanic Garden, and in 1950, upon independence, it was renamed the Indian Botanic Garden. On January 1, 1963, the Botanical Survey of India took over administration of it. Thousands of herbaceous plants and more than 12,000 trees and shrubs from 1400 species are grown outdoors in 25 Divisions, glass houses, green houses, and conservatories. The garden is home to the richest collection of palm trees (about 109 species) in all of South East Asia in addition to maintaining the germplasm collections of bamboos, bougainvillea, citrus, jasmine, pandanus, and water lilies.

In its Flower Garden, National Orchidarium, and Student Garden, among other botanical and arboricultural plants, are cultivated succulents, Hibiscus, Ficus, Aromatic plants, Gymnosperms (in two Pinetums), Creepers, Ferns, and some other species. The Medicinal Plant Garden, known as ‗Charak Udyan, is enriched with a multitude of medicinal plants. A handful of the garden's intriguing flora are the Mad Tree, Shivalinga tree, Branched Palm, Bread Fruit Tree, Double Coconut, Giant Water Lilies, Krishnabot, and so on. Additionally, studies on the introduction, growth, and conservation of plants are carried out. Every year, millions of people go to the Indian Botanic Garden to see the Great Banyan Tree (Ficus bengalensis L.). With 2800 prop roots covering 1.5 hectares, it is nearly 250 years old and has the appearance of a tiny forest. This garden's big palm house is home to a number of unusual species, such as the Double Coconut (Lodoiceamaldivica), which is known to generate the largest seeds in the entire plant kingdom.

Lloyd’s Botanical Garden-- In the West Bengali city of Darjeeling, there is a unique botanical garden called Lloyd's Botanical Garden. An area of around forty acres, donated by William Lloyd in 1878, was established as a branch institution of the Royal Botanic Garden Calcutta.

5.5 BOTANICAL SURVEY OF INDIA (BSI) -- A government organization called the Botanical Survey of India conducts systematic surveys to investigate the nation's botanical resources. For the benefit of science and the personnel who work in universities and other academic institutions, it obtains precise and comprehensive information about the occurrence, distribution, ecology, and economic usefulness of plants in India. Plant material that may be used for teaching and research is gathered, identified, and distributed by it.

5.5.1 HISTORY

Established in 1890, the Botanical Survey of India and reorganized in 1954. Because its size and the wide range of geographical features it possesses, India offers a diversity of flora and forest kinds inside its borders that may not be found in any other country in the world. India's abundant vegetable resources have drawn people from all over the world since ancient times. Egypt was the first country to initiate commerce with India for luxury goods derived from vegetables and other sources.

In the 18th century, there was a growing interest in India's botanical collections. Many individuals, including missionaries, doctors, employees of the Hon'ble East India Company, and the governments of Madras, Bombay, and Bengal, were actively involved in exploring various forest regions and compiling priceless collections. Among them were Koenig, Roxburg, Heyne, Wight, Campbell, Klein, Rottler, Gibson, and so on; these were more significant.

Additionally, plans were made to move the Linneaus collection to Hooker, Sir Joseph Banks, India House, the Linnean Society, and a few other locations. Horticulture also gained prominence alongside these botanical endeavors, and new botanical gardens were established at several significant locations with the goal of introducing and raising exotic species.

The Hon'ble East India Company was given 350 acres of land at Sibpur, Calcutta, in 1857, to establish a garden. In addition, comparable gardens were established in Bombay, Saharanpur, Madras, and a few other locations at the same time. Every garden of the type has its own herbarium. Assist in the study of vegetable taxonomy, forest flora taxonomy, horticultural methods, and forest usage and conservation. These endeavors are founded on individual endeavors.

After the country's governance was transferred from the Hon'ble East India Company to the Crown in 1858, the serious endeavor to establish a central survey for a coordinated activity for an in-depth study of the flora of the nation began.

5.5.2 Botanical Survey of India (Between 1937 - 1952)

Mr. C. C. Calder was the last incumbent to the post of the Director, BSI. In 1936 the govt. Of India sanctioned the post of Superintendent for four zone instead of Director BSI.From 1930 forward, the survey's condition of affairs was gradually decline and deteriorate.

The social and economic goals of a free India emerged with World War II and India's declaration of independence, creating the conditions for both scientific and economic growth. When the Botanical Survey was to be reformed in 1952–1953, the Indian Botanic Gardens' Systematic Division, Indian Museum, and Industrial Section made up the new organization.

5.5.3 ACTIVITIES OF THE BOTANICAL SURVEY OF INDIA

1. Currently, the primary goal of the Survey is to provide an inventory of India's flora. Experts from various parties involved are compiling the narratives of numerous families for this reason. Universities and other researchers have also been given access to family accounts. A large number of family accounts have already been resolved and released.
2. Manuals and Editorials - Research on certain genera and families is also being done monographically.
3. The Botanical Survey of India has worked on cryptogams in addition to higher plant surveys.

4. The current work of the survey also includes supplementary laboratories for study on anatomy, phytochemistry, cytotaxonomy, palynology, biosystematics, and ecology.
5. The Survey offers comprehensive research on economic and therapeutic plants through its own museums and herbarium.
6. Research on ethnobotany and the preservation of uncommon and endangered plant species has also been conducted by the Survey.
7. The Survey has established many scholarships for research on India's flora. The scholarships are offered by some colleges and by a number of Survey offices.
8. The Survey conducts studies in nearly every field of botany and provides researchers and the general public with information on every facet of plant life. Additionally, towns, other organizations, and garden enthusiasts receive seedlings and plant materials.

5.6 SUMMARY

This chapter covered the Botanical Survey of India (BSI), living plant collections (botanical gardens), and the preservation of plant material as herbarium. Luca Ghini (1490–1556) created the first herbarium, which marked the beginning of the science of herbarium.

Herbarium covered significant collections of plants from over the world, taxonomic literature, flora writing, flora usefulness, and monographs. The history, purpose, unique varieties, and significance of botanical gardens were discussed. The Botanical Survey of India (BSI) covered a number of topics, including its history, current organizational structure, impact from regional flora, restructuring, four regional centers, and operations.

Key Words-

Herbarium: Collection of dried and pressed plant specimens placed on suitable sheets and grouped in accordance with a recognized classification system.

Flora: Plant occurring in a given regions with systematic study

BSI: Botanical Survey of India.

UNIT-6

RANUNCULACEAE CARYOPHYLLACEAE LILIACEAE AND POACEAE

6.1 Objectives

- **Ranunculaceae Family**
- **Caryophyllaceae Family**
- **Liliaceae Family**
- **Poaceae Family**

6.2 Family- Ranunculaceae

Systematics

General characters

Economic importance

Bentham and Hooker classified the Ranunculaceae family, one of the eight orders, under the family Ranales. The family is referred to as the Buttercup family. Dr. John David (2010) states that the Ranunculaceae are a part of the Ranunculales, which is the only order in the superorder Ranunculanae, together with the Eupteleaceae, Lardizabalaceae, Menispermaceae, Berberidaceae, and Papaveraceae.

The Ranunculaceae is the only family in the Ranunculales that Takhtajan (1997) classified as belonging to a subclass, the Ranunculidae, rather than a superorder. Prior to this, Thorn (1992) classified the Ranunculaceae as belonging to the Superorder Magnolianae's Berberidales order. Prior to this, in 1981, Cronquist classified the Magnoliidae, which he considered to be a subclass, to comprise the Ranunculaceae and seven additional families in the Rancunculales.

Diagnostic characteristics - Herbaceous; leaves are divided palmately; flowers contain multiple stamens; the gynoecium is made up of numerous simple pistils; the fruit is a collection of achenes or follicles.

Distribution pattern

There are 1900 species in 50 genera, it is a large family. It is primarily found in the Northern Hemisphere's temperate zones. This family is represented by 20 genera and 165 species in India, the majority of which are found in the Himalayan area that separates Pakistan and India.

6.2.1 Classification

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledons	Dicotyledons	Dicotyledons
Polypetalae	Archichlamydeae	Herbaceae
Thalamiflorae	Ranales	Ranales
Ranales	Ranunculaceae	Ranunculaceae
Ranunculaceae		

6.2.2 General Characteristics

Habit: Herbs (Annual or Perennial) , rarely vines (*Clematis*). Aquatic herbs (*Rannunculas aquatilis*), Perennial species (*Aconitum & Ranunculus*)

Root: Tap root, tuberous root (*Aconitum*)

Stem: Woody (*Paeonia*), Herbaceous (*Rannunculas*)

Leaves: Cauline or ramal, Petiolate. Exstipulate or stipulate *(Ranunculus*) , Simple, pinnately compound(*Clematis*), generally simple,alternate or opposite (*Clematis),* unicostate or multicostate reticulate venation.

Inflorescence: Solitary terminal *(Nigella*), axillary (*Clematis*), raceme *(Delphinium*), Dichasial Cyme (*Rannunculas* sp.).

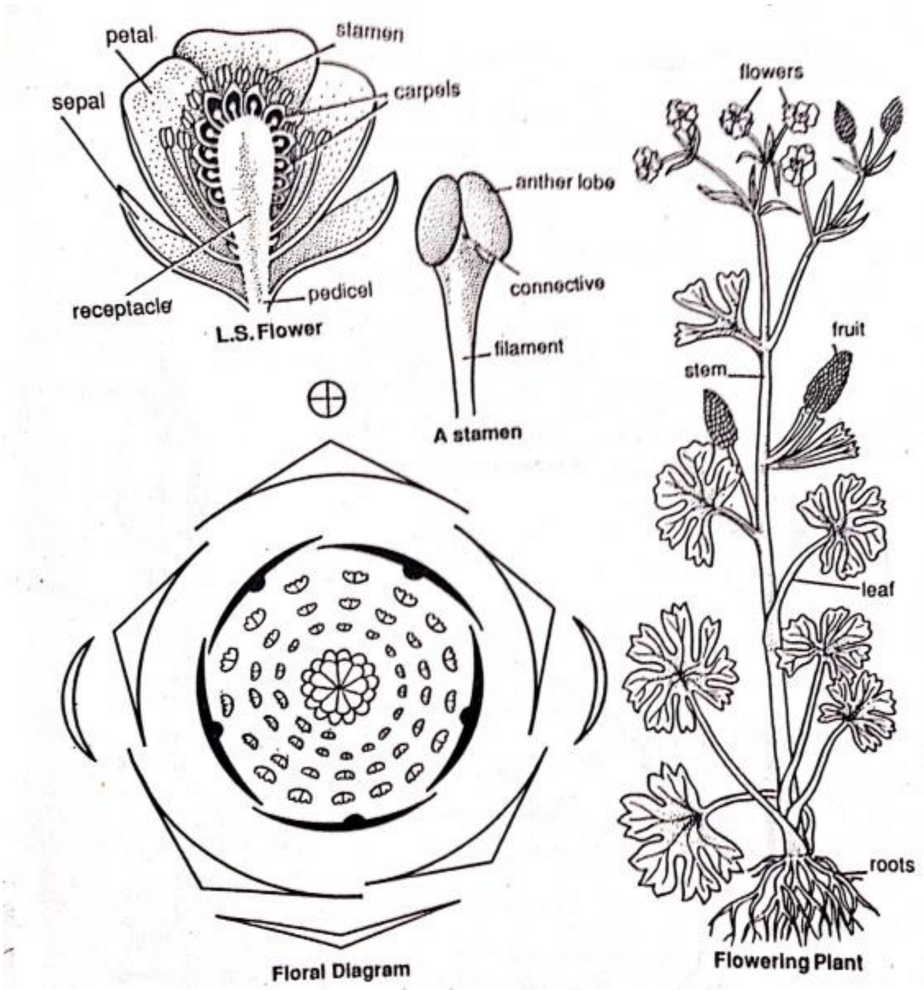
Flower: Pedicillate, ebracteate rarely bractate, hermaphrodite, (unisexual in Thalictrum). Mostly actinomorphic (Ranunculus) rarely zygomorphic (Aconitum) hypogynous, complete, pentamerous, Regular. Spiral arrangement , an involucres of leaves is position outside the calyx.

Calyx: Sepals 5 distinct and usually deciduous, free, In *Delphinium* the sepals are petaloid and the posterior sepal is spurred. Imbricate aestivation.

Corolla: 5 or more petals or sometimes petals may be absent, polypetalous, variously colored, Sometimes, petals are changed into nectaries, The posterior pair of petals forms spur (*Delphinium),* other pair of the petal if present is very much reduced (*Aconitum).* Petals are altogether absent and sepals become petaloid (*Clematis*).

Androecium: Stamens are indefinite, polyandrous. Arrangement of stamens are spirally on the thalamus, The stamens are arranged in definite rings *(Nigella* and *Aquilegia*), anthers adnate, dithecous, extrose, dehiscent longitudinally.

Gynoecium: Indefinite free carpels (Polycarpellary) spirally arranged on thalamus (carpels in *Delphinium*), apocarpous rarely syncarpous (*Nigella*), ovary superior, one to several ovules in each ovary. Basal placentation or marginal. style and stigma one.



Fruits: An etaerio of achenes or follicles, sometimes berry or capsule.

Seed: Endospermic seed

Pollination: Entomophilous

Floral Formula: **Br** Brl ⊕ ⚥K 5 C5 Aα $\underline{G\alpha}$ *(Ranunculus*)

Br Brl ⊕ ⚥K 5 C5 Aα $\underline{G1}$ (***Delphinium)***

6.2.3 Economic importance

1-Ornamental plants: The majority of plants, such Clematis, Thylictrum, and Ranunculus (buttercup), are grown for their exquisite blossoms.

2-Medicinal plants: Certain members are utilized as herbal remedies. Aconitum napellus produces aconite, an alkaloid used as a nerve relaxant and for rheumatism. Mamira yields thallicorm. The purpose of its usage is to treat ophthalmia. Certain clematis species are used to treat blood disorders and leprosy. Some species of Ranunculus juice is used to treat sporadic fever. The Hydrastis canadensis root is used as a snake bite remedy.

3-Condiments: Some members are used as condiments for flavoring. Seeds of Nigella (Black fennel, Kala jeera) are used as drug for bronchial asthma, fever and cough

4-Importance for honey: This family's majority of members have nectaries. For honey bees to produce honey, flower nectaries are very important.

5. Poisonous species: This family includes several individuals that secrete an acrid liquid. It is extremely toxic.

6.3 Family- Caryophyllaceae

Systematics

General characters

Economic importance

The Caryophyllaceae family of flowering plants is also referred to as the pink or carnation family.

Bentham and Hooker propose that it is a member of the Caryophyllales order. Amaranthaceae and Caryophyllaceae are currently sister groups.

Because Caryophyllaceae pigments are anthocyanins rather than betalins, However, cladistic studies support betalin as a true synapomorphy of the suborder, showing that Caryophyllaceae developed from ancestors that possessed betalin. Traditionally, there are three subfamilies within this family:Alsinoidae: no stipules, petals not united Silenoideae: no stipules, petals united Paronychioideae: fleshy stipules, petals separate or united.

Diagnostic characteristics: The members vary widely in habitat and appearance; most have enlarged stem and leaf joints. Although they contain five petals and five sepals, it is believed that the petals originated as modified stamens. An ovary is borne above the stamens, which are typically 5 or 10. The ovarian cavity often has no walls separating it from the ovules, which are carried at its center.

Distribution: Caryophyllaceae is a family herbaceous annuals and perennials, mostly found in north temperate regions, that is made up of about 86 genera and 2,200 species. The temperate zones of the Northern Hemisphere are home to many members of this family. A few taxa are found in the highlands of tropical climates, while others are found in the Southern Hemisphere. This family of plants, which includes Stellaria, Spergula, Dianthus, and others, grows in our country's hilly areas or on the plains in the winter.

6.3.1 Classification

Bentham & Hooker	**Engler& Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Herbaceae
Thalamiflorae	Centrospermae	Caryophyllales
Caryophyllinaeae	Caryophyllaceae	Caryophyllaceae
Caryophyllaceae		

6.3.2 General Characteristics

Habit: Annual or perennial herbs. small shrubs,e.g., *Acanthophyllum*

Stem: Erect, branched, green, herbaceous, solid and mostly swollen at the nodes.
Leaves: Simple, opposite decussate (rarely alternate), entire and stipules ansent. The leaves sometimes possess shortly connate perfoliate base, e.g., in *Dianthus*. linear to lanceolate in shape.

Inflorescence: Dichasial cyme, rarely solitary.

Flower: Bisexual rarely unisexual Pedicellate, actinomorphic, pentamerous., complete and hypogynous

Calyx: 5 sepals. free or united together into a tube.. imbricate (quincuncial) aestivation.

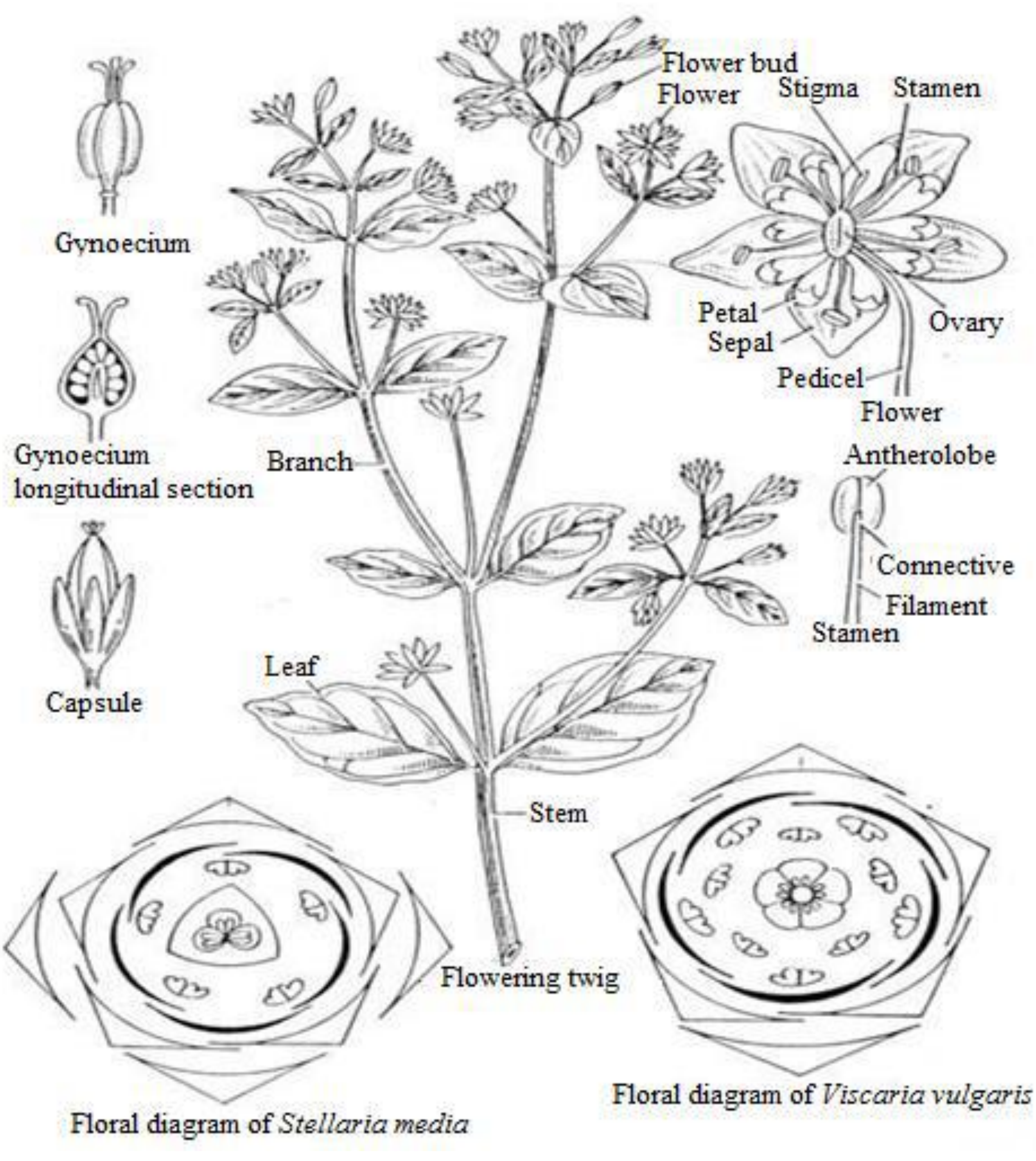
Corolla: 5 and rarely of 4 petals. free and usually differentiated into lomb and claw. aestivation is imbricate.

Androecium: Stamens are twice the number of petals (ten or eight) in two equal and alternate whorls. Sometimes the number of stamens reduces to eight, five, four, three or even
one. Polyandrous, obdiplostemonous. The filaments are distinct or slightly connate at the base. Dithecous, introrse and dehiscence longitudinal.

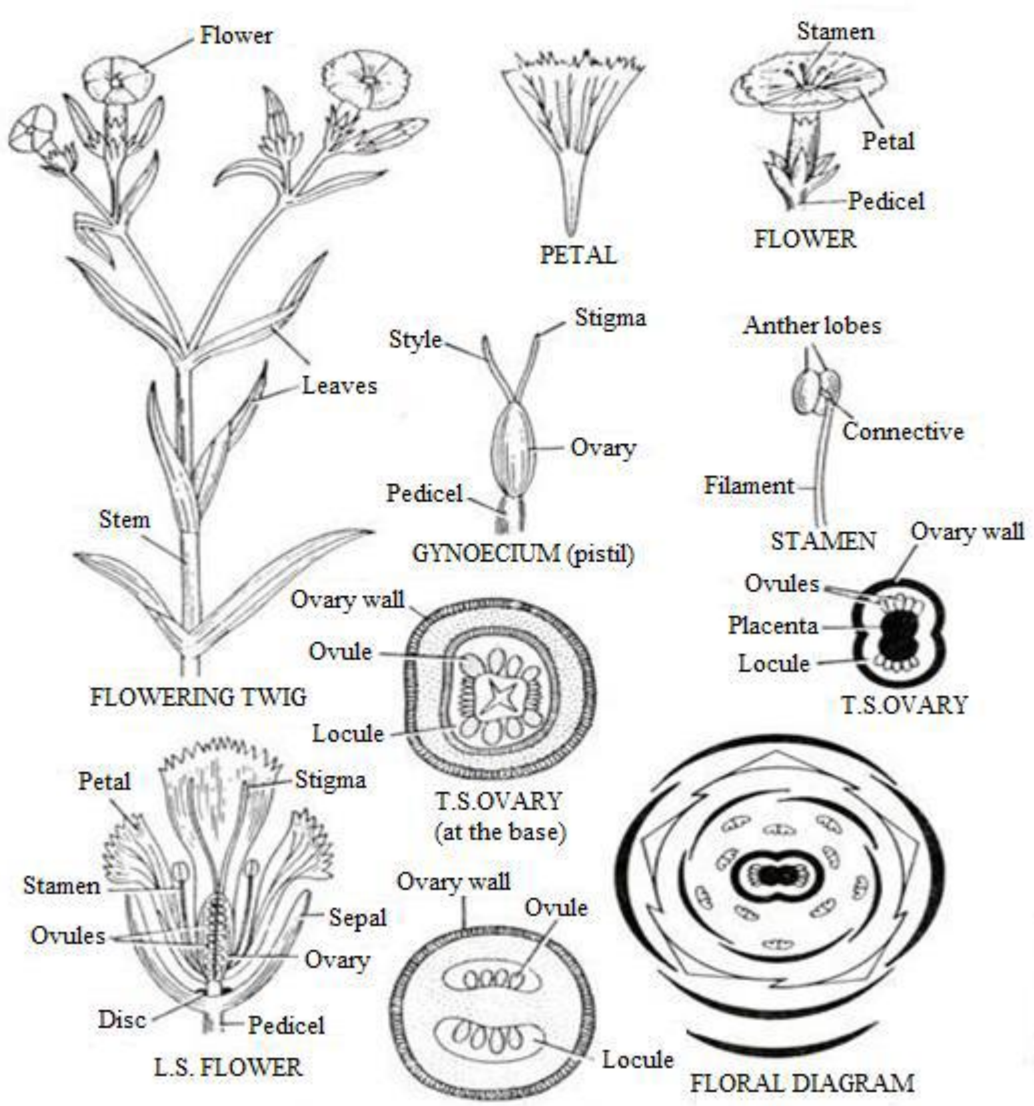
Gynoecium: two carpels (*Dianthus*) or three to five (*Cerastium, Spergula and Stellaria*) carpels; syncarpous. The styles are free. Ovary superior and unilocular; free-central placentation characteristic of the family.In Stellaria the number of carpels is
reduced to three. A disc is present at the base of the stamens which is annular or divided into
glands.

Floral formula: Br Brl ⊕ ⚥ K 5 C5 A5+5 G(3) (*Stellaria media*)

Fruit: Capsule, e.g., *Stellaria*, *Arenaria*, *Spergula*, etc. In some cases the fruit, may be an achene or a nut, e.g., *Herniaria, Dysphania, Scleranthus*, etc.



Stellaria media



Dianthus

Seeds- Small and endospermic. In embryo curved endosperm found.

Pollination: Entomophily.

6.3.3 Economic Importance of Family

The members of the family are important as ornamentals and as the source of medicines

(I) **Ornamental-**Species of *Dianthus* , *Gypsophila* and Agrostemma represented by several ornamental plants.

(II) Medicinal

* *Stellaria semivestita* shows anti- cancer activity
* Decoction of Stellaria vestita relieves bone ache and rheumatic pain
* Seeds of Spergula arvensis are employed against pulmonary tuberculosis

(III) Other uses

* The plant juice *of Saponaria vaccaria, Lychnis* etc. are used as a substitute of soap.
* The shoots of *Stellaria aquatica* (Eng.-Chick weed; Verna.-Badeola) are eaten as vegetable.
* *Spergula arvensis* is used as fodder. It is diuretic.

6.4 Family- Poaceae

Systematics

General characters

Economic importance

The vast and almost universal family of monocotyledonous flowering plants known as grasses is called Poaceae, or Gramineae. The Poaceae family of grasses comprises of cereal grasses, bamboos, and grasses found in natural grasslands as well as developed pastures and lawns. Grasses feature thin, alternating leaves that are borne in two rows, and hollow stems that are only present at the nodes. Each leaf has a bottom portion that forms a leaf sheath that encloses the stem.

Diagnostic characteristics

A mostly herbaceous plant with a fistular, cylindrical stem, simple, alternate leaves, sheathing, sheath open, ligulate, compound spike inflorescence, zygomorphic, hypogynous flowers shielded by palea, three versatile stamens, one carpel, two or three styles, feathery stigma, basal placentation, fruit caryopsis, and testa fused with pericarp.

Distribution: Poaceae is one of the biggest families of monocots, with over 6000 species and 620 genera. The distribution of members is global. As hydrophytes, xerophytes, and mesophytes, the plants embody the three ecological categories. Roughly 900 species are in existence in India.

6.4.1 Classification-

6.4.2

Bentham and Hooker	**Engler & Prantl**	**Hutchinson**
Monocotyledons	Monocotyledoneae	Monocotyledons
Glumaceae	Glumiflorae	Glumiflorae
Poaceae	Poaceae	Poaceae

Poaceae and Cyperaceae are closely related families; Engler and Prantl put Poaceae and Glumiflorae in the same order, but Bentham and Hooker placed Glumaceae. Hutchinson (1964) and other contemporary botanists divided the family into the Cyperales and Graminales orders based on a number of distinctions, including: 1. Leaf sheath; 2. Joint and unjointed stem 3. Lemma, palea, and a single bract 4. Seed covering, etc. According to Hutchinson (1959), the formation of grasses occurred parallel to the Cyperaceae family tree.

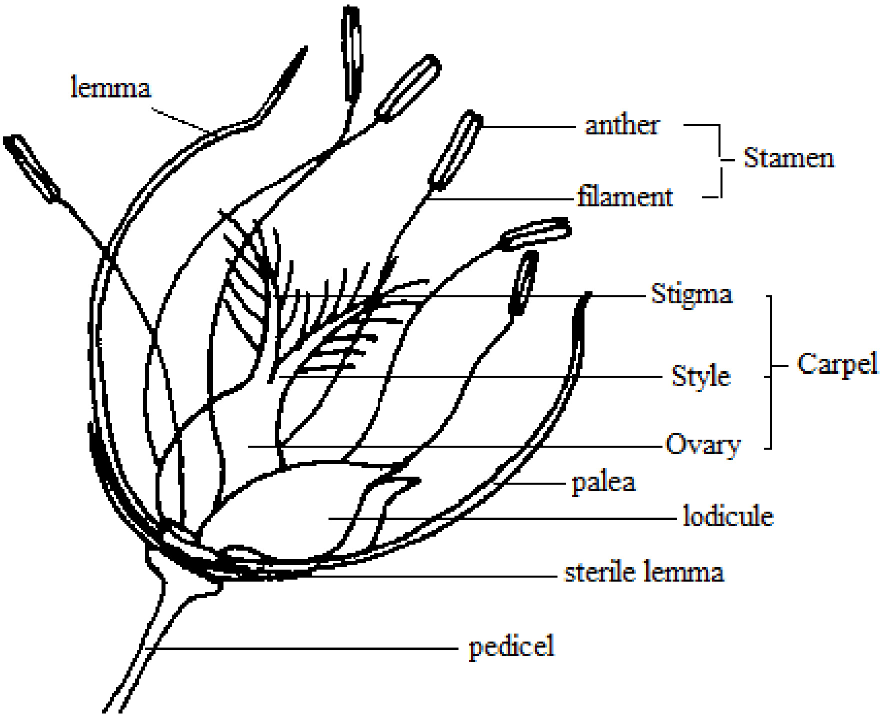
6.4.2 General Characteristics-

Habit: Herbs (annuals or perennials) or shrubs, rarely trees like (Bamboos).

Root: Fibrous, Adventitious

Stem: Herbaceous or woody ,cylindrical; jointed, hollow at internodes. Sometimes, forms rhizome or runner. Stem of grasses is called a culm.

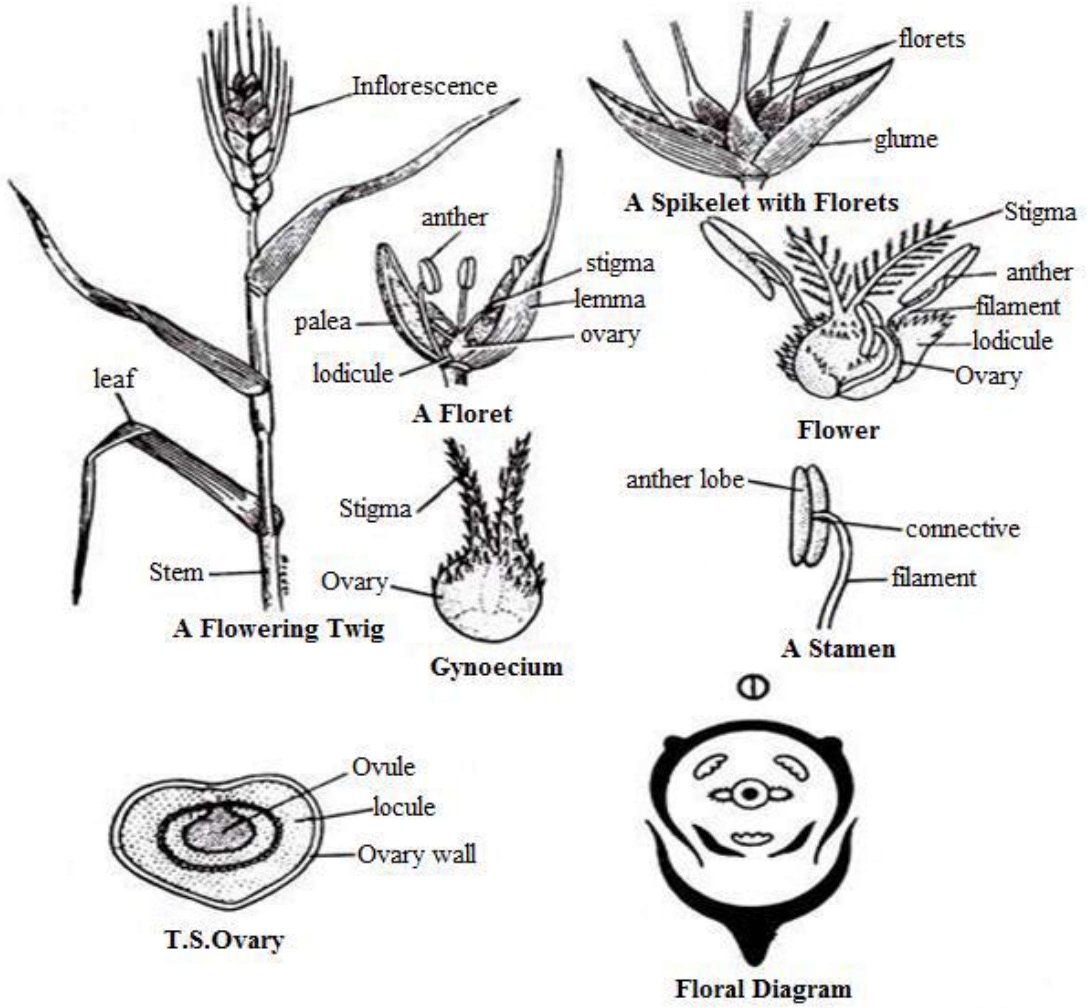
Leaves: Alternate, simple, exstipulate, sessile, ligulate. The sheath and the blade (lamina) are the two main components of every leaf. The sheath that forms the base of the leaf encircles the culm to produce an open, tubular sheath. The blade is the leaf's uppermost part; it is typically flat but can occasionally be long, whole, hairy, or rough, with a linear, parallel venation. A ligule, a fragile membrane protrusion with a highly variable morphology among taxa, is located at the inner surface junction of the sheath and blade.



Spikelet of family Poaceae

Inflorescence: Spike of spikelets or panicles of spiklets. Each spikelet is composed of 2-5 flowers. It is enclosed by a pair of bracts called glumes. Spike of spikelets: The spiklets form dense clusters in sessile manner on main axis as in wheat. Panicles of spikelets: The spiklets are arranged on a branched axis-panicle as in oat.

Flower: Pedicillate bracteate, bracteolate, sessile, incomplete, bisexual or unisexual (Zea mays), irregular, zygomorphic, hypogynous, cyclic.



Floral details of *Triticum aestivum* (Wheat)

Perianth: Lodicules are small, fleshy, hyaline membrane-like structures that resemble scales and are typically used to show it. The lodicules are position above and to the back of the superior palea; they may be absent, many (Ochlandra), three, or two.

Androecium: 3 Stamens in whorl sometimes 1,2 or 6; polyandrous; anther , filaments are long and free, basifixed, anthers dithecous, versatile and linear, extrorse.

Gynoecium: Monocarpellary, ovary superior unilocular with single anatropous ovule adnate to the adaxial side of the ovary, stigma usually 2; feathery; basal placentation.

Fruit: A caryopsis (fruit wall is completely fused with the seed coat) .

Seed: Endospermic .

Floral Formula: % ⚥ P 0 or 2 (Lodicules) A 3 or 6 G1

6.4.3 Economic Importance

Among all angiosperm families, Poaceae is the most important in terms of economic significance. The world's population uses rice (Oryza sativa) and wheat (Triticum aestivum) as basic foods. They raised from the beginning of time. Economic categories of the family are as follows.

Food: This family includes all millets and grains. These form the staple diet of humankind. These are *Triticum* sp. (wheat) plants. *Zea mays* (corn), *Oryza sativa* (rice), and *Avena sativa* (oats). *Pennisetum*, *Sorghum vulgare* (Jowar), *Hordeum vulgare* (Barley), and Scale cereale (rye) typhoides (Bajra), *Eleusine coracana* (Finger millet, Ragi*), Panicum miliaceum* (common millet), and *Setaria italica* (Italian millet).

Fodder plants: This family provides the majority of the animal feed. Numerous grasses, including Poa, Panicum, Cymbopogon, and Cynodon dactylon, are used for feed. The cattle are fed with the dried leaves and stems of the grain harvests.

Sugar: Sugar is obtained from the juice of *Saccharum officinarum* .

Aromatic oils: Numerous grasses produce fragrant oils that are used in perfumery, such as *Andopogon odoratus* (ginger grass), *Cymbopogon citratus* (lemon grass), and *Cymbopogon martinii. Vetiveria zizaniodes* (Khus-khus) yields vetiver oil from its roots. Lemon grass, or Cymbopogon throws, provide lemon grass oil. This oil is used to make infusions in the soap and perfume industries.

Paper industry: Paper is made from a few types of bamboo and grasses.

Ropes: Fibre is obtained from the leaves of *Saccharum munjo.* Ropes are made with this fiber.

Uses of Bamboo: Bamboo, or bambusa, is utilized in construction. Bamboo is used to thatch homes, make canoes, carts, pipes, and other items. Their broken stems are woven into hats, fans, course umbrellas, and mats. Horses are given its leaves to treat colds and coughs.

6.5 Family- Liliaceae

Systematics

General characters

Economic importance

It is commonly known as Lily Family‖. Considered to be a typical monocot family, Liliaceae is the fundamental monocot stock from which many other families have formed.

Diagnostic characteristics: Rarely are herbs shrubs with underground stems like corn or bulbs; the leaves are alternate; the flowers are actinomorphic, trimerous, hypogynous, with six segments of the perianth, each of which can be free or fused; the stamen is 3+3, epiphyllous, and antiphyllous; the gynoecium is tricarpellary, syncarpous, with superior ovary, axile placentation, and two to many ovules per loculus; the fruits are capsules or berries; the seeds are endospermic.

Distribution: A large, globally distributed family. In temperate and tropical climates, they are widely distributed. Four thousand species, belonging to 250 genera, are distributed all over the world. There are 169 species that are found in India. Perennial and annual herbs are typically found among the plants. Mostly in the Himalayas, it arises in our nation. Asparagus spp., Dracaena spp., Lily spp., and Onion (*Allium cepa)* are examples.

6.5.1 Classification:

Bentham and Hooker	Engler & Prantl	Hutchinson
Monocotyledons	Monocotyledoneae	Monocotyledons
Coronarieae	Liliflorae	Corolliferae
Liliaceae	Liliaceae	Liliales
		Liliaceae

20 tribes divided by Bentham and Hooker from the family. The family divided into 12 smaller families by Engler and Krause. The absence of a corona and the presence of a superior ovary distinguish the family apart from Amaryllidaceae, with which it has close affinities. Although their seeds differ in their petaloid perianth, they are similar to Juncaceae . The cytological, embryological, and anatomical features of the family exhibit significant variety, suggesting a polyphyletic origin.

6.5.2 General Characteristics

Habit: Herbs (*Asphodelus*), rhizome (Aloe), bulbs (*Lilium*, *Tulipa*, *Allium*), climber (*Asparagus*, *Smilax*), tree *(Dracena*), xerophytic plants like *Yucca*, *Aloe*; cladodes in *Asparagus*.

Root: Adventitious, Fibrous,tuberous (*Asparagus*)

Stem: herbaceous or woody, solid or fistular, underground; aerial, climbing or erect; underground stem may be corm, bulb or rhizome.

Leaves: Alternate, opposite o, basal (*Allium and Lilium*) or cauline, sessile or petiolate, simple, entire venation parallel, stipules absent

Inflorescence: Usually racemose (Lilium) solitary (*Tulipa*), panicled raceme (*Asphodelus*), solitary axillary (*Gloriosa*).

Flower: Pedicellate, bracteate , actinomorphic rarely zygomorphic,bisexual, hypogynous, complete or incomplete (in unisexual flowers), trimerous.

Perianth: 6 tepals arranged in two whorls, polyphyllous (*Lilium*, *Tulipa*) or gamophyllous (*Aloe*, *Asparagus*) and of various shapes, petaloid or sepaloid, imbricate in bud, valvate in aestivation ,

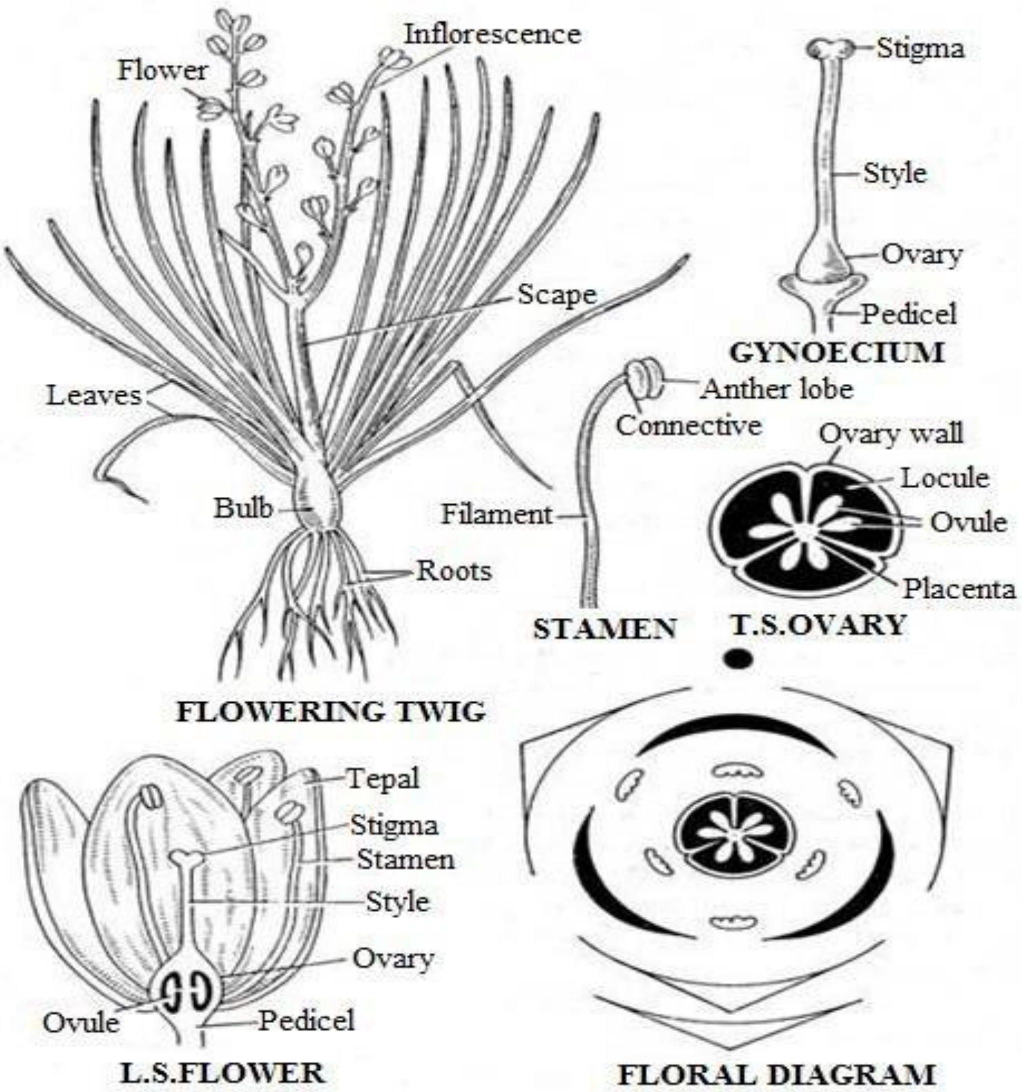
Androecium: Stamens 6 arranged in two alternate whorl. Opposite to the tepals and sometimes adnate to perianth or 3 (*Ruscus*), 8 in Paris; polyandrous, epiphyllous, filaments long, anthers versatile or basifixed, dithecous, introrse or extrorse.

Gynoecium: 3 carpels, united, ovary superior , trilocular, axile placentation, style simple; stigma trilobed or 3-parted.

Seed: Endospermic.

Pollination: Entomophilous.

Floral Formula: Br ⊕ ⚥ P 3+ 3 or (3+3) A 3+3 $\underline{G(3)}$



Asphodelus tenufolius

<u>6.5.3 Economic Importance:</u> The Liliaceae family produces fiber, food, medicine, and decorative plants.

1. Edibles: Onions, or *Allium cepa*, are widely used as vegetables, pickles, and flavorings. Fresh garlic juice has antibacterial qualities. *Allium sativum*, or garlic, is primarily grown as a spice and condiment crop. It is a vermifuge, a stomach stimulant, a tonic, and heart-healthy. *Asparagus officinalis* fleshy shoots are used as a vegetable.

2- Medicinal- Useful medications are produced by *Smilax, Aloe, Gloriosa, Veratrum, Colchicum, Scilla*, and *Urginea. Scilla* bulbs and urgine are sources of rat poison. Aloe vera is used to cure fissures and piles, and it generates aloin. Asparagus racemosus roots are used to make a tonic. *Colchicum luteum* seeds and corms are beneficial for liver and rheumatism. In plant breeding, an alkaloid called "Cochicine" is extracted and utilized to promote polyploidy.

3-Fibres- fibre of commerce used in cordage obtain from *Yucca* and *Phormium tenax*.

4-Resin-*Dracaena* and Xanthorrhoea yield resin. From the acrid resin of Xanthorrhoea sealing wax is prepared.

5-Ornamentals-The common cultivated garden plants *are Tulipa, Lillium, Gloriosa, Aloe, Ruscus, Dracaena, Asparagus, Yucca, Hemerocallis* etc.

Summary

You can now summarize the key characteristics of the families whose students were investigated in this chapter. The characteristics of Ranunculaceae exhibit a combination of primitive and advanced traits. Because of its mostly herbaceous habit, bisexual and actinomorphic flower, many free and spirally distributed stamens and capels, and follicular fruit, the Ranunculaceae family is regarded as primitive. Their zygomorphy, connation in the gynoecium, whorled appendages, unisexuality, and achenial fruit are examples of their advanced characteristics.

It is believed that the family Caryophyllaceae evolved from either ranalian ancestors or the order Ranunculales. It is a member of the Caryophyllinae order, which is characterized by actionomorphic blooms, ovary unilocular with free center placentation, and stamens that are often twice as many as petals. Herbs with opposite and simple leaves, an inflorescence that splits into a dichasial and monochasial cyme, actionomorphic, pentamerous, hypogynous flowers with sepals and petals numbered 4-5 and obdiplostemonous stamens, an ovary that is unilocular with free central placentation, and capsules with two to six valves are the distinguishing characteristics of this family.

monocotyledons characterized by a single cotyledon, a fibrous and adventitious root that emerges from the base of the stem, narrow leaves with parallel veins, a herbaceous stem, an uneven distribution of vascular bundles within the stem, a trimerous flower, and a perianth that is frequently difficult to separate into the calyx and corolla.Poaceae is classified under Series Glumaceae, Liliaceae under Series Coronarieae, and Family Orchidaceae under Series Microspermae.

The Liliaceae family is considered to be a typical monocot family, representing the fundamental monocot stock from which several other families have sprung. Almost never shrubs, herbs have underground stems in the form of rhizomes, corms, or bulbs; leaves are alternate; flowers are actinomorphic, trimerous, hypogynous, with six whorls of three each, free or fused; stamens are 3+3, epiphyllous, and antiphyllous; gynoecium is tricarpellary, syncarpous, ovary superior, axile placentation, and contains two to numerous ovules per loculus; fruits are capsules or berries, and seeds are endospermic.

Key words-

Actinomorphic- A flower with radial symmetry

Adnate – Grown together or fused, used only to describe unlike parts. For comparison, connate.

Bract – A very smaller leaf, typically resembling scales, and generally connected to flower or inflorescence

Bracteole- Secondary bract at the base of individual flower

Calyx – The sepals that make up the outer whorl of the perianth are typically smaller and greener than those in the inner group.

Capsule – A dry dehiscent fruit produced from a compound pistil.

Complete- The flower with all the four whorls i.e. calyx, corolla, androecium and gynoecium**.**

Hypogynous- Situated below the gynoecium or ovary referring to stamens, petals and sepals.

Multiple Choice Questions:

i) Which one of the following is more primitive than others.

(i) Ranunculaceae (ii) Caryophyllaceae

(iii) Rutaceae (iv) Fabaceae

Ans. (i)

ii) Which one of the following is commonly known as Pink family.

(i) Ranunculaceae (ii) Caryophyllaceae

(iii) Rutaceae (iv) Fabaceae

Ans. (ii)

iii) Aconite, an alkaloid is present in

(i) Thalictrum (ii) Aconitum napellus

(iii) Clematis (iv) Ranunculus

Ans. (ii)

iv) Obdiplostemonous condition of stamens is general criterion of which one of the following families

(i) Ranunculaceae (ii) Caryophyllaceae

(iii) Rutaceae (iv) Fabaceae

Ans.(ii)

v) In Poaceae the fruits are usually

(i) Follicle (ii) Nutlets

(iii) Capsule (iv) Caryopsis

Ans. (iv)

vi) Botanical name of onion is

(i) Solanum tuberosum (ii) Lycopersicon esculentum

(iii) Allium cepa (iv) Nicotiana tabacum

Ans. (iii)

vii) A plant that belongs to Liliaceae in which stipules are modified into tendrils is

(i) Gloriosa (ii) Yucca

(iii) Lilium (iv) Smilax

Ans. (iv)

viii) The inflorescence of Paddy is

(i) racemose (ii) catkin

(iii) panicle (iv) verticillaste

Ans. (iii)

ix) Poaceae the Lodicules are

(i) Petals (ii) Perianth leaves

(iii) Sepals (iv) Bracts

Ans. (ii)

UNIT-7

MODERN TRENDS OF PLANT TAXONOMY

Today, taxonomists accept that physical traits alone should not be taken into account when classifying plants in a systematic manner. The fundamentals of many different fields, including cytology, genetics, anatomy, physiology, geographic distribution, embryology, ecology, paleontology, phenology, biochemistry, numerical taxonomy, and transplant experiments, can be used to fully understand taxonomy. By offering extra characters, these have been proven to be helpful in resolving some of the taxonomy issues. Classification's appearance has shifted from alpha, or classical, to omega, or modern. As a result, the new systematic has improved as a taxonomy.

- **Chemotaxonomy**
- **Cytotaxonomy**
- **Numerical taxonomy**

7.1 Chemotaxonomy- The area of plant taxonomy, or chemotaxonomy, is growing and aims to use chemical data to enhance plant classification. Since man first began to categorize plants as edible or inedible, presumably based on their chemical distinctions, chemical evidence has actually been used. In herbals written about five centuries ago, chemical information about therapeutic plants focused on the location and use of physiologically active secondary metabolites such alkaloids and saponins. Chemotaxonomy is a scientific field that use chemical data as a taxonomic characteristic. Let us take a minute to consider the many types of plants in before we examine the foundation of this contemporary movement in plant taxonomy. Our regular existence. We distinguish between tea and coffee based on their distinct flavors and aromas, which we enjoy in our drinks. In a similar vein, we discover that fruits like apples, bananas, and mangoes have distinct flavors when we consume them.

The roots of chemotaxonomy may be found in very early classical taxonomy, despite the fact that it is thought to be a very new addition to modern taxonomy.

It is likely that the medical plants were recognized for their potential to treat ailments, while the spice plants were recognized for their fragrant qualities. The chemical components of the plants, which have been used by taxonomists to classify them since ancient times together with morphological characteristics, are primarily responsible for the aromatic qualities or therapeutic value of these plants.

But chemotaxonomy are not recognized as a significant subject of research until recently.

All of a plant's chemical components may be useful to a taxonomist in theory, there are certain compounds that are more beneficial than others in real life. Thus, we may employ chemical characteristics that are directly observable, such crystals, raphides, or starch grains found in many plants.

As an alternative, we may employ chemical analysis to determine the various chemical elements of plant material and utilize this knowledge for taxonomic reasons. The majority of chemotaxonomists identify primary metabolites, secondary metabolites, and semantides as the three major classes of chemical substances that are significant from a taxonomy standpoint.

7.1.1 Directly Visible Chemical Characters

The majority of green plants have food reserves in the form of starch grains, one of the very few chemical components that can be directly viewed; these molecules have been employed for chemotaxonomic reasons (fig. 14.4). There is no room for doubt when using the knowledge on the very distinct starch grain types found in various plants. In order to provide chemotaxonomic information, Reichert (1913) studied the starch granules in 350 distinct plant species and determined their differentiation and specificity of occurrence in respect to genera and species. Tateoka (1962) examined the starch grain morphology in the Poaceae family of grasses and utilized this knowledge together with other data to create tribes within the family. For instance, while other genera, like Lolium, Nardus, and Papapholis, have simple starch grains, the Tribe Hordeae's typical members, such Hordeum, have complicated starch grains.

The calcium oxalate crystals known as raphides are visible and found in big cells in many plant tissues. They are easily recognized because they are long, needle-shaped crystals that are pointed at both ends and typically appear in bundles. They are widely distributed throughout the Araceae family of plants, including Pistia and Eichhornia, which are water plants.

Among a few other important characteristics, the presence or absence of raphides is crucial to the family Rubiaceae's natural categorization. The tribe Rubioideae is made up of all members of the Rubiaceae family that have raphides.

Druses, a different kind of crystal composed of calcium oxalate, offer strong taxonomic support. An enormous number of crystals gathered together is called a druse. They belong to the family Apocyanaceae, Caricaceae, etc.

7.1.2 Primary Metabolites

Primary metabolites are substances that play a key role in metabolic processes, as their name suggests. They are ubiquitous and have minimal significance in chemotaxonomy. But when their abundance changes significantly between species, these compounds become valuable as chemotaxonomic characteristics. In the genus Sedum, for instance, vast amounts of the sugar "sedoheptulose" are kept as a reserve food. This major metabolite's existence so makes it simple to identify members of this genus.

Amino acids are the components that make up proteins. For chemotaxonomy, they can offer valuable macromolecular data. Different proteins may have their amino acid sequences examined, and the degree of similarity between them is probably correlated with their genetic relatedness. But of the approximately 3 lakh species of angiosperms, very few have had their amino acid sequences examined. For instance, the link between the genera of wheat and barley, as proposed by traditional taxonomists, is confirmed by the amino acid data.

7.1.3 Secondary Metabolites- The macromolecules known as secondary metabolites, sometimes known as secondary plant products, are more significant from a taxonomic standpoint than primary metabolites since they are rare and nitrogen-free. Numerous chemical types, including flavonoids, terpenes, iridoids, alkaloids, anthocyanins, glucosinolates, cyanogenic glycosides, polyacetelenes, etc., are included in this category. They are mostly used for storage and often do not perform essential tasks.

FLAVONOIDS- Secondary metabolites, flavonoids—the most prevalent phenolic chemicals found in leaves—have shown to be extremely helpful in the field of chemotaxonomy. For these chemicals, which exhibit worldwide distribution, structural variety, and chemical stability, both monocots and dicots have been thoroughly investigated. They give crucial chemical features for taxonomic purposes and are quickly and simply identifiable. Giannasi, for instance, studied the flavonoid chemistry of 80 species of plants belonging to the Ulmaceae family (1978). The majority of species have flavonols, but a small number also have glyco-flavonols, and no species ever contains both types of flavonoid molecules at the same time.Interestingly enough, the family Ulmaceae is classified into two subfamilies, Ulmoideae and Celtoideae, in most traditional classification systems. These subfamilies are likewise distinguished by their flavonoid chemistry. Consequently, the family Ulmaceae may be divided into two separate families using morphological criteria and flavonoid dichotomy: family Ulmaceae is characterized by the presence of flavonols, whereas family Celtaceae is characterized by the presence of glucoflavonols.

The taxonomy of several families, including the Orchidaceae, Rutaceae, Lemnaceae, Labiatae (Lamiaceae), Arilidaceae, and others, has been studied using flavonoid chemistry in a number of different research.

TERPENES- Terpenes are a second class of secondary metabolites that chemotaxonomists frequently study. Essential (ethereal) oils, which belong to the orders Laurales, Piperales, Austrobaileales, and Magnoliales, are mostly composed of volatile terpenes. Families Myrtaceae, Rutaceae, Apiaceae, Lamiaceae, and Asteraceae have also been found to include them**.**

These substances may be categorized as monoterpenes, diterpenes, triterpenes, sesquiterpenes, etc. based on their molecular structures, and each category can be utilized for taxonomic purposes. For instance, on the basis of monoterpenes genus Salvia 19 species distinctly identify and classify. Similarly, the taxonomy of the families Cucurbitaceae and Compositae (Asteraceae) has benefited greatly from the presence of triterpenes and sesquiterpenes.

ALKALOIDS

Alkaloids are a class of structurally varied compounds that are produced from mevalonic acid or amino acids. Colchicines, atropine, morphine, codeine, and cocaine Among the significant alkaloid plant compounds are quinines. Because of their great diversity, the plant groupings in which they are biosynthesized are not of systematic interest.

ANTHOCYANINS AND BETALAINS

Only the families Caryophyllaceae and Molluginaceae, as well as the Order Caryophyllales, contain betalains, which are nitrogenous red and yellow pigments. On the other hand, most other plants include pigments called anthocyanins, which are red, yellow, blue, or purple.

Because they have never been discovered together in the same species, betalins and anthocyanins are mutually.

7.2 Cytotaxonomy-- The study of cell shape and physiology is known as cytology. For the purpose of categorization, the number, shape, and pairing of chromosomes during meiosis are recorded. chromosomal number, morphology, ploidy level, ploidy type, and chromosomal aberrations are all used as data for categorization in cytotaxonomy. Studies involving observations of chromosomal pairing or behavior during meiosis are included in the field of cytogenetics.

You will learn about the significance of chromosomal number, structure, and behavior during meiosis as taxonomic evidence in the subsections that follow.

7.2.1 Chromosome Numbers- Each cell in each individual of a single species contains the same number of chromosomes. The more closely related species are also expected to have a higher number of chromosomes, whilst the more distantly related species will have a lower number. Chromosome number becomes a significant and often utilized taxonomic characteristic as a result of this relative conservatism. Furthermore, the angiosperms have a very wide range of chromosomal counts, ranging from 2n=530 in Poa litorosa (Poaceae) to as low as 2n=4 in Haplopappus gracilis (Asteraceae). Numerous angiosperms have had their chromosome counts examined, yielding valuable taxonomic data

For instance, different species in the genus Festuca have various numbers of chromosomes, which combine to generate a mathematical series (See Table 14.2). The numbers of the chromosomes are 2n = 14, 28, 42, 56, 70, and so forth. It is possible to draw the generalization that several species may share some characteristics based on this knowledge. Given that x = 7 serves as the common denominator for all of these chromosomal values, we may see the various species as having multiples of x. This denominator, or base number (x = 7), can be thought of as the fundamental genetic information that plants carry. As a result of this fundamental genetic information being multiplied, several species have evolved. When the basic number (x) in a series is equal to the haploid number of chromosomes in a diploid animal (for example, x = n = 7), the series is said to be polyploid. Tetraploid (4x = 2n), hexaploid (6x = 2n), octaploid (8x = 2n), and decaploid (10x = 2n) would then be the other species.

7.2.2 Chromosome Structure- Studies on chromosomal morphology have revealed that the centromere's location is the most important aspect of chromosome structure. The link between the two arms of the chromosomes is revealed by the centromere, or constriction, in the length of the chromosome. So, chromosomes are classified as metacentric, acrocentric, or telocentric based on where the centromere is located. Chromosomes that are metacentric are thought to be more evolved than those that are acrocentric.The appearance of the basic chromosome set in a dividing cell is known as the karyotype of the cell. This can be analysed to provide information not only of the chromosome number, but also about the chromosome size,chromosome volume, and type of chromosomes in the cell. This information is used by taxonomists for identifying plants and understanding relationships. The karyotype can be represented diagrammatically as an idiogram or karyogram, and these diagrams can be compared for taxonomic purposes. Another interesting observation is that the absolute size of the chromosomes of a karyotype is fairly constant since it is controlled by the genotype. Taxonomists have found that monocots generally have larger chromosomes than dicots, and that smaller chromosomes are found in hardwood plants in comparison to their herbaceous relatives.

Polygonum plants occurring in three distinct habitats were thought to belong to separate species because of their morphological differences. It's interesting to note that chromosomal morphology was identical across all of them. As a result, Polygonum amphibium is the collective name given to them.

According to chromosome karyotype studies, Limnocharis, Hydrocharis, and Tenagocharis should remain in the family Alismataceae, while the genus Butomus should be placed in its own family, the Butomaceae. Because members of the groups Cyperaceae and Juncaceae share homocentric chromosomes, closer affinities between them have been determined.

The Agavaceae family identified as distinct from the Amaryllidaceae family based on karyotype investigations. Yucca's move from the family Liliaceae to the family Agavaceae was aided by the presence of five large and twenty-five small chromosomes in their cells.

7.3 Numerical Taxonomy-- The term "numerical taxonomy," also known as "taximetrics," is used to describe the use of various mathematical techniques to numerically encoded character state data for organisms under investigation. Phenetics is a more relevant term presently.

In other words, it involves the numerical analysis of the similarities or affinities of taxonomic units, which are subsequently grouped into taxa based on these affinities, and the examination of various forms of taxonomic data using mathematical or electronic techniques.

Therefore, numerical taxonomy is a biological systematics classification system that deals with the numerical grouping of taxonomic entities according to their character states. Instead of classifying them according to a subjective assessment of their attributes, it attempts to classify them using numerical procedures such as cluster analysis.

The notion was initially formulated in 1963 by Robert R. Sokal and Peter H. A. Sneath, who further refined it.They separated the science into two categories: cladistics, which bases classifications on the branching patterns of the estimated evolutionary history of the species, and phenetics, which bases classifications on patterns of general similarity.

Heywood defines numerical taxonomy as the process of placing organism groupings into higher ranked taxa based on a numerical assessment of their resemblance to one another.

The initial approaches and theories of numerical taxonomy developed between 1957 and 1961. Plants are categorized according to their characteristics. The first person to propose a system for valuing an organism's resemblance to another was the French botanist Michel Adanson. He suggested that all characteristics should be given the same weight when categorizing plants.

7.3.1 Principles of Numerical Taxonomy:

Numerical taxonomy involves two aspects:

(a) Construction of Taxonomic Groups:

i. In numerical taxonomy, characteristics are initially identified by selecting individuals. The maximum character count that is taken into consideration is unlimited. Nonetheless, a greater character count indicates a more effective method for taxonomic generalization.

ii. The similarity between individuals is then determined by character analysis, which frequently occurs with computer aid; the accuracy of this analysis is dependent upon the suitability of the characters. Using the most characteristics possible and giving each one an equal amount of weight is the best method for classify taxa.

(b) Discrimination of the Taxonomic Groups: Discrimination should be utilized to choose the taxonomic categories for the research when they exhibit character overlap. Numerous methods that have been specifically developed for this purpose can be used to do discrimination analysis. Therefore, the foundation of numerical taxonomy is a set of ideas known as neo Adansonian principles.

7.3.2 Sneath and Sokal specified the following seven numerical taxonomy principles:

(i) A classification system's accuracy increases with the quantity of information it includes and the number of characters it takes into account.

(ii) When establishing new taxa, each character needs to be given the same weight.

(iii) The specific similarities in each of the numerous characteristics that are taken into consideration for comparison determine the overall similarity between any two things.

(iv) Character correlation varies among the research organism groups. Different taxa can therefore be identified.

(v) Character correlations and the taxonomic organization of a group can be used to predict phylogenetic conclusions, provided that certain evolutionary paths and processes are present.

(vi) The study and application of taxonomy are seen as empirical sciences.

(vii) The basis for categorization is phenotypic similarity.

7.3.3 Merits of Numerical Taxonomy

- Sokal and Sneath list the following benefits of numerical taxonomy over traditional taxonomy:
- Numerical taxonomy uses a higher quality and quantity of specified characteristics than traditional taxonomy, hence its data is superior. The information is gathered from many different sources, including morphology, chemistry, physiology, and more.
- Numerical method is more accurate in defining taxa, the information gathered may be effectively utilized with the aid of computer data processing systems to build improved keys and classification schemes, as well as to create maps, descriptions, catalogues, and other materials. In actuality, there have been a number of significant adjustments to the traditional classification schemes provided by numerical taxonomy.
- Numerous biological ideas have undergone reinterpretation in light of numerical taxonomy.
- Numerical taxonomy allows more taxonomic work to be done by less highly skilled workers

7.3.4 Demerits of Numerical Taxonomy:

Numerical taxonomy has the following disadvantages---

Phenetic classifications benefit from the use of numerical method, not phylogenetic ones.

The proponents of “biological” species concept, may not accept the specific limits bound by these methods.

The main drawback of this approach is character chosen Inadequate character selection for comparison may result in a less than ideal outcome when using statistical approaches.

Various taxonometric methods may provide various outcomes, according to Steam. Choose the right process and character count for these mechanical assistance to provide excellent results is a significant challenge. It is imperative to determine if utilizing a larger character count would yield more satisfying outcomes than use a smaller one.

7.3.5 Applications of Numerical Taxonomy:

- Analyse the similarities and differences between various animal groups, bacteria, and other microorganisms.
- Delimitation of a number of angiospermic genera, including Farinosae of Engler and a few others, as well as Oryza and Sarcostemma Solarium.
- In the investigation of several additional angiospermic genera, such as cultivars of maize, wheat, oenothera, zinc, chenopodium, crotalaria, cucurbita, oenothera, and salix.
- Mondal et al. used a numerical analysis of phytochemical data from study using seed proteins and mitochondrial DNA RELP tests to examine the interspecitic differences between eight species of cassia L.Following Sokal & Sneth and Romero Lopes et al.'s methodology, the degree of pairing affinity (PA), also known as the similarity index, was computed using the electrophoretic pattern data.

$$PA = \frac{\text{Bands common to species A and B}}{\text{Total bands in A and B}} \times 100$$

Summary

The characteristics, character states, and qualities offer helpful inputs for identifying and categorizing plants. They are collectively referred to as taxonomic evidences. These kinds of proofs might be chemical, biological, or physical.

Physical taxonomic evidence is comprised of taxonomic evidence derived from several fields like as morphology, anatomy, embryology, palynology, and cytology.

Chemical taxonomic evidence consists of primary and secondary metabolites. Biological taxonomic evidences are biomacromolecules that convey information, such proteins and nucleic acids. Another name for them is semantides.

The study of pollen grain morphology, size, polarity, symmetry, and structure is known as palynology. Palynological data from extant and extinct plants is a crucial source of physical taxonomic information.

Very instructive taxonomic evidences include chromosomal morphology, karyotype studies (idiograms), centromere location inside a chromosome, and chromosome behavior during meiosis.

In plants, directly visible compounds found within cells, such as starch grains and crystals, can also be used to identify and decipher connections. Secondary metabolic taxonomic evidences include substances like flavonoids, iridioids, alkaloids, betalains, anthocyanins, glucosinates, polyacetylenes, cyanogeneic glycosides, terpenes, etc.

Multiple Choice Questions:

i) A taxonomic system based only on the traits that reflect the order in which branches arose in a phylogenetic tree is called:

A) Phylogeny

B) Cladistic

C) Classical evolutionary taxonomy

D) Phenetics

ii) The lowest ranking taxa in numerical taxonomy is:

A) Species

B) Operational taxonomic unit

C) Character states

D) Variety

iii) Taxonomy, when strengthened by incorporating data from semantides and non-s emantides, is called:

A) Numerical taxonomy

B) Cytotaxonomy

C) Chemotaxonomy

D) Alpha taxonomy

iv) Cladistic relationship is expressed in terms of correlation amongst individuals with regard to:

A) Phenotypic characters

B) Their evolutionary history

C) Relationship between operational taxonomic unit

D) Their chromosomal behaviour

v) The principles of Numerical taxonomy were developed by:

A) Bentham and Hooker

B) Engler and Prantl

C) Sneath and Sokal

D) Takhtajan and Cronquist

UNIT- 8
INTRODUCTIONS to ECOLOGY

8.1 Objectives

- Explain the scope of ecology;
- Describe the types of ecology;
- Explain the aspects and importance of ecology

What are your thoughts about ecology? The study that examines the interactions between organisms and their surroundings is known as ecology. Although the word "ecology" derives from the Greek words "Oikos," which means "place to live," and "Logos," which means "science," The science of the interaction between organisms and their surroundings is thus what is meant to be understood when one speaks about ecology. Some ecologists define ecology as the entire study of the link between organisms and their environment (Ernest Heackel, 1866), whereas C.J. Krebs (1972) defined ecology as the study of the abundance and interactions of organisms.

8.2 Plant ecology

The range of interactions between related plants, other plants, and their physical environments is the subject of the scientific field of plant ecology. This knowledge leads to the conclusion that plants affect one another's daily activities. One unique aspect of plant ecology is the ability of plants to transform inorganic elements into organic matter and chemical energy into potential energy. When talking about plant ecology, ecosystems and plant ecology go hand in hand. Abiotic (temperature, water, soil, humidity, and light) and biotic (living things, such as humans, animals, plants, and microorganisms) variables all have an impact on ecosystems.

8.3 Ecological Scope

The following is the ecological scope:

1. Individual: a solitary member of each specific species. A person, a lion, a cat, a fish, and so forth are examples.

2. Population: a collection of members of the same species living in the same location at the same time. For instance, a group of people, an ant colony, a cluster of trees, and so on.

3.Community: a group of people who communicate with one another. As an illustration, consider the populations of birds, caterpillars, snakes, and prairie communities.

4. Ecosystem: Living organisms and their surroundings are mutually dependent. for instance, ecosystems found in forests, the ocean, and other places.

5. Biosphere: Earth's highest organizational level where life exists

8.3.1 Aspects About Plant Ecology

There are three primary components of ecology, and they are as follows: Agronomic features.

The term "agronomic aspect" refers to the science or study that addresses how to manage production and the surrounding environment in order to achieve higher and more optimum output or outcomes than previously.

This seeks to determine the link between a place or site and the environment, as well as the effects it has on the environment, when it comes to using it as a venue for production processes. The practice of agronomy itself has many drawbacks or deadly outcomes since improper management and usage of the environment might upset the existing organisms or even lead the poorly managed soil to fail to produce.

This means that there are still a lot of unknown variables that might arise while applying the agronomy approach, particularly for those who lived in earlier eras or before the invention of contemporary technologies. Back then, people didn't give a damn about the land that had been utilized; they just wanted to take the product that they had grown.

They are forced to relocate when the processing yields less money than they might have made otherwise in order to accommodate the crops.

Customs that date back thousands of years, followed by people who are unaware of the potential consequences of processing a place before abandoning it, can have catastrophic consequences. It's also possible that not all of the locations they utilize are able to provide products that are superior. due to damage and lack of treatment, which prevents it from being used again

8.3.2 Aspects of Plant Physiology

Plant physiology is the study, investigation, and application of processes or procedures that take place in the interior sections of plants, especially higher plants, that are not visible without harming or inspecting the internal organs in question. Based on the "karim" statement, it can be inferred that the science of plant physiology originates from structural observations and how those observations are linked to the function of the plant, making it easier to understand the traits and features of the plant itself.

The arrangement of the plants themselves allows for the identification of factors that affect the plant's growth and yield, as well as the knowledge of how to increase the plant's potential yield. This allows for the eventual use of the obtained potential to enhance the quality and manner in which the plant is grown, and finally, the influence of the environment in which the plant grows.

Agricultural Climatological Aspects

The scientific field of climatology examines how one location differs from another in terms of environmental conditions and factors that affect plant growth. Once a relationship has been established, this knowledge is linked to human activity in the surrounding area. What elements can therefore have an impact on the plant itself depending on the condition of the surrounding environment and the plant's specific location? This climatology also covers the reasons for regional variations in the weather and climate, as well as the variables that affect and contribute to these variations.

This climatology has many advantages for agriculture, forestry, transportation, telecommunications, tourism, and trade. It is highly influential on a plant's growth period because it is focused on the climate, and the measurement of the climate controls the growth rate experienced by a group of plants.

Based on these three factors, it can be concluded that the three factors are related, which progressively clarifies how the management process is followed by how to understand the characteristics of the plant itself. It is also evident how the plant's internal organs and the surrounding weather or climate affect the plant's ability to grow.

8.4 Benefits of Plant Ecology

Humans utilize plant ecology for the following purposes:

1. Understanding Biodiversity

Understanding ecology helps people appreciate the variety of life on Earth and the habitats that each one of them has. For instance, penguins are evolved to live in extremely cold temperatures, whereas camels are able to survive in the hot heat of the desert.

2. Understanding How Living Things Act

Through ecology, humans may learn about the behaviors of other living creatures and apply that knowledge to improve their own quality of life. Take bats as an example, whose behavior can adapt to submerged solar systems.

3. Understanding Humans' Role in the Environment

Ecology allows people to understand how a product affects its surroundings. For instance, using High Level Disinfection (DTT) to get rid of bugs might contaminate the environment and affect both people and other living things.

4. Mapping Food Consumption

The composition and size of food in all living things are known to humans. For instance, decomposers will create breakdown, which will be used again by producers as a source of energy, while plants act as producers, herbivores as first-level consumers, carnivores as second-order consumers, and humans as third-order consumers.

5. Resolving Issues in Agriculture

Humans may assist in resolving agricultural issues that arise. For instance, keeping the soil fertile might introduce some microorganisms that can nitrate and ammonium create.

6. Resolving Energy-Related Issues

The availability of energy to maintain life may be ensured in part by humans. One instance of alternative energy utilization is the generation of electrical energy using solar power.

7. Resolving Health Issues

Humans can assist in resolving the health issues they have encountered. For instance, dengue disease, which is spread by the Aedes aegypti mosquito, can be eliminated by humans by medication or other measures.

8.5 Ecology Types

The types of ecology are as follows:

1. Human Ecology

The study of the status of the human environment is known as human ecology. The first people to propose the idea of human ecology were sociologists Ernest W. Burgess and Robert E. Park. Hawley (1950) asserts that the ecology of plants and animals that might symbolize the unique application of a broad viewpoint in a life is the scope of human ecology.

2. Plant Ecology

Plant ecology is a subfield of ecology that focuses only on plants as living things, ignoring animals and people. Plant ecology, according to Keddy (2004), is the study of all environmental elements that have an impact on a plant species' (species ecology) or a plant community's (community ecology) ability to exist in a particular location. The following environmental elements have an impact on plant ecology: people, animals, plants, and microbes.

3. Animal Ecology

Animal ecology is a subfield of ecology that focuses only on animals as living things, excluding plants and people. Understanding the fundamental components of an animal's performance base as an individual, a population, a community, or an inhabited ecosystem—such as pattern recognition and interaction recognition—is the aim of animal ecology.

Autecology and synecology encompass animal ecology. A synecological community is one in which there are interactions between different demographic groups. For instance, looking at the quantity of a specific kind of fish in a tidal zone. On the other hand, autecology is an ecological feature of individual animals or groups of animals. Investigating the nuances of Drosophila spp. life, including as food, habitat, reproduction, behavior, and reaction, among other things, is one example.

4. Population Ecology

A subfield of ecology known as population ecology examines the relationships between populations of species, their individual numbers, and the factors that affect population size and dispersion. For instance, populations of fish and sumpil are found in river ecosystems because they have fulfilled the necessary conditions to exist as populations. For more precise data, the population can conduct experiments, observe events, and conduct surveys.

5. Habitat Ecology

A subfield of ecology called "habitat ecology" studies the characteristics of a habitat. Habitat, in the words of Sambas Wirakusumah, is a species' ability to tolerate environmental conditions inside its orbit. A species' orbit is its living area against a large geographic backdrop, whereas its habitat is the actual area it inhabits.

6. Social Ecology

The study of the interaction between people and technology and the natural world is known as social ecology. The Chicago school of social ecology theory was developed by Mr. R.E. Park (1864–1944). The structure of the intercity in terms of how the various areas of the city interact is addressed by social ecology theory. The biotic and social levels are the two layers of society that are explained by social ecology theory. The biotic level serves as both society's foundation and the sub-social structure that implements the dependent and competitive principles and causes society to evolve according to predetermined patterns. Although the social level is associated with the sociocultural aspects of society, which are governed by community, communication, values, norms, and changes that take place in society.

7. Language Ecology

The study of the interaction between language and the human environment, as seen in ethnolinguistics and sociolinguistics, is known as language ecology. The dialectical ecolinguistic perspective (Steffensen, 2007) holds that language is both shaped and formed by social activity. The term "social praxis" describes all of the community's behaviors, actions, and interactions with other communities as well as the environment.

8. Space Ecology

The field of ecology known as "space ecology" focuses on ecosystems that support human existence while in orbit. A subfield of ecology known as "space ecology" studies the creation of ecosystems that can partly or fully regenerate to sustain human existence during extended space travel.

Summary

Ecology is the scientific study of the relationships that exist between living things and their surroundings, including both biotic (non-living) and abiotic (living) elements. Its purview include comprehending how these interplays mold ecosystems, impact biodiversity, and propel mechanisms like nutrient cycle and energy transfer. Population dynamics, community structure, ecosystem functioning, and the effects of human activity on natural systems are important facets of ecology. There are several categories of ecology, such as population, community, behavioral, ecosystem, and global ecology. It is crucial for maintaining the sustainability of life on Earth by offering insights into conservation, managing natural resources, and tackling environmental issues like climate change.

Keywords

Ecology: Ecology is the study of the interactions between living things and their surroundings.

Environment: surrounds and affects organisms is the culmination of all biotic and abiotic forces.

Atmosphere: The gaseous envelope around a planet is called its.

Biosphere: biosphere is the planet Earth plus its atmosphere, which supports life on Earth.

Hydrosphere: it is the portion of the globe that is made up of water (lake, river, ice cap, ocean, etc.).

Lithosphere: Earth's outer solid shell is known as the lithosphere.

MCQ

1. **What is ecology?**

   A) The study of rocks and minerals

   B) The study of human history

   C) The study of interactions between organisms and their environment

   D) The study of celestial bodies

   Answer: C)

2. **Which of the following is an abiotic factor?**

   A) Plants

   B) Animals

   C) Microorganisms

   D) Temperature

   Answer: D)

3. **What does population ecology focus on?**

   A) Individual organisms

   B) Groups of organisms and their interactions

   C) The dynamics of species populations

   D) The biosphere and global patterns

   Answer: C)

4. **Which type of ecology studies energy flow and nutrient cycling within ecosystems?**

   A) Autecology

   B) Community Ecology

   C) Ecosystem Ecology

   D) Global Ecology

   Answer: C)

5. **Why is ecology important for environmental conservation?**

   A) It helps in studying rocks

   B) It helps in conserving biodiversity

   C) It focuses on ancient civilizations

   D) It explores the universe

   Answer: B)

Short questions:

1. Define ecology and explain its significance.
2. Describe the scope of ecology and list its major levels of study.
3. What is the difference between autecology and synecology?
4. Explain the importance of studying nutrient cycling within an ecosystem.
5. How does landscape ecology differ from ecosystem ecology?

UNIT-9
ORGANISM & POPULATION

9.1 Objectives

- Explain Population growth;
- Describe the characteristics of growth;
- Explain the plant interaction

9.2 Organisms

A biological system that is linked to its surroundings is called an organism. Certain structures and behaviors can be retained by these living organisms. Humans, animals, plants, fungus, and bacteria are a few examples of biological entities. Populations are made up of a grouping of these creatures. A community is formed by the aggregation of people and helps ecosystems function. Every living thing is capable of adjusting to different environmental circumstances. Because of their genetic differences, organisms have this ability. Their survival chances only rise as a result of this. example: polar bears' thick fur coat allows them to withstand the bitter cold, whereas camels adapt to live in arid environments.

9.2.1 Organisms and Environment

Many variables influence how organisms grow and develop in their specific surroundings. The environment and the creatures who inhabit it are impacted by certain differences.

One of the geological elements is the earth's rotation around the sun.

The temperature fluctuations are caused by the axis' tilt.

These are the elements that cause different seasons to exist on Earth.

The primary biomes' creation is influenced by variations in the aforementioned variables as well as the yearly change in precipitation (deserts, rainforests, and tundras).

It is significant to remember that the development of habitat in biomes is influenced by certain biotic and abiotic elements.

Variations result from the various ways in which these components interact with one another. The biotic elements of the ecosystem consist of diseases, parasites, predators, and rivals. They communicate with the physio-chemical elements of their environment.

Known as abiotic factors, these physio-chemical elements are essential to the creation of habitats.

9.3 Introduction to Population

"Populus" is derived from the Latin word "populus," which means "people." In ecology, the term "population" refers to the collective of species or kinds of organisms. A population is an assembly of unique creatures in one location that share traits, are of the same origin, and are able to freely create children due to no barriers between their individual members.

A population is a collection of individuals belonging to the same species that are present in the same area at a given moment. Similar to individual creatures, populations possess distinct features and/or traits including growth rate, age distribution, gender ratio, and death rate. These people belong to heterosexual groupings. Approximately 5,000,000 plant species, 10,000,000 animal species, and 2-3 million or less microbes are thought to exist on Earth today; of these, only 10% have been recognized and given names. i.e., the remaining 90% is a substantial amount that has not yet been identified.

Communities always undergo periodic changes as a result of variables including births, deaths, migrations, and the spread of individuals among other communities. The population can grow quickly if the resources that organisms require are plentiful and the environmental circumstances are favorable. Biotic potential is the capacity of a population to grow to its maximum under ideal circumstances. The majority of the time, environmental resistance limits the availability of scarce resources, unfavorable environmental conditions, climate, food, habitat, water, and other elements that promote population expansion. There is a maximum number of people that the environment can sustain in a population. Carrying capacity is the maximum number of people that a habitat or ecosystem can support. Numerous demographic traits are associated with ecology, including population density, population increase, and the actual population's composition.

9.3.1 Population Growth

Living organisms are known to grow and develop. For example, an expanding plant population will produce more new individuals in order to prevent the extinction of the species. The formula (Number of members of the initial population/time) may be used to represent the rate of population expansion in terms of the number of persons divided by the time period during which the population rises, or the time these additions occur. It is inevitable that only his descendants will make up the population if there is a decrease or rise in the number of individuals owing to migration, relocation, or entry from another region. It is possible to determine an individual's natality or birth, however as creatures always reproduce and eventually pass away, this will always be related to their death or mortality rate. The growth rate is what ensures that the type is maintained for the following generation. Exponential expansion is the fundamental idea behind the phenomena of population growth.

9.3.2 Population characteristics

A population possesses certain traits or qualities that are exclusive to the group as a whole, not to any one person. Measuring these attributes allows comparisons across different populations. These characteristics include dispersion, natality, mortality, and population density. Demography is the study of a population's group characteristics, how they change over time, and how to anticipate future changes.

9.3.3 Population Density

Migration, or the movement of individual organisms, is often what determines the quantity or size of a plant or animal population in a given region. Every species in a given location will never be the same in terms of size and population since both the physical environment and food have an impact. These kinds of plants will eventually decline and die on their own when the environmental factors do not support the habitat of animals and plants and the plants are unable to adapt to the less supporting environment.

Density, a population's essential attribute, represents the size of the population. It is commonly represented as the population biomass or number of persons per unit area or volume. There are two sorts of densities that are discussed: specialized (or ecological) density and crude density. The density per unit of total space is known as the crude density. Populations often do not occupy the entire region since not all of it may be livable. Hence, specific density refers to density per unit of livable space. It only encompasses the area of the complete universe that humans may truly occupy.

9.3.4 Determining population size

Population density and the area inhabited (geographic distribution) determine population size (or abundance). The usual method for estimating population size is to count every person in a smaller sample area and then extrapolate that number across a broader region. When the population is not mobile, it can be approximated by counting the number of people in a given region. When people are highly mobile and often shift locations, we can count them using a widely used technique known as the mark-recapture appro

This technique involves capturing, marking, and releasing a tiny random sample of the population to spread over the larger population. In a short period of time, the marked and unmarked people freely mix, resulting in a random mixing of the population. The number of marked and unmarked individuals is counted after resampling the population. Next, we assume that the marked-to-unmarked individual ratio in the second sample is equal to the marked-to-unmarked individual ratio in the first sample.

We can calculate total population size (N) by:

<u>Total individuals marked in first sample × Size of second sample N</u>

Number of marked individuals recaptured in second sample

This expression is known as the Lincoln-Peterson index to population size. To further grasp the mark-recapture technique, let's look at an example. Let's say we capture fifty Labeo rohita fish in a lake and label (color) them. The marked fish are then all released as soon as possible and as near to the collecting location as feasible. After allowing the population enough time to mingle randomly, we collect 40 fish (a second sample) a week later, of which 5 are previously marked fish. Assuming that there have been no fish births or deaths and no immigration or emigration—both of which are quite possible in a closed system such as a lake—the total population size of fish is 400 (50×40/5).

People of all ages make up a population at any particular moment. An age pyramid is the structure that results from plotting the age distribution (individuals per cent of a certain age or age group) for the population. The age pyramids typically display the age distribution of both males and females in a combined figure for the human population. The population's growth status is indicated by the form of the pyramids: (a) expanding, (b) constant, or (c) falling.

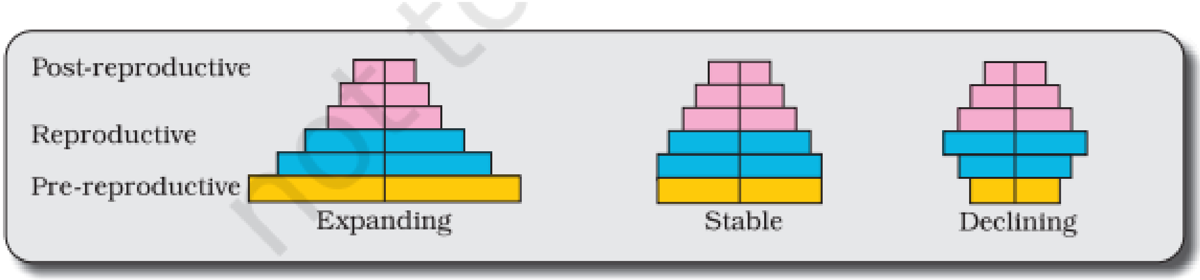


Figure **2: Representation of age pyramids**

The population structure of a plant is influenced by several factors, namely:

Natality

The term "natality" describes the birth rate of a population. The number of children born to each female in a certain amount of time is known as the natality rate, often known as the birth rate. Bases such as per population, per individual (which is the number of births per individual per unit of time), and per 1000 individuals are frequently used to express "rate." Maximum natality and ecological natality are two types of natality. The potential maximum number of individuals generated under perfect environmental conditions (i.e., no ecological limiting factors) is known as maximum natality, commonly known as absolute or physiological natality. It is a constant for a given population. Ecological or realized natality is the quantity of offspring generated**.**

Mortality

Naturally, all plant processes are disturbed by environmental disturbances like forest fires, and pole and tree seedling phases are abruptly terminated. And in some places, this will have an impact on the density of individuals.

9.4 Environmental factor

It is well recognized that three environmental conditions—soil pH, humidity, and air temperature—determine the measurement of environmental data. These elements' presence will result in a plant's growth and development. Similar to palm trees, sugar palm plants require certain growth conditions, including soil moisture, light intensity, wind speed, and height. When it comes to the cultivation of sugar palm trees, Paramentan (2013) states that the ideal air temperature range for both growth and development as well as reproduction is between 20 and 25 C. This poses a constraint for sugar palm trees. Because humidity keeps a plant's water content constant, it is considered a moist air condition for sugar palms. A plant that is exposed to excessive humidity may soon lose its air content or evaporate. Robust sugar palm trees thrive in environments with high annual rainfall of 1,200–3,500 mm. This kind of rainfall is possible in humid environments. Because of the high acid content in the soil, a pH of less than 7 is not ideal for the growth and development of sugar palm pole stages, because the high acid content in the soil causes the pH of the soil to be somewhat acidic, which impacts the growth difficulties in the seedling, weaning, and pole stages.

Exponential growth

If there are no restrictions on population growth, i.e., in a perfect, limitless environment, then the population will rise exponentially. The number of children born per individual is known as the per capita rate of growth, and it reaches its maximum in an ideal, limitless setting. The number rises in a geometric sequence of 2^0, 2^1, 2^2, 2^3, ... during exponential expansion. Geometric growth expresses the rate of rise as a constant fraction or an exponent (e.g., 2, 4, 8, 16) multiplied by a certain population. On the other hand, arithmetic growth refers to a pattern of growth that rises at a consistent rate per unit of time, such as 1, 2, 3, 4 or 1, 3, 5, 7... A basic model based on the exponential equation may be used to depict the exponential type of growth.

$dN/dt = rN$ or, $dN/dt * 1/N = r$ (N is the population size and r is intrinsic rate of increase)

The intrinsic rate of rise is the greatest per capita rate of increase during exponential population expansion in an ideal, limitless environment. The word biotic potential, often known as reproductive potential, is a commonly used and less specific way to refer to the highest value of r. It is the highest rate of per capita growth possible when there is no resistance from the environment. Environmental resistance is the culmination of all environmental elements working together to prevent an organism's full biotic potential. It encompasses abiotic elements like fire, flood, and drought as well as biotic elements like parasitism, competition, and predation. Different species have different levels of biotic potential; for example, populations of deer can expand more quickly than those of elephants.

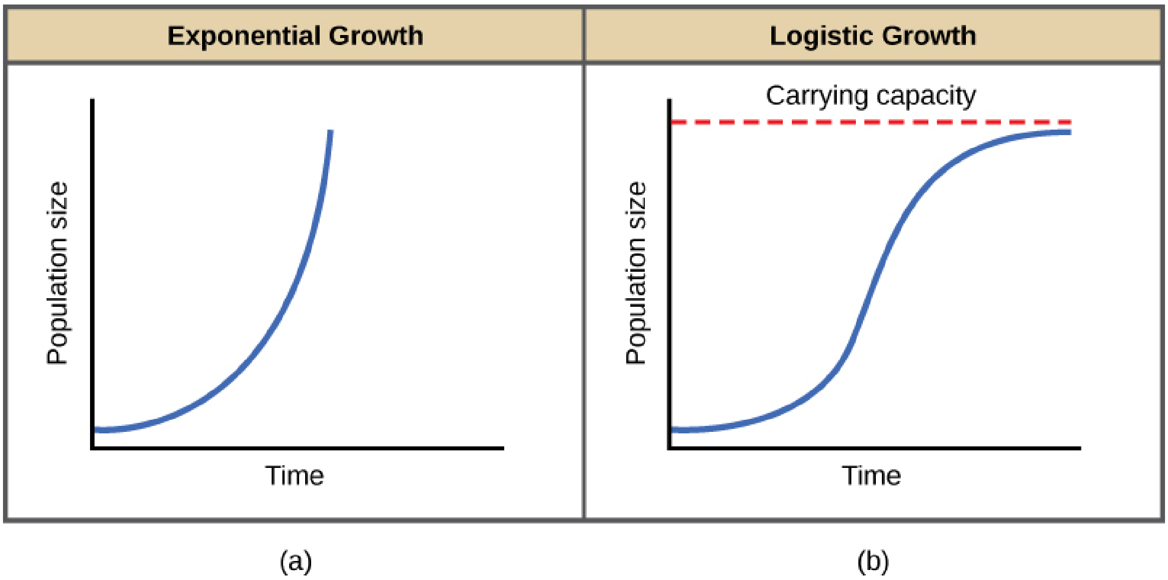


Figure 2.1: a) Exponential Growth curve   b) Logistic growth

The per capita birth rate (b) less the per capita death rate (d) is the definition of r in a closed population.

dN/dt = (b - d) N where, r = b – d

When per capita birth rate exceeds per capita death rate (b > d), the population is increasing and r is positive; when death rate exceeds birth rate (d > b), then r is negative and the population is decreasing.

The integral form of the exponential growth equation is:

$N_t = N_0 e^{rt}$

Where, N_t = Population size after time t,

N_0 = Population size at time zero,

r = Intrinsic rate of increase and

e = Exponent, a mathematical constant

$N_t / N_0 = e^{rt}$

By taking the natural log of both sides,

$\ln N_t - \ln N_0 = r t$

Every member of a species has the capacity to develop exponentially when there are infinite resources (food and space) available in their environment. Plotting population size (N) against time (t) yields a J-shaped growth curve for a population that grows exponentially at a constant rate.

Logistic Growth

Only in situations where there is an endless supply of natural resources is extended exponential growth feasible; this is not the case in the actual world. In his depiction of the "struggle for existence," Charles Darwin acknowledged this fact, stating that people will compete for few resources with members of their own species as well as those of other species. Natural selection holds that those who succeed are more likely to live longer and pass on their advantageous features to the following generation. The logistic growth model was created by population ecologists to simulate the realities of few resources.

Exponential growth is not sustainable in the actual world due to resource constraints. When there are few persons and lots of resources available, exponential growth may occur; but, as the population grows, the resources will run out and the pace of expansion will slow down. The growth rate will eventually level out or plateau. The carrying capacity, represented by the letter K, is the population size that results from the maximum population size that a certain ecosystem can support. Real populations frequently experience a population overgrowth that exceeds carrying capacity, leading to an increase in the death rate over the birth rate and a subsequent reduction in population size that either falls below or returns to carrying capacity. The majority of populations typically vary within an area's carrying capacity. A logistic growth graph produces the S-shaped curve. Compared to exponential growth, this population growth model is more accurate. An S-shaped curve is divided into three halves. Because there are many resources accessible and few persons, the expansion is exponential at first. Then, the growth rate slows when resources start to run out. Eventually, the population number barely changes over time as the growth rate reaches the environment's carrying capacity.

Bacteria cultured in a flask with plenty of nutrients may expand exponentially at first, whereas bacteria generated in a flask with few nutrition may grow logistically.

Population regulation

Are populations regulated? If so, how? What is the true meaning of population regulation? Numerous methods for population regulation have been uncovered by population ecologists. In general, population growth is controlled by either density-independent or density-dependent causes.

Density-dependent factors Population growth is influenced by density-dependent variables that rely on population density. Predation, sickness, and competition for resources are some of these issues. For instance, the population of rabbits may grow exponentially until intraspecific competition results in an increase in the death rate or a decrease in the birth rate, which leads to a net loss in the reproductive rate and a corresponding drop in population density. Density-dependent issues frequently include scarce resources like water, nutrients, and space.

Population size can be positively or negatively correlated with density-dependent characteristics. Either the birth rate decreases, the death rate rises, or both increase with population growth. It's a critical comment. Density-dependent variables do not, however, necessarily have a negative relationship with population size. In certain instances, growth rate rises as population size does. This phenomenon, which is an illustration of positive feedback, is known as the Allee effect (named for W. Allee, who initially reported it). Numerous factors affecting reproduction and survival can lead to a positive link between population size and fitness.

Mate restriction is a well-established cause of the Allee effect. In small populations, mate constraint lowers reproduction because sexual reproduction necessitates interaction between male and female gametes. The heightened susceptibility to predators is the second explanation. Greater numbers of prey have a lower per capita risk of predation than smaller populations do. Allee impacts, finally, might result from genetic causes. For many species, an Allee effect can result from inbreeding depression when population size is limited, lowering average fitness as population size decreases.

Density-independent factors Population density has no bearing on population increase; instead, variables other than density have an impact. Although their impacts are independent of population density, these elements are typically linked to abiotic events—changes in the physical environment—that either stimulate or inhibit population expansion. Seasonal variations in weather patterns and natural disasters like hurricanes and floods can be examples of density-independent causes.

9.5 Plant Interactions with Other Organisms

9.5.1 Competition

When one plant interferes with another's demand for the same environmental resource (such as light, minerals, or space) or when individuals within one population interfere with each other's needs for the same environmental resource, competition develops. In plants, competition usually occurs indirectly through the resource rather than directly between individual leaves. Although they live in slightly distinct microenvironments, plants that have the same life form and growth needs frequently compete with one another. As a result, the resource is often used more effectively, and as natural selection takes hold over time, the community becomes more diverse.

9.5.2 Allelopathy is a specific type of direct competition in which a fungus, such as Penicillium, or a species of plant generates a material that is harmful to another. In certain cases, the material prevents the seeds or spores from the producer from developing. When leaves fall and decompose, the chemicals may seep into the soil from the roots of the plant or build up in the soil surrounding it. Terpenes that volatilize and disperse as aerosols in the atmosphere make up some of them. Many plants are poisoned by the essential oils of plants belonging to the mint family and black walnut oil. Many types of seedlings are inhibited in their growth by the caffeine found in tea and coffee plants.

Plants that generate secondary metabolites—chemicals that shield the plants from herbivores—wage a different form of chemical warfare. Without a doubt, alterations in one species sparked responses and additional evolutionary changes in the other, leading to the coevolution of plants and their predators.

Some of the metabolites are substances that mimic hormones, enzymes, or other vital components of animal bodies rather than only acting as deterrents. One molecule inhibits the juvenile growth hormone, interfering with insect metabolism. Other substances, such as the alkaloids cocaine and morphine, have an impact on the nervous system of humans. Caffeine, while stimulating in humans, is poisonous to plants and deadly to fungus and insects. Certain plants contain estrogens, which are unknown to the plants but well-known to be important for human reproduction and a reason to be concerned while eating veggies.

Different types of defense compounds shield plants from fungal and bacterial invasions. When leaves or stems are injured, these compounds, known as phytoalexins, function as natural antibiotics and shield the plant against bacterial and fungal infections. Tobacco plants produce nicotine in reaction to wounds.

9.5.3 Symbiosis

Two distinct species coexist in close, nearly eternal companionship when they are in a symbiotic relationship. The classic illustration of a symbiotic relationship between a cyanobacterium or alga and a fungus is seen in lichens. Another example of a symbiotic relationship between fungus and vascular plant root cells is mycorrhizae. A symbiosis is referred to as mutualism if the interactions between the symbionts are beneficial to both parties; commensalism is used when one party gains and the connection is unimportant to the other; parasitism is used when one partner gains and the other suffers.

9.5.4 Mutualism

Mutualism is the word for direct plant-plant interactions that are advantageous to both species. Legumes and the nitrogen-fixing bacteria that reside in their root nodules are an excellent illustration of this arrangement, if we extend the definition of plants to include microorganisms. Legume photosynthesis provides the bacteria with the required glucose energy, while the legume benefits by receiving nitrogen from the bacterium. In fact, the free-living bacteria transform into bacteroids, which are unable to survive outside of the roots. Known as mycorrhizae, these fungal-root relationships are present in the great majority of higher plants. The fungus obtains a supply of carbon compounds from the plant, and the vascular plants benefit since the fungus is considerably better at collecting and concentrating phosphorus (and maybe other mineral nutrients) than the root tissue. Numerous mutualisms have evolved in seed plants, with the most advanced being the relationships between insects, birds, bats, and a few other creatures that guarantee flower pollination, particularly through cross-pollination. The colors, fragrances, and nectars of the flowers draw pollinators to them, and once they are there, a variety of structural floral adaptations ensure that the bee receives a dusting of pollen to carry to the next flower it visits. The plant receives a messenger service that is more efficient than random breezes, and the pollinator receives sustenance.

Fruit and seed distribution systems are also highly developed, coevolved mutualisms. Succulent edible fruits, which are frequently found on plants that generate seeds with hard seed coats, are excellent dispersion tools for bigger animals due to their fragrances and colors. The covering could be so impenetrable to water that it prevents germination unless a chemical solvent or mechanical abrasion is used. Birds' gizzards are efficient grinders, while mammals' stomach acids remove a large portion of the hard-coated seed coat before the seeds are evacuated in feces.

9.5.5 Commensalism

Commensalism is when two species dwell in close proximity to one another (the host), sharing resources such as shelter or other environments necessary for existence without endangering or benefiting the host. Neoregelia spp., which are hosts of orchids and bromeliads, reside on the trunk or branches of their hosts, where they get nutrients and water from the air or the bark's surface without entering the host's tissue. Vascular epiphytes are characterized by stocky roots and xeromorphic leaves that aid in absorbing and holding onto water (epiphyte means to live upon another). In the tropical rain forest, bryophytes, lichens, and fern epiphytes are so common that they frequently contain more plant material than the host trees they are attached to. The Saguaro cactus (Cereus giganteus) seedling growth, which usually takes place under the shade of paloverde trees or other plants, serves as another example of a facilitator. These plants provide the cactus with a better water-relationship environment and shield it from the sun's harmful rays. "Nurse" plants are frequently used in farming operations to temporarily enhance the environment for the primary crop. For instance, alfalfa and oat can be sown together to provide the alfalfa seedlings with improved soil surface moisture and shade from the oat.

9.5.6 Parasitism

Neither vascular plants that parasitize other vascular plants nor bacteria, viruses, or fungus have spared the plants as hosts for their parasitic existence. Since the definitions of mutualism, commensalism, and parasitism are dependent on assessments of the degree of damage or benefit to the symbionts, the distinctions between them are sometimes hazy. Vascular plant parasites are found in over 3,000 species worldwide. While some of them have completely lost the capacity to photosynthesize, others cling on their hosts' vascular systems and use the water and minerals that are being transported there for their own photosynthesis.

Summary

Ecology's study of plant population expansion entails comprehending the dynamics and variables that affect a plant's ability to multiply or decrease over time within a certain ecosystem. Combinations of biotic and abiotic variables impact its growth. Reproduction rates, competition for resources (such as light, water, and nutrients), illness, herbivory, and symbiotic interactions are important biotic variables. Climate, soil properties, water availability, and disturbances like as fire or human activity are all considered abiotic variables. A variety of mathematical models, including logistic and exponential growth models, may be used to simulate the growth of plant populations. A J-shaped curve is the product of exponential growth, which happens in perfect, limitless conditions and is defined by a constant growth rate. By taking environmental carrying capacity into consideration, logistic growth, on the other hand, produces an S-shaped curve where the growth rate falls as population size approaches the carrying limit. Growth rates are regulated by density-dependent variables, such competition and predation, which become increasingly important as population density rises. On the other hand, variables such as harsh weather or natural catastrophes have an impact on population size regardless of density. For conservation biology, agriculture, and ecosystem management, an understanding of plant population increase is crucial because it makes predictions about how plant communities will react to alterations in their environment and human activities. This information is essential for developing effective management plans that protect biodiversity, guarantee sustainable resource use, and lessen the effects of climate change.

Keywords

Symbiosis: A close living connection or evolutionary interaction between creatures of various species is called symbiosis.

Population regulation: the natural mechanisms that restrict population expansion. Allelopathy: the chemical suppression of one organism (plant or other) by another; Mutualism: advantageous to both involved organisms

MCQs

1. **What term describes the maximum population size an environment can sustain?**

   A) Birth rate

   B) Carrying capacity

   C) Death rate

   D) Exponential growth

   Ans: D)

2. **In the logistic growth model, what does the "S-shaped" curve represent?**

   A) Exponential growth

   B) Linear growth

   C) Logistic growth

   D) No growth

   Ans: C)

3. **In which stage of the logistic growth model does the growth rate decrease as the population approaches carrying capacity?**

   A) Lag phase

   B) Exponential phase

   C) Decline phase

   D) Plateau phase

4. **Which mathematical model is commonly used to describe the exponential growth of a plant population?**

   A) Logistic model

   B) Geometric model

   C) Linear model

   D) Exponential model

   Ans: D)

5. **What is the primary reason for a plant population to experience logistic growth rather than exponential growth in a natural environment?**

A) Unlimited resources

B) High reproductive rates

C) Limited resources and environmental resistance

D) Human intervention

Ans: C)

6. **What does the "r" represent in the equation dN/dt=rNdN/dt = rNdN/dt=rN for exponential growth?**

   A) Carrying capacity

   B) Birth rate

   C) Intrinsic rate of increase

   D) Population size

   Ans: C)

Short Questions

1. Define carrying capacity and explain its significance in plant population growth.
2. Describe the difference between exponential and logistic growth in plant populations.
3. Explain how density-independent factors can influence plant population growth. Provide examples.
4. What is the importance of studying plant population growth in ecology?
5. Illustrate and explain the phases of the logistic growth curve for a plant population.

UNIT-10
ECOSYSTEM

10.1 Objectives

- Explain type and components of ecosystem;
- Describe the food chain and food web;
- Explain the nutrient cycle

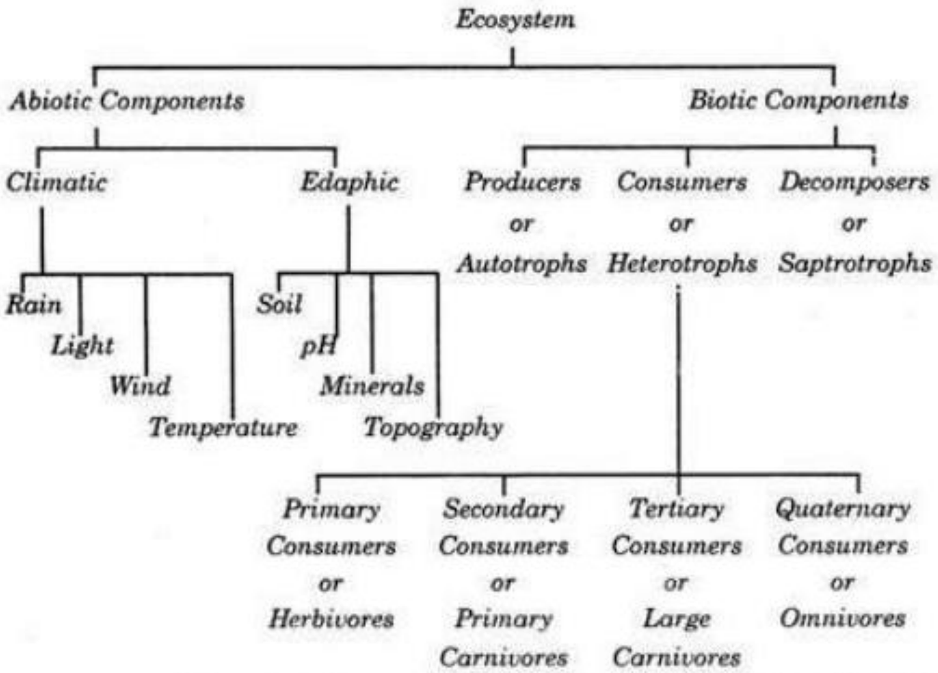
10.2 Concept of an Ecosystem

Living things are dependent on their non-living surroundings for resources and energy to survive. In other words, a biotic community interacts with its surroundings to form a stable system that is known as an ecosystem, which is a naturally occurring self-sufficient unit. Ecosystems are the areas of the natural world where organisms interact with one another and their surroundings. English botanist A.G. Tansley first used the term "ecosystem" in 1935. The structural and functional building block of ecology, or nature, an ecosystem comprises intricate interactions between its biotic—or living—and abiotic—or non-living—components. Ponds are an excellent illustration of ecosystems. Common examples of ecosystems include ponds, lakes, deserts, grasslands, meadows, and forests.

10.3 Structure and Function of an Ecosystem:

Each ecosystem has two main components:

(1) Abiotic (2) Biotic



Schematic Representation of the Structure of an Ecosystem.

(1) Abiotic components (Nonliving): The abiotic component can be grouped into following categories:-

(a) Climatic Factors: Which include rain, temperature, light, wind, humidity etc.

(b) Edaphic Factors: Which include soil, pH, topography minerals etc.

The functions of important factors in abiotic components are given below

- Compared to simple sediments, soils have far more complexity. They are made up of a variety of materials, including organic matter, living things, weathered rock fragments, and significantly changed soil mineral particles. For creatures, soils offer food, water, shelter, and a structural growth medium. Because of nitrogen cycling, the plant that grows on top of soil is intimately related to this aspect of an ecosystem.
- The atmosphere supplies oxygen for respiration and carbon dioxide for photosynthesis to species that live in ecosystems. Water is cycled between the Earth's surface and atmosphere through the processes of transpiration, evaporation, and precipitation.
- Ecosystems employ solar energy to warm the atmosphere as well as to evaporatively and transpiratorily release water into the atmosphere. Photosynthesis also requires sunlight. The energy required for plant growth and

metabolism, as well as the organic food needed by other living things, are produced via photosynthesis.

- Water makes up a very large portion of most living tissue—up to or even over 90%. Few cells' protoplasm can endure if their water content falls below 10%, and the majority of them perish if it falls below 30–50%.
- Mineral nutrients enter and are translocated within plants through the medium of water. It is also essential for photosynthetic chemical processes and for maintaining the turgidity of leaves. The soil and surface of the Earth provide water to plants and animals. This water originally came from precipitation that fell from the sky.
-

Structural Aspects

Components that make up the structural aspects of an ecosystem include:
1) Inorganic aspects – C, N, CO_2, H_2O.
2) Organic compounds – Protein, Carbohydrates, and Lipids – link Abiotic to biotic aspects.
3) Climatic regimes – Temperature, Moisture, Light & Topography.
4) Producers – Plants.
5) Macro consumers – Phagotrophs – Large animals.
6) Micro consumers – Saprotrophs, absorbers – Fungi.

Types of Ecosystems

Terrestrial Ecosystems	Aquatic Ecosystems
Forest	Pond
Grassland	Lake
Semi arid areas	Wetland
Deserts	River
Mountains	Delta
Islands	Marine

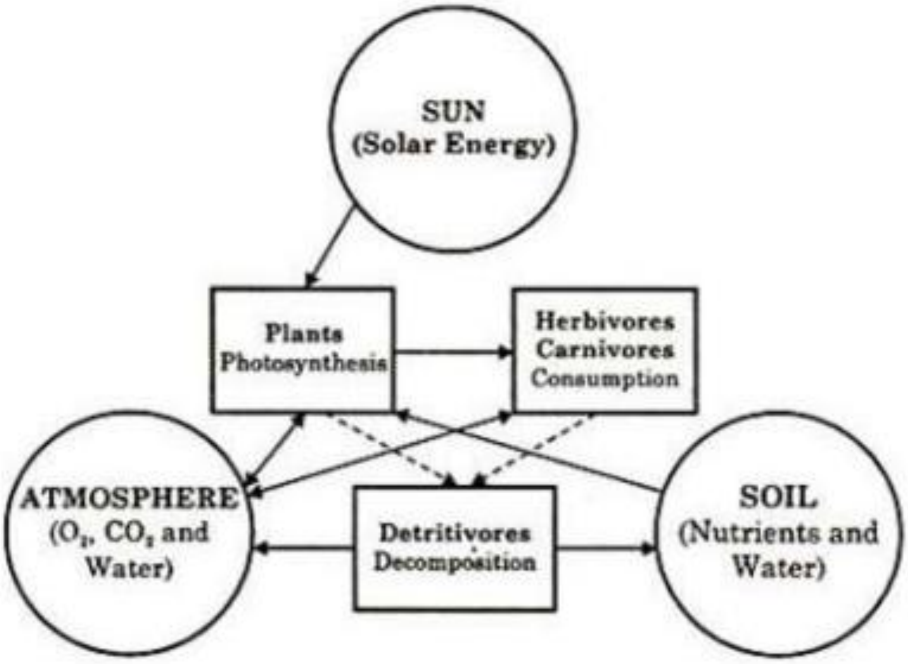
Figure:

2) Biotic components: Biotic Components

It is made up of all the elements that make up the living world, such as the numerous interconnected populations of various species coexisting in the same area. The animal, plant, and microbial populations are the ones that comprise the populations. The three groups that make up the biotic community are autotrophs, saprotrophs, and heterotrophs. In Greek, autotrophs (auto = self, trophos = feeder) are sometimes referred to as producers, transducers, or convertors. These are photosynthetic plants, often chlorophyll-bearing ones, that use the sun's assistance to create a high-energy complex organic molecule, or food, from inorganic basic materials. This process is known as photosynthesis. The foundation of every biotic system is the autortoph.

Autotrophs in terrestrial environments are often rooted plants. The primary producers in aquatic environments are the shallow-rooted, floating plants known as macrophytes and the floating plants known as phytoplankton.

The consumers, or heterotrophs (Greek: heteros, other; trophs, feeder), are often creatures that devour other species. The term "phagotroph" also refers to consumers (phago = to swallow or eat), whereas herbivores and carnivores are often macro consumers. Since herbivores consume only green plants, they are sometimes referred to as first order or main consumers. Cattle, deer, grasshoppers, rabbits, and other animals are examples of consumers in the terrestrial environment. Protozoans, crabs, etc. are consumers in the aquatic environment.



Relationship within an Ecosystem.

Figure:

Animals that hunt or consume other animals are known as carnivores. Animals that devour herbivorous species are classified as primary carnivores or second order consumers. For instance, foxes, frogs, tiny fish, raptors, snakes, etc.

Animals that consume primary carnivores are known as third order consumers or secondary carnivores. Like wolves, owls, peacocks, etc. Prey for certain bigger predators is secondary carnivores. Animals that consume secondary carnivores are referred to as quaternary consumers or tertiary carnivores. Take the tiger, lion, etc. as examples. There are no other animals that consume them. The term "top carnivores" also refers to bigger carnivores that are incapable of being further preyed upon.

10.4 Productivity

For every ecosystem to survive and operate, solar energy must be continuously inputted. The quantity of biomass or organic matter generated by plants during photosynthesis per unit area over time is known as primary production. It is stated as either energy (kcal m–2) or weight (g–2). Productivity is the rate of biomass production. The productivity of various ecosystems is given in terms of g –2 yr –1 or (kcal m–2) yr –1 for comparison. It is split into two categories: net primary productivity (NPP) and gross primary productivity (GPP). The rate at which organic matter is produced in an environment during photosynthesis is known as its gross primary productivity. Plants use a significant portion of GPP during transpiration. Net primary productivity (NPP) is calculated as gross primary production less respiration losses (R). R – GPP = NPP The biomass that is available for consumption by heterotrophs, or herbivores and decomposers, is known as net primary productivity. Consumers' rate of production of new organic matter is known as secondary productivity. The plant species that are present in a given region determine the primary productivity of that area. It also depends on a number of environmental variables, nutrition availability, and plant photosynthetic ability. As a result, it differs across various ecosystem types. The biosphere as a whole produce around 170 billion tons (dry weight) of organic matter annually as net primary production. Of this, the productivity of the seas is just 55 billion tons, while making up over 70% of the surface. Naturally, the remainder is on land.

Saprotrophs are also known as reducers or decomposers (from the Greek sapros, which means rotting, and trophos, which means feeder). They disintegrate the intricate organic components found in dead stuff, such as animals and plants. They do not consume the food, decomposers. Rather, they break down the organic material by secreting a digestive enzyme into the rotting remnants of deceased plants or animals. The complex organic chemicals in the dead matter are broken down by the enzymes. To sustain themselves, decomposers take in some of the byproducts of decomposition. During the mineralization process, the residual material is added to the substratum as minerals. Plants, who are the producers, employ the released minerals as nutrients again or as needed.

10.5 Energy flow

The primary source of energy needed by all living things is the chemical energy found in food.

Along the food chain, this energy is transferred to various trophic levels. The basis for this energy flow is provided by two distinct thermodynamic principles.

According to the first rule of thermodynamics, energy can only shift from one form to another and cannot be generated or destroyed.The second law of thermodynamics indicates that an increasing amount of energy is lost throughout the transfer process. One of the main things that allows for the survival of so many different kinds in the ecosystem is the flow of energy. Solar energy is the main energy source for nearly all living things on Earth. The fact that less than 50% of the sun's effective radiation reaches Earth is humorous. Effective radiation is defined as the radiation that plants can employ to perform photosynthesis.

The earth's atmosphere typically reflects back into space the majority of the solar energy that strikes it. The term PAR, or photosynthetically active radiation, refers to this effective radiation.

Only 2–10% of the energy that is obtained by photosynthetically active radiation is actually utilized by plants for the process of photosynthesis, whilst the remaining 40–50% is received by us. Since plants are the ecosystem's producers and all other creatures rely on them either directly or indirectly for existence, this percentage of PAR thus sustains life on Earth.

The food web and food chain facilitate the transfer of energy. Plants, which are the ecosystem's producers, use their chloroplasts to collect sunlight, and during the process of photosynthesis, some of that energy is converted into chemical energy. When herbivores eat plants as food and transform the chemical energy accumulated in plant products into kinetic energy, or heat, energy is degraded. This energy is stored in various organic products in the plants and transferred to the primary consumers in the food chain.

The secondary consumers come next. Additional deterioration will take place when these herbivores are eaten by first-order predators, or secondary consumers. Finally, energy will be lost once more when tertiary consumers eat the carnivores. As a result, energy flow is unidirectional in nature.

Organisms are categorized according to their trophic level, which is determined by the source of their food or nourishment. The first trophic level includes producers, followed by herbivores (primary consumers) in the second and carnivores (secondary consumers) in the third.

It's crucial to remember that energy content drops with increasing trophic level. Any deceased creature is transformed into detritus, or dead biomass, which provides decomposers with energy. For their energy needs, organisms at every trophic level rely on those at the lower trophic level. Every trophic level has a standing crop, which is a certain mass of living material present at a given time. The biomass, or mass of living things in a given area, is used to quantify standing crops. A species' biomass is reported as either fresh weight or dry weight.

Furthermore, the energy flow in a food chain abides by the 10 percent law. This rule states that 90% of energy is lost to space and just 10% is transmitted from one trophic level to the next.The term "food chain" refers to the recurrent eating and being eaten process that occurs as food energy moves from the producers via a succession of species (herbivores, carnivores, and decomposers).

Grazing food chains and debris food chains are the two main categories of food chains seen in nature. Ecosystems are dynamic due to the functional characteristics of food chains and energy movement. They serve as a bridge between the biotic and abiotic elements of an ecosystem.

An ecosystem's functional characteristics enable the interdependence of its constituent elements. The natural events or energy exchanges that occur in living organism across the globe's many biomes are known as ecosystem functions. For instance, green leaves produce food that is subsequently ingested by herbivores and carnivores, while roots collect nutrients from the ground. Decomposers perform the operations that reduce complicated organic components into simply comprehended inorganic products that manufacturers can employ.

The flow of nutrients and energy within the food chain is the essence of ecosystem activities. These exchanges sustain the planet's plant and animal life as well as the decomposition of organic materials and the production of biomass. The ecosystem's many functions are all made possible by well-regulated and balanced processes.

10.6 Food chain

A food chain is the arrangement of living things in a community wherein one creature feeds on the others and is fed by them in return to exchange energy. Another definition of a food chain is "a chain of organisms that exists in any natural community and transfers energy through them."

All living things, regardless of their size or environment, require food in order to thrive, from microscopic algae to enormous blue whales. In many ecosystems, the structure of the food chain varies depending on the species. Every food chain serves as an essential conduit for nutrients and energy within the environment.

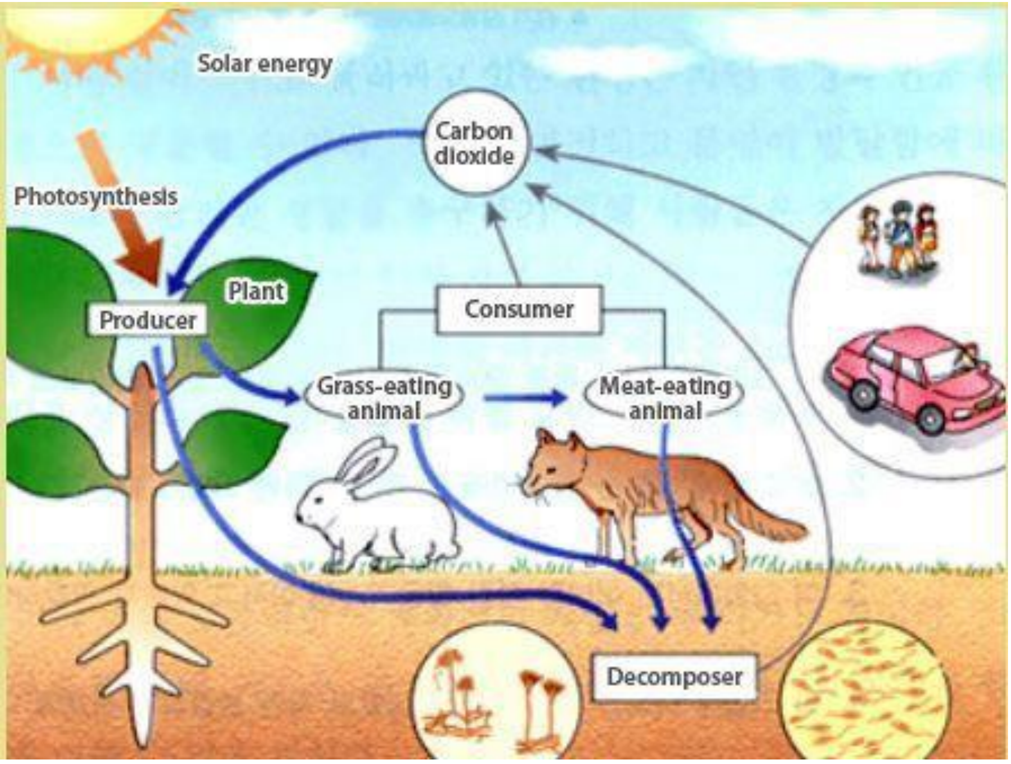


Figure 4.1: Food chain

The African-Arab scholar and philosopher Al-Jahiz originally described food chains in the ninth century. Charles Elton popularized the concept in a book he wrote in 1927.

A producer, like plants, is the first link in a food chain. The foundation of the food chains is the producer. Next, there are several order consumers. species that consume other species are called consumers. With the exception of the initial organism, every creature in a food chain is a consumer.

Because they employ photosynthesis to create their own food, plants are known as producers while consumers depends on plants or other animals for food. Every creature receives energy from the ones at the levels below it in a particular food chain. There is consistent energy transmission at every link in a food chain. The body does not absorb all of the energy at a given level of the cycle in the following stage.

10.6.1 Trophic Levels in a Food Chain

The various groupings of organisms in a food chain are referred to as trophic levels. They are listed below.

Producers (First Trophic Level) − Also referred to as autotrophs, synthesize their own food via photosynthesis. In every food chain, they make up the base. Autotrophs include plants, single-celled animals, certain kinds of bacteria, algae, etc.

Consumers (second trophic level) depends upon others for food.

Primary Consumers (Second Trophic Level) − eat the producers. They are called herbivores. Deer, turtle, and many types of birds are herbivores.

Secondary Consumers (Third Trophic Level) − eat herbivores. They can be carnivores (meat eaters) and omnivores (animals that eat both animals and plants).

Tertiary Consumers (Fourth Trophic Level) − eat other carnivores.

Decomposers − Decomposers, who are sometimes absent from the visual depiction of the food chain, are crucial to its completion. These creatures decompose garbage and dead organic matter. The primary decomposers in many ecosystems are bacteria and fungi, which derive their metabolic energy from the chemical energy found in waste products and dead matter.

There are two types of food chains:

(i) Grazing food chains: It begins with the green plants, which provide food for herbivores, who then provide food for predators. Such a food chain places an immediate demand on ecosystems for solar radiation.

Thus, the autotrophic energy collection mechanism and the transfer of this collected energy to herbivores are essential to this kind of cycle. This form of food chain is seen in the majority of natural ecosystems. Below is a simplified grazing food chain (GFC) diagram:

phytoplanktons →zooplanktons →Fish

or

the grasses →rabbit →Fox

(ii) Detritus food chains: It begins with detrivore creatures feeding on dead organic materials, which then provides food for carnivores, protozoa, and other species. Organic debris is the starting point of the detritus food chain (DFC). It is composed primarily of bacteria and fungus, which are heterotrophic decomposers. They break down detritus, or dead organic stuff, to obtain the energy and nutrients they need. Another name for them is saprotrophs (sapro: to break down). Digestive enzymes secreted by decomposers break down trash and dead materials into basic inorganic components that are then absorbed by them.

Within an aquatic ecosystem, GFC serves as the main energy transfer pathway. In contrast, a substantially higher proportion of energy moves via the debris food chain in an alien habitat than through the GFC. The grazing food chain and the detritus food chain may be related on certain levels. In a natural environment, certain species, such as crows and cockroaches, are omnivores, and some DFC creatures are prey for GFC animals.

Parasitic food chain

An additional food chain is the parasitic food chain. It generally starts with the host and ends with the parasite.

Knowing the food chain facilitates our understanding of the interactions and feeding relationships that exist between an organism and its environment. It also makes it possible for us to understand how energy moves across an ecosystem.

10.7 Food Web

The term "web" refers to a network. "A network of interrelated food chains so as to form multiple feeding relationships among different organism of a biotic community" is the definition of a food web.

In an ecosystem, a food chain cannot exist in isolation. There might be many chains that include the same food source. At the lower tropic level, the resource is capable of doing this.

Every food chain within an ecosystem is referred to as a food web. Understanding that every organism in an ecosystem is a link in a network of food chains is crucial

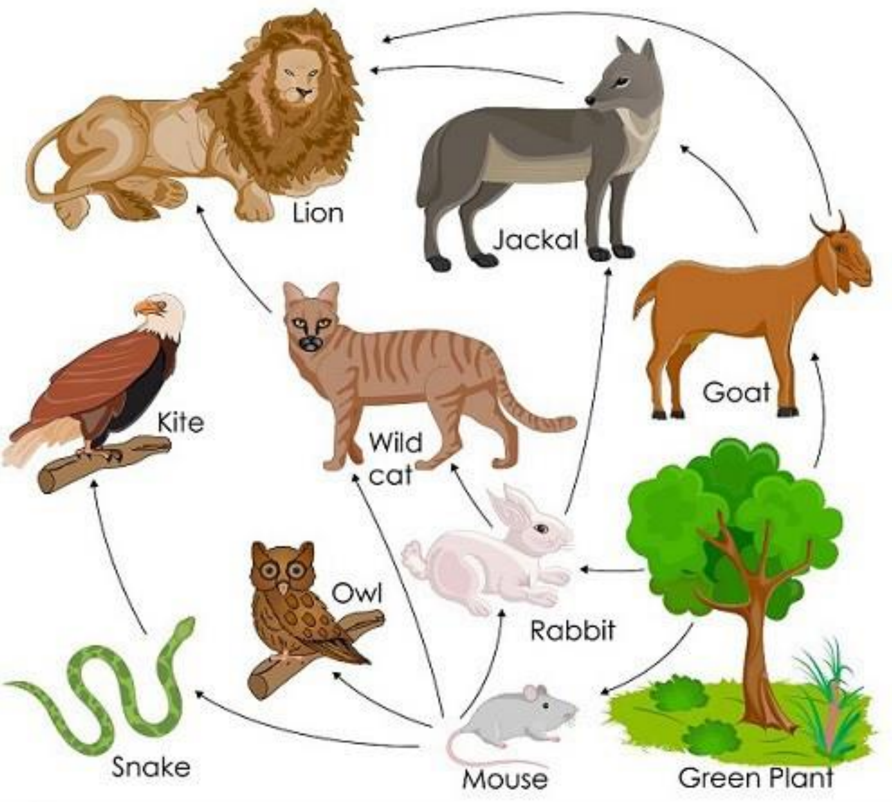


Figure 4.2: Food web

The only viable route for energy and nutrients to travel through the ecosystem is via a single food chain. A food web is made up of all the linked and overlapping food systems within an ecosystem.

Food webs are important resources for comprehending how plants support all ecosystems and food chains by giving the necessary nutrients and oxygen for life to exist and reproduce. The ecology is stabilized by the food web.

Quaternary consumers devour the tertiary consumers. Consider a hawk that preys on owls. Every food chain has an apex predator and an animal without natural enemies at the bottom (such as an alligator, hawk, or polar bear).

Differences between food chain and food web

Food chain	Food Web
1. Food chain is defined as the phenomenon of transfer of energy through series of organisms falling on successive trophic levels.	1. Food web is an interconnection of food chains which shows relation between them.
2. In food chains, usually member of high trophic level feed upon a single type of organism of lower trophic level.	2. In food web members of higher trophic level feed upon many organisms of lower trophic level.
3. In food chains, separate and isolated food chains increase the instability of the ecosystem.	3. In food web, stability of the ecosystem increases by the presence of complex food webs.
4. It comprises of only one chain.	4. It comprises of many chains.
5. Removal of one group of organism disturbs the whole chain.	5. Removal of one group of organism not at all disturbs food web.

10.8 Ecological Pyramid

It is a graphical (pyramidal) representation of the number of organisms, biomass, and productivity at each trophic level. It is also known as Energy Pyramid. They are as follows –

10.8.1 Pyramid of Biomass

This displays the quantity of live biomass at each trophic level that is present per unit area. The top predators are at the tip, while the producers are at the base of the drawing.

Typically, to determine the biomass pyramid, all organisms belonging to each trophic level are gathered independently and their dry weight is measured. Standing crop, defined as the mass of living creatures (biomass) or the number in a unit area, is the specific mass of living material at a given moment in each trophic level.

10.8.2 Upright Pyramid of Biomass

The majority of terrestrial ecosystems are composed of erect biomass pyramids with a sizable base of primary producers and a smaller trophic level positioned on top.
Producers or autotrophs have the highest biomass. The principal consumers at the next trophic level have a lower biomass than the producers. Comparatively speaking, secondary and tertiary customers make up a smaller portion of the market than its lowest level. There is remarkably little biomass at the apex of the pyramid.

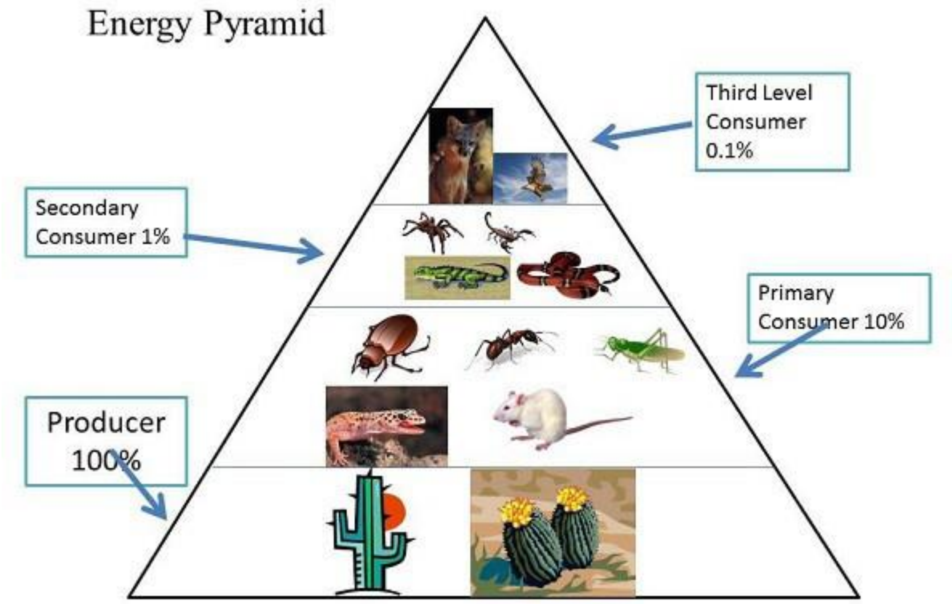


Figure **4.3: Upright pyramid of biomass**

10.8.3 Inverted Pyramid of Biomass

However, the majority of aquatic ecosystems have a reverse pyramidal shape. In this case, the biomass pyramid can take on an inverse shape. On the other hand, the aquatic ecosystem's numerical pyramid is erect.
The producers in a body of water are microscopic phytoplankton, which multiply and expand quickly. Under these circumstances, the base of the biomass pyramid is modest,

with the producer biomass supporting the heavier consumer biomass. It takes on an inverse form as a result.

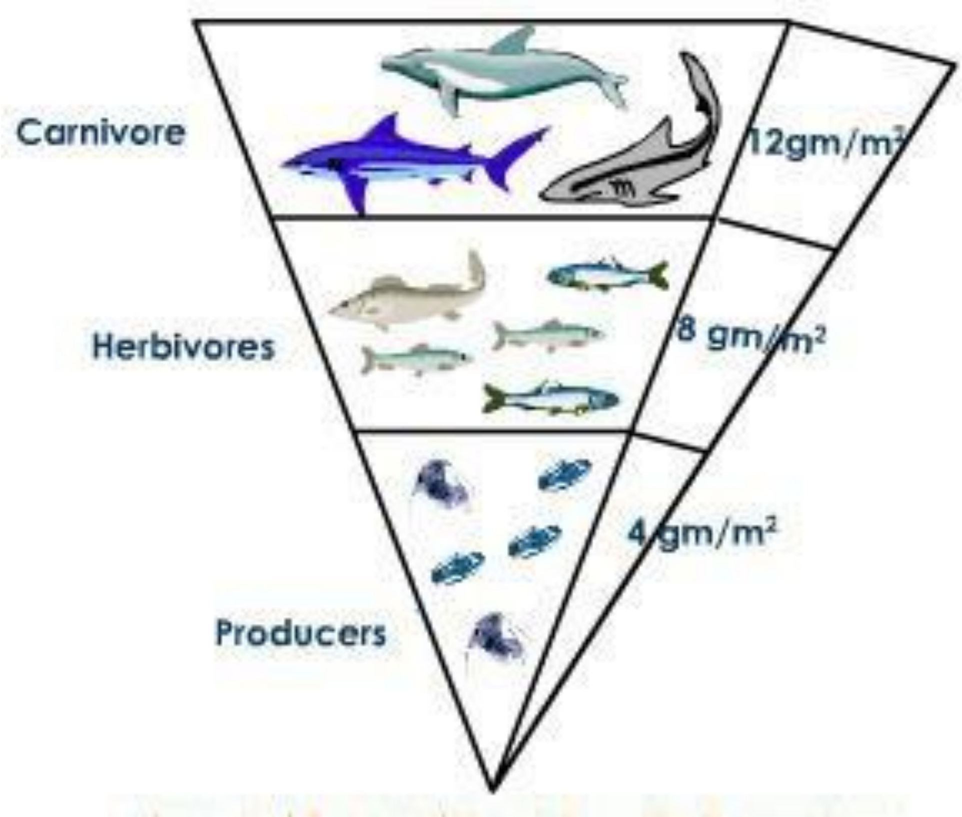


Figure: Inverted pyramid of biomass

10.8.4 Pyramid of Numbers

It is a graphical representation of the number of people in each trophic level per unit area. A greater number of producers often make up the base, whereas fewer top predators or carnivores tend to occupy the tip. The numerical pyramid's form differs depending on the ecology.

For instance, there are many autotrophs or producers per unit area in grassland or aquatic environments. Less herbivores are supported by the producers, and fewer carnivores are supported as a result.

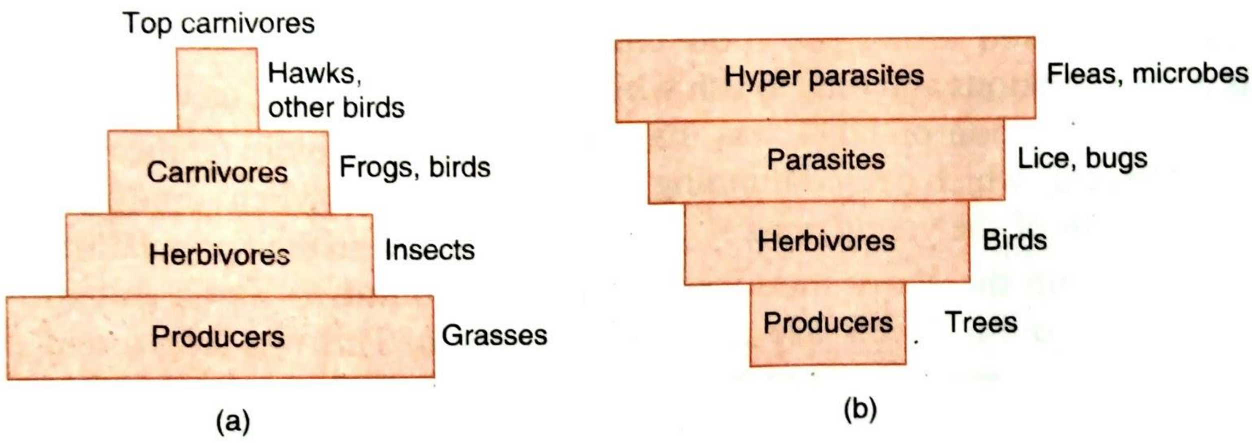


Figure 4.5: pyramid of number a) Upright b) Inverted

10.8.5 Upright Pyramid of Numbers

The number of people falls from the lower level to the upper level in an upright pyramid of numbers. The environments of ponds and grasslands are often home to this kind of pyramid. Because of its abundance, grass in a grassland environment is at the lowest trophic level, followed by herbivores (such as grasshoppers). The number of grasshoppers is quite less than that of grass. Then there are the main carnivores, such rats, which are far less common than grasshoppers. The secondary consumers, such snakes that eat rats, make up the next trophic level. Subsequently, there are apex predators like hawks, who consume snakes and have a smaller population than snakes.

10.8.6 Inverted Pyramid of Numbers

From the lower to the higher trophic levels, there are more individuals in this area. The environment of trees, for instance.

10.8.7 Pyramid of Energy

It is a diagram that shows how energy moves through the trophic levels of a food chain in a specific area of the natural world. Each trophic level's energy content is represented as an energy pyramid, with energy loss at each level moving to a higher trophic level.

The energy pyramid, also known as the trophic or ecological pyramid, is a helpful tool for calculating the amount of energy that moves up the food chain from one creature to another.

Moving up the trophic pyramid from the base to the top results in a reduction in energy. The energy pyramid is therefore continuously pointing upward.

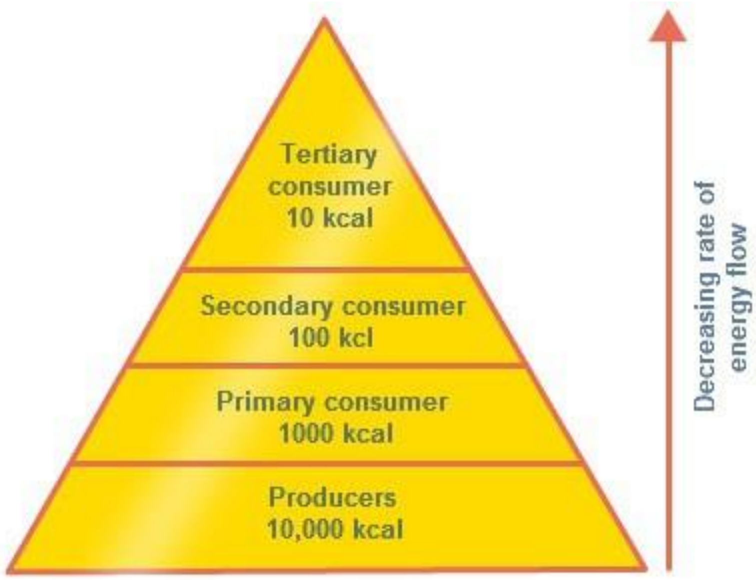


Figure 4.6: Upright pyramid of energy

10. 9 NUTRIENT CYCLING

Every element on Earth is continually recycled. The primary components that comprise organisms are oxygen, carbon, nitrogen, phosphorus, and sulfur. The movement of these kinds of chemicals and elements between living things and their physical surroundings is referred to as a biogeochemical cycle. Chemicals ingested by living things are returned to the land, air, and water by processes including decomposition, excretion, and respiration after moving up the food chain. An element frequently creates compounds with other elements as it progresses through this cycle as a result of natural interactions in the atmosphere, hydrosphere, or lithosphere as well as metabolic activities in living cells. We refer to this type of periodic material exchange as the "biogeochemical cycle" between live things and their non-living surroundings.

There are two types of nutrient cycles: sedimentary and gaseous. The reservoirs for the sedimentary cycle (such as the phosphorus and sulfur cycle) and gaseous type of nutrient cycle (such as the nitrogen and carbon cycle) are found in the Earth's crust and atmosphere, respectively.

The soil, moisture content, pH, temperature, and other environmental variables control how quickly nutrients are released into the atmosphere. The reservoir's purpose is to make up for the shortfall brought on by an imbalance in the rates of input and outflow.

10.9.1 Carbon Cycle

Through the process of photosynthesis, carbon is converted from carbohydrates into carbon dioxide, which is then absorbed by living things. The producers of these organic materials (food) then transfer them to the consumers (herbivores & carnivores). The process of respiration or the breakdown of plants and animals by the decomposers ultimately returns this carbon to the surrounding medium. Moreover, carbon is recycled when fossil fuels are burned.

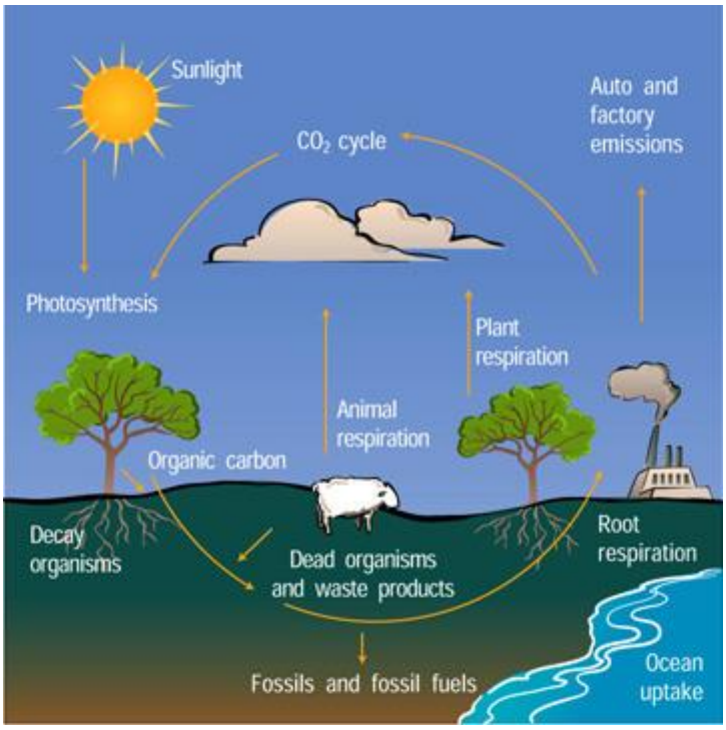


Figure: Carbon cycle

10.9.2 Nitrogen cycle

Life requires nitrogen as a necessary element. Instead of being immediately consumed by living things, nitrogen must be transformed into other organic substances.

Nitrogen may be transformed into various forms by various methods, which include: Ammonia is produced by bacteria that fix nitrogen from the atmosphere, and nitrifying bacteria turn ammonia into nitrate. Plants take up this transformed nitrate. Lightning may directly transform atmospheric nitrogen into nitrates.

Proteins and amino acids from deceased creatures are broken down by decomposers. Denitrification is the process by which the denitrifying bacteria convert ammonia to nitrogen and nitrates to nitrous oxide.

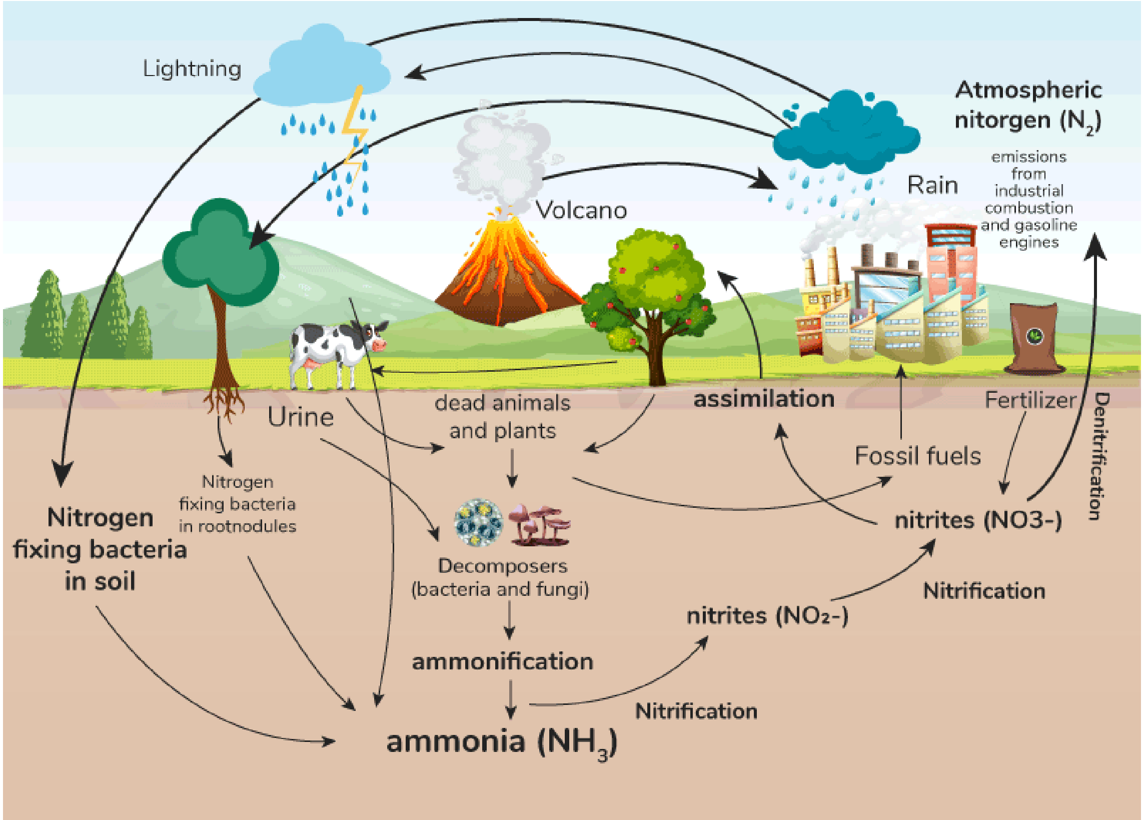


Figure: Nitrogen cycle

10.9.3 Hydrologic cycle or Water cycle

Water is necessary for life. Without water, no life can survive. Rain, snow, slush dew, and other forms of precipitation are the only sources of water on Earth. The term "water cycle" refers to the continual flow of water in the biosphere caused by water absorbed from the atmosphere and returning to it as water vapour as a consequence of direct evaporation and evapotranspiration (hydrological cycle). Earth is a watery planet in the solar system, with water covering nearly two thirds of its surface. Nevertheless, only a very little portion of this is accessible to plants and animals. The distribution of water on Earth's surface is not uniform. The majority of water on Earth, around 95%, is chemically bonded to rocks and does not cycle. Of the remaining 5%, 2.1% is found as polar ice caps and almost 97.3% is found in the seas. As a result, just 0.6% of the water is fresh water found in soil, ground, and atmospheric water vapor. The water cycle is fueled by two factors: 1) solar radiation, and 2) gravity. The water cycle involves two primary processes: precipitation and evaporation.

These two procedures switch places with one another. The heat energy of the sun causes the water in lakes, ponds, rivers, and streams to evaporate. Additionally, plants transpire enormous volumes of water. When water is left in the air, it condenses into clouds that move with the wind. In the mountains, clouds collide with the chilly air.

Evaporation removes 84% of the water from the surface of the seas on average. However precipitation accounts for 77% of its increase. Seven percent of the water that flows from land into rivers and seas is used to make up the ocean's evaporation deficit. On land, 23% of precipitation and 16% of evaporation occur.

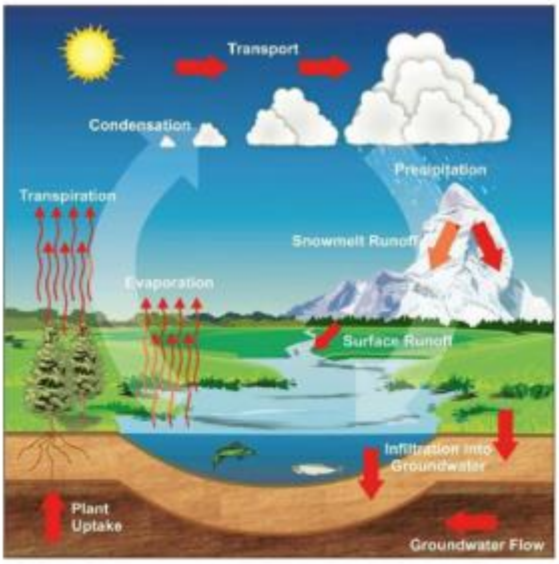


Figure: Water cycle

10.9.4 Phosphorus Cycle

Nucleic acids, biological membranes, and cellular energy transfer mechanisms all include phosphorus. Large amounts of this element are also required by many creatures in order to form their teeth, bones, and shells. Rock is a natural source of phosphorus because it includes phosphates, which are phosphorus ions. Small quantities of these phosphates dissolve in soil solution when rocks weather, and plant roots absorb them. Other animals, including herbivores, get this element from plants. Phosphate-solubilizing bacteria break down waste materials and dead creatures to release phosphorus. There is no respiratory release of phosphorus into the atmosphere, in contrast to the carbon cycle.

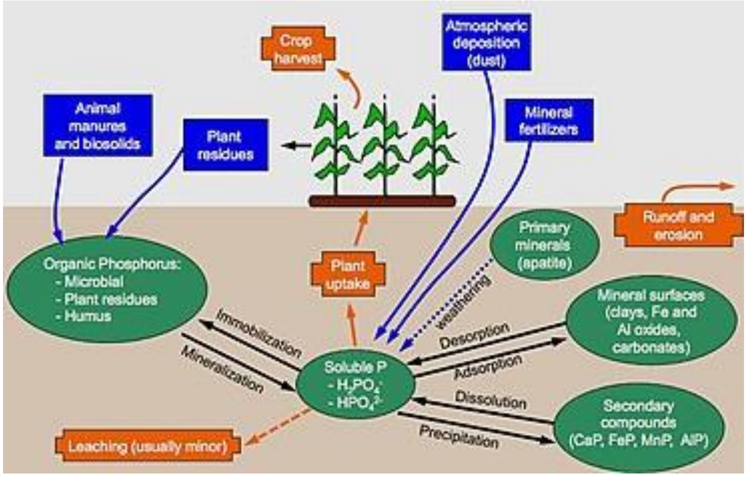


Figure: Phosphorus Cycle

Summary

A range of biotic and abiotic elements that work in concert with one another make up ecosystems. A few of the most crucial elements include soil, atmosphere, solar radiation, water, and living things. Both live things, or biotic factors, and non-living things, or abiotic factors, are present in an ecosystem. The environment's physical and chemical features are the non-living elements, also referred to as biotic factors. Energy may be shown moving sequentially from one tropic level to another within an ecosystem. Such a food chain places an immediate demand on ecosystems for solar radiation. The study of the food chain aids in our comprehension of the interactions and eating patterns amongst creatures within an ecosystem.

Keywords

Abiotic: The environment's nonliving components include things like soil, light, temperature, and air gases.

Consumer: it is an organism that gets its energy from eating another creature.

Decomposer: they break down organic materials.

Detritus: the accumulated organic waste left behind by deceased creatures; in a food web.

Food chain: The term "food chain" refers to a linked network of creatures that shows the relative positions of predators and prey.

Food web: A food web is an ecosystem's network of linked food chains. Herbivores are organisms that solely consume algae or plants. Heterotropy: An organism that consumes complex organic materials is said to exhibit heterotropy.

Omnivore: An organism that obtains its energy from both plants and meat. Producers employ the process of photosynthesis.

MCQs

1. Which one is the important biotic factors in ecosystems:

I. Temperature.

II. Water.

III. Wind.

A. I only.

B. II only.

C. III only.

D. I, II, and III.

Ans. D)

2. All of the following statements about ecology are correct except:

A. The study of ecology examines how biotic and abiotic elements of the ecosystem interact.

B. The study of ecology is distinct from the study of natural selection and the history of evolution.

C. Ecologists may research organismal populations and communities.

D. Ecology encompasses a progressively wider range of organizational levels, from people to ecosystems.

Ans. B)

3. Choose the correct sequence of arrangement from most to least inclusive:

A. Ecosystem, community, population, individual.

B. Community, ecosystem, individual, population.

C. Individual, population, community, ecosystem.
D. Population, ecosystem, individual, community.

Ans. A)

4. Choose the correct biotic factors that can affect the structure and organization of biological communities:

A. Nutrient availability, soil pH, light intensity.
B. Precipitation, wind, temperature.
C. Predation, competition, disease.
D. None of these.

Ans. C)

5. Landscape ecology is best described as the study of:

A. The array of interacting species within a community.
B. A biotic factor and the community of species that exist in a particular area.
C. The factors affecting the abundance of single species.
D. Related arrays of ecosystems.

Ans. D)

Answers:

1. (d) **2. (b)** **3. (a)** **4. (c)** **5. (d)**

Important Questions

1. Explain the concept of an ecosystem.
2. Discuss the energy flow in the ecosystem.
3. Explain about structure and function of an ecosystem.
4. What are the functions of management?
5. Explain about food chains, and food webs.
6. What are ecological pyramids?
7. Discuss about the producers, consumers and decomposers.
8. What are difference between consumers and decomposers?

UNIT-11
SUCCESSION & ADAPTION

11.1 Objectives

Explain the causes of succession;

- Describe the types of succession;
- Explain the processes of succession; and
- Explain the ecological adaptation

11.2 INTRODUCTION

Ecological succession, sometimes referred to as community development, is the slow alteration in species composition and community activities over time.

For the purpose of managing ecosystems, as well as for the knowledge of vegetation potential and dynamic changes in the landscape, it is crucial to comprehend the process, rates, and pattern of ecological succession. Two categories of changes can be distinguished in terms of ecological and community standing, those that happen over a medium time scale, such in 1–1000 years, and those that happen over a geological time scale (million years).

Palaeoecological changes are community changes that take place across a geological time span. Based on fossil records like as leaves, twigs, cones, pollen, and seeds, these modifications are synthesized. For instance, fossil evidence suggests that during the tertiary era, the vegetation in the Indian desert of Rajasthan was mostly composed of tree species associated with wet environments. Later, as a result of the environment being drier, desert flora took over.

11.3 CAUSES AND TRENDS OF SUCCESSION

The causes of succession are as follows:

- Initial/Initiating causes: These include both biotic and climatic factors. The elements include wind, fire, erosion and deposition, biological activity, etc. These factors either leave the land barren or wipe off the local people.
- Ecesis/Persistent causes: These are the mechanisms—migration, ecesis, aggregation, competition, response, etc.—that lead to repeated waves of

population growth as a consequence of modifications, mostly in the edaphic characteristics of the region.

- Stabilizing causes: These bring about the community's stabilization. Clements asserts that the area's climate is the primary source of stability and that other elements are merely incidental.
-

Trends in Succession

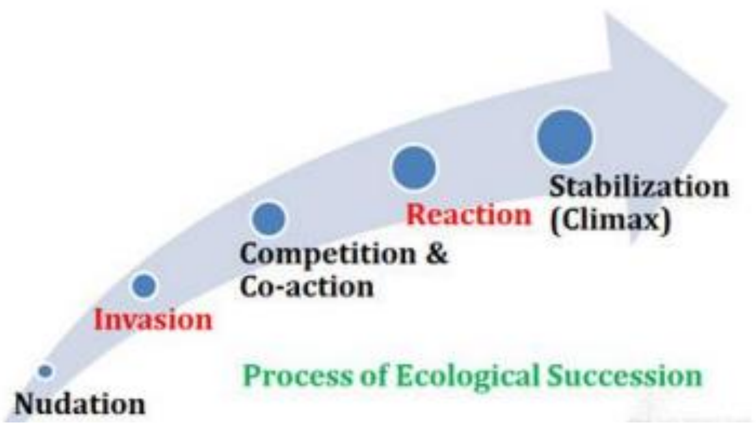
i. Variations in the species composition (i.e., the number of species often increases and plant types vary regularly with succession).

ii. A shift in diversity or variety (species tend to become more diverse as they go through succession).

iii. A steady rise in biomass, or the total amount of organic matter—both alive and dead.

iv. A change in the metabolism of the population, marked by an increase in respiration and a reduction in output. P/R>1 (P=production, R=respiration) in a young pond, P/R=1, P/R<1 in a stable pond (heterotrophic succession).

GENERAL PROCESS OF SUCCESSION



1. **Nudation**: It is the first step in ecological succession. The formation of a barren region devoid of all living things. Numerous factors, including landslides, erosion, deposition, and other catastrophic agencies, might contribute to the area's development. Possible reasons of nudity include:
    - Topographic: Landslide, earthquake, volcanic activity, erosion of soil, etc
    - Climate: Ice sheets, arid spells, storms with hail, frost, fire, etc.

- Biotic: The loss of forests as a result of urbanization, agriculture growth, industrialization, and illnesses brought on by bacteria, fungus, etc.

Ø *Definition*: Nudation is the development of a bare area (an area without any life form).

Figure: Nudation

2. **Invasion**: The successful emergence of a species in a barren region is called invasion. In reality, the species travels from any other location to this new location. It entails going through multiple phases.

   i. Migration, also known as dispersal: The species' seeds, spores, or other propagules arrive at the bare spot. The wind, water, animals, and humans are the agents that cause dispersion.

   ii. Ecesis (establishment): After a species arrives in a region, it successfully establishes itself by adapting to the local conditions. This process is called ecesis. The biotic, edaphic, and climatic conditions affect this process. A plant's ability to thrive is influenced by biotic, edaphic, and climate variables. Following migration, seeds or propagules in plants germinate, seedlings develop, and adults begin to procreate. Few of them can survive in such hard, prehistoric conditions, and as a result, the majority of them vanish. Individuals of a species establish themselves in the environment as a result of ecesis.

   iii. Aggregation: A species' individuals proliferate and become closer to one another as a result of reproduction.

Figure: Invasion

3. **Competition and coaction**: This phenomenon is the battle for survival between two or more organisms that are growing in the same region and making progressively identical demands of the soil. Usually, the conflict involves two members of the same species who have comparable needs in terms of resources like light, water, nutrients, and space. Competition may occur intraspecifically (among members of the same species) or interspecifically (between two distinct species). Competition leads to the elimination of weak individuals and the retention of stronger ones. The dead remains of the exterminated plants and animals decompose and nourish the soil with humus.

4.

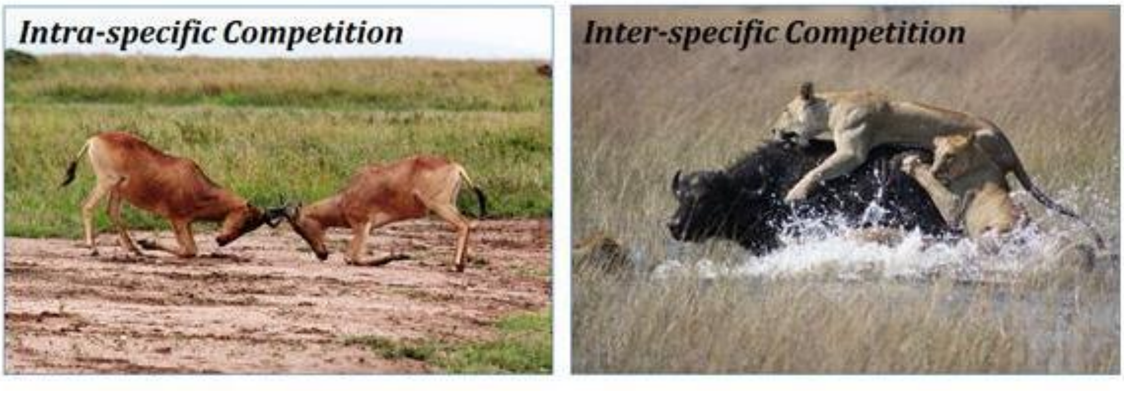


Figure: Ecological competition

5. **Reaction:** The most crucial phase of the succession is this one. Reaction is the term used to describe the process by which living things alter their surroundings. Reactions cause changes in the environment's soil, water, light, temperature, and other elements.

   For instance, when humus is added to the soil over time, plants alter the composition and texture of the soil. Because of all of these, the environment changes and becomes inappropriate for the current community, which eventually gets replaced by another group.

6. **Climax community**: Individual responses affect the environment more broadly as a whole. If there is forest as the climax vegetation, the local climate is genuinely altered. Until the formation of the climax community, the responses maintain the vegetation in an active condition. Despite the fact that vegetation is never considered steady in a literal sense. However, when the community reaches maturity and becomes less susceptible to future mesic changes, it can be considered rather stable. Consequently, we witness the emergence of a community that coexists peacefully with its surroundings as a consequence of its responses.

Figure: different type of climaxes in a ecological succession

11.3.1 DIFFERENT TYPES OF SUCCESSIONS

1. **Primary succession** Primary succession is the process of succession starting from a primary bare region or primitive substratum that hasn't had any physical alterations from organisms. Pioneers are the first class of plants to establish themselves there. Prisere is the term for the sequence of developmental phases. For instance, succession on a rock that is barren (lithosere).

2. **Secondary succession:** This type of succession occurs when it begins in a previously inhabited but cleared-off secondary region. Subseres are the developmental phases that follow one another. In subseres, the substratum is composed of humus, preexisting soil, and maybe seeds. Compared to primary succession, the rate of change is faster and the completion period is substantially shorter. For instance, succession in a forest region where severe natural disasters have destroyed the vegetation.

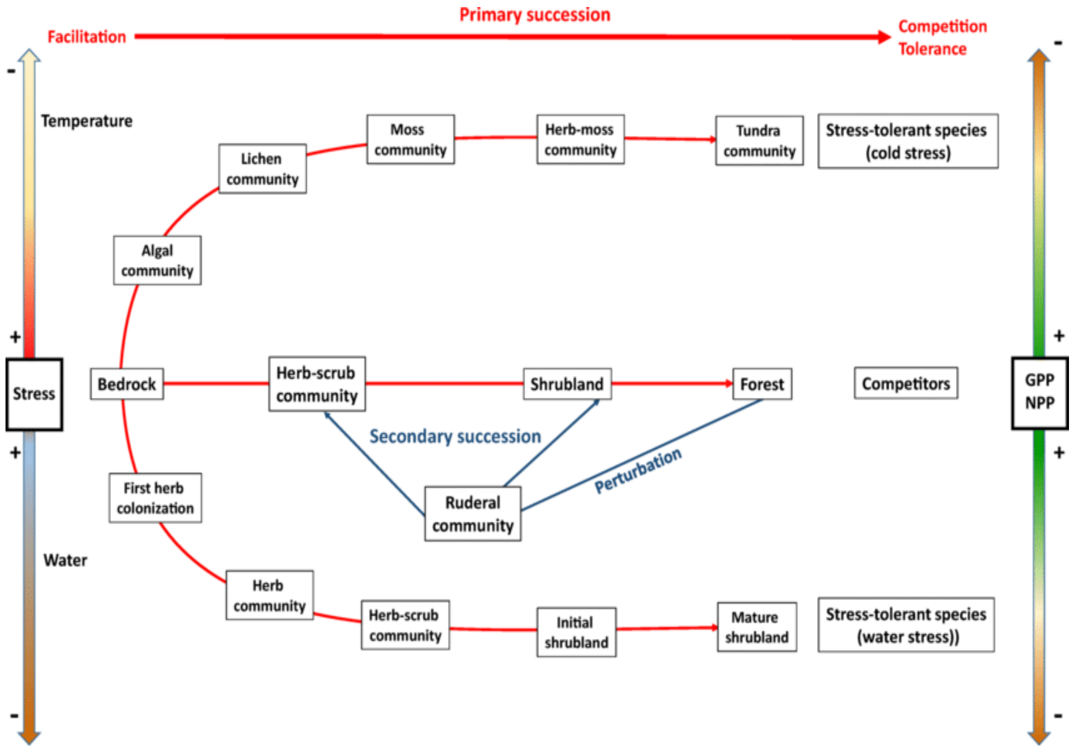


Figure: primary and secondary succession in terrestrial ecosystems

3. **Autotrophic succession**: A succession in which autotrophic species, such as green plants, predominate early and persist throughout. The energy flow starts in an environment that is primarily inorganic and continues endlessly. The organic matter content is gradually rising and is being sustained by energy flow.
4. **Heterotrophic succession**: a kind of succession in which animals, fungus, and bacteria predominate early on. The energy content gradually decreases and it starts in an environment that is mostly organic.
5. **Induced succession:** The production of the climax community is lower than that of the starting communities. In a climax community, organic matter production is nearly balanced by respiration. As a result, not much is left for human harvesting.
6. **Allogenic succession**: This occurs when significant environmental alterations take place that are outside the purview of native species. Winds, dust bowls, and dry spells alter the vegetation's pattern. External forces that alter the environment include climatic shifts, nutrient loss from the soil, a rise in the concentration of salt in the soil, and sand or salt deposition.
7. **Autogenic succession**: A succession that happens as a result of the local population changing its own surroundings. Plants in a developmental condition, for instance, alter their environment at first to promote their growth, but these modifications continue past the point of maximum benefit, making the environment unsuitable for the plants. It creates the conditions for the emergence of a different kind of plant community.
8. **Retrogressive succession**: Due to the harmful impacts of organisms, climax vegetation can occasionally decline and be replaced by a community from an earlier stage of succession. Sometimes the process of succession becomes retrogressive rather than progressive, e.g., a forest may turn into grassland or shrubby areas, and the formation of disturbed communities is prevented.
9. **Deflected succession**: A succession in which a successional type is either added to or substituted for, rather than going through the regular phases of development, by the vegetation.
10. **Serule (Microsere)**: A microhabitat, such as fallen logs of rotting wood, tree, bark, etc., is home to a microscopic succession of microorganisms such as

fungus, bacteria, actinomycetes, etc. Heterotrophic by nature, serules start out on substrates high in organic materials.

11.

11.4 Example of succession

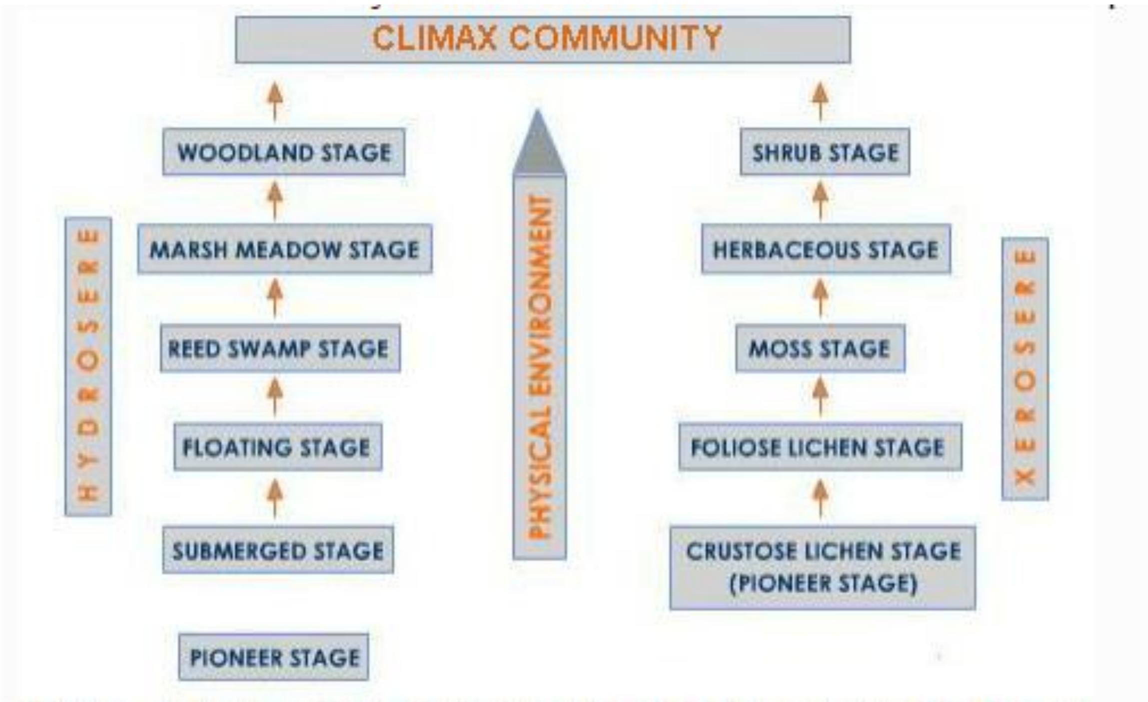


Figure: diagramatic representation of developmental stages of plant succession during hydrosere and xerosere

11.4.1 Hydrosere

Plant successions that start in marshes, ponds, lakes, or other bodies of water are referred to as hydrarchs, and distinct phases are known as hydroseres. In the center, the water is deep, but as it gets closer to the shore, it gets shallower.

1. **The pioneering phase** This is distinguished by a bottomless void of plant life. Phytoplankton is one of the pioneers. This includes tiny bacteria, diatoms, algae, and protozoa. Following death, this phytoplankton sinks to the bottom. The soils have a pH of no more than 5, which is much lower.

2. **Submerged Stage**: This occurs in areas when the water is no deeper than twenty feet. The plants are fully immersed in water. Pond weeds (Potamogeton), hornwort (Ceratophyllum), eelgrass (Vallisneria), water weed (Elodea),

Hydrilla, bladderwort (Utricularia), Chara, and ranunculus are notable examples of submerged plants. All of them are rooted plants. The dead leaves of these plants sink to the bottom and turn into humus. The humus holds the muddy, squishy soil together. Additionally, these plants aid in the deposition of soil particles near the bottom. These reactions cause the water to become shallow, which makes the environment unsuitable for submerged plants. Floating plants then take over the area.

3. **Floating stage**: This stage occurs in shallow water, usually between 6 and 8 feet. This stage include freefloating plants such as Pistia, Azolla, Lemna, Spirodella, Wolffia, Eichhornia, etc. and rooted plants like as Nyphaea (water lily), Nelumbium, Limnanthemum, Aponogeton, Monocharia, Trap. By now, the pond's water level has significantly dropped, making it shallower. As a result of their decomposition and death, humus is created, which raises the concentration of salts and organic matter in the water and eventually makes it unsuitable for these floating plants. Reed swamp vegetation eventually take their place.

4. **Reed-swamp stage:** Also referred to as the amphibious stage, this stage is characterized by partially submerged plants with roots at the bottom and leaves above the water's surface. It takes place in environments with water depths between one and four feet. Cattail (Typha), bulrush (Scirpus), reed grass (Phragmites), arrow head (Sagittaria), Rumex, and other significant plants are included in this stage. By blocking off the light from the floating plants, these plants further reduce the depth of the water by settling sediments washed into the lake and accelerating the buildup of humus. The environment has altered to one that is ideal for the growth of plants in the following seral stage, or marsh-meadow stage.

5. **Marsh-meadow Stage:** This stage contains hydrophytes, or plants that prefer water. The soil at this point turns marshy because the substratum is barely covered by 1-2 inches of water. There are now several different kinds of sedge invading here. Polygonum, spike rush (Eleocharis), carice (Carex), juncus, etc. Sedges can also be found mixed up with a variety of plant species, such as

bellflower (Campanula), marsh marigold (Caltha), and mint (Mentha). All of these hydrophytes respond to their surroundings by raising the surface through the binding of dirt that is brought by wind and water, accumulating plant waste, and transpiring large amounts of water. As a result, the soil is more suited for mesophytes and terrestrial plants. Because hydrophytes cannot survive in these conditions, they move inward, making place for grasses and woody plants.

6. **Woodland Stage:** In a dry environment, grasslands form; in a wet climate, woodlands with particular plants and tiny trees form. The plants that can withstand soggy soil surrounding their roots are what define this stage. The plant species of the forest stage include shrubby willow (Salix), dog woods (Cornus), buttonbush (Cephalanthus), alder (Alnus), cotton wood (Populus), tree willows, etc. As a result of these plants, the soil becomes unsuitable for them and is better suited for shade-tolerant herbs that support the growth of trees and shrubs.

7. **Climax forest:** This is the last phase of the hydrarch. Alder (Alnus), willow (Salix), cottonwood (Populus), elm (Ulmus), ash tree (Fraxinus), oak (Quercus), and other mixed forests are included in it. Following a few generations, a pure forest with hickories or oaks may appear.

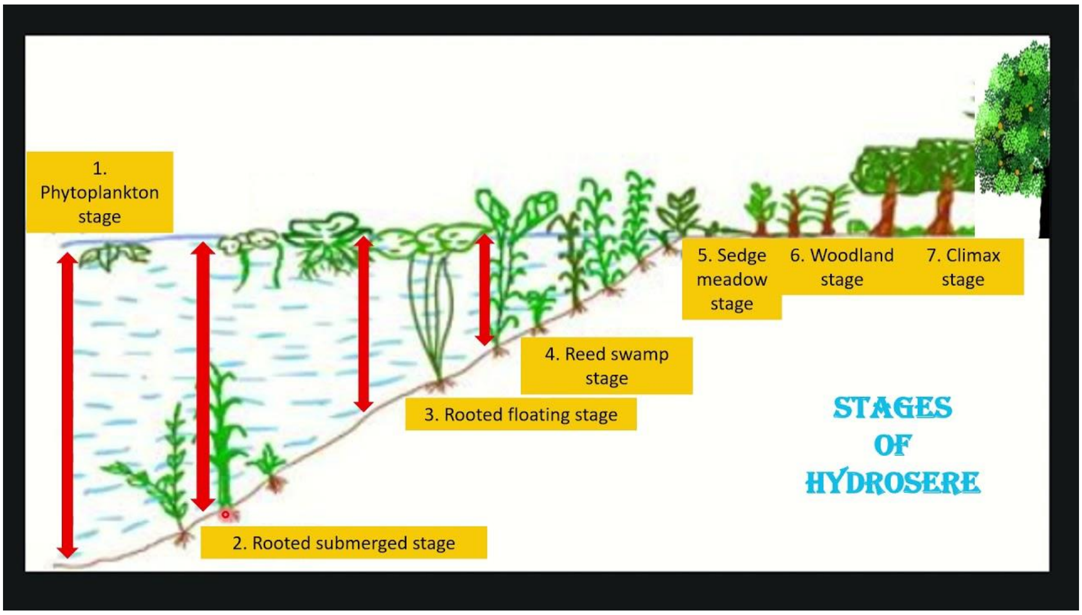


Figure: stages of hydrosere

11.4.2 Lithosere (Xerarch)

The succession of stages known as xerosere appear in barren, water-deficient places. The following is succession on a barefoot rock:

1. **Pioneer stage**: Extremely xeric and inhospitable rocky environment (Crustose lichen stage). Since the substratum does not absorb precipitation, there is no water.

   There's no system in place to retain nutrients. The temperature of the surface rises dramatically when exposed to sunlight. Only crustose lichens, which are able to withstand high levels of desiccation and harsh temperatures, have the potential to establish themselves as pioneer colonies in such environments. Through spores, bits of lichen, and wind-borne soredia, these lichens are able to reach the bare rock. The carbonic acid that the lichens create corrodes rock material.

   $Co2 + H2\ o \rightarrow H2\ Co3$ Generally, species of Rhizocarpon, Rinodena, Lecidea and Lecanora establish themselves on the bare rocks.

2. **Foliose Lichen stage**: When a small amount of soil has accumulated on the unweathered section of rock and in depressions or other somewhat less exposed conditions, foliose lichens, or those adhered to the substratum at a single point or along a single edge, arise. They supplant the crustose form gradually. The crustose lichens may be totally shaded by these spreading, leaf-like thalli, which would cause the crustose species to wither and perish. Water is more likely to gather and soak above the foliaceous invaders. Vapor loss is significantly reduced. Lichen pieces carried by wind and water, dust particle lodge, and humus collect more quickly due to its slower rate of oxidation. The acid created by both live and dead plants keeps eroding the rocks more and more. It is plausible that the transition from crustose to foliage lichen represents a shift in environment. A new class of invaders emerges when the crustose give way to foliose species including Dermatocarpon, Parmelia, and Umbilicaria.

3. **Moss Stage:** When enough soil has gathered in the minuscule cracks and depressions, xerophytic mosses start to show themselves. These are common species of Polytrichum, Tortula, and Gerimmia. Wind-blown spores that become

trapped in little amounts of soil and along foliose lichens may have carried them over great distances before germinating. For nutrients and water, their rhizoids compete with those of foliose lichens. The height of the mosses' upright stems frequently surpassed that of the lichens. These pioneers have about the same ability to tolerate desiccation as lichens do

The most stringent foliose species that can coexist or be indexed are these ones. Foliose lichens may occasionally appear before the mosses. As the plants die below and continue to grow above, accumulating soil along the upright stems, they build up the substratum and continuously expand their territory. Usually, the soil beneath the cushion-like mat is at least one inch deep. Alongside mosses, crustose lichens such as Cladonia grow.

The mosses contribute significantly to the formation of a thick soil substrate by forming dense mats. Over the course of several years, their constant growth, death, and decay create a healthy soil that is ideal for the growth of herbaceous plants.

4. **Herbaceous Stage**: Certain xerophytic herbs, particularly short-lived annuals, have such a strong soil-forming and soil-holding response that their seeds can germinate and mature quickly. They have stunted development and grow slowly since the soil is still unfavorable and deficient in minerals. Conditions are also drought-ridden. These xeric plants' roots keep growing and eroding the rocks. As more humus accumulates, their dead remnants improve the soil even more. The invasive herbs that are flourishing in the neighboring areas include Saxifraga, Solidago, and Potentilla. The environment becomes less dry as they develop. Grass is accompanied by microfauna, fungus, and bacteria. Additional soil layers are added by their demise and degradation.

5. **Shrub stage**: These places are overrun by woody shrubs such as Sassafras, Rubus, and Rhus glabra. Herbs cannot grow under their shade and eventually perish. There is a reduction in wind velocity and an increase in humidity. When organic matter is added to the soil, its water-holding capacity rises and its texture and structure are altered, which helps tree seeds locate a good location to develop.

6. **The Climax Forest** The trees that give them rise are xeric, dwarf-sized, and grow in distinct directions. But when the climate gets more mesic, mesophytes take their place. Trees like Quercus and Tilia are found in climax communities.

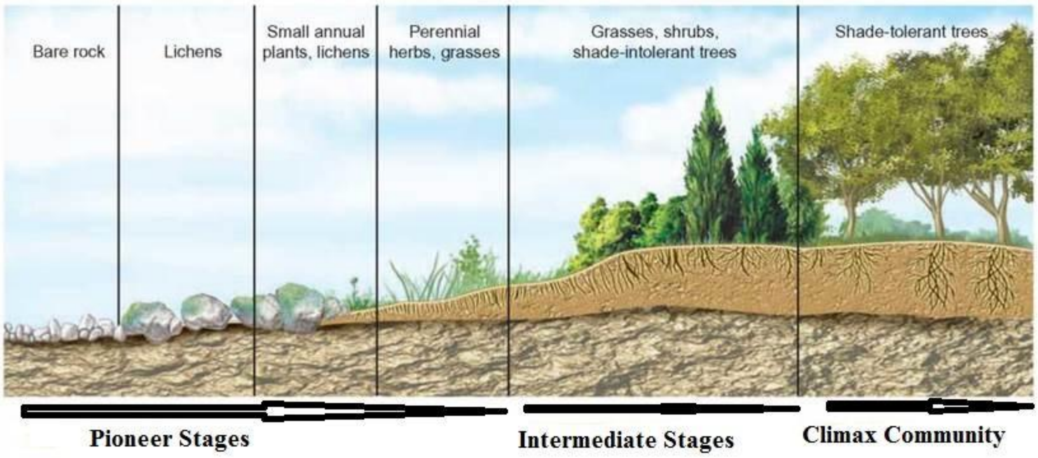


Figure: Stages of Lithosere

11.5 CLIMAX COMMUNITY

The climax community, which is the last result of succession after seral communities, is a rather stable community. Contrary to popular belief, climax communities are susceptible to change due to a variety of biotic and abiotic factors, including disease, aging, storms, and other environmental events. A climax community is defined by Hanson and Churchill (1961) as follows:

i. Its population, structure, and productivity are all in a steady state.

ii. The species populations within and between stands of the same climax community exhibit variety, stability, and homogeneity.

iii. Every stand is durable and self-maintaining.

iv. The climax undergoes constant replacement and fluctuation changes, and all environmental conditions impact its population and composition, resulting in a mosaic of climax types that match the mosaic of habitats.

Nature of Climax Community:

1 Monoclimax Concept

E.E. Clements, an American plant ecologist, first proposed this idea in 1916. He asserts that only one authentic climax community, primarily determined by climatic variables, is conceivable in a given climatic zone. A climatic climax is thus one of several types of climaxes. It is not impacted by geography or soil. Stable, edaphically managed societies are the exception rather than the real pinnacle. Clements offered four more names to account for a range of more or less stable communities that differed from the regional climatic maximum.

- Disclimax: the vegetation that replaces the true climax as a result of a persistent biological disturbance in the environment, such as the grasslands in the Gangetic Plains that arise from grazing in a deciduous forest climax.
- Subclimax: succession is arrested at a stage that persists for a long time in response to physiological or edaphic factors, before being replaced by the climatic climax.
- Preclimax: Some of the pine forests in the Himalaya are examples of preclimax localities that have a self-sustaining community distinct from the climatic climax;
- Postclimax: postclimax localities in the climatic climax region that have slightly "better moisture" may support a different yet self-sustaining community, such as the Terminalia arjuna community growing near river banks in a dry deciduous forest climax.

The monoclimax concept has drawn a lot of criticism because it recognized certain stabilized plant communities in the same area as subclimaxes that could only theoretically be replaced by the climax, while regionally dominant undisturbed vegetation that occupied the majority of the land surface was considered the real climax.

2. Polyclimax Concept

Whittaker (1953) and Tansley (1954) both endorsed this idea. This idea states that a climax reflects edaphic, biotic, and other environmental complex elements in addition to climatic ones. There are several more types of climaxes that differ from the local climatic climax. In a vast region, climax is determined by a number of factors other than climate. In order for edaphic, topography, and biotic climaxes to occur in specific locations within the same climatic zone, other elements such as biotic, topographic, and edaphic factors are equally crucial.

i. Climatic climax: The point at when the climate, soil, and terrain are normal and there is no disturbance.
ii. Edaphic climax: In contrast to the local climatic climax, self-perpetuating vegetation is produced by well-pronounced substrate features.
iii. Topographic climax: Topographic changes that result in a variety of microclimates, each of which supports self-sustaining vegetation.
iv. The fire climax: Self-perpetuating vegetation grows and fire-sensitive species are eliminated by repeated burning of the vegetation.
v. Zootic climax: A self-sustaining society that arises in response to zoological circumstances; for example, grazing creates the grassland's zootic climax.

Primary climaxes are topographic, edaphic, and climatic; secondary disclimaxes are zootic and fire.

11.5.1 Factors Determining the Nature of Climax Community:

The climax community's characteristics are influenced by a variety of elements, including soil nutrients, moisture, slope, exposure, and others. Another essential component of many climax communities is fire. Certain species that can withstand fire are given preference, whereas those that would have taken over are not. Certain pine species discharge their seeds in response to fire. In the absence of rivals, pine saplings develop quickly after the fire has subsided.

Another element that influences the type of climax community is grazing pressure. Grazing too much might convert grassland to shrub land. Cacti and shrubs can grow since they are not suitable as food. Numerous herbivore species may be suppressed by their grazing, favoring rival plants that are less appetizing as food.

Transient and cyclic climax:

The climax community is always changing with new members joining, but once it has become established, its overall look remains the same. All climaxes, nevertheless, do not last forever. It is impossible to establish a stable climax community for very long because of the negative impacts of natural disturbances like storms, fires, cold waves, seasons, etc. Fluctuations in a community's floristic and faunal makeup that are non-sequential, transient, and reversible are also typical. These are regarded as instances of fleeting climax. Temporal ponds and animal carcasses are examples of transient habitats and resources where transient climaxes form.

In seasonal ponds, the evolution of animal and plant communities is a straightforward example of a temporary peak. Pond waters often ruin the settlements because they either freeze solid in the winter or dry up in the summer. Every year during the growth season, these communities regenerate themselves from the pores and dormant phases that are left behind by microbes, plants, and animals.

The remains and excrement of deceased creatures provide as another illustration. They provide as resources for a multitude of scavengers and feeders of trash. In the savannas of Africa, a series of vultures feast on the corpse of a huge animal. The greatest amounts of meat are first consumed by the bigger, aggressive species, smaller species that extracts little pieces of flesh off the bones come next.

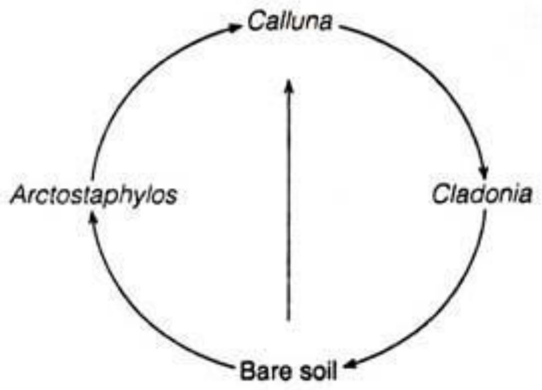
A few dominant species in a few simple communities may create a cyclic climax, which develops when each species becomes established only in association with some other species. The change in cyclic pattern occurs due to the life cycle of dominant species. Lastly, another kind of vulture invades the area, cracks open the bones, and feeds on the bone marrow. Later, scavenger mammals, maggots, and micro-organisms enter the area and ensure that nothing edible remains. After the feast is over, all of the scavengers disperse. Hence, no climax is present in this type of succession, or we may consider all of the scavengers as a part of a climax.

Typically, stable cyclic climaxes have a cyclic pattern, with bare substrate frequently occurring in one of the phases.

Cycles culminate in harsh physical circumstances as cold, high winds, etc. Watt explored examples of periodic variations in vegetation (1947). Watt discovered that the predominant shrub in Scotland was the dwarf Calluna heath. As it matures, the lichen Cladonia invades it and causes it to lose its vitality. The earth becomes bare as the lichen mat dies. Bearberry (Arctostaphylos) has taken over this exposed region. In response, Calluna invades it. Arctostaphylos and

Cladonia are permitted to take the space that Calluna has momentarily cleared out, but Calluna is the dominating plant.

Thus, the life history of this dominant plant controls the cyclic sequence:



The notion of climax community encompasses both mosaic patterns of distribution and cyclic patterns of change. The dynamic, self-evident state is the climax. The secret to climax is persistence. Every species in a climax ecosystem, even dominant species, may consistently reproduce well and endure in a region with a constant climate.

11.6 ECOLOGICAL ADAPTATIONS

Both cyclic patterns of change and mosaic patterns of distribution are included in the concept of climax communities. The culmination is the dynamic, self-evident condition. The ability to persevere is key to climax. In a region with a steady climate, all species in a climax ecosystem, even dominating species, may reliably reproduce and survive.

Ranges of tolerance

Every organism has a spectrum of tolerance to changes in the physical and chemical elements of its environment while it exists in the wild. The development, reproduction, and spread of the organism adapt to changes in the surrounding environment. A limiting condition or factor is any physical or chemical aspect of the environment that might prevent the growth of living things, either by being present insufficiently or excessively. Low temperatures, for instance, restrict plant development at higher elevations; water availability in deserts restricts plant growth; shifting salt levels impact organisms in estuaries; and low phosphorus availability restricts phytoplankton growth in deep lakes.

The Law of Liebig's Minimum

"Plant growth is dependent on the amount of food stuff which is present to it in minimum quantity," according to Liebig's law of minimum. Temperature and wetness are the two limiting elements that impact terrestrial organisms the most; oxygen and light are the two key limiting factors that affect aquatic plants and animals. When inflows of energy and materials balance outflows, steady state conditions are maintained by the laws of minimum and limiting factors.

11.6.1 The Tolerance Law

However, an organism's development and spread may be restricted by both too little and too much of a given item. Victor E. Shelford added the idea of the influence of both the maximum and minimum to the rule of tolerance (1913). This rule states that there are ecological minimums and ecological maximums for the majority of environmental elements, including temperature, light, and moisture (or "too little" and "too much," respectively). Tolerance bounds are represented as the range between these two circumstances.

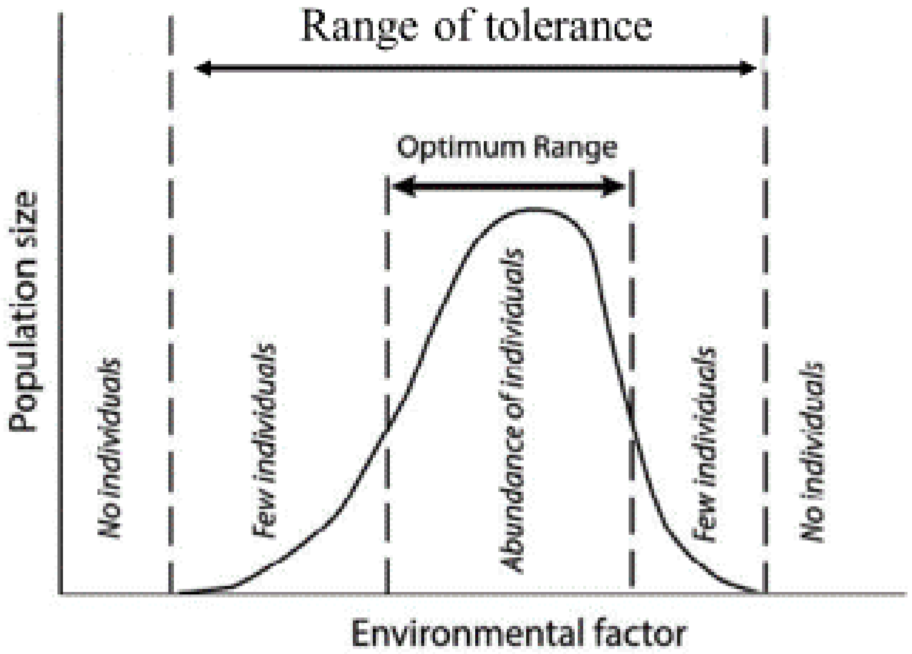


Figure: The bell-shaped curve shows the response of an organism to a range of single environmental variable.

The fitness and survival of an organism are gauged by its tolerance curve. Plotting survival or fitness metrics against the environmental gradient yields a bell-shaped outcome. The ideal range is made up of those environmental factors that allow an organism to develop and reproduce to their fullest potential. The organisms exhibit restricted distribution when the tolerance range for one or more parameters is narrow, and wide distribution when the tolerance range for all factors is wide. Reproduction is most important at limiting levels, whereas factor interaction affects an organism's fitness.

11.6.2 Ecological Adaptation in Hydrophytes

Hydrophytes are plants that are submerged in water all the time. They display aerenchyma, or big air gaps, in the leaves and petioles and can be fully or partially buried. Aerenchyma tissue aids in the storage of oxygen generated during photosynthesis and allows it to freely diffuse to other areas, such as roots that could be located in aerobic soil. These tissues affect the plants' buoyancy as well.

Typical hydrophyte adaption characteristics include:

- Tissue's porosity as a result of the existence of sizable air spaces or cavities (lacunae).
- Some plants—like the submerged Ceratophyllum and the free-floating Wolffia—may have poorly formed roots that lack branches, root hairs, and root caps, or they may have no roots at all.
- Cuticle in leaves is either nonexistent, as in submerged plants like Potamogeton, or poorly formed. As a result, they do not require an excessive number of stomata or a thick cuticle to manage the water loss. Similar to this, some submerged plants have no stomata or only have them on the top leaf surface; floating plants have them on both leaf surfaces, while emergent plants mostly have them on both. Chloroplasts may be restricted to the outer layers of leaves and finely divided to adapt to limited light availability.
- In submerged species, leaves are thin, linear, and finely dissected;
- Tissue differentiation is low, including that of vascular bundles; and mechanical tissue, such as sclerenchyma, is typically completely absent. The finely divided leaf was considered a helpful adaptation against fast currents that may tear the entire leaf apart.

- The majority of hydrophytes develop vegetatively quickly and have the capacity to reproduce asexually. They may reproduce asexually by producing seeds, rhizomes, tubers, and turions all at the same time. For instance, Potemogeton pectinatus

Ecological Adaptation in Mesophytes

Land plants that thrive in typical environments are known as mesophytes. Mesophytes thrive in conditions that are neither too dry nor excessively wet. They flourish in regions with typical relative humidity and air temperature. Mesophytes include things like wheat, peas, tomatoes, guavas, and mangos. These plants have huge, wide leaves and an upright stem with well ingrained roots in the ground. The biggest ecological category of terrestrial plants are called mesophytes. These plants do not have any unique morphological changes. Their leaves are green, wide, and flat. They can absorb water because to their large, fibrous root system. Mesophytes' distinctive adaptive traits are as follows:

- Mesophytes have broad, thin, and a variety of shaped leaves that are rarely tiny. The leaves have no hairs or waxy covering and are arranged horizontally.
- The cuticle is fully formed in the sections of the plant that are aerial.
- Mesophytes have aerial, freely branching stems; the epidermis of the plant is very well-developed; it lacks hair or a waxy covering; and the cells lack chloroplasts.
- In general, leaves have stomata on both surfaces. Palisade and spongy parenchyma with many intercellular gaps are the two distinct types of mesophyll found in leaves. Guard cells are responsible for the opening and shutting of the stomata, which typically occurs frequently.
- Both the mechanical and vascular tissues have undergone proper development and differentiation.
- Because the cells' osmotic pressure is low, the plants will droop rapidly if there is insufficient water supplied.
- These plants frequently experience transient wilting in the middle of the summer.
- The evergreen plants exhibit xeromorphic traits to withstand the dry spells, and the mesophytes may also lose their leaves at this time.

11.6.3 Ecological Adaptations in Xerophytes

Desert plants have evolved to withstand hot temperatures and arid soil. Ephemerals are the plants that avoid the dry environment. When rain starts to fall, these plants go through several stages of growth in a short period of time, including germination, blooming, and seed distribution. When dry circumstances return, the plants take center stage. High temperatures hinder both photosynthesis and respiration, with photosynthesis being more susceptible to high temperatures than respiration. The temperature at which CO2 fixed during photosynthesis equals that released during respiration is known as the temperature compensation point.

During periods of high temperature stress, plants produce a significant amount of chaperons, which are low molecular mass heat shock proteins that help with membrane fluidity and protein folding. The distinctive qualities of xerophytes are:

- With a high volume-to-surface ratio, leaves are compact and tiny. • In many types of dryland shrubs, leaves are replaced by thorns, which almost never transpire; they also have thick blades, small sunken and dense stomata on the lower surface, dense covering of hair (pubescence), a thick cuticle, strongly developed palisade mesophyll, and fewer intercellular spaces.
- Hair has been thought to inhibit transpiration, although evidence has also been shown showing transpiration decreased when hair was removed. There's a chance that xerophytic plants' hair has other functions, such shielding the leaves from insects and enhancing their overall radiating surface temperature.
- Plants exhibit adaptations in terms of storing water in their roots (as in the case of asparagus) and stems (succulents), as well as deep root penetration that makes deep water-soil available.

11.6.4 Ecological Adaptation in Halophytes

Plants that are found in saline areas and have evolved to high salt concentrations in soil or water are known as halophytes. Halophytes are found in salty soils, mangroves, tidal marshes, and coastal dunes. Mangroves are found near the borders of the ocean and in the damp, marshy environments of tropical deltas. Few mangrove species have salt glands on their leaves that allow them to expel salt. In order to cope with high salinity levels and osmotic potential, many plants have the ability to pump excess salt back into the soil through their roots. This is why many mangroves contain high concentrations of organic solutes including proline, glycine betaine, amino acids mannitol and sorbitol.

To deal with high concentrations of salt, mangroves have evolved defense mechanisms such as pneumatophores, prop and stilt roots, and vivipary, which allows seeds to germinate on the tree.

Pneumatophores are present in Avicennia and aid in the uptake and transportation of oxygen to the main roots. Pneumatophores are aerial roots that emerge from water and ascend into the atmosphere. Lenticels and porous tissues enable oxygen to permeate into their roots. The seed of the red mangroves (Rhizophora) sprouts on the tree before falling into the river. In order for the seeds to pierce the muck, the wave carries them into shallow water. In many mangrove species, the plant receives support from its prop and stilt roots.

Summary

The process by which ecosystems adapt and grow over time in the wake of a disturbance or the establishment of new habitat is known as ecological succession. The first step in this process is primary succession, which takes place in arid places without soil, including those left over from a volcanic eruption. Lichens and mosses are examples of pioneer species that are the first to settle in these regions. They enable the emergence of new plant species by dissolving rock into soil. When a disturbance, like fire or human activity, destroys an established community but leaves the soil untouched, secondary succession takes place. The reason this kind of succession moves along faster than primary succession is that the soil already has the nutrients and seeds needed for plant development. Ecosystems go through many changes as succession moves forward. Slower-growing, shade-tolerant species eventually supplant the early successional species, which are frequently fast-growing and tolerant to light. As a result, the ecosystem's structure and function alter as biodiversity rises. A peak community, which can support itself throughout time and is typified by a stable and diversified ecology, may eventually be attained.

An important aspect of the succession process is plant adaptability. Pioneer species are able to endure in hard, nutrient-poor conditions because of their adaptations. These adaptations include methods for long-distance seed dispersal, fast rates of reproduction, and rapid development. As the environment gets better and the soil gets more nutrient-rich, other plants that have evolved differently take control. These latter successional species frequently have deeper root systems to get water and nutrients, bigger leaves to absorb more sunlight in shady areas, and symbiotic partnerships with bacteria or fungi to improve nutrient intake. In general, plant adaptation and ecological succession are related processes that propel ecosystem growth and stability, emphasizing the dynamic character of the natural world.

Keywords

Biodiversity: Diversity between plant and animal species in a particular habitat.

Biogeochemical cycle: A chemical element or molecule travels through the atmosphere, hydrosphere, lithosphere, and biosphere via a biogeochemical cycle.

Xerophyte: A plant with an affinity for arid environments.

Soil: The loose, unconsolidated, naturally occurring layer that covers the surface of the Earth; a component of the pedosphere.

Succession: is the process by which one type of population is replaced by another in the vegetation and animal life, leading to a climax.

Limiting factor: Any necessary resource that is scarce in a particular environment and hence restricts the potential for change in other areas of the same ecosystem.

Tropical rain forest: A biome known for its high biodiversity, frequent, intense rainfall, and humidity levels of at least 80% is the tropical rain forest.

MCQ

1 **What is ecological succession?**

A) The process by which species evolve over time

B) The gradual process of change and replacement of the types of species in a community

C) The immediate response of an ecosystem to a disturbance

D) The migration of species from one habitat to another

Answer: B

2 **Which of the following best describes primary succession?**

A) Occurs in an area that has never been colonized before

B) Follows the clearance of an existing community

C) Occurs in aquatic environments only

D) Is driven by human activities

Answer: A

3 **Which stage of ecological succession is characterized by the presence of pioneer species?**

A) Climax community

B) Intermediate stage

C) Early stage

D) Secondary stage

Answer: C

4 **In which type of succession do plants colonize a region after a fire or flood?**

A) Primary succession

B) Secondary succession

C) Climax succession

D) Pioneer succession

Answer: B

5 Which of the following adaptations is most likely found in plants living in a desert environment?

A) Broad, flat leaves

B) Shallow root systems

C) Thick, waxy cuticles

D) High growth rate

Answer: C

Short questions

1. In what ways do xerophytes adjust to dry settings?
2. What are the primary forms of ecological succession, and what is it?
3. What distinguishes secondary succession from primary succession?
4. What function do pioneer species serve in the ecological succession?
5. Could you explain how hydrophytes have adapted to watery environments?
6. What part do structural adaptations play in a plant's ability to survive in its surroundings?

UNIT-12
ECOLOGICAL FACTORS

12.1 Objectives

- To understand about the ecological factors
- To discuss about abiotic factors- climatic edaphic and physiographic factors
- To know about biotic factors

12.2 INTRODUCTION

A living thing is impacted by several forces and variables in every ecosystem that are referred to as "eco-factors" or "ecological factors." There are two main categories of environmental factors that affect an organism's behavior, growth, distribution, abundance, and eventual survival: the biotic (living) environmental factors that include interactions between populations and instinctive control mechanisms that are inherent to the population, and the abiotic (non-living) environmental factors that determine interactions within the population.

All these ecological factors can be divided into the following three groups:

1. Abiotic factors
2. Biotic factors

12.3 ABIOTIC FACTORS

The non-living components of the environment constitute an abiotic factors. It includes 2 types 1) Climatic factors 2) Edaphic factors 3) Physiographic factor.

1. Climatic Factors

The long-term weather patterns of a certain area are called its climate. One of the key natural elements that influences plant life and establishes the climatic conditions of a location is its climate. Its field of study is called climatology. These categories comprise the climatic factors.

1. Light
2. Temperature
3. Water (Humidity and Precipitation)
4. Wind

Light: One of the most crucial abiotic elements that is necessary for life to survive is light. Sunlight, moonlight, stars, and light emitted by luminescent creatures are the main sources of natural light. The primary source of light is the sun. The portion of the electromagnetic spectrum that is visible to the human eye is called light. Scientists refer to the complete range of light that exists as the electromagnetic spectrum. The electromagnetic spectrum is commonly separated into seven sections: radiowaves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma rays. These regions are arranged in decreasing wavelength and increasing energy and frequency order. Every photon, which is a type of electromagnetic radiation particle, contains a certain quantity of energy. Photons in radiation types with short wave lengths have high energy, whereas those with long wave lengths have low energy. The electromagnetic spectrum is divided into three distinct groups by scientists. With wavelengths less than 0.4 to 0.7 mm, cosmic rays, x-rays, and ultra violet rays are classified as short wave radiation. Another name for this is PAR, or photosynthetically active radiation.

If the wave length is more than 0.740 mm, it is referred to as an infrared wave. On a clear day, 10% of radiant energy reaches the earth's surface in the ultraviolet, 45% in visible light, and 45% in infrared wavelengths. This solar energy takes the form of small particles known as quanta or photons and travels in waves. Violet, indigo, blue, green, yellow, orange, and red (VIBGYOR) are the seven distinct colors that sunlight exhibits when it passes through a prism. A visible spectrum of light comprising all these colors influences plant physiological activities, such as photosynthesis. Three different forms of UV radiation exist based on wave length. They are as follows:

- UV-A radiation (320 to 400 nm)
- UV-B radiation (280 to 320 nm)
- UV- C radiation (100 to 280 nm)

Of these three forms of radiation, UV-C is the most deadly to living things, while UV-B is toxic to them. The amount of light that reaches the earth's surface changes depending on a variety of climatic and topographical factors, including the season, time of day, latitude and altitude, incidence angle, and amount absorbed and diffused by the atmosphere.

Importance of light to plants:

(i). Photosynthesis: For plants, sunlight is the primary energy source. Being autotrophic means that they require light to complete the process of photosynthesis. When chlorophyll is present, photosynthesis is the process by which plants transform light energy into chemical energy, which is then utilized to create carbohydrates from carbon dioxide and water. The different Not every wavelength of sunlight is used equally by photosynthesis. Instead, pigments—light-absorbing molecules—are found in photosynthetic species. Only certain visible light wavelengths are absorbed, while others are reflected. The absorption spectrum of a pigment is the collection of wavelengths that it absorbs. For photosynthesis, visible light in the blue (450–500 nm) and red (600–700 nm) ranges is most beneficial. As a result, the blue and red wavelengths are where photosynthesis prefers to get its light. The least effective light is green (500–570 nm). The reason plants appear green is because their chlorophyll molecules reflect other colors while absorbing blue and red light, giving the appearance of green. When there is sporadic light as opposed to continuous light, photosynthesis proceeds more quickly.

(ii). Respiration: Respiration is the process by which cells get chemical energy through the consumption of oxygen and the release of carbon dioxide. In order to provide energy for plant development, plants use oxygen and the sugar created during photosynthesis to respire. The following is a representation of the respiration process:

$$C_6h_{12}O_6 + 6O_2 \xrightarrow{\text{Enzymes}} 6CO_2 + 6H_2O + 32\ \text{ATP (energy)}$$

All types of living cells respire, which is commonly referred to as cellular respiration. The breakdown of glucose molecules inside of cells releases energy, a process known as cellular respiration. There are two ways that cells can respire: aerobically, utilizing oxygen, or anaerobically, without using oxygen.

(iii) Growth and flowering of plants: The day length, the quality and intensity (photoperiodicity) of light are the most essential variables which determine development and flowering of plants. Based on photoperiodic reactions plants may be categorized into three groups:

(a) Short-day plants: When the days are shorter than twelve hours, short-day plants often begin to blossom. Examples include cocklebur, sugarcane, and bean. The duration of the day is important and differs for each species.

(b) Long-day plants: When days are longer than twelve hours, long-day plants begin to blossom. Example: *Spinacea oleracea* (spinach), *Daucus carota* (carrot), and *Lactuca sativa* (lettuce).

(c) Day-neutral plants: These are plants whose flowering is determined by other factors, such as age, node count, and history of cold treatment, rather than day duration. Tomatoes (*Lycopersicon lycopersicum*), for example, are "day neutral" plants that do not blossom in response to day or night duration. Rather, tomato plants just begin to blossom once they reach a specific growth stage. Additional instances are *Gossypium hirsutum* (cotton), *Cucumis sativus* (cucumber), and *Helianthus annuus* (sunflower).

(iv) Effect on transpiration and opening and closing of stomata: The biological process known as transpiration is how water from aerial portions of plants, such as stems, flowers, and leaves, evaporates as water vapor. Excess water will build up inside plant cells in the absence of transpiration, eventually causing the cells to explode. The stomata close at night and open throughout the day. The rate of transpiration is closely correlated with the presence of light. Light has a heating impact, changes the permeability of the plasma membrane, and affects the opening and shutting of stomata. These all have an impact on transpiration, which has an impact on water absorption.

(v) Germination: darkness, while others function best under constant sunshine. According to specialists at Thompson and Morgan, germination is aided by red light and hindered by blue light. This is due to the fact that red light has an impact on phytochrome, a pigment found in plants that controls processes such as seed germination (photoblasty), chlorophyll synthesis, seedling elongation, leaf size, shape, and movement, as well as the timing of adult plant blooming. But blue light can also be required if the plants are behind a dense leaf cover. On the other hand, yellow light has been reported to both counteract the inhibitory impact of blue light and enhance seed germination in Typha species.

2. Temperature: One of the most significant ecological variables is temperature. Together, temperature and moisture have a major role in determining a region's climate and the distribution of plant and animal life (Smith, 1977). The temperature around a plant affects its development and growth rate, and each species has a unique temperature range that is represented by a maximum, lowest, and optimal. All of an organism's metabolic activities that are essential to existence begin at a minimal temperature. The term "optimum temperature" refers to the setting where physiological systems operate most efficiently. The lowest temperature at which any metabolic activity required for life cannot begin and continue at its slowest is known as the minimum temperature.

The highest temperature at which no signs of biological activity are visible is known as the maximum temperature. Cardinal temperatures are the lowest, optimal, and maximum temperatures. They differ across species and within a person as well as from one portion to another. For instance, given the right circumstances, certain hot-spring algae may survive in water as high as 73°C, and certain arctic algae can finish their life cycles in locations where the temperature hardly rises above 0°C. At temperatures above 90 °C, non-pathogenic microorganisms that live in hot springs can actively thrive. The majority of plant functions, such as respiration and transpiration, are influenced by temperature

(a). Cell and temperature: There are deadly minimum and maximum temperatures impacts on the constituent cells and their parts. Proteins within the cell may freeze to ice due to the extremely low temperature. Conversely, heat causes proteins to coagulate (Lewis and Taylor (1967). Because proteins denaturate at high temperatures, very few species can withstand temperatures beyond 45°C. Because heat-stable proteins allow certain creatures to survive at greater temperatures, other organisms may survive at slightly lower temperatures by employing antifreezes like glycerol and salts.

(b) Temperature and metabolism: Different types of enzymes typically regulate the various metabolic activities of plants, animals, and microbes. Since enzymes are in turn influenced by temperature, an increase in temperature, up to a certain point, results in increased enzymatic activity and an increased rate of metabolism. However, a bigger rise in temperature may cause the metabolic rate to drop.
(c) Temperature and reproduction: The process of thermoperiodism, which is the

culmination of a plant's reactions to suitably varying temperatures, influences flowering in plants. In terms of a plant's phenology, temperature is crucial. The study of plant recurring events, such as flowering time in relation to temperature, fall leaf fall and color changes, is known as phenology.

(d) Temperature and sex ratio: In certain species, the sex ratio is influenced by the ambient temperature. For instance, temperature affects the sex ratio of the copepod Macrocyclops albidus. There is a notable rise in the proportion of men as the temperature rises. Normal conditions in Daphina result in the production of parthenogenetic eggs that mature into females. However, as the temperature rises, they produce sexual eggs, which can fertilize to produce either female or male offspring.

(e). Temperature and parasitic infection: Unfavorable temperatures, such as high temperatures combined with wind and high humidity, can lead to the spread and development of bacterial illnesses in plants.

(f) Temperature and growth: The temperature surrounding a plant affects its ability to grow and develop. Every species has a distinct range of temperatures. Extremely hot or extremely low temperatures can both be detrimental to plant development. The increased fluidity of the lipids in the membrane causes a loss in membrane stability at high temperatures. Cold injuries including dehydration, chilling injuries, and freezing injuries can be brought on by low temperatures. Because wintertime transpiration is high and absorption is sluggish, desiccation causes tissues to become dehydrated and damaged. A variety of low temperatures that are not quite freezing for that species can cause chilling injuries. The growth, color, and function of cells are all negatively impacted by chilling. Also, it may result in tissue death.

(g) Temperature and transpiration in plants: Water is lost from a plant's aerial surface during transpiration. An rise in temperature causes the air's ability to contain more moisture in the vapour form, which causes a difference in vapour pressure faults and an increase in the rate of transpiration. In addition to speeding up transpiration if the temperature goes over critical levels, the plant falls dormant and may produce choruses.

Classification of organisms according to temperature tolerance:

Based on how plants react to environmental temperature, all of the vegetation may be categorized into four groups:

(i). Megatherms are plants that need a high temperature that is nearly constant throughout the year. desert vegetation and tropical rain forests, for example. (ii). Mesotherms: Plants that live in environments that are neither extremely hot nor cold. Certain plants are not able to withstand extremely high or low temperatures. aquatic plants and tropical deciduous woods, for instance.

(iii).Microtherms: Low temperatures are necessary for the development of these plants. These plants are not able to withstand extreme heat. This group includes all high altitude plants found in tropical and subtropical areas.

(iv). Plants known as hekistotherms are those that flourish in extremely cold climates. They can withstand the lengthy, bitterly cold winters. For example, alpine vegetation

2. **Water:** Water is the essential element for all life on Earth. Water comprises a significant amount of both plant and animal bodies; for example, 70–80% of an organism's mass is found in its cytoplasm. One oxygen atom and two hydrogen atoms make up the molecule known as water. Among all the compounds discovered in organisms, it is the most prevalent. Water is a substance that travels around the planet continuously and can be liquid (rain, water droplets), solid (snow, sleet, hail, and ice), or gas (water vapour). The hydrological cycle, also referred to as the water cycle, is controlled by solar energy. By evaporating water from the lakes, rivers, seas, and even the soil, this solar energy powers the cycle. Transpiration is the process by which more water leaves plants and enters the atmosphere. Through condensation, the water vapor in the air creates clouds, which then return to Earth as rain and snow. The amount of water available affects a plant's ability to absorb nutrients, the pace and volume of photosynthesis, respiration, growth, and other metabolic activities. Water has a variety of functions in plants. It cools the leaves during transpiration as it evaporatively removes from the leaf tissue. It is also a key element in respiration and photosynthesis

Minerals and carbohydrates are carried through plants by water, which acts as a solvent. Water is found in the atmosphere in the form of water vapor. We refer to this as atmospheric humidity. The amount of solar radiation, wind, water, soil condition, temperature, altitude, and other factors all have a significant impact on humidity. The primary sources of atmospheric humidity are plant transpiration and water evaporation from the earth's surface. The majority of plants are unable to benefit from atmospheric humidity, however a few mosses, lichens, filmy ferns, and epiphytic orchids are able to take moisture straight from the atmosphere. Humidity can be seen in the form of fog and clouds. A psychrometer and hygrometer are used to measure humidity, which is expressed as a percentage. Three terminologies are used to characterize humidity: (a). The ratio of the actual amount of water vapor in the atmosphere to the amount that can be retained in the air at a specific temperature and pressure is known as relative humidity.

(b) Specific humidity: This stands for "per unit weight of air, the amount of water vapor present."

(c). The term "amount of water vapours present per unit volume of air" describes absolute humidity.

Effects of humidity organisms: It affects how quickly plants transpire. Lower transpiration rates are associated with higher humidity levels. Low relative humidity has an impact on plant development and promotes water loss through transpiration. It affects how quickly people sweat as well. So, perspiration increases with high humidity. It serves as a vital water supply for epiphytes, such as mosses and lichens. In the process of fungal spore germination, it is crucial.

Precipitation: The discharge of water from clouds that results in rain, sleet, hail, or other precipitation falls to the earth. When a section of the atmosphere reaches 100% relative humidity and is saturated with water vapor, precipitation happens because the water condenses and "precipitates," or falls. Season, pressure, temperature, and wind all affect precipitation. The productivity and species richness of a community or perennials, as well as the vegetation in a specific area, are greatly influenced by precipitation. In many dry and semi-arid environments, precipitation can change germination, seedling development and survival, and phenology (the study of repeated events), which in turn can change yearly production and species diversity.

Both the amount and the timing of precipitation at a particular location have an impact on plant production. Since water is the most scarce resource in arid and semiarid environments, seasonal precipitation has a greater impact on productivity than total precipitation.

The most prevalent forms of precipitation are rain, snow, and hail, however there are also a few less frequent forms such ice pellets, diamond dust, and freezing rain. Because the water vapor does not condense to the point where precipitation occurs, mist and fog are really suspensions rather than precipitation. The most frequent type of precipitation is rain.

4. Wind:

The gas combination that is invisible and exists in the troposphere is called air. Wind is the motion of air. The unequal heating of the earth by the Sun and the planet's rotation causes wind, which is the movement of air. varying forms of patterns and storms may be produced by wind moving at varying speeds, altitudes, and over land or sea. They are a massive tropical storm that is spinning. The world's greatest equalizer of atmosphere, wind carries heat, pollution, moisture, and dust over vast distances. Aeolian landforms are the result of wind-related processes and landforms. Wind affects trees and other living things by acting as a facilitator of disturbances as well as a source of ecological services. Wind's effects on plants are mostly determined by its speed, duration, and degree of penetration in canopy layer

Effects of wind

i. Transpiration rate is influenced by wind. Strong wind areas experience higher transpiration, which causes a water deficit in the tissues.Wind causes the atmosphere to become more turbulent, which increases the amount of carbon available.

ii. Gving the plants more dioxide, which increases the rates of photosynthesis. The rate of photosynthesis becomes constant at a given wind speed.

iii. In addition to altering the hormone balance, wind causes rice and barley to produce more ethylene.

iv. Dwarfing: Turgidity aids in the maturation of a plant's cells to normal proportions. When plants grow in the presence of drying winds, they never reach a stage of turgidity that allows them to divide their forming cells. All organs thus get shrunken as a result of their cells growing to subnormal size.

v. Heat-induced desiccation of plants occurs due to the replacement of humid intercellular air with dry air in these spaces. For instance, the rice crop exhibits tip drying throughout the months of June and July.

vi. Transpiration is accelerated by the wind. Plants can only develop properly if they can maintain a balance between their water intake and expenditure. Partial or whole stomata closure may occur when transpiration rate surpasses water absorption rate, hence limiting the flow of carbon dioxide into the leaves. Growth, yield, and the rate of photosynthesis will all decline as a result.

3. Soil (Edaphic Factor)

Among the most significant ecological variables, or edaphic parameters, is soil. According to Treshow (1970), soil is a complex physical biological system that gives plants support, water, nutrients, and oxygen. The top layer of the earth's crust that is loose, friable, and unconsolidated is called soil. It is a mixture of organic and mineral substances that also includes water, air, and microorganisms. The first soil scientist, Dokyachev (1879), asserted that the soil is the product of the interactions and reciprocal effects of parent rocks, climate, topography, vegetation, animals, and land age. The most crucial component of ecological function is soil as it provides nutrients, water, temperature, and moderation—all necessary for the growth of terrestrial plants. It is the outermost layer of the earth's surface, where plants receive their water and nutrients as well as produce roots that attach them. Pedology is the Study of Soil Science.

Formation of soil: A complex mixture of minerals, water, air, organic debris, and many microorganisms—the decomposing remnants of once-living things—make up soil. The process of soil formation involves the disintegration and breakdown of rocks through weathering, fragmentation, and bacterial and fungal activity, as well as interactions between different chemical components found in the soil.

Soil Profile: The vertical cross-section of the soil, consisting of layers parallel to the surface, is referred to as a soil profile. Soil horizons are the names for these strata. The thickness, texture, color, structure, consistency, porosity, and acidity of each differ from one another. The letters O, A, E, B, C, and R stand for these horizons or strata. These horizons neatly show the following strata as they descend from the surface:

O horizon: O horizon, often known as the litter zone, is the topmost horizon in the soil profile. It is mostly made up of organic material, such as grasses, dried leaves, dead leaves, fallen trees, tiny rocks, twigs, surface creatures, and other organic stuff that has broken down. It consists of the next two sublayers:

O1 horizon: This is the top layer of soil and is mostly made up of organic items including grasses, tiny pebbles, twigs, fallen trees, bark, dried leaves, dead leaves, fruits, flowers, and animal excrement. Because organic matter is present, the soil is often dark brown or black in color.

O2 horizon: Containing blackened, unidentifiable degraded trash, O2 horizon is located underneath O1, also known as the litter horizon. The top layer of the O2 horizon is known as the "duff layer" because it includes partially degraded debris. The humus, or entirely degraded, light, and amorphous organic materials, is found in its lowest portion. Humus enriches the soil with nutrients, increasing its fertility. This stratum contains a wide variety of living things, including beetles, worms, and others.

A horizon: The topsoil, also known as the A horizon, sits under the litter zone. A horizon consists of the three subzones listed below:

(i) The A1 Horizon is the area where soil minerals and humus are incorporated. It is the topmost layer of the soil and is made up of deeply mixed organic components with a fair amount of degraded matter and mineral soil. Microorganisms including fungus, bacteria, and earthworms are found in this stratum.

(ii) A2 horizon: The zone of maximal leaching is located underneath A1 horizon. It is a lighter-colored horizon with less humus that is seeing the fastest removal of elements like aluminum, silicates, clays, and so on.

(iii) The A3 horizon is in transition to the B horizon, which is situated underneath it. It is the area where the horizons A and B meet.

E horizon: Nutrients that have been leached from the O and A horizons make up the E horizon. Only older soils and soils from forests contain it.

B horizon: The area below A horizon is referred to as the subsoil. In this zone, roots do not grow very well. Packed with minerals that gathered here after leaching (moving down) from the A horizons. Additionally, it is separated into B1, B2, and B3 zones. Together, the horizons A and B depict the actual soil.

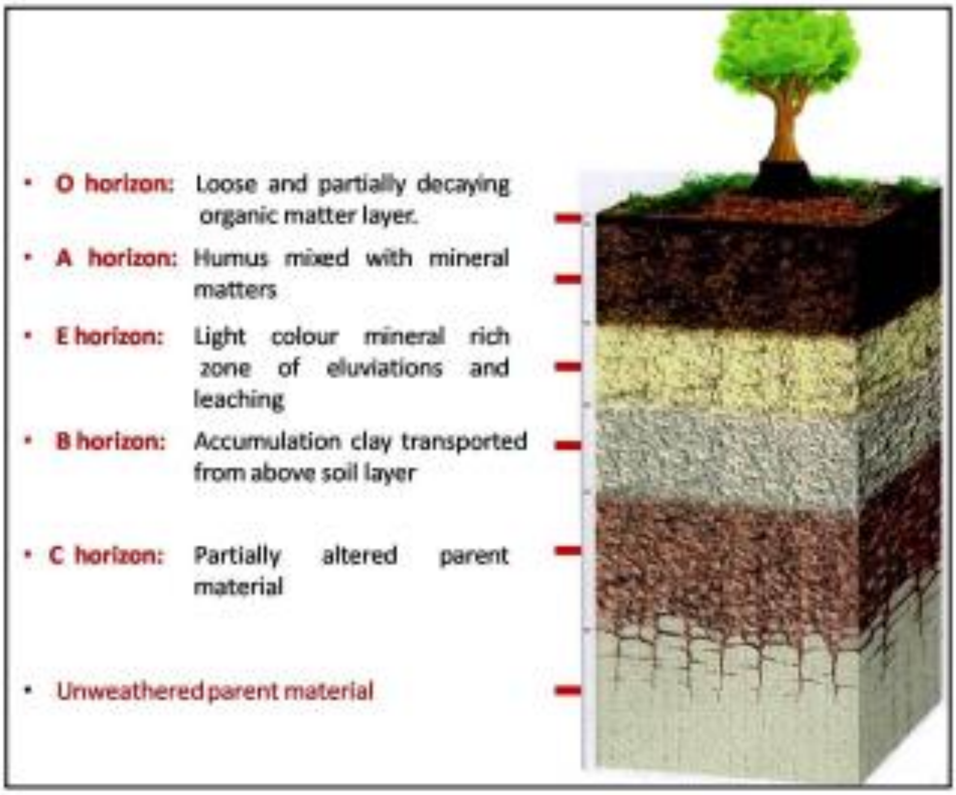


Fig. 2.1 A representation of the soil horizons within the profile of a typical forest soil. Forests soils tend to have 5 layers, including a surface layer of decomposing plant debris, as well of a zone of leaching. (Image recreated by author. Original source of image: https://www.ctahr.hawaii.edu/mauisoil/a_profile.aspx)

C Horizon: It appears beneath horizon B. The parent material for the mineral portion of the soil is worn rock or silt, which makes up this layer. It has a pale color and is devoid of any organic material. Another name for this stratum is saprolite.

R horizon: The unweather bedrock known as the R horizon lies under the C horizon. This layer is glued and compacted. This location has a variety of rocks, including granite and limestone.

The following are the key edaphic elements that influence the vegetation:

1. Soil moisture: Rainfall, temperature, soil properties, and other factors all have an impact on soil moisture, which is the water that is held in the soil. Rainfall is the primary source of soil water. Water types found in the soil:

(A) Gravitational water: This is a free type of water that seeps through the crevices between soil particles and collects there as ground water. The ecological significance of this soil water lies in its ability to drain nutrients.

(b) Capillary water: Capillary water is the volume of water that is held in minuscule interstitial gaps as thin films around the soil particles. This is readily accessible to plants and has a favorable water potential.

(c) Hygroscopic water: A little amount of water in the soil surrounds the soil particles in an incredibly thin, firmly bound film. We refer to it as hygroscopic water. The soil holds the water in such a way that roots are unable to absorb it.

(d). Water vapor: This is the water vapor found in the air that epiphytes' hanging roots may collect since they have hygroscopic hairs and spongy velamen tissue.

(e). Combined water: A little amount of soil water in the soil is chemically bonded to soil particles; this is known as combined water. The plants cannot get this kind of water.

Holard is the total quantity of water in the soil. The quantity of water that plants may consume is referred to as chères or accessible water. Water that is unavailable to plants is referred to as echard or non-available water. Numerous factors, including the size of the soil particles, the amount, length, and intensity of rainfall, the distribution of precipitation throughout the year, and the pace at which water percolates, affect the availability of soil moisture.

The amount of soil water that plants have access to greatly influences the kind, composition, and stature of flora in any given area.

2. Soil pH:

The number of active hydrogen ions in the soil or the alkalinity or acidity of the soil solution are measured by the soil reaction, often known as pH. Certain soils are basic, whereas others are neutral or acidic in nature. A pH value that is less than 7 is acidic, whereas one that is more than 7 is alkaline. Soil with a pH of 7.0 is considered neutral. Soils typically have a pH of between 2.2 and 9.6. The soil's pH value affects the availability of vital nutrients. For instance, certain plants (Calciphytes) flourish on basic soils because they need large levels of calcium. Oxylophytes are plants with minimal calcium requirements. Extremely salty or alkaline soils, as well as excessively acidic soils, are frequently detrimental to the growth of microorganisms and plants. Zinc, copper, manganese, aluminum, and iron typically become poisonous at low pH values. Nonetheless, the majority of plants thrive on neutral or slightly acidic soils.

3. Soil Nutrients: One of the main sources of nutrients that plants require for development is soil. Ion exchange occurs at the surface during the process of roots absorbing nutrients. Plants often absorb inorganic solutes in their ionic forms. The main inorganic elements found in soil include iron, calcium, sodium, magnesium, aluminum, silica, and magnesium compounds. Trace elements like manganese, copper, boron, zinc, iodine, cobalt, and molybdenum are also present in soil. Humus, a dark-colored, amorphous material created by the partial breakdown of decomposing organic matter, is the major organic component of soil. Chemically speaking, humus is composed of methyl sugars, hexose sugars, sugar alcohols, aromatic compounds, proteins, purines, oil, fat, and waxes, among other things.

4. Soil atmosphere: The soil atmosphere is made up of gases contained in the pore spaces of soil profiles. If the solid soil particles are free of water, air fills the gaps between them. Three primary gases are found in the soil atmosphere: oxygen, carbon dioxide, and nitrogen. The concentration of CO_2 and moisture in soil air is higher than that of atmospheric air, but the concentration of O_2 is lower. Rainfall, temperature, and wind all have an impact on the atmosphere of the soil. Loam soils that include humus are ideal for most crops since they have a typical ratio of water to air (about 66% water and 34% air).

5. Soil temperature: The temperature of the soil is measured, and a soil thermometer may be used to find the temperature. The earth's internal heat, sun radiation, and decaying organic matter are some of the sources of thermal energy that soil absorbs. A number of variables, including solar radiation, soil color, mulching, land surface slope, plant cover, organic matter content, and evaporation, influence how much

heat is provided at the soil surface. The temperature of the soil drops when water evaporates, making it colder. More radiant heat is absorbed by dark-colored soils than by light-colored soils. Temperature in the soil controls the physical, chemical, and biological activities that occur there.

7. **Soil organism:** Soil organisms are any living things found in the soil. The size range of soil creatures is known as fauna and includes macrofauna (earthworms, moles, and millipedes), mesofauna (mites and springtails), and microfauna (nematodes and protozoa). Higher plant roots, soil fungus, algae, bacteria, and soil actinomycetes are examples of soil plants, or flora. In addition to breaking down toxic materials, decomposing animal and plant residues, fixing nitrogen in the soil, cycling organic matter, aerating the soil (particularly through earthworms), breaking down pesticides and other toxicants, producing humus, and producing polysaccharides to improve soil aggregation and increase plant nutrients in forms that are available to plants are just a few of the many activities that soil organisms engage in. Certain soil bacteria release toxic substances like organic acid and aldehydes when there is no oxygen present.

3. Physiographic factors (Topographic factors): Factors related to an area's physical characteristics are known as physiographic factors. These variables include the region's terrain, the land's slope, its elevation above sea level, the degree of erosion, sand blasting and silting, etc. These elements have an impact on the vegetation, which can lead to climatic fluctuation over an area. Consequently, a confined microclimate is created. The localized climate conditions, such as those found in close proximity to plants and animals, are referred to as the microclimate. We'll talk about a few of the key physiographic characteristics below.

1. Altitude of the place: The height of the land above sea level is known as altitude. Faster winds, reduced pressure and temperature, increased humidity, and stronger light are all present at higher altitudes. The combination of all these elements results in a distinct vegetational zone pattern. The rate of transpiration is aided by the wind's increased velocity as altitude rises. The influences of wind lead plants growing at higher elevations to develop more slowly.

2. Steepness and exposure of the slope: The gradient or steepness of a certain Earth surface is known as its slope. It has an impact on the daily dose of solar radiation. The sun radiation is increased by the steep slopes, particularly at higher elevations. In the northern hemisphere, solar energy is distributed more evenly between the southern and northern slopes. This is most likely due to the fact that during the day, sunlight almost entirely strikes the steep southern slope, but it only obliquely strikes the northern slope in the morning and evening. Slopes have a significant impact on the characteristics of the soil. Rainwater travels downward, removing dirt from a slope and carrying it down to potentially deposit in a valley. The top soil is eroded by water flowing down the slopes leading to disappearance of vegetation.

3. Direction of mountain chains: The amount of rainfall in a location is significantly influenced by the orientation of mountain ranges. Mountain ranges control the direction of the wind, retain wind-borne moisture on specific sides, and condense water vapor in the form of rain and clouds in higher altitudes. This might be the cause of the high mountain's uneven vegetation; although on some sides it is abundant, on others it is sparse.

12.4 BIOTIC FACTORS

Living together, organisms have a direct or indirect impact on one another's nutrition, growth, and reproduction. Pollination, fruit and seed dissemination, grazing, symbiosis, parasitism, and other processes are the outcomes of these interactions. We refer to the impact of living forms on plants as "biotic factors." The roles of biotic factors are broken down into those of microorganisms, humans, animals, and plants.

1.ROLE OF PLANTS

The presence of other plants or other biotic variables affects the vegetation in a given area. Plants in the same species or different species, as well as plants from one community over another, compete with one another to survive. ex: Trees, shrubs, and herbs In a forest, climbers grow together. They fight for minerals, water, light, and space.

A] Tree effects: Tall trees with many branches create a canopy that blocks sunlight from reaching the forest floor. This has the effect of inhibiting the growth of plants known as heliophytes (light-loving plants). It promotes the development of schorophytes, or plants that like shade. similar to Pteridophytes and Bryophytes.

B] Climbers' effects: Weak stemmed plants, climbers require the help of other plants in order to grow upright. These can uproot or kill plants or branches. For example, in forests Pothas are root climbers.In order to receive sunlight, betel, or Alocasia, grows adventitious roots that grip the supporting plant. Tendrils are long, thin, coiled, wiry structures that aid in climbing in those who use them. Ex: Antigonon, the passion flower.Woody climbers have woody stems that thread around the stems of trees for support and reach the canopy.For example, Lianas.

C] Parasite effect: Heterotrophic method of nutrition is led by parasites. They grow into button-shaped structures termed Haustoria that enter the host, make their way to the vascular bundles, take up nutrients from them, and eventually kill the host.

Ex: Bacteria, Fungi, Flowering plants like Striga, Santalum, Cuscuta , Viscum.

D] Impact of New Species: - Due to climate and edaphic component changes, new species encounter several challenges in their early stages of growth in a new area. When they eventually adapt, take over, and eradicate earlier thriving plants. New species will eventually blanket the entire area. Ex: Toxic chemicals produced by lantana, parthenium, eicchornia, and acacia damage nearby plants.

E] Symbiont Effect: Certain plants grow within or on top of other plants. There are benefits to both parties from this cooperation. For example, in lichens, algae and fungi are in close, constant interaction as the algae produce food and supplies the fungi, while the fungi offer the algae shelter. Nitrogen fixers: The Rhizobium bacteria, which are found in the root nodules of leguminous plants, fix gaseous nitrogen and release it for plant uptake. Blue-green algae found in the corolloid roots of Cycas include Nostoc and Anabena. Mycorrhizae: Fungi grow inside orchid roots and on the exterior of pine and oak trees to form a structure that aids in the absorption of water, minerals, and/or hormones.

2. ROLE OF ANIMALS:

There are several ways that animals and plants interact:-

A] Grazing animals: Grazing is the act of eating grass. These animals' constant grazing turns the vegetated field into a desolate region. If left uncontrolled, it results in the "desertification" of the desert. Ex: Domesticated animals such as goats, sheep, cattle, and cows.

B] Browsing animals: The term "browsing" refers to the consumption of delicate plant branches. In addition to destroying plants, their paws and hooves also kill creepers, which are little herbs.For example: Cow, Goat, Ass Horse, and Sheep. They kill plants that detest dung (Caprophillos plants) and spread massive amounts of manure. Unrestricted browsing quickly turns a forest into a scrubby jungle full with prickly plants including cactus, canthium, and zizipus.

C] Worms and insects consume plant components, hinder the growth of the plants, or infect and kill the plants.

D] Insect and animal pollination: Insects that feed on nectar cause cross-pollination. Salvia orchids have altered their flowers to draw in insects. Certain flowers release scents, while others have different colors to draw in specific insects. Additionally, several animals aid in cross-pollination.

E] Fruit and seed dispersal: The easy and even dispersion of fruits and seeds, as well as the growth of plants on our planet, are caused by the dispersal of these materials by animals.

F] Carnivorous plants: A nitrogen deficit affects certain plants that thrive in marshy areas. These plants rely on insects to provide the nitrogen they need. "Insectivorous or Carnivorous plants" is the term used for these.

G] Myrmicophily: This is a form of proto-cooperation in which ants dwell in close proximity to plants, obtain food and shelter from them, and in exchange, defend the plants from outside threats.

3. ROLE OF MICRO ORGANISMS:

In plant life, microorganisms have both positive and negative roles.- A] Beneficial role saproprous Bacteria and fungi decompose dead matter, clean the earth's surface, and add nutrients to the soil.Bacteria like Clostridium and Azatobacter and blue-green algae like Nostoc and Syntranea work together to fix molecular nitrogen and enrich soil. Fungi help plants absorb water and produce growth hormones. They coexist with higher plants.

B] Negative role: Soil nitrogen content is reduced by denitrifying bacteria through denitrification.

The bodies of other living things are home to parasitic bacteria and fungi that infect them and cause illnesses. Examples of these include cholera, typhoid, citrus canker, kole roga, rust, and leaf spot.

4. ROLE OF HUMAN BEINGS: Humans have a beneficial and destructive role on the environment, but the negative effects outweigh the benefits. A] Negative impacts; Growing urbanization, civilization, and industry have a detrimental impact on vegetation because they cause pollution, overuse of natural resources, uncontrolled tree cutting, and climate change. In addition to destroying Twiners, cutting down trees also kills Epiphytes, Climbers, Sciophytes, Insects, Animals, and Birds that consume fruits. It causes certain species to become extinct. Careless human activity has the potential to start a forest fire, which would wipe all the local flora and animals. As a result of growing urbanization and progressive civilization, plant riches is exploited, ecosystems become unbalanced, soil erosion is encouraged, humidity levels are disturbed, and climate change causes species extinction.

B] Beneficial aspects: farming by lay An region that is devoid of vegetation is transformed into a forest or vegetation field by human reforestation, or forestation. Man's efforts in agricultural plant breeding have produced high yielding, disease-resistant cultivars, the preservation of endangered species, and biodiversity conservation. The development of dams has led to an expansion in farmed land and the emergence of new species. It is advantageous to domesticate and distribute commercially significant, economically significant plants.

Summary

The scientific study of interactions between living things and their surroundings is known as ecology. Any biotic or abiotic element that affects plants and other creatures is considered an ecological factor. Climate, physiography, edaphic, biotic, and anthropogenic variables are the five categories into which ecological factors may be divided. The following categories comprise the climatic factors: wind, fire, light, temperature, precipitation, and atmospheric humidity. The variables that affect plants through soils are known as edaphic factors. The physical characteristics of the place are known as physiographic factors. These variables include the area's terrain, land's slope, height above sea level, sand silting and blowing up, degree of erosion, etc. The other living things, such as plants, animals, and bacteria, are known as biotic factors.

Keywords:

Soil profile: The soil's stratified, vertical structure.

Humidity: The quantity of moisture or water vapor in the atmosphere is its definition.

Humus: The organic parts of soil created by soil microbes breaking down leaves and other plant matter.

Capillary water: Water in the soil that is left over after gravitational water has been removed is known as capillary water.

Gravitational water Free water that is drawn through the earth by gravity is known as gravitational water.

MCQ

1. Which of the following is a primary climatic factor affecting ecosystems?

   A) Soil pH

   B) Temperature

   C) Soil texture

   D) Topography

   Answer: B)

2. Which of the following best describes an edaphic factor in an ecosystem?

   A) Annual rainfall

   B) Soil texture

   C) Latitude

   D) Wind speed

   Answer: B)

3. Which of the following is an example of a physiographic factor?

A) Humidity

B) Soil nutrient content

C) Altitude

D) Precipitation

Answer: C) Altitude

4. Which of the following is a primary climatic factor that influences the distribution of vegetation in an ecosystem?

A) Soil pH

B) Temperature

C) Soil texture

D) Altitude

Answer: B)

5. Edaphic factors are crucial in determining the types of plants that can grow in an area. Which of the following is an edaphic factor?

A) Rainfall

B) Soil texture

C) Wind speed

D) Aspect of the slope

Answer: B)

6. Physiographic factors affect the physical landscape of an ecosystem. Which of the following is considered a physiographic factor?

A) Humidity

B) Soil moisture

C) Altitude

D) Solar radiation

Answer: C)

Short questions

1. Give an explanation of physiographic factors and some instances.
2. What effects does height have on the plants and climate?
3. What are the edaphic variables in an ecosystem, and what makes them significant?
4. How does the pH of the soil affect plant growth?
5. What constitute an ecosystem's primary climatic factor components?
6. What impact does temperature have on plant species distribution?
7. What part does soil fertility depend on the texture of the soil?

UNIT-13
PLANT COMMUNITIES

13.1 Objectives

- To understand about the type and characteristics of community
- To discuss about ecotone
- To know about Edge effects

A community is a collection of species or populations that are present in a given location at a given point in time. The species are able to communicate with one another. They stand for biotic, or alive, ecosystem components. Although the species are neither biologically or dynamically related to one another, they do share a habitat and feeding connections. The characteristics of an ecological community are the result of interactions between the species and/or populations that comprise it. Example: Different grass species, insects, worms, birds, and animals interact with one another in different ways in the field. Insects and animals can find food in gruese, while worms and birds can find refuge in them. Birds eat worms, thus insects provide them with food. What about mammals? Are all birds carnivorous?). A field community is made up of all of these creatures.

Similar to this, there are many different kinds of living things in forests, deserts, mountains, rivers, and lakes. They are a significant part of the communities in which they live. The different species are therefore significant components of natural communities.

Through food chains, species in a group have a feeding connection. For nourishment, every species is dependent on several other species. Functionally, these species are unrelated. As a result, even while species within a community may not be directly connected to one another, they may nonetheless share a variety of feeding relationships.

There are fluctuations in the community's size. In vast communities like forests, there are many different kinds of plants, birds, insects, reptiles, and mammals coexisting. A log of wood, on the other hand, is a representation of a little community of insect species. Forest communities, for example, are autotrophic. This is due to the fact that they include plant species that need solar energy to perform photosynthesis.

Communities located in caverns and springs are heterotrophic because they get their energy from organic materials like trash. A community of plants that belong to the same species and age group is called a stand. An region of vegetation that is quite uniform is referred to by this phrase. An example of a wheat field is a collection of plants that are nearly of the same age and are located in the same location.

13.2 COMMUNITY CHARACTERS

Communities are characterized by presence of species, their biological physical characters.

Form and structure (physiognomy)

A community's shape and organization can be evaluated based on certain traits and roles. The vegetation inside a terrestrial community defines its structure. A community's vegetation can be classified as tall, medium, short, evergreen, deciduous, woody, herbaceous, herbs, shrubs, and so forth. There are other differences highlighted within each category.

As an illustration, evergreen trees might have needle- or broad-leaved leaves. The vegetation may consist of grasses and/or forbs (herbaceous dicots), shrubs, succulents, rosettes, and herbs.

1. Analytical Characters

Analytical characters are further characterized as quantitative and qualitative.

A. Qualitative characters

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

a. **Floristic composition:** This is a reference to the kind of species that exist in a community. Certain species are known as dominant species because they are widely distributed across every community. Animals and plants coexist in a community, but because plants are sedentary and stay in one area their whole lives, the community gets its name from the dominant plant species. A thorough analysis is conducted on the community's floristic makeup. A species list of the species found in a community is created. Vascular species are classified as plants. Consideration is given to species that occur in various seasons. The species that is more common and present throughout most of the year is honored in the community's name. The floristic composition measurement provides insight into the following:

• A species' interactions with the local environment and other species that live there.

• The various species' habitats.

• The species' ecological amplitude

• The community's current state and anticipated future developments.

Adhatodha vasica, for instance, is a winter annual plant. It flourishes in cold climates and alongside plants like Capparis sepiaria. It demonstrates a connection to the environment and other animals.

b. **Stratification of vegetation**: It is yet another crucial aspect of a community's vertical strata. The vertical structure of the plant, including its size, branching, and leaves, is determined by its growth form. Physical elements like light have a big impact on the vertical structure.

Stratification arises from the differences in physiological and ecological amplitude between various plant species with regard to soil, biotic variables, temperature, moisture content, and light intensity. Every society has a stratification of discrete vertical strata that make up its vertical structure. The vertical structure of a plant is determined by its growth, which is expressed in terms of size, branching, etc. The vegetation in a well-developed forest ecosystem is arranged in layers. It is home to species including grasses, herbs, trees, and shrubs. The layers are as follows: forest floor, herb/ground layer, shrub layer, understory layer, and canopy layer. In tropical woods, this kind of vertical stratification is present. Apart from the several strata present in these woods, there are also climbers and lianas. The canopy is where photosynthesis takes place to fix energy. The canopy system found in forests. When light enters the lowest levels of a canopy, it is said to be open. Shrubs and understory plants are well-developed in these locations. The majority of light in a closed forest is blocked by trees, leaving the plants without any light. Shade-tolerant plants with low herbaceous layer development occur in these locations. A forest that contains four strata, as opposed to grassland vegetation, which has just two, may sustain a wider variety of living types.

c. Periodicity (phenology, aspection): It speaks of the seasonal variations in a community's features. Every species has distinct needs in terms of moisture, light, temperature, and other environmental elements. As a result, each species experiences different growth events during different phases, including seed germination, vegetative development, blooming and fruiting (the reproductive phase), fruit and seed dispersal, and seed dissemination. Phenomenology is the study of gathering data during these events. In a plant's existence, it is also known as "the calendar of events." A phenogram is a diagrammatic depiction of these occurrences. Every species in the population has a phenology that varies greatly.

c. **Vitality and vigor**: The ability of a plant to finish its life cycle is known as vitality. A plant's vigor refers to its state of development or health at a specific point in its life cycle. It depends on how quickly and how much growth occurs. Changes in height, the area covered by foliage, the color and turgidity of the stems and leaves, the extent of insect damage, the emergence of flowers and fruits, and the growth of new stems and leaves are among the characteristics. Daubenmire separated individuals into many classes based on their vitality:
V1: plants that lose their seedlings;
V2: seedlings that develop but are sterile
V3: Vegetative reproduction occurs in,
V4 : sexual reproduction occurs in, but is infrequent and
V5: sexual reproduction occurs.

d. **Life forms:** The form and organization of the community can be inferred from the vegetation's character. Different forms of vegetation, including herbs, shrubs, and trees, can be identified. The next level of classification is based on characteristics like height (tall or short), texture (woody or herbaceous), and occurrence type (evergreen or deciduous). The properties of the leaves have led to the suggestion of other classifications, such as needle-leaved evergreen, broad-leaved evergreen, broad-leaved deciduous, grasses, etc. In Raunkier's (1903) approach, plants were categorized based on how far above the ground they were in relation to their pernnating organ. The term "perennating organ" refers to an organ that endures from one growing season to the next, being active in the summer but dormant throughout the winter. The embryonic or meristematic tissue of buds, bulbs, tubers, roots, and seeds is often included. The following five plant types have been classified: i) Phanerophytes; ii) Chamaephytes; iii) Hemi cryptophytes iv) Cryptophytes v) Therophytes.

Phanerophytes: Perennating organs, such as buds, are found on upright shoots that are above ground. The buds are exposed to the outside world and are nude. These are plants found in tropical climates, such as trees, shrubs, and climbers.

Chamaephytes: Shoots that are near or slightly above the ground have perennating organs on them. The snow cover and falling leaves shield the buds from the outside environment. These include the creeping woody plants and herbs that grow in arctic and alpine environments, which have chilly, dry conditions.

Hemi cryptophytes: These plants have perennating organs close to the ground, where they are shielded from the elements by dirt and fallen leaves. These consist of perennial and biennial herbs that grow in rosettes. The plants grow in moderate, cold climates. When adverse conditions arise, the plant portions that are above ground perish.

Cryptophytes: These plants have perennating organs or buds that are hidden in the earth, or beneath the surface of the soil. The buds are shielded from drying out or freezing. These include the bulbous or tuberous plants that are mainly found in dry regions.

Therophytes: These plants are annuals, finishing their life cycle during the summer or another suitable period. They just need a few months to complete their life cycle in a single season. The perennating organs, seeds, hibernate during the unfavorable season. These include plants found in grasslands and deserts.

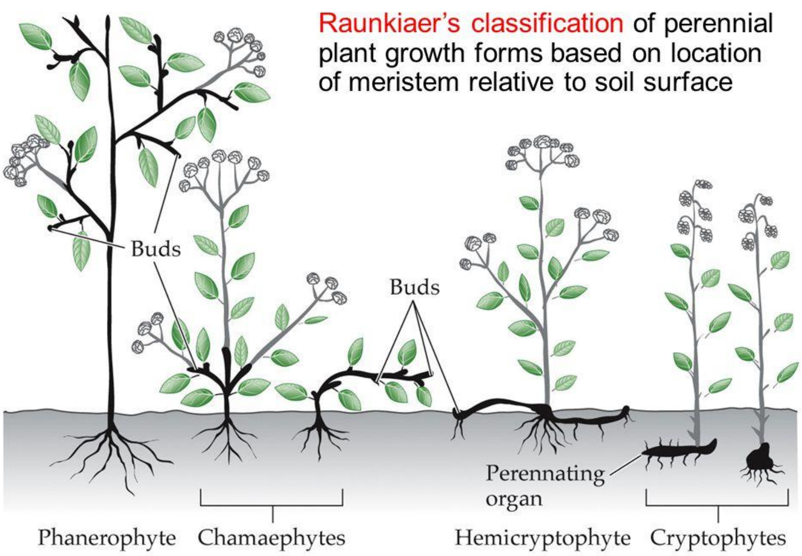


Figure: Different plant forms based on their occurrence from the ground (Raunkiers classification of plant forms).

13.2.1 Quantitative characters

1. **Population density:** It shows the numerical strength of a community by showing the number of members of a certain species in a unit. We can determine the abundance of a species by measuring this characteristic. It also provides information on the level of competition among the species' members.

It is stated as the number of people per unit area. It is calculable using the formula.

Density = Number of individuals of a species in all the sampling units/Total number of sampling units studies

Ecological density is the number of individual locations where they occur often.

2. **Cover (herbage cover):** It describes the portion of the plant that is above ground and is made up of the leaves, stem, and inflorescence. Every layer of vegetation is taken into account independently. The units that overlap are also taken into account. The plants growing beneath the taller ones are scored differently. Ground is referred to as basal area., pierced by stems, or the plant's section that grows into the ground. Is the region under the plant that covers the soil surface known as the canopy area? The term "canopy" describes the topmost stratum. The soil's leaf-covered surface is known as foliage cover. A herbaceous cover is considered closed when it creates a continuous layer.

3. **Plant height:** One useful measure of how well vegetation is performing is the plant's height. Another name for it is stratification. It provides information on a species' success in a range of environments. It shows that there are good environmental conditions present. Stratification leads to a larger proportion of light reaching the upper layers, or canopy. a difference in the community's plant stratification and structure**.**

4. **Weight of plants (biomass):** It is among the crucial quantitative characteristics of plants. It provides us with insight into growth. Usually, it is stated as the dry weight of the plants. The weight, or biomass, of underground plant elements like roots and above-ground plant parts like stems, leaves, fruits, and flowers may be measured independently. After drying the plant for two days at 80°C, it is measured. We may also learn a lot about the species' or the feed's yield from the data.

13.3 ECOTONE

Ecotones are regions on an environmental gradient when two ecological communities, ecosystems, or ecological zones abruptly change from one another. Ecotones can be man-made or naturally occurring, and they exist in a wide range of spatial scales. They include mountain treelines (e.g., Mediterranean and dry) and transitions between major biomes and ecoregions. Ecotones are often found along ecological gradients. Changes in soil, temperature, elevation, and many other environmental factors throughout time and space have resulted in these gradients. Ecotones are often found in environmental gradients when there is a sudden change in the climate.

They are found throughout a wide range of geographic scales, from microhabitats and local vegetation communities overlapping at small scale ecotones to the transitions between major biomes at the continental scale. They exhibit a range of border types, including urban ecotones and man-made ecotones, as well as natural barriers like altitudinal and latitudinal transitions. Examples of these include clear-cut margins in forests and forests. Species richness and abundances have been shown in several studies to generally rise in ecotonal zones.

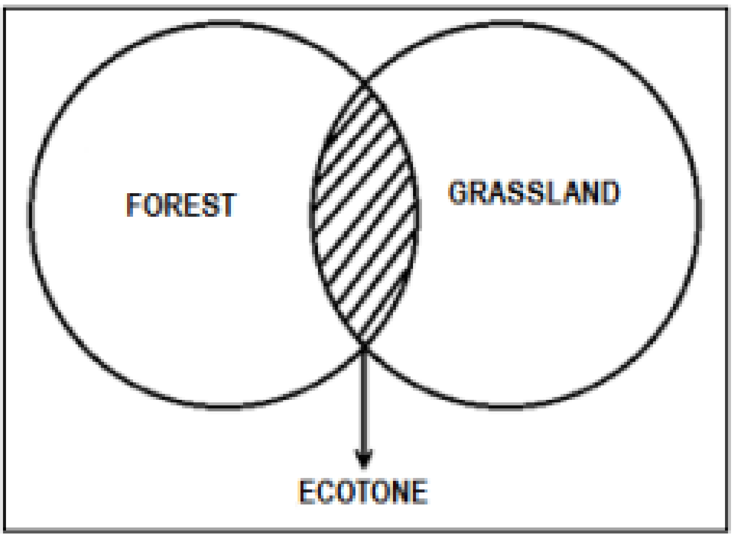


Figure: representation of ecotone between forest and grassland community

Ecotones provide as ideal settings for studying a range of evolutionary processes, such as speciation—the process by which new species are created. Some studies suggest that because ecotones may serve as hotspots for biodiversity and speciation, they should be the subject of substantial conservation commitment.

13.3.1 Formation of Ecotones

A clear and noticeable boundary between two groups is created when the natural surroundings change, as going from a forest to a pristine plain. Furthermore, a gradual blended interface happens in places like mountain ranges where different local species coexist with species common to both interacting populations. The majority of wetlands, including the forests of Western Europe, are ecotones.

13.3.2 Type of ecotone

a) Halocline (salinity gradient)

b) Thermocline (temperature gradient)

c) Pycnocline (water density gradient)

d) Chemocline (chemical gradient

13.3.3 Characteristics of Ecotones

- An abrupt shift in vegetation, such the grass's color, denotes the presence of an ecotone.
- A key ecotone marker for physical variations across plant species is physiognomy.

An ecotone is characterized by changes in species, with certain creatures found on one side of the ecotone boundary and others on the other.

- Spatial mass effect: Because new plants cannot establish self-sustaining populations in other ecotones, their introduction or migration hides an ecotone. On the other hand, if the ecotone continues to exist between two groups, it shows species richness.
- An ecotone can reveal the kind of biome and the efficiency with which two populations coexist on their territory by closely observing the number of alien species.
- The most effective model for researching a varied ecology.
- An ecotone denotes a shift in dominance.
- The ecotone provides an ecological niche for the species that settle near the intersection known as the edge effect.
- Ecoclines: Related to ecotones, ecoclines are areas of physical transition between two biological systems. It demonstrates how an ecotone is signaled by

physiochemical environmental changes, such as microclimatic shifts or chemical indicators like pH, salinity, or hydrothermal gradients.

Edge effects

Ecotones display edge effects, or changes in population that contribute to community structure and allow for increased biodiversity along the edges of combined ecosystems. Two ecosystems form their unique types of plant and environmental circumstances when they are divided by smart edge effects, or ecotones.

Types of edge effect

1. Narrow Edge Effect: A narrow edge effect occurs when one habitat terminates abruptly at the beginning of another.
2. Wide Edge effect: Also referred to as an ecotone, this phenomenon happens when two environments are quite different from one another.
3. Induced edge effect: it describes structural changes that occur over time as a result of either natural or human-caused disturbances (like fire).
4. Inherent Edge effect: The inherent edge effect refers to the boundary that is preserved and created by natural characteristics between two ecosystems.
5. The perforated edge effect: Spaces that allow two habitats to sustain one another and their neighbouring habitats.
6. Convoluted Edge effect: This phenomenon is brought about by two habitats being partitioned nonlinearly.

Edge effects on Succession:

As vegetation grows, edge effects have an impact on succession. distinct species cause a distinct distribution of species depending on whether they colonize the center or the periphery. Along with the orientation change, the edge also moves, participating in different vegetation patterns. Possible additional structural factors include diurnal and seasonal changes. The communities' populations fluctuate in both space and time. Pattern diversity serves as the foundation for community organization. Among other things, the patterns may include horizontal or vertical segregation.

Summary

A group of plant species that live together in a specific setting and engage with their surroundings is referred to as a plant community. The kinds, quantities, and spatial arrangements of the plants within these communities characterize them. Numerous elements, including temperature, soil type, altitude, and disturbance regimes (such as fire, grazing, or human activity), can affect a plant community's composition. Plant communities are essential to the health of ecosystems because they provide animal habitat and food, aid in the cycling of nutrients, and have an impact on soil hydrology and structure. A transitional zone between two different biological groups, ecosystems, or biomes is known as an ecotone. This zone frequently supports a distinct group of species and has traits of both adjacent systems. Ecotones can be the consequence of human activity, like agricultural fields bordering natural landscapes, or they can occur spontaneously, like the line separating a forest from a meadow. Because they contain both species that are specific to the transition area and species from nearby communities, ecotones are usually characterized by great biodiversity. They are crucial indicators for ecological monitoring and conservation initiatives since they are also frequently dynamic and sensitive to environmental changes.

Keywords

Community: is a collection of people who share a common attribute or reside in the same area.

Ecological diversity: is the study of how variations in the local environment impact the ecosystem, flora, and fauna as a whole.

Ecotone: is a zone of transition created by the interaction and convergence of two biological populations.

Ecological niche: is characterized by a species' suitability for a particular environmental situation.

Environment: the surroundings or circumstances in which a human, animal, or plant lives or operates are referred to as the environment.

Keystone species: is one that, in relation to its abundance, has an outsized impact on its natural environment.

MCQs

1. **What is a plant community?**

   A) A group of plants growing in the same area with similar environmental requirements.

   B) A group of plants of the same species growing together.

   C) A group of plants and animals interacting in an ecosystem.

   D) A group of plants that have the same root structure.

   Answer: A)

2. **Which of the following is a characteristic of a climax community?**

   A) High species diversity

   B) Dominance of pioneer species

   C) Rapid changes in species composition

   D) Low levels of competition

   Answer: A)

3. **Which of the following terms refers to the physical and biological factors affecting a plant community?**

   A) Habitat

   B) Niche

   C) Environment

   D) Ecosystem

   Answer: C)

4. **What is an ecotone?**

   A) A region with extremely harsh environmental conditions.

   B) An area where two different ecosystems meet and integrate.

   C) A habitat that supports only one species of plant.

   D) An area devoid of vegetation.

   Answer: B)

5. **Which of the following best describes the species diversity in an ecotone compared to the adjacent ecosystems?**

A) Lower than both ecosystems

B) Higher than both ecosystems

C) The same as the more diverse ecosystem

D) The same as the less diverse ecosystem

Answer: B)

6. **The phenomenon where ecotones have a higher density of certain species compared to neighbouring ecosystems is known as:**

A) Edge effect

B) Climax effect

C) Niche differentiation

D) Succession

Answer: A)

Short questions

1. What is the difference between an ecotone and a biome?
2. What role do ecotones play in biodiversity?
3. What are the main techniques for analysing the structure of plant communities?
4. What is the effect of succession on the long-term growth of plant communities?
5. What effects do invading species have on communities of native plants?
6. What elements influence a plant community's composition?

UNIT-14
PHYTOGEOGRAPHY

14.1 Objectives

- To understand about the principles of phytogeography,
- To discuss about endemism
- To know about biogeographical zone in India

The field of biogeography known as phytogeography, or botanical geography, is concerned with the geographic distribution of plant species and their impact on the surface of the world. The term comes from the Greek words phyton, which means "plant," and geographia, which means "geography," which also means distribution. All facets of plant distribution are covered by phytogeography, including the variables that determine the makeup of whole communities and floras as well as the controls on the distribution of individual species ranges at both large and small scales (see species distribution).

The primary goal of plant geography, according to Campbell (1926), is to identify the parallels and differences between the floras and plants of the past and present that are found in geographically dispersed regions of the planet.

Phytogeography is defined by Wulff (1943) as the study of plant species distribution in their natural environments and the clarification of the genesis and development history of floras.

Phytogeography, according to Croizat (1952), is the study of plant movement and evolution over time and distance.

Major Divisions of Phytogeography:

There are two major divisions of Phytogeography:

(i) Descriptive or Static Phytogeography: This addresses the detailed descriptions of floristic or vegetational categories that are present globally. Plant geographers from the past sought to categorize the planet into floristic and botanical zones and characterized the flora.

(ii) Interpretive or Dynamic Phytogeography: This relates to the dynamics of plant and flora movement and evolution. It explains why various plant species are distributed differently around the planet. It is a borderline science that synthesizes and integrates information and ideas from many specialist fields, including geology, physiology, ecology, taxonomy, evolution, and genetics. Several scholars, including Good (1931), Mason (1936), Cain (1944), and others, have identified the variables influencing plant dispersion.

14.2 Principles of Phytogeography

Lowerence (1951) has suggested the following thirteen modern principles of Phytogeography which are classified into four groups:

A. Principles concerning environment:

The main factor influencing plant dispersion is the climate.

2. Throughout geological history, there have been variations in climate that have impacted plant migration.

3. Historically, there have been different relationships between land masses and oceans. The massive land masses broke apart to create new land masses or continents that drifted apart and shifted. Terrestrial bridges served as likely pathways for the movement of plant and animal species between continents. With the passage of time, the land bridges were drowned under the water, and the chance of plant and animal migration across continents vanished forever.

4. The distribution of vegetation is secondary to soil conditions on plains and mountains of various land masses. The development of calcicols, calcifobs, halophytes, and psammophytes is a result of edaphic circumstances.

5. Biotic variables are also crucial for the establishment and dispersal of plant species.

6. The environment is holocentric, meaning that a location's vegetation is influenced by a combination of environmental elements (Ale & Pank, 1939).

B. **Principles concerning plant responses:**

7. Plant tolerances set a limit on their distribution range. Every species of plant has a different spectrum of edaphic and climatic parameters. As a result, the combined tolerance of all the species that make up a big taxon is its tolerance.

8. Genetics is the basis of tolerances. Plants' responses to their surroundings are determined by their genetic composition.

Numerous crops can now flourish in a greater range of environmental circumstances because to breeding and genetic modifications. It has been shown that hybrid plants in the wild have a greater tolerance spectrum than their parent species.

9. The tolerances vary throughout ontogentic periods. Plants exhibit varying degrees of tolerance at different developmental stages. For instance, adult plants and seeds are more tolerant of temperature and moisture than their seedling counterparts.

C. Principles concerning the migration of floras and climaxes:

10. There have been significant migrations. The Mesozoic and Tertiary eras have seen extensive plant and animal migrations, according to fossil and palaeoecological data.

11. Establishment and transportation led to migration. Through their propagules, such as spores, seeds, bulbils, etc., plants are distributed to new habitats during the process of migration, and if the environmental circumstances are favorable, they establish themselves there. There, plants develop and multiply, and via ecological changes, their offspring go on.

D. Principles concerning the perpetuation and evolution of floras and climaxes:

12. Migration is the primary factor in the persistence of a species, followed by the capacity of the species to pass on advantageous mutations to their progeny.

13. Migration, species evolution, and environmental choices all influence the evolution of floras and climaxes.

14.3 Distribution:

On the basis of area of the earth surface occupied by the plants, the various taxa are categorized as under:

1. Wides.
2. Endemics.
3. Discontinuous species.

1. Wides: The term "wides" refers to plants that are widely dispersed over the planet in distinct climatic zones and throughout the many continents. Although the term "cosmopolitan" is used to describe wides, no plant truly embodies this concept. Chaenopodium album and Taraxacum officinale are typical examples of wides. Tropical plants are referred to as pantropical plants. Not only may very cold temperature plants be found in the Arctic, but they can also be found in tropical and subtropical climates in the alpine zone of mountains. We refer to these as arctic-alpine flora.

2. Endemics: An organism is considered endemic to a region if its distribution is limited to that region. The taxon can be of any rank, but it is typically found at the family level or below, and its distribution range might be as broad as a continent or as small as a few square meters. The idea of endemism is significant since it served as the foundation for the creation of biogeographic areas in the past. A biogeographic region's boundaries are created where the outer bounds of several taxa exist, which is accomplished by mapping the distributions of taxa. Finding the degrees of similarity between geographic regions is a different approach to identifying biogeographic regions. A.P. de Candolle introduced the idea of endemic plant distribution (1813). According to Engler (1882), there are two types of endemic forms: indigenous or native forms that are limited to a certain area and paleo-endemics, which are remnants of extinct forms. The species can be classified as continental, national, provincial, regional, or local endemics (limited to valleys, hills, islands, etc.) based on their area of distribution.

Now the endemic species have been grouped into the following categories:

(i) Relics or Palaeoendemics:

These are the remnants of formerly widely dispersed ancestral species, such as Sequoia sempervirens, which is only found in the coastal valleys of California, and Ginkgo biloba, which is only found in China and Japan. Agathis australis, Metasequoia (Restricted to a single Chinese valley). These organisms are referred to as epibionts or paleoendemics. This type of endemic species has numerous fossil relatives, with the vast majority of them. Another name for them is living fossils. Due to their limited range, endemic species are exclusively suited to a certain habitat, and even when they spread to other regions, they are unable to establish a foothold.

(ii) Neoendemics: The remaining endemic species may be modern species that haven't had enough time to migrate far and wide to take up residence. We refer to them as neoendemics. Many of these genera have many endemic species, or only a small number of endemic species. Neoendemics grow in a variety of habitats, exhibit good diversity, have a large number of biotypes, and have a broad tolerance for environments. Among the well-known endemic genera found in Indian flora are *Petalidium, Butea, Catenaria, Mecanopsis, and Chloroxylon swietenia. Among the well-known endemic species of Indian flora are Eleusine coracana, Venda caerulea, Ficus religiosa, Piper longum, Piper nigrum, Eletteria repens,* and *Shorea robusta*.

The terms "local endemics," "retrogressive endemics," and "micro-endemics," which refer to the endemics of lower groups, are used to describe different aspects of these endemics. Local endemics are found in small land features, while progressive endemics tend to spread over time.

Pseudo endemics:

These endemics develop as a result of population mutation in a specific location. These mutants, sometimes known as pseudo-endemics, might or might not stay long in the original region. Endemism is the outcome of a species' inability to spread its seeds, fruits, spores, or propagules due to the presence of huge obstacles like mountains, seas, and vast deserts. Numerous endemic species may be found on the oceanic islands, which are cut off from the rest of the world by vast bodies of water. These species' ability to migrate outside of their native environment is inhibited by the water barrier.

3. Discontinuous Distribution: when plants may be found in two or more far-flung locations around the globe that are hundreds or thousands of kilometers apart from one another by land or sea. A distribution like this is said to as discontinuous or disjunct. The regions of South America, South Africa, and Australia that are surrounded by large bodies of water are home to the genera Nothofagus and Jovellona.

The significant phytogeographical causes for discontinuous distribution are as follows:

(i) It is possible that the species underwent many evolutionary events and that obstacles prevented them from migrating beyond their initial habitats.

(ii) Species that were formerly extensively spread have now vanished from certain regions and are only found in a few far-off places.

(iii) Species distribution discontinuities might potentially be caused by the climate. Certain types of plants may be found in geographically distant places with comparable climates; for instance, plants from the Arctic can also be found in the alpine zone of high mountains in tropical and subtropical countries. In the arctic and alpine zones, the distribution of Salix and Silen species is irregular.

14.3.1 Theories of Discontinuous Distribution:

1. Theory of Land Bridge: This idea holds that land bridges that exist between the split continents have aided in the migration of different species across the continents. During the Palaeozoic era, it is thought that the uniform distribution of plants and animals throughout the earth was caused by such land bridges. The land bridges were eventually submerged under the water, and the linkages between the continents broke apart faster than creatures could disperse, leading to a discontinuity in the distribution.

2. Theory of Continental drift: Wegner proposed the notion of continental drift in 1912 and 1924. He asserts that during the Paleozoic epoch, the whole landmass of the globe was a single supercontinent. He gave it the name Pangaea. The supercontinent known as Panthalassa had a sea around it on all sides. Pangaea divided into two sizable landmasses during the Mesozoic Era: Laurasia in the north and Gondwanaland in the south. The Tethys Sea divided the two landmasses. On the other hand, Du Toit (1937) proposed that both Laurasia and Gondwanaland were present from the start. The two sizable landmasses with distinctive wildlife and plants separated to form new landmasses known as continents. Similar to how Gondwanaland gave rise to South America, Africa, India, Polynesia, Australia, Antarctica, and other regions, Laurasia gave origin to Eurasia, Greenland, and North America. The continents started to realign some 135 million years ago. The oceans were pushing the continents apart. We refer to this as continental drift. The existence of Gondwanaland and Laurenasia is supported by the presence of dinosaurs and a large number of fossilized plants. The division of continents resulted in the division of the distribution ranges of many plant and animal species, giving birth to discontinuous distribution zones.

14.3.2 Factors Affecting Distribution of Species:

1. Geological history and distribution,
2. Migration, and
3. Ecological amplitude.

1. Geological history and distribution: A species' center of origin is the location of its initial emergence. The process of species evolution is gradual yet ongoing. While the vast majority of the species in the current flora are relatively recent, some are rather old.
The process of species differentiation involves:
(i) Hybridization between the related species as well as mutation and (ii) The natural selection of the hybrid and mutant populations.
Only the fittest individuals that find the habitat circumstances within their ecological amplitudes are selected, while the least fit ones are removed. Not all hybrids and mutants are picked by nature throughout the selection process.
The emergence of new species has also been significantly influenced by climate change. Over time, a number of ancient species went extinct; fossils of some of these species can still be seen today. The fossils offer concrete proof of the historical presence of several species.

2. **Migration:** The recently developed species begins to migrate to new regions while also undergoing more evolutionary modifications. There are several agents that contribute to the dissemination of germules and propagules, including wind, water, glaciers, insects, animals, and even humans. After dispersal, ecasis occurs.
Certain circumstances referred to as migration barriers have the potential to negatively impact migration and occasionally even prevent it entirely. There are three categories of barriers to species dispersal: geographical, environmental, and ecological. The spread and establishment of species are significantly influenced by the climate, an ecological barrier. Certain species are forced to migrate due to unsuitable temperature conditions or climate change in a specific location, while some species eventually become extinct because they are unable to move. Geographical obstacles, such as high mountains, large oceans, or deserts, exist in addition to climate.
For instance, if a freshwater plant's propagules are solely appropriate for freshwater dispersal, they cannot spread across oceans. Similarly, land plant germules or propagules from one nation cannot spread to another country that is divided by large bodies of water or mountains. If a species originated in a certain location, it is referred to as a native of that location. The species is known as alien beyond its native region. By migration, exotic species expand their geographic range. Introduced species are those that are purposefully brought into a new location by humans.

3. **Ecological amplitudes and distribution:** In addition to affecting a plant's life and growth, environmental factors also determine a plant's presence or absence, vigor or weakness, and relative success or failure in a given habitat. Every plant species within a community has a certain range of tolerance for the habitat's physical and biological conditions.

The term ecological amplitude describes this. While the existence of a species at a given location undoubtedly implies that the habitat's environmental circumstances are within its ecological amplitude, the absence of a species from a given location does not always imply that the environment is unsuitable for that species.

Because the genetic makeup of the species in question determines the ecological amplitude, various species have distinct ecological amplitudes that occasionally overlap just slightly. Furthermore, certain species may exist in distinct geographic areas depending on the circumstances and when their ecological amplitudes are met. As an illustration, certain temperate plants, such as conifers, may also be found in the alpine zone of tall mountains in tropical and subtropical climates.

Ecological amplitude's variation over time is another aspect to take into account when determining plant dispersion. When closely related species hybridize, the progeny of sexually reproducing plants have a different genetic makeup. Plant species adapt to changing environmental conditions by altering their ecological amplitudes, which is made possible by genetic variations. It is possible for a species to include many genetically distinct populations that are adapted to distinct ecological circumstances.

These groups are referred to as ecological populations, ecological races, or ecotypes. For instance, there are two main populations in *Euphorbia thymifolia*: the calcicole, which loves calcium, and the calcifuge, which hates it. Comparably, the photoperiodic needs of *Ageratum conyzoides* and *Xanthium strumarium* ecological races vary. The species' geographic range is expanded by the presence of ecotypes within the species.

14.4 Biogeographical Classification of India

For thousands of years, a diversity of species has existed on Earth to meet human needs. Civilizations have relied on the support system created by the diversity of life on Earth to thrive and flourish. Over the course of a century, several scientists have endeavored to categorize and classify the diversity of life provided by nature, which has resulted in the split of its organization into plants and animals. This knowledge of the diversity of nature has aided man in harnessing the biological resources of the planet for the good of humanity and is crucial to the process of development (Roy, 2016). or fossil, and the regions they inhabit may be summed up as biogeography. Alternatively put, "one of the aspects of geography which deals with the correlation among the animals, plants, and their geography" is how biogeography is defined. The multidisciplinary field of biogeography studies how organisms and communities are distributed throughout time and space. A biogeographer's main objective is to provide a clear image of the temporal and geographical fluctuations, processes, and causes of the spatial patterns of distribution of plants and animals. The biosphere, or a portion of it, serves as the fundamental spatial unit for biogeographical research. The biosphere, the greatest environment, is divided into several ecosystems based on the study's goals and geographical scope, including the ecosystems of mountains, crops, deltas, grasslands, and so forth (Singh, 2010).

Eventually, the study of biogeography split into the independent fields of zoogeography (the distribution of animals) and phytogeography (the distribution of plants). In the field of biogeography, a great deal of attention is placed on the study of phytogeography because, unlike animals, which are dynamic and move from place to place with a great deal of behavioural variability, plants have a static distributional pattern that makes it easy to study. Some people think that because biogeography is frequently concerned with the study of the physical environment and how it impacts organisms and shapes their distribution throughout space, it is a subfield of physical geography.

Any location's vegetation is influenced by its climate, geology, and biotic environment. The vast majority of the Indian subcontinent has a diverse range of climates, which are reflected in the variety of plants found there. The following biogeographical zones comprise India.

1. Trans-Himalayan Region: The Trans Himalayas are the Himalayan range that is directly to the north of the Great Himalayas. The icy deserts of Ladakh, Jammu and Kashmir, North Sikkim, and the Luhil-Spiti regions of Himachal Pradesh serve as symbols for this region. The mountain ranges of Zaskar, Kailash, Ladakh, and Karakoram make up this area. It is projected to encompass 186200 km2 in India, making about 5.6% of the country's total land area. The predominant kind of vegetation is a dry alpine scrub formation. The genera Saxifraga, Draba, Ephedra, Kobresia, and Carex are among those that contribute to the scant vegetation. The largest number of wild sheep and goats may be found in this area, along with other uncommon wildlife like snow leopards and migrating black-necked cranes. The environment in this area is quite delicate.

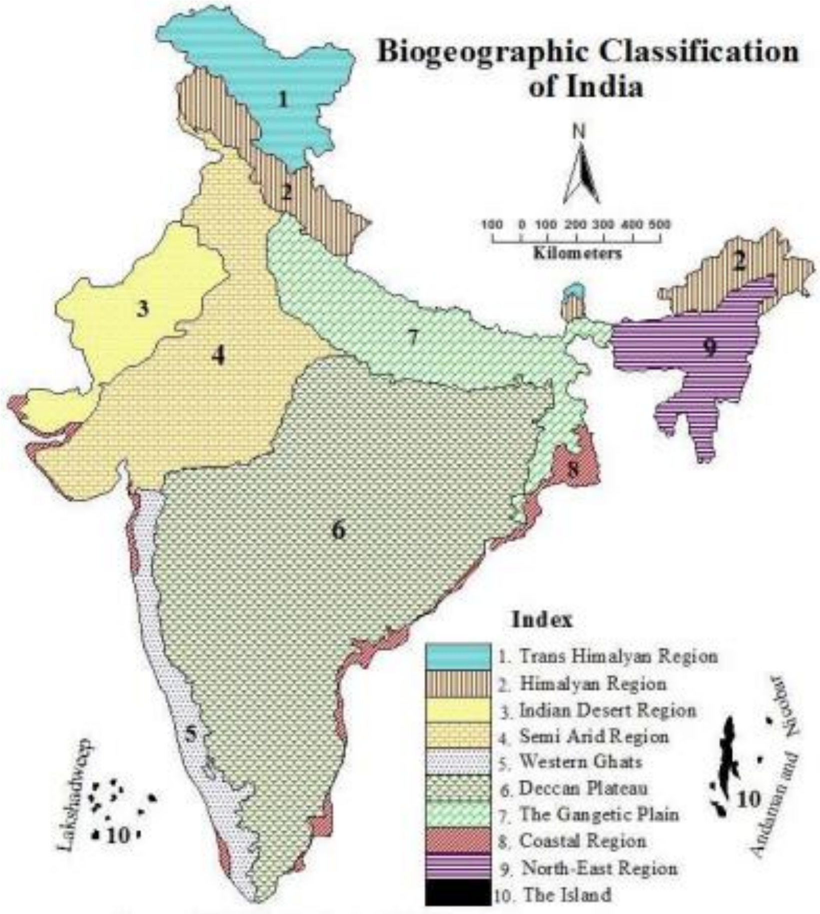
2. Himalayan Region: This region, which includes some of the world's tallest peaks, makes up 6.4% of the entire geographical area. This area, which stretches up to 2400 km from Kashmir to Arunachal Pradesh in the east, is home to an amazing variety of plant formations. About half of the flowering plant species in this region are endemic, out of the over 8000 species that are estimated to exist. Tall conifers abound in the subtropical and temperate zone of the West Himalaya, whereas broad-leaved species predominate in the east Himalaya. In the West Himalaya, oaks are widespread and have a clear altitudinal distribution. The East Himalayan slope is known for its abundance of colorful rhododendron species, over 85 varieties of bamboo, and a wide range of orchid species. This area is home to several endangered bovid species, including Musk Dear and Hungul, as well as Bharal, Ibex, Markhor, and Takin.

3. Indian Desert Region: This area makes approximately 6.8% of the total land area. This area is primarily in the Indian state of Rajasthan, although it also includes small portions of Gujarat, Haryana, and Punjab. The Aravalli highlands in the northeast, the Rand of Kutch along the coast, and the Indus River's alluvial plains in the west and north-west are the boundaries of the desert region. This region has a diverse ecology and habitat since the desert is also characterized by hillocks and sandy gravel plains. When compared to other desert regions throughout the world, this one has incredibly abundant vegetation, human civilization, and animal life. This area is home to the following plant and tree species: Prosopis Cameraria, Tecomella, and Acacia. A few endangered animal species, including wolves, caracals, desert cats, chinkaras, blackbucks, chosinghas, nilgai, and gazelles, are also found in this area. Along with eagles, harriers, falcons, kestrels, and vultures, other birds that may be found here include the Houbara Bustard and Great Indian Bustard.

4. Semi-Arid Region: The Greek word "arere," which meaning to be dry, is where the term "arid" originates. Generally speaking, an area of the earth that receives little or no rainfall and consequently no vegetation is referred to as being arid. This region, which makes up 16.6% of the nation's total land area, is a transitional area between the Western Ghats' lush forest and desert. The states of Gujarat, Punjab, Haryana, and the western portions of Rajasthan comprise the majority of India's semi-arid area. The unpredictable rainfall can occasionally be accompanied by a brief, strong storm that releases a lot of water, which causes excessive runoff rather than recharging the groundwater. The thorn-scrub woods of Capparis deciduas, Prosopis cineraria, and Flacourftia make up the majority of the semi-arid vegetation. The largest biomass of animals is supported in this zone by the presence of grass and a palatable shrub layer. Sambar and Chital are confined to the more humid valley regions and the better forested slopes, respectively. The wolves, lions, caracals, and other endangered animals are also protected in this area.

5. Western Ghats: This region makes up 4.0 percent of the entire land area. The Himalaya is the biogeographic zone with the most floristic richness and variety, followed by the Western Ghats. It is anticipated that this area would support over 4000 blooming plant species, 1500 of which are indigenous. Highly prized timber species including Indian Rosewood, Kauha/asaina/black murdah, Indian Kino Tree and Teak may be found in the wet deciduous woods at lower elevations. In terms of wildlife, some notable endemic species found in this area are the Malabar Grey Hornbill, Grizzled Giant Squirrel, Lion Tailed Macaque, and Nilgiri Langur.

6. Deccan Plateau: With 42.0% of the country's total land, this region is the richest biogeographic region in India. It is a semi-arid terrain that is under the Western Ghats' rain shadow. The best forests in India are found in this bio-geographic zone, which is by far the largest in peninsular India and is mostly found in the States of Madhya Pradesh, Maharashtra, and Odisha. The vast majority of the woodlands are deciduous. The main catchment area for several of the major river systems in south India, including the Narmada, Tapti, Mahanadi, and Godavari, is the Deccan highland. Tropical moist and dry deciduous forests, degraded shrub lands, and tropical thorn forests cover a large area of the Deccan peninsula.



7. The Gangetic Plain: This region makes up around 10.8% of the entire land area. This is the biggest section of India's vast plains, encompassing the states of West Bengal, Uttar Pradesh, and Bihar, and extending from Delhi to Kolkata. The area's unique wildlife includes hog deer, buffalo, swamp deer, rhinos, elephants, and hispid rabbits. The native flora in this area has mostly been replaced by planted vegetation. The tall grasses of Saccharum, Phragmites, and Kangaroo Grass (Themeda) are the predominant types of natural vegetation found in the Terai regions, which are the foothills of the Himalayas. Other trees that are frequently found in this area are Serpentine Wood, White Sandalwood, Mango, Mahua, Neem, and Shikakai. The most significant feature of this region is that it serves as India's "food bowl," providing millions of people with foodgrains due to its plain topography, which is ideal for agriculture, and its perennial rivers, which offer irrigation throughout the year.

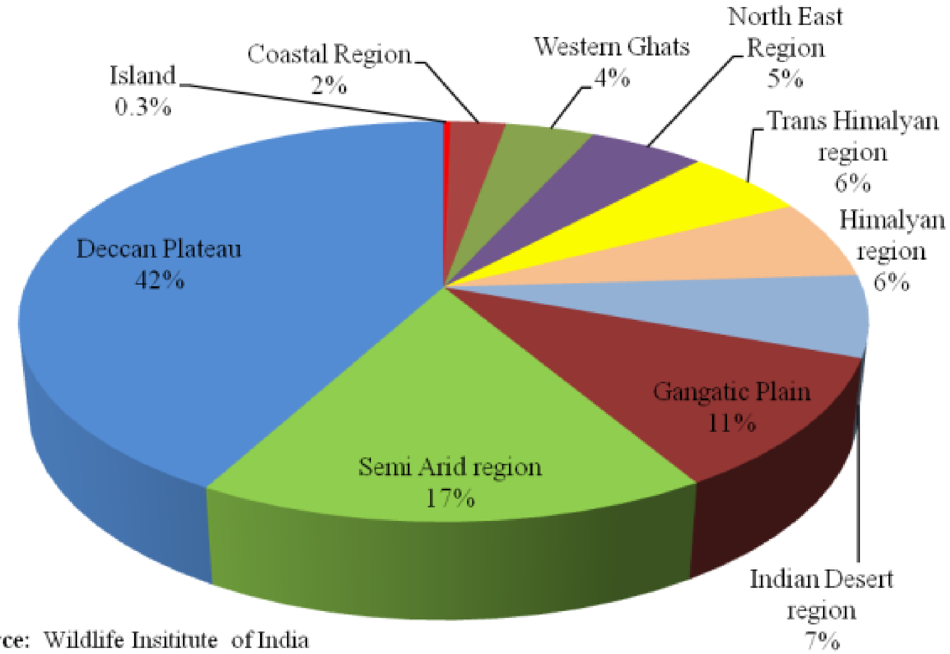
8. North-East Region: The area in question makes up 5.2% of the entire land area. In addition to serving as a meeting place between Peninsular India and the Himalayan Mountains, the region signifies the biogeographical transition zone between Indian, Indo-Malayan, and Indo-Chinese regions. In terms of species richness, endemic species, and community diversity, this zone has the highest concentration of biological variety. This zone, which includes a area of Arunachal Pradesh, is home to almost 50% of all species found in India. In addition to the dense concentration of primitive flowering plants, this area is home to some of the oldest species of extant angiosperms. Other plant families that demonstrate greatest variety in this area include orchids, bamboos, ferns, musaceae, and cucurbitaceae.

9. Coastal Region: This region, which makes up 2.5 percent of the country's total land area, is known for its riches and health due to its sandy beaches, mangroves, mud flats, coral reefs, and marine angiosperm pastures. India's coastline is home to two important types of vegetation: beach forests and mangrove forests. The Australian pine tree, cashew tree, and Indian doomba oil tree are the three most distinctive tree species found in coastal forests. The Lakshadweep are a group of 25 islets that are rich in biodiversity and feature typical reef lagoon systems due to their coral origins. The real mangrove genera Rhizophora, Sonneratia, Heretiera, and Xylocarpus make up the majority of the mangrove forests, which are located along deltas, estuaries, and backwaters.

10. Island: This area makes up 0.3 percent of the entire planet's surface. With 348 islands, the Andaman and Nicobar groupings of islands in the Bay of Bengal have an intriguing biogeography. These islands sustain a diverse range of corals and are home to some of India's best evergreen forests. They are also centres of high endemism. Approximately 2200 kinds of higher plants are found on these islands. Of the approximately 210 indigenous species, 75 are tree species.

The islands' lush vegetation may be largely divided into two categories: upland and coastal varieties. The mangroves, such as red mangrove/Asiatic mangrove, Garjan, grey or white mangrove (Avicennia marina), fish poison tree/sea poison tree, Indian doomba, and Andaman bulletwood/Sea Mahua (Manilkara) comprise the coastal forests. The inland vegetation consists of evergreen and deciduous woods that are home to many commercially significant timber species.

Share of Biogeographical Regions of India



Source: Wildlife Insititute of India

Summary

The study of plant species and ecosystems' global distribution, or phytogeography, sheds light on trends in plant diversity and the forces that have shaped these trends throughout time. comprehending the elements that affect plant distribution, such as climatic circumstances, soil types, past occurrences, and interactions with other species, is essential to comprehending the fundamentals of phytogeography. These concepts aid in explaining why particular plants are found in particular areas as well as how climatic changes and geographic obstacles contribute to the establishment of unique floral assemblages. A wide variety of biogeographical zones, such as the Deccan Peninsula, Gangetic Plain, North-East India, Indian Ocean, Indian Desert, Semi-Arid, Himalayan, and Islands, define phytogeography in India. Because of the distinct temperature, geography, and evolutionary background of each zone, each one has its own distinct flora. India has a remarkable rate of endemism, or the presence of species that are only present in a certain geographic area. This is especially true in biodiversity hotspots like the Eastern Himalayas and the Western Ghats. Long-term geographic isolation, a variety of climates, and intricate topographical characteristics have all contributed to this high endemism by enabling the separate evolution of several plant species. Because endemic species are frequently more susceptible to habitat loss and environmental changes, endemism research is essential for conservation efforts. For the purpose of ecological study, biodiversity protection, and efficient management of natural resources in the face of changing environmental circumstances, an understanding of phytogeographical patterns and principles is vital.

Keywords

Phytogeography: studied the geographical distribution of plants.

Adaptation: The process of alteration that makes a species or creature more adapted to its surroundings

Endemism: indigenous and limited to a certain area

MCQ

1. **What is phytogeography?**

   A) The study of plant fossils

   B) The study of plant diseases

   C) The study of the geographic distribution of plant species

   D) The study of plant anatomy

   Answer: C

2. **Phytogeography helps in understanding which of the following?**

   A) Plant evolution and adaptation

   B) Geological history of Earth

   C) Human impact on vegetation

   D) All of the above

   Answer: D

3. **The concept of vicariance is associated with which of the following?**

   A) Dispersal of plants

   B) Geographical separation of species

   C) Genetic mutation in plants

   D) Introduction of new plant species

   Answer: B

4. **How many biogeographical zones are identified in India?**

A) 3

B) 5

C) 10

D) 12

Answer: D

5. **Which biogeographical zone in India is characterized by high rainfall and dense evergreen forests?**

A) Western Ghats

B) Deccan Plateau

C) Himalayas

D) Desert

Answer: A

6. **The Sundarbans, known for its mangrove forests, is part of which biogeographical zone in India?**

A) Western Ghats

B) Gangetic Plain

C) Coastal Zone

D) Islands

Answer: C

7. **What does the term "endemism" refer to in phytogeography?**

A) The introduction of alien species

B) Plants that are widespread globally

C) Species that are restricted to a specific area

D) The extinction of species

Answer: C

8. **Which of the following is an example of an endemic plant species in India?**

A) Banyan tree

B) Himalayan Blue Poppy

C) Rose

D) Sunflower

Answer: B

9. **Why is endemism important for biodiversity conservation?**

A) It helps in the survival of alien species

B) It ensures genetic uniformity

C) It highlights the unique flora of a region and helps in conservation efforts

D) It focuses on widespread species

Answer: C

Short questions

1. What is phytogeography's main area of study?
2. What distinguishes generic biogeography from phytogeography?
3. What role does the idea of "floristic regions" have in phytogeography?
4. What role does the vicariance principle play in the explanation of plant distribution?
5. What is the number of important biogeographical zones in India?
6. List the three biogeographical zones that make up India and explain a salient feature of each.
7. What elements support the Western Ghats' biodiversity?
8. What is endemism, and how does conservation biology benefit from it?
9. Give an instance of an Indian indigenous plant species.
10. What role does endemism play in isolated places like islands?

Refrerences-

- Sharma P.D., 'Ecology and Environment', Rastogi Publication, Meerut
- Shukla R.S. and Chandel P.S., 'A textbook of Plant Ecology', S.Chand& Company pvt. Ltd., New Delhi
- Pandey B.P., Botany for Degree Students, S.Chand& Company pvt. Ltd., New Delhi
- Verma P.S. and Agarwal V.K., Environmental Biology (Principles of Ecology), S. Chand& Company pvt. Ltd., New Delhi
- Anjaneyulu Y., Introduction to Environmental Science published by BS Publications,Hyderabad.
- Angiosperms by Singh, Pande and Jain, Rastogi Publication. Meerut.
- Angisoperms by B. P. Pande, S. Chand & Co., Delhi.
- Chopra G.L. (1977). Angiosperms (Systematic and Life cycle), Nagin and Company, Delhi.
- Flowering Plants Angiosperms, Lalit M. Tewari & Jeewan S. Jalal(2011) Jagdamba Publishing Company, New Delhi.
- Lawrence G.H.M. (1951). Taxonomy of Vascular plants Macmillan, New York.
- Mathur R.C. (1972). Systematic Botany: Angiosperms, Agra Book Store, Agra.
- Gupta R.K. (1981). T text book of Systematic Botany, Atma Ram & Sons, Delhi
- Street HE (ed) (1978) Essays in Plant Taxonomy, AP London & New York.
- Stace CA (1989). The Plant Taxonomy and Biosystematics, Edward Arnold, London