# PLANT SYSTEMATICS

## M.Sc. BOTANY

## SEMESTER-I, PAPER-I

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**M.Sc. BOTANY: PLANT SYSTEMATICS**

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# *FOREWORD*

***Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining 'A+' grade from the NAAC in the year 2024, Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from over 221 affiliated colleges spread over the two districts of Guntur and Prakasam.***

***The University has also started the Centre for Distance Education in 2003-04 with the aim of taking higher education to the door step of all the sectors of the society. The centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even to housewives desirous of pursuing higher studies. Acharya Nagarjuna University has started offering B.Sc., B.A., B.B.A., and B.Com courses at the Degree level and M.A., M.Com., M.Sc., M.B.A., and L.L.M., courses at the PG level from the academic year 2003-2004 onwards.***

***To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise in the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.***

***It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn be part of country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will go from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic Coordinators, Editors and Lesson-writers of the Centre who have helped in these endeavors.***

***Prof. K. Gangadhara Rao***
*M.Tech., Ph.D.,*
***Vice-Chancellor I/c***
***Acharya Nagarjuna University***

# M.Sc. BOTANY
# SEMESTER-I, PAPER-I
# 101BO24-PLANT SYSTEMATICS

# SYLLABUS

## UNIT-I

1) Systematics: Concepts and basic components;
2) Taxonomic structure; Taxonomic hierarchy-species to division;
3) International Code of Nomenclature (ICN) of algae, fungi and plants;
4) Principles, Rules and Recommendations, Ranks, Principle of Priority, Typification, Author citation, Effective and Valid publication.

## UNIT-II

1) System of Classification of Armen Takhtajan and its Merits and Demerits;
2) Angiosperm Phylogeny Group (APG) Classification;
3) A brief account of selective clades like Basal angiosperms, Magnolinids, Monocots (including Commelinids),
4) A brief account of Selective Clades like Eudicots, Rosids, Asterids.

## UNIT-III

1) Taxonomic evidence: Morphology, Anatomy, Embryology, Palynology and Cytology in relation to taxonomy;
2) Data Information Systems;
3) Botanical Survey of India (BSI): Objectives, Activities, Organization and Publications.

## UNIT-IV

1) Process of Plant Identification: Construction, Types and Use of Taxonomic keys;
2) Herbarium Methodology: Collection of Plants, Processing and Preservation of Specimens;
3) Important World and Indian Herbaria;
4) Major Botanical Gardens of the World and India;
5) DNA Barcoding in Plants and its Practical Implications.

## UNIT-V

1) Chemosystematics: Primary and Secondary Metabolites, Semantides and Non-Semantides etc. in Plants;
2) Phylogenetic Systematics: operational units, characters, coding and construction of cladograms;
3) Serosystematics: Methodology and its applications in systematics;
4) Molecular Systematics: Gene sequences, Phylogenetic analysis, Restriction site analysis, allozymes etc.

**REFERENCE BOOKS:**


1) International Code of Nomenclature for algae, fungi, and plants (Schenzhen Code), 2018. (Online Version) adopted by the *Nineteenth International Botanical Congress, Chenzehen, China*.
2) Angiosperm Phylogeny group, 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnaean Society* 181: 1-20.
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**ACHARYA NAGARJUNA UNIVERSITY : CENTRE FOR DISTANCE EDUCATION**
**M.Sc. – Botany - Program code: 01**

## Program Structure

| Program code | Program | Internal assessment | External exams | Max. Marks | credits |
|---|---|---|---|---|---|
| SEMISTER 1 | | | | | |
| 101BO24 | Plant Systematics | 30 | 70 | 100 | 4 |
| 102BO24 | Reproductive Biology of Angiosperms | 30 | 70 | 100 | 4 |
| 103BO24 | Biology and Diversity of Viruses, Bacteria, Algae and Fungi | 30 | 70 | 100 | 4 |
| 104BO24 | Outlines of Bryophytes, Pteridophytes, Gymnosperms and Plant Fossils | 30 | 70 | 100 | 4 |
| 105BO24 | Plant Systematics and Reproductive Biology of Angiosperms | 30 | 70 | 100 | 4 |
| 106BO24 | Biology and Diversity of Viruses, Bacteria, Algae, and Fungi and Outlines of Bryophytes, Pteridophytes Gymnosperms and Plant Fossils | 30 | 70 | 100 | 4 |
| SEMISTER 2 | | | | | |
| 201BO24 | Plant Ecology and Biodiversity | 30 | 70 | 100 | 4 |
| 202BO24 | Plant Physiology | 30 | 70 | 100 | 4 |
| 203BO24 | Compulsory Foundation – Cell Biology | 30 | 70 | 100 | 4 |
| 204BO24 | Plant Structure and Development | 30 | 70 | 100 | 4 |
| 205BO24 | Plant Ecology and Biodiversity and Plant Physiology | 30 | 70 | 100 | 4 |
| 206BO24 | Cell Biology and Plant Structure and Development | 30 | 70 | 100 | 4 |
| SEMISTER 3 | | | | | |
| 301BO24 | Plant Pathology | 30 | 70 | 100 | 4 |
| 302BO24 | Plant Metabolism | 30 | 70 | 100 | 4 |
| 303BO24 | Ethnobotany and Ethnomedicine | 30 | 70 | 100 | 4 |
| 304BO24 | Molecular Biology of Plants | 30 | 70 | 100 | 4 |
| 305BO24 | Plant Pathology and Plant Metabolism | 30 | 70 | 100 | 4 |
| 306BO24 | Ethnobotany and Ethnomedicine and Molecular Biology of Plants | 30 | 70 | 100 | 4 |
| SEMISTER 4 | | | | | |
| 401BO24 | Plant cell, Tissue and Organ Culture | 30 | 70 | 100 | 4 |
| 402BO24 | Genetic engineering and Bioinformatics | 30 | 70 | 100 | 4 |
| 403BO24 | Cytogenetics and Plant Breeding | 30 | 70 | 100 | 4 |
| 404BO24 | Horticulture and Landscaping | 30 | 70 | 100 | 4 |
| 405BO24 | Plant cell, Tissue and Organ Culture and Genetic engineering and Bioinformatics | 30 | 70 | 100 | 4 |
| 406BO24 | Cytogenetics and Plant Breeding and Horticulture and Landscaping | 30 | 70 | 100 | 4 |

**(101BO24)**

# M.Sc. DEGREE EXAMINATION, MODEL QUESTION PAPER
## FIRST SEMESTER
## BOTANY
## PAPER-I: PLANT SYSTEMATICS

**Time: Three hours** **Maximum: 70 marks**

**Answer All Questions** **5 × 14 = 70M**
**Each Question carries equal marks (5X14=70)**

### UNIT-I

1 a) Give a detailed note on what is Systematics and their Concepts with basic components.

**OR**

b) Give a brief note on International Code of Nomenclature (ICN) of algae, fungi.

### UNIT-II

2 a) Give a detailed note on Angiosperm Phylogeny Group (APG) classification.

**OR**

b) Give a brief account on selective clades like basal angiosperms, Magnoliids.

### UNIT-III

3 a) Give a detailed note on Taxonomic evidence based on morphology, anatomy, embryology.

**OR**

b) Give a detailed note on Botanical Survey of India (BSI).

### UNIT-IV

4 a) Give a brief note on Process of Plant Identification based on Herbarium Methodology.

**OR**

b) Give a brief note on DNA barcoding in plants and its practical implications.

### UNIT-V

5 Give an account on Chemosystematics.

**OR**

Give a detailed note on Serosystematics, methodology and its applications.

# CONTENTS

# LESSON-1

# SYSTEMATICS: CONCEPTS AND BASIC COMPONENTS

**OBJECTIVE:**

This chapter attempts to present the changes in species concept and basic components of plant systematic

**STRUCTURE:**



## 1.1 CONCEPTS:

The word ‘systematic’ is derived from the Greek word '*systema*' meaning system/ order/ sequence/ organized whole. This word was applied to the system of classification developed by Linnaeus in the 4$^{th}$ Edition of his historical book “Systema Nature” in 1735.It was initially regarded as more inclusive field of study concerned with the diversity of organisms and their classification and evolution. In other words, it deals with the evolutionary relationships between organisms. So, the systematics is the scientific study of the biological diversity and the classification of organisms based on their evolutionary relationships.

Relationships are visualized as Phylogenetic trees (Cladograms/ evolutionary trees/ Phylogenies). They have two components.

a) Branching order: It shows group relationships

b) Branch length: It shows amount of evolution.

**Phylogenetic trees of species and higher taxa are used to study:**

1) The evolution of traits e.g., anatomical, molecular characteristics etc.

2) Biogeography (the distribution of organisms).

John Lindley (1830) is probably the first person to define systematics although he used the term "Systematic Botany" rather than using the term "systematics". Simpson (1961) defined systematics as a scientific study of the kinds and diversity of organisms and relationships between them. According to Blackwelder (1967), systematics is that science which includes both taxonomy and classification, and all other aspects dealing with kinds of organisms and the data accumulated about them. Ornduff (1969) proposed the same view as Simpson. Michener *et al.* (1970) defined systematic biology (called simply systematics). According to him, systematics is the field that (a) provides scientific names for organisms, (b) describes them, (c) preserves collections of them, (d) provides classifications for the organisms, keys for their identification, and data on their distributions, (e) investigates their evolutionary histories, and (f) considers their environmental adaptations and taxonomy is that part of systematics.

The term systematics is used often synonymously with taxonomy and may be confined with scientific classifications. Europeans use the term systematics for the field of study of biodiversity, whereas North Americans tend to use taxonomy more frequently. Mayden (1992) defined systematics as the field of science concerned with reconstructing the evolutionary/ancestral-descendant (derivative) relations of groups of organisms, whether fossils/recent on the basis of heritable traits. Christofferson (1995) defined systematic as the theory, principles and practice of identifying (discovering) systems, i.e., of ordering the diversity of organism (parts) into more general systems of taxa (wholes) according to the most general causal processes. According to Padian (1999), systematic can be seen as the philosophy of organization nature, taxonomy as the use of sets of organic data guided by systematic principles, and classification as the tabular or hierarchical end result of this activity.

Randall Schuh (2000) says that systematics and taxonomy are the same things and consist of three activities (a) recognition of species, (b) classification into a hierarchical scheme, and (c) placing this in a broader context. Gurcharan Singh (2004) also treats both taxonomy and systematics as identical activities.

**The Systematics is of Two Types:**

**1. Classical Taxonomy**:

The classical taxonomy is based on visible morphological characters of one or a few species with supporting evidences from other fields.

**2. New Systematics:** (Modern Taxonomy/ Population Systematics/Biosystematics);

The term 'new systematics' was coined by Julian Huxley (1940). It is systematic study which takes all types of characters into consideration. Besides classical morphology, it includes anatomy, cytology, physiology, biochemistry, ecology, genetics, embryology, palynology etc. of the whole population rather than a few species.

**Approaches of classification of Plant Systematics**:

There are three approaches of classification of plants.

1) **Cladistics**: Cladistics is based on the evolutionary history of a plant to classify it into a taxonomic group. Cladograms are used to represent the evolutionary pattern of descent. The diagram of a cladogram will show a common ancestor in the past, and origin of different species developed from the common ancestor over time. A synapomorphy is a trait that is shared by two or more taxa and was present in their most recent common ancestor but not in earlier generations. If a cladogram uses an absolute time scale, it is called a phylogram.
2) **Phenetics**: Phenetics use an overall similarity and physical characters to characterize plants rather thanevolutionary data.
3) **Phyletics:** Phyletics is difficult to compare directly with the other two approaches, but it may be considered as the most natural approach, as it assumes new species arise gradually. Phyletics is closely linked to cladistics, but does not clarify the ancestors a descendants.

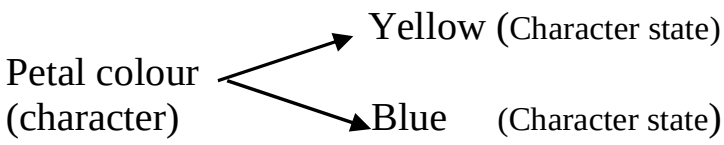
## 1.2 BASIC COMPONENTSOF PLANT SYSTEMATICS:

For scientific study of a plant, it is necessary to describe it, identify it, have a name for its communication and assign it to a category on the basis of phylogeny. So, systematic includes five basic components. These are: 1. Description (D), 2. Identification (I), 3. Nomenclature (N), 4. Classification (C) and 5. Phylogeny

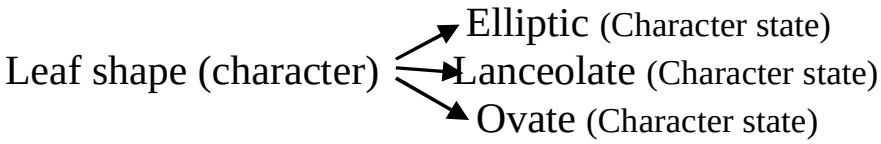
### 1.2.1. Description (Characterization):

It is orderly recording of maximum possible characters of a taxon (an organism)or the assignment of features to a taxon or the listing of features by recording the appropriate character states. Generally a shortened description is used in palnt systematics. This description is consisting of only those taxonomic characters which help in the separation of a taxon from other closely related taxa and forms the diagnosis and these characters are called 'diagnostic characters'. They determine the circumscription. Numerous characters and character state terms are used in plant systematics. Characters are usually described in terms of their states.

e.g., a) Petal colour is one character, for which 2 character states are yellow and blue.




b) Leaf shape is one character, for which 2 character states are elliptic, lanceolate and ovate




The characters and character states are used as tools of communication for categorizing the taxa. Description is recorded in as set of pattern (Habit, Stem, leaf etc.).An accurate and complete listing of characters is one of the major objectives of systematics.

**1.2.2. Identification (Determination):**

It is the process of recognizing an unknown species. This identification is based on overall similarities and differences with an already known species Winston (1999) defined identification as "refereeinga species to a previously classified and named group". The comparison of unknown species is directly with known species which has been authoritatively predeterminedor indirectly with the help of taxonomic keys, descriptions, illustrations etc. An unknown can be identified by first noting its characters by describing it. Then these features are compared with those of other taxa for confirmation. Generally, these characters are derived from morphology. These are sufficient for identification, but other characters are also considered for the identification. In case, the species does not agree with existing predetermined specimen, it is taken to be new one. Plant taxa can be identified in many ways. A taxonomic key especially a dichotomous key is the best one. There are different methods of identification. They are:

**a) Expert determination**: It is an accurate, reliable and best method of identification. Experts are engaged in Botanical Gardens, Herbaria, Museums, Research Institutes etc. It is based on extensive past experience of identifier with plants.

**b) Comparison**: It involves comparison of unknown with already identified and named specimens, illustrations, photographs or descriptions.

**c) Use of taxonomic keys, taxonomic literature**: This method does not require long time and experience. Identification can be achieved by various types of taxonomic literature such as Floras, Monographs, Manuals, Journals etc. Taxonomic Keys are provided in these sources. After the unknown specimen has been provisionally identified, it can be confirmed by comparison with the detailed description of the taxon.

In recent years, the method of taking photographs of plants and plant parts, uploading these pictures on the website and making an enquiry from concerned electronic lists is gaining popularity. The development of various molecular techniques that generate molecular markers has made it possible to identify the plants accurately. The portable computers and digital cameras are useful for automatic species identification (Jin et.al.,2015).Recently, Matchar (2017) mentioned that i Naturalist, a social networking service of naturalists, scientists, biologists built for biodiversity, plans to start an app that uses AI technology to identify the plants.

**1.2.3 Nomenclature (Latin: Nomen=name; clare=to announce/ call):**

It deals with the determination of the correct name for a taxon (plant) following a precise and universal system of rules used and accepted by botanists. Once a taxon has been identified, it becomes necessary to assign it a correct botanical name. Nomenclature of algae, fungi and plants is governed by "International Code of Nomenclature of algae, fungi and plants (ICN)" through its principles, rules and recommendations and various provisions framed by International Botanical Congress (IBC). This meeting is held at regular intervals. The code is updated every six years.

An already existing list of botanical names is provided in the code which avoids inconvenient name changes for some taxa. However, naming of cultivated plants is governed by a separate "International Code of Nomenclature for Cultivated Plants (ICNCP)".

**Draft Bio Code**: The Draft Bio Code opts for a compromise between zoology and botany. The first draft of Biocode was prepared in 1995. After successive reviews, the 4$^{th}$draft, named Draft Biocode (1997) was prepared by the International Committee for Bionomenclature. It was published by Greuter et.al. available on the Web. The committee proposed to replace all existing codes.

In 2011, a revised *Bio Code* was proposed that, instead of replacing the existing *Codes*, would provide a unified context for them, referring to them when necessary. Changes in the existing codes are slowly being made in the proposed directions.

**Phylocode:** The Phylocodeis a rankles code and it is based on the concept of Phylogenetic Systematics. It would regulate phylogenetic nomenclature instead of the traditional Linnaean nomenclature. Its current version is specifically designed to regulate the naming of clades except the based on the concept of recognition of monophyletic groups.

**1.2.4. Classification**:

It is the arrangement of taxa into groups. on the basis of similarities. Stace (1989) defined classification as "the production of a logical system of categories, each containing any number of organisms which allows easier reference to its components". An enormous number of species of plants presenton the earth. So, it is impossible to study them individually. It is necessary to study them or place them into small or large groups on the

basis of their differences and similarities. These groups are, in turn, assembled into inclusive groups, until all the organisms have been assembled into a single most inclusive group. These groups are then arranged according their levels and assigned to categories in a sequential manner.

**Kingdom-Division-Class-Order-Family-Genus-Species**

Each category is given a name following the rules of an International Code of Nomenclature. The similar plants are grouped under species, similar species under a genus, similar genera under a family and so on. Classification also includes the determination of the position or rank for new as well as old taxa that have been recommended, splitted, united, transferred or altered in rank.

Once established, a classification provides an important mechanism of source of storage and usage of organisms. The classifications are of several types.

a) **Artificial classifications**: They are based on easily observable characters such as habit, color, number, form etc. e.g., Sexual system proposed by Linnaeus.

b) **Natural classifications**: It is based on natural affinities of plants and uses overall similarity in grouping of organisms. e.g., Bentham and Hooker`s system.

c) **Phenetic Classification**: It uses overall similarity in terms of a phenetic relationships based on data from all available sources. These were strongly advocated by Sneath & Sokal (1973).

e.g. Numerical Classification.

d) **Phylogenetic classification**: It is based on phylogenetic history and relationships of plants. If some descendants have been left out (Paraphyletic), these are brought back into the group to make it monophyletic. e.g. Thakhtajan, Cronquist, Angiosperm Phylogeny Group classifications.

### 1.2.5. Phylogeny (Gk. Phylon= tribe/race; Genesis= origin/ source):

Phylogeny is the study of the Geneology (=the study of ancestor-descendant relationships and lineages) and evolutionary history of a taxonomic group or group of organisms. The relationships are depicted or represented through a diagram known as a Phylogram (The term ‘cladogram’ is used for a diagram constructed through cladistic methodology). A Phylogram is a branching diagram which represents the evolutionary pattern of descent (=the sequence of ancestral-descendent populations through time).The longest branch representing the most advanced group. The lines (branches) of a cladogram are called lineages or clades. The branching of the cladogram represents lineage divergence. Changes in the genetic makeup of populations may occur in lineages over time. Evolution may be recognized as a change from apre-existing (ancestral) character state to a new (derived) character state. The ancestral character state is called ‘plesiomorphy’ while the derived character state is called an ‘apomorphy’.

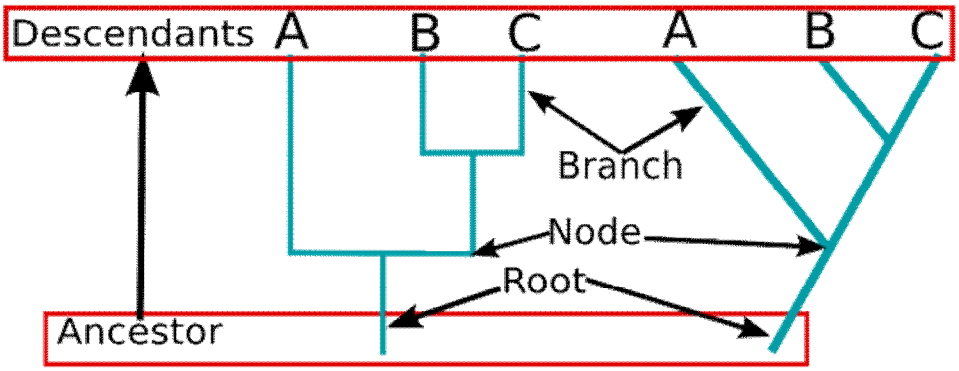



**Fig.1 Diagrammatic Scheme of Plesiomorphy and 'Apomorphy'.**

## 1.3 SUMMARY:

Systematics is the scientific study of biological diversity, focusing on classifying organisms based on their evolutionary relationships. The term derives from the Greek "systema", meaning an organized whole. It emerged from Linnaeus's work on classification in 1735. Systematics involves creating phylogenetic trees (or cladograms) that illustrate these relationships, with branching order indicating group relationships and branch length showing evolutionary changes. Systematics includes two types: A. Classical Taxonomy: Based on visible morphological traits of species and B. New Systematics (Modern Taxonomy): Incorporates a broader range of characteristics, such as genetics and biochemistry Three different types of Plant Classification Approaches are

1) Cladistics: Based on evolutionary history and common ancestors.
2) Phenetics: Focuses on overall physical similarities, and
3) Phyletics: Assumes species evolve gradually over time, similar to cladistics but without clear ancestor-descendant relationships. Systematics consists of key components: description, identification, nomenclature, classification, and phylogeny. Each step helps classify and understand organisms, often through standardized systems like the International Code of Nomenclature for plants.

## 1.4 SELF-ASSESSMENT:

1) Give a detailed account on concepts of Concepts:
2) Explain in detail the Basic components of systematic
3) Give a detailed on Identification
4) Give a detailed on Nomenclature (n)
5) Give a detailed on Classification (c)
6) Give a detailed on Phylogeny

## 1.5 REFERENCES:

1) International Code of Nomenclature for Algae, Fungi, and Plants (Schenzhen Code), 2018. (Online Version) adopted by the Nineteenth International Botanical Congress, Chenzehen, China.

2) Angiosperm Phylogeny Group, 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnaean Society 181: 1-20.

3) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J. 2016. Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.

4) Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, Canada.

**Dr. P. Sathya Narayana Raju**

# LESSON-2

# TAXONOMIC STRUCTURE AND TAXONOMIC HIERARCHY

**OBJECTIVE:**

This chapter attempts to present Taxonomic Structure and Taxonomic Hierarchy.

**STRUCTURE:**



## 2.1 TAXONOMIC STRUCTURE:

Taxonomic structure is a hierarchical arrangement of categories to which taxomomic groups are assigned. It is a hierarchical system that classifies living organisms into successive levels. It explains how species within a clade are distributed among genera and other categories.

Subordination of organisms in groups results from evolutionary divergence. When an ancestral form undergoes divergence during course of time, the descendents (derivatives) are resulted in modified forms. But they resemble each other in decreasing degrees. Members of a species resemble each other because they genetically more close to each other. This resemblance decreases progressively in different species of the same genus, different genera of the same family, different families of the same order, different orders of the same class and so on. The establishment of such relationships is one the main concerns of the plant systematics. In any biological classification, this is accomplished by taxonomic hierarchy.

## 2.2 CONCEPT OF TAXA:

A taxonis a group of one or more populations of an organism(s).The term taxon was first used by Adolf Meyer for animals (1926). It was used for plants in the $7^{th}$ International Botanical Congress (1950).According to Code of Nomenclature, taxonomic groups of any rank will be referred to as taxa."So, at family level, taxa may be represented by the Annonaceae, Fabaceae, while *Annona*, *Crotalaria* are examples of generic taxa.

## 2.3 TAXONOMIC CHARACTERS AND CHARACTERISTICS:

Any part or shape of an organism that is used for classifying the organism is called a character. For example, characters such as the shape of the leaves, arrangement of the reproductive organs etc. are used in classification. On the other hand, characters by which an organism or group of organisms can be recognized is called "characteristics". Taxonomic characters are actually features that are assessed in isolation from the rest of the plants by taxonomists for making comparisons and interpretations. It is important to differentiate between characters and character states.

**Problems of hierarchy in taxonomic structures:**

A biologist faces a peculiar type of problems especially in circumscribing the categories and taxa in biology. For example, traditionally there were 2 kingdoms, Animalia and Plantae. Whittaker gave a 5 kingdom classification. Edwards recognized 7 kingdoms under 2 super kingdoms (Prokaryota and Eukaryota).

**Species Concept**:

A species is a smallest fundamental and structural unit of classification. It includes individuals which are alike and can breed with each other. The species is defined in various ways by different biologists. Still, the definition of the term species is a matter of discussion and controversy. Various views have been put forward by biologists.

**Different species concepts include:**

1) **Nominalistic Species Concept**: This concept was put forward by Buffon and Lamarck in mid $18^{th}$ Century. It suggests that 'the Nature produces the individuals and nothing more'. Species is nothing but the brain child of man and have no actual existence in nature. Only individuals exist. According to Burma (1954) and Spurway (1955), species has been invented as a device to refer to large number of individuals collectively.

2) **Typological Species (Aristotelian) Concept**: This concept was first proposed by John Ray and elaborated by Linnaeus. According to this concept 'the species by themselves are fixed as created by the Almighty'. There is an inner essence that makes species.

3) **Non-dimensional Species Concept:** It was introduced by John Ray. "The relationship of two different species can be defined as reproductive isolation". Breeding relationship as the basis of species. One species never produced from the seeds of other species.

4) **Taxonomic (Morphological) Species Concept**: It was developed by Darwin based on morphology. According to this concept, "species is regarded as an assemblage of individuals with morphological features in common and separable from other ones by correlated morphological discontinuity in a number of features".

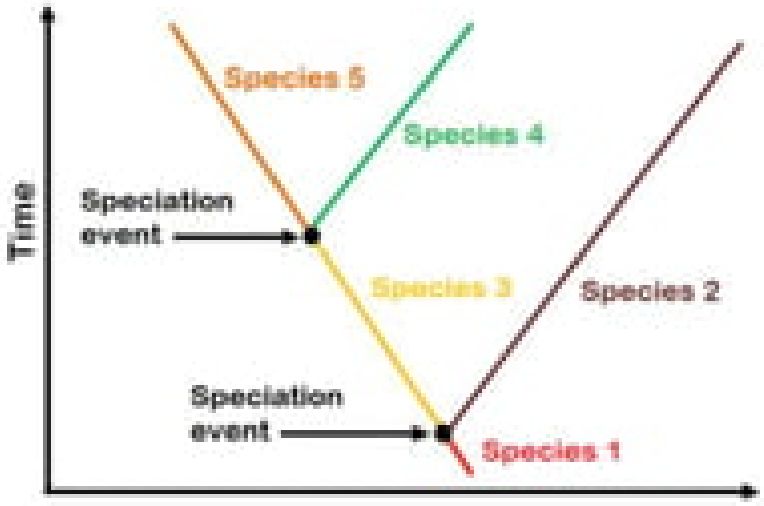
5) **Biological Species Concept**: It was first formulated by Mayr. It suggests that "a species is a group of inbreeding natural populations that are reproductively isolated from other such groups". Species consists of individuals that share common gene pool (total set of genes and alleles in a population).

6) **Evolutionary Species Concept**: It was developed by Simpson, Wiley etc. According to this, "an evolutionary species is a single lineage of ancestor-descendant populations of organisms which maintains its identity from other such lineages (in space and time) and which has its own evolutionary tendencies and history.

7) **Ecological Species Concept**: "Species is a lineage which occupies an adaptive zone minimally different from that of any other lineages outside its range". It was proposed by Van Valen.

8) **Selection Species Concept**: Species is a system of genetically similar individuals and populations maintained as a cohesive unit by a set of selection pressures that balance the disruptive forces imposed by the environmental factors, mutations or genetic recombination.

9) **Cladistic Species Concep**t: Species as a set of organisms between two speciation events or between one speciation event and extinction event. According to this concept, species comes to exist when a lineage of organisms is split into two. When a speciation event occur, the ancestral species becomes extinct, giving rise to two new species.




**Genus Concept:**

Mayr defined genus as "a taxonomic category which contains either one or more species and is separable from other genera by a decided discontinuity group".

Tournefort was regarded as 'The Father of Genus Concept". A genus is a group of related species that share specific characteristics. Davis and Heywood (1963) have suggested 3 main parameters for the determination of the generic status.

1) Naturalness
2) Delimitation of closely related genera
3) Practicability of keeping them distinct or including them in other genera.

The concept of monophyletic taxa has proved satisfactory in determining the naturalness and demarcation between different genera. Legendre and Vaillancourt (1969) defined the genus as a monophyletic group of species which occupies a adaptive zone.

**Family concept:**

A taxon consisting of related genera is called a family. Ideally, families have to be natural and monophyletic. Both vegetative and reproductive characters are used in delimiting families. There are two types of families (Walters, 1961).

**Definable:** These are very homogenous and natural groups. They can be easily recognized from other.

e.g. Brassicaceae, Apiaceae

**Indefinable:** They show great diversity of structure and are not distinctive.

e.g. Ranunculaceae

Taxa above family level: Order, Class, Division and kingdom are the categories above the family level. One more category "Super order" has been included by Armen Takhtajanin his classification.

## 2.4 TAXONOMIC HIERARCHY:

A taxonomic hierarchy is a ranked series of categories each category is subordinate to the one above it. It is the process of arranging various organisms into successive categories/ levels of the biological classification either in a decreasing or an increasing order from kingdom to species and vice versa. Taxonomic hierarchy was introduced by a Swedish botanist Carolus Linnaeus during the $18^{th}$ Century. Hence, it is also called "Linnaean Hierarchy". This system of classification is followed globally till date.

It is not possible to study and document information about more than 2.5 lakhs of vascular plants, if there is no mechanism for grouping the plants. The plants are first recognized and assembled into groups on the basis of their relations. These groups are in turn assembled into larger and more inclusive groups. This process is repeated until finally all the organisms have been assembled into a single, largest and more inclusive group.

These groups are then assigned to various categories. The most inclusive group is assigned to the highest category and least inclusive group is assigned to the lowest category (Species). Once all the taxonomic groups are assigned to the categories and named, the taxonomic structure is completed.

Any assemblage of individuals or small groups sharing common characters is called a taxonomic group. Taxonomic category is a level or rank assigned to a taxonomic group. The categories are purely artificial, subjective and unrealistic.

Different types of categories were recognized by Massion (1950). The categories are like shelves of an almirah, having no significance when empty. Categories are like shelves whereas the ranks are like partitions. Practically there is no difference between category and ran, except in grammatical sense.

### 2.4.1 Advantages of Taxonomic Hierarchy:

1) Grouping of organisms into different categories on the basis of degrees of diversity exhibited by them is possible.
2) Such classification helps one to refer a particular group of plants into appropriate classes.

**Types of Taxonomic Categories:**

Kingdom (Plantae)

Division (Embryophyta/ Angiospermae/ Magnoliophyta)

Class (Dicotyledonae/ Magnoliopsida)

Order (Sapindales)

Family (Anacardiaceae)

Genus (*Mangifera*)

Species (*indica*)

### 2.4.2 Types of Taxonomic Categories:

There are 2 types of taxonomic categories.

1) Major categories
2) Minor categories

**Major Categories**: These are not the part of the plant name. They include:

**Kingdom:** It is the highest category/ level / rank of the classification. The kingdom is divided into subgroups at various levels. There are 5 kingdoms in which the living organisms are classified, namely, Plantae, Animalia, Fungi, Protista, and Monera on the basis of factors like the types and number of cells and nutrition mode. e.g. Plantae, Animalia.

**Division (=Phylum)**: It is the next category/ level the hierarchy within the Kingdom. It is made up of classes. e.g. Magnoliophyta, Bryophyta, Pteridophyta. The divisions may be divided into subdivisions.

**Class**: It consists of a group of orders. It is the rank below the division and above the order which share few similarities. e.g. Magnolliopsida, Liliopsida. It is further divided into subclasses.

* Below the class and above the order, super order was recognized by some botanists in their classifications (Takhtajan, 1999).

**Order**: It consists of a group of families which show less similarities among them. e.g. Annonales, Brassicales. Sometimes, it splits into suborders.

**Family**: It comprises a number of related genera. Larger families may be splitted into subfamilies, tribes and subtribes.

**Minor categories**:

These are part of the name of the plant. They include

**Genus:** It is a group of related species. A genus may include one or many species. They are precisely delimited by a set of well defined characters. They have similar characters but differ from the species of another genus. In some cases, the genus is splitted into subgenus, section, subsection, series, and subseries.

**Species:** The name species came from 'specere' which means 'to look at'. It refers to appearance. It is the lowest level of classification and shows the high level of similarities. It is considered to be the basic or fundamental unit of taxonomy by the facts that:

1) In majority of cases, there is no infra specific names.
2) Species can be described and recognized without relating to taxa of other ranks

Davis (1978) called the species as Building bricks in Biological classification.

**Infraspecific Categories**: They are the categories below the ranks of the species. These are recognized within the minor categories.

**Subspecies**: It is a taxon within a species. They differ in small ways. Although they can breed with each other, they are usually found in various places or in different populations (geographical distribution).

**Variety**: They are the morphological variants which may or may not have a clear geographical distribution. Sometimes, they represent only habit phase/ colour. A variety produced by agricultural / horticulture techniques and not found in natural populations is called a cultivated variety/ cultivar. It may be splitted into subvarieties.

**Form (Forma):** It is the lowest rank normally used for sporadic (occuring at irregular intervels) distinct variants occur in populations. e.g. Flower colour. It is splitted intosubform/ subforma.

## 2.3 SUMMARY:

A taxonomical hierarchy consists of a number of categories. A category is an abstract concept. A group of plants are assigned to such categories for the purpose of classification. The categories are employed in a conventional order which must be strictly adhered to. The level at which a category stands in the hierarchy is known as rank. The group of plants themselves are known as taxa (singular: taxon). The taxa of lower rank are always "sub-ordinate to" and "included in" those ranks which are higher to it.

## 2.4 SELF-ASSESSMENT QUESTIONS:

1) Describe the taxonomic hierarchy
2) Describe the historical development of taxonomic hierarchy

## 2.5 REFERENCES:

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# LESSON-3

# INTERNATIONAL CODE OF NOMENCLATURE FOR ALGAE, FUNGI AND PLANTS-I

**OBJECTIVE:**

This chapter attempts to present Broad outline Rules and Recommendations, Ranks, and Typification of International Code of Nomenclature For Algae, Fungi And Plants-I.

**STRUCTURE:**



## 3.1 BROAD OUTLINE OF INTERNATIONAL CODE OF NOMENCLATURE:

This Schenzhen code of nomenclature was adopted by the 19$^{th}$ International Botanical Congress in July, 2017 in Shenzhen, China. As this code was adapted in Schenzhen, it was named as 'Schenzhn Code'. It was prepared and edited by Nicholas J. Turland et al. and published in 2018.

### 3.1.1 Preamble:

This code begins with a preamble. It contains 14 points which highlights the phylosophy of the code. This code of nomenclature are divided into 3 divisions and some of these are further divided into Chapters and sections as shown below.

**Division I. Principles (1-6)**

**Division II. Rules and Recommendations**

**Chapter I. Taxa and their ranks**

**Chapter II. Status, typification and priority of names**

Section 1. Status definitions

Section 2. Typification

Section 3. Priority (Art. 11-12)

Section 4. Limitation of the Principle of priority

**Chapter III. Nomenclature of taxa according to their rank**

Section 1. Names of taxa above the rank of family

Section 2. Names of families and subfamilies, tribes and subtribes

Section 3. Names of genera and subdivisions of genera

Section 4. Names of species

Section 5. Names of taxa below the rank of species*(Infraspecific taxa)*

Section 6. Names of organisms in cultivation

**Chapter IV. Effective publication**

Section 1. Conditions of effective publication

Section 2. Dates of effective publication

**Chapter V. Valid publication**

Section 1. General provisions

Section 2. Names of new taxa

Section 3. New combinations, names at new ranks, replacement names

Section 4. Names in particular groups

**Chapter VI. Citation**

Section 1. Author citations

Section 2. General recommendations on citation

**Chapter VII. Rejection of names**

**Chapter VIII. Orthography and gender of names**

Section 1. Orthography

Section 2. Gender

**Chapter F. Names of organisms treated as fungi**

**Chapter H. Names of hybrids**

**Division III. Provisions for governance**

Glossary

Indices

Appendices I-VII

## 3.2 PRINCIPLES OF ICN:

It belongs to Division I of ICN. The ICN is based on six principles which provide guidelines for the taxonomists.

**Principle I.** The nomenclature of algae, fungi, and plants is independent of zoological and prokaryotic nomenclature.

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

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

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

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

**Principle VI**. The rules of nomenclature are retroactive unless expressly limited.

## 3.3 RULES AND RECOMMENDATIONS:

It is the Division II of ICN. It has eight chapters in addition to chapter G and chapter F

### 3.3.1 Chapter I. Taxa and their Ranks

According to Article 1, taxonomic groups of any rank will be referred to as taxa (singular taxon). The system of nomenclature provides a hierarchical arrangement of ranks and every organism is treated as belonging to a number of successively higher taxa, each assigned a particular rank with species as a basic unit.

e.g. Annona squamosa-species

Annona-genus

Annonaceae-family

There are 7 principle ranks and these ranks in descending sequence are:

1. Kingdom 2. Division 3. Class 4. Order

5. Family 6. Genus 7. Species

* The secondary ranks of taxa in descending sequence are tribe, section, series, variety and form

Kingdom (=Regnum) name is ended with ‘bionta’ e.g. Embryobionta

Subkingdom (=Subregnum) name is ended with ‘amae’ e.g. Cryptogamae

Division (=Phylum / Division) name is ended with ‘phyta’ e.g. Magnoliophyta

Subdivision (=subdivisio) name is ended with ‘phytina’ e.g. Magnoliophytina

Class (=Classis) name is ended with ‘opsida’ e.g. Asteropsida

Subclass (=subclassis) name is ended with ‘opsidae/ odeae’ e.g. Asteridae

Order (=ordo) name is ended with 'ales' e.g. Malvales

Suborder (=subordo) name is ended with 'ineae' e.g.Malvalinae

Family (=Familia) name is ended with 'aceae' e.g. Malvaceae

Subfamily (=subfamilia) name is ended with 'oideae' e.g. Asteroideae

Tribe (=tribus) namer is ended with 'eae' e.g. Heliantheae

Subtribe (=subtribus) name is ended with 'inae' e.g. Helianthinae

Genus (gen./g.) e.g. Helianthus

Subgenus (subg.)

Section (=sect.)

Subsection (=subsect.)

Series

Subseries

Species (sp. = singular, spp.= plural

Subspecies (ssp / subsp. = singular, spp / subspp = plural)

Variety (var.)

Subvariety (subvar.)

Form/ forma (= f.)

Subforma (subf.)

*The principle ranks of hybrid taxa (=nothotaxa) are nothospecies (=nothosp.), nothogenus

*'notho' indicates the hybrid character.

### 3.3.2 CHAPTER II. TYPIFICATION AND PRINCIPLE OF PRIORITY:

#### 3.3.2.1 A. Typification (Type Method):

According to ICN, the names of the taxonomic groups are based on type method by which a certain representative of the group is the source of the name for the group. This representative is called "Nomenclatural Type" or simply 'Type' or 'Typus'. This methodology is called 'Typification' or 'Type method'.

e.g. Mimosa is the type for family Mimosaceae.

Annona is the type for family Annonaceae.

"A nomenclatural type is that element to which the name of a taxon is permanently attached whether as the correct name or as a synonym".

**Important Nomenclatural Types:**

1. Holotype 2. Isotype 3. Paratype 4. Syntype 5. Lectotype

6. Neotype 7. Epitype 8. Topotype 9. Ex-type 10. Autotype

1) **Holotype (= Type):** "This is the specimen or other element (may be illustration) used by the author or designated by him as the nomenclatural type" This type is chosen by the original author from a single gathering at one time and expressed definitely at the time of original publication.

2) **Isotype:** "Any duplicate of the holotype (part of a single gathering by a plant collector at a time".

3) If several samples of plants are collected at the same time, one specimen is chosen as the holotype, the rest are isotypes.

4) **Paratype:** A specimen from a collection (cited with the original description) other than holotype or isotype, but on which the description of the new taxon is based". e.g. If a new plant is collected without flowers and fruits in one season and the same plant is collected with flowers and fruits in a different season , these collections have different field numbers. Out of these two collections, the author will select one collection as holotype and isotype, while the collections of the second season will be called paratypes.

5) **Syntype:** "It is one of the two or more specimens cited by the author when no holotype is designated or any one of the 2 or more specimens originally designated as types".

6) **Lectotype:** "It is a specimen or other element selected from the original material as nomenclatural type when no holotype was designated at the time of publication or as long as it is missing". e.g. When a holotype is lost or destroyed or 2 or more specimens have been designated by author as types of a species, the lectotype is selected from the isotypes or from holotypes.

7) **Neotype:** "If a specimen or other element selected to serve as a nomenclatural type as long as all the material (holotype, isotype, syntype or paratype) is missing".

8) **Epitype:** "A specimen or other element selected to serve as an interpretative type , when the holotype, lectotype, neotype or all original material associated with a validly published name is ambiguous demonstratably".

9) **Tototype (=Topotype):** " It refers to the name given to the specimen collected from the same locality where the holotype was originally collected".

10) **Ex-type:** "In case, where the name is a culture permanently preserved in a metabolically inactive state, any isolate from the culture is called Ex-type or Ex-holotype, Ex-isotype".

11) **Autotype:** "When within a species, an infraspecific variant is recognized for the first time, it automatically establishes 2 infraspecific taxa. One which includes the type specimen of the species must have the same epithet as that of the species". e.g. Acacia nilotica subsp. Nilotica. Such name is called autonym and the specimen is called an autotype. Another infraspecific variant is Acacia nilotica subsp. tomentosa

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# LESSON-4

# INTERNATIONAL CODE OF NOMINCLATURE-II

**OBJECTIVE:**

This chapter attempts to present Principle of Priority, Author citation, and Effective and Valid publication of International Code Of Nomenclature For Algae Fungi And Plants-II.

**STRUCTURE:**



## 4.1 PRINCIPLE OF PRIORITY:

Principle of priority is concerned with the selection of a single correct name for a taxonomic group. It is the most important principle and provides a stable method of naming the taxonomic groups. This method involves identification of illegitimate and legitimate name and selecting a correct name from among legitimate names.

In case, more than one name exists for a taxon, the earliest legitimate name in the same rank forms the correct name except for 8 families for which alternate names have been given.

| Earliest legitimate name | Alternate name |
|---|---|
| 1) Cruciferae | Brassicaceae |
| 2) Guttiferae | Clusiaceae |
| 3) Leguminosae | Fabaceae |
| 4) Umbelliferae | Apiaceae |
| 5) Compositae | Asteraceae |

| | |
|---|---|
| 6) Labiatae | Lamiaceae |
| 7) Palmae | Arecaceae |
| 8) Gramineae | Poaceae |

Strict adherence to the principle of priority was recommended in the Rochester Code (1892) in view of the huge collection of plants from different countries of the world. e.g. Indian coral tree (Erythrina variegata) has as many as 200 scientific names.

The common apple was first described by Linnaeus (1753) as Pyrus malus. Later, the species was transferred to the genus Malus. But the combination Malus malus is a tautonym. So. It could not be taken as a correct name. The other binomials under Malus available for apple are Malus pumila (published in 1768) and Malus domestica (published in 1803). As per the principle of priority, Malus pumila, the earliest name, has been selected as the correct name.

**Limitation of the Principle:**

Application of principle of priority creates many problems. This principle starts with the "Species Plantarum" of Linnaeus published on 1-5-1753, the starting date for limitation of principle of priority for seed plants, pteridophytes, bryophytes, most algae, slime mouldsandlichens. The publication before this date for respective groups was ignored while deciding the priority. Similarly, adhering strictly to this principle, several problems are arised in the nomenclature of genera, families and intermediate taxa. For these, ICN provides lists of names that are conserved. This principle of priority is not applicable above the family rank.

## 4.2 NOMENCLATURE OF TAXA ACCORDING TO THEIR RANK: CHAPTER III:

Names of taxa above the rank of family: The name of a taxon above the rank of the family is treated as a noun and is written with an initial capital letter. The names of divisions, classes and orders are taken either from distinctive characters (e.g., Mycota) or from a name of an included genus (e.g., Magnoliophyta).

The name of a family is a plural adjective used as a noun and taken from a name of an included Genus. The names of families of long usage are treated as validly published. These families include: Cruciferae, Guttiferae, Leguminosae, Umbelliferae, Compositae, Labiatae, Palmae, Gramineae .

**Names of genera and subdivisions of Genera**:

The generic name is a uninominal, singular word treated as noun and written with initial capital letter. The generic name may be based on any source. The common sources are:

1) Commemoration of a person: Such names are given directly to commemorate a distinguished person.e.g. *Bauhinia* named after Gaspard Bauhin and Jean Bauhin Victoria named after Queen Victoria.

2) Based on a place:

   e.g. *Araucaria* named after 'Arauco', a province of Chile of South America Arabis refers to Arabia

3) Based on an important character:

   e.g. *Cercocarpus* means a coiled fruit, Xanthoxylem means yellow wood, Trifolium means 3 leaves

4) Aboriginal names: They are taken from a language other than Latin.

   e.g. *Narcissus* is named after famous Greek God and Vanda is a Sanskrit name.

5) Combination of words:

   e.g. *Hygrophila*neans marsh loving and polygala means more milk.

   *Asteracantha* means spreading spines

   *Some generic names are fanciful, mythlogical, ethical or poetic origin.

   e.g. *Putranjiva* means putra-ratna- jiva, *Theobroma* means God's food and *Nymphaea* means lovely water nym

**Names of Species:**

The name of a species is a binomial (binary combination) consisting of 2 words, a generic name followed by a specific epithet. All specific epithets should begin with a lower case initial letter.

A specific epithet may be derived from any source.

**1. Name of a person**

e.g. *Indigofera linnaei* is named after Linnaeus; Euphorbia senguptae-named after Sengupta

**2. Based on place**

e.g. *Rosa indica* means Indian origin

**3. Based on important character**

e.g. Chenopodium album (alba = white; Sida acuta (acuta=acute leaf tip)

**4. Noun in apposition (grammatical construction)**

e.g. Pyrus malus (Gk malus = apple) and Allium cepa (Latin cepa = onion)

* Both generic name and specific epithet are underlined when written or typed. When printed they are in Italics or bold face.

**Names of taxa below the rank of species (Infraspecific Taxa):**

The name of an infraspecific taxon is a combination of the name of a species and an infraspecific epithet. A connecting term is used to denote the rank.

**Subspecies:** The names of subspecies are trinomials within a species

e.g. ***Acacia niloticas*p.Himalaica**

Genus Specific epithet Subspecies

**Variety**: The names of variety are quadrinomial within a species.

e.g. ***Carissa congesta* sp. *congesta* var. *congesta***

Genus Specific epithet Subspecies variety

**Names of organisms in cultivation:**

Organisms brought from the wild into cultivation retain the names that are applied to them when growing in nature. The names of cultivated plants are governed by "International Code of Nomenclature for Cultivated Plants"(ICNCP). In addition to the categories of ICN, an additional rank "Cultiver" (CV.) has been recognized. (Culti (vated ) + var (iety) = Cultivar)

## 4.4 EFFECTIVE PUBLICATION: CHAPTER IV:

### 4.4.1 Conditions of Effective Publication:

The publication is effected

1) By distribution of printed matter to the general public or at least to scientific institutions with generally accessible libraries.
2) By distribution on or after 1 January 2012 of electronic material in PDF in an online (accessible electronically via the World Wide Web) publication with an International Standard Serial Number (ISSN) or an International Standard Book Number (ISBN).The name is not considered effective
3) If communicated at a public meeting and
4) By placing of names in collections or gardens open to the public.

### 4.4.2 Dates of effective publication:

1) By indelible autograph before 1-1-1953 is effective.
2) When a publication is issued in parallel as electronic material and printed matter, both must be treated as effectively published on the same date.
3) Publication on or after 1-1-1953 in catalogues (itemized display) or news papers does not constitute publication.
4) The distribution on or after 1 January 1953 of printed matter accompanying specimens does not constitute effective publication.
5) The date of effective publication is the date on which the printed matter available.

**4.5 Valid Publication Chapter V.**:

The important provisions for valid publication are as follows

1) A name of a taxon must be effectively published on or after the starting point date of the respective group e.g., the starting date for spermatophyte is 01-05-1753
2) Names of epithets published with an improper Latin termination but otherwise in accordance with this code are regarded as validly published.
3) Autonyms are accepted as validly published name, dating from the publication in which they were established.
4) The date of a name is that of its valid publication.
5) New names in specified ranks included in publications listed as suppressed works (Opera Utiqueappressa) are not validly published.
6) A name of a taxon is not validly published when it is not accepted by the author in the original publication.
7) A name published on or after 01-01-1953 without mentioning the rank of taxon is not validly published.

**NAMES OF NEW TAXA:**

A name of a new taxon published must be accompanied by a description/diagnosis of the taxon (Art. 38) when published on or after 2012. Publication on or before 01-01-1958 of the new taxon of rank of the genus or below is valid only when the type of the name is indicated.

**New combinations, names at new ranks, replacement names**:

A name should be properly formulated and its nature indicated by a proper abbreviation after the name of the author.

(i) sp. nov. for species nova (New species)

(ii) comb. nov. for combination nova is added to the name change involving the epithet of the basionym (original name)

(iii) nom. nov. for nomen novum is used if the total name is changed.

**Names in particular groups:**

A name of a new a fossil taxon published on or after 01-01-1996 must be accompanied by a Latin / English description /diagnosis or by a reference.

**4.6 AUTHOR CITATION CHAPTER VI:**

Citing the person who validly published a scientific name is called author citation. The name of a taxon should be followed by the name of the author (s) who first published the name validly. e.g. Annona squamosa L. Commonly, names of the authors are abbreviated and the names are never underlined / typed in Italics.

e.g. L. or Linn. = Linnaeus DC. = de Candolle

HBK = Humboldt, Bonpland and Kunth R. Br.=Robert Brown

Benth. = Bentham Hook. = William Hooker

Hook. f. = Sir J. D. Hooker Scop. = G. A. Scopoli

(f = filius, the son)

1) Use of 'et' or & (ampersand) : When a name is published jointly by 2 authors, the names of both are connected by 'et' or &. e.g. Delphinium viscosum Hook. f. et Thompson or Hook. f.

2) Use of 'et al'. (= and others): When a name is jointly published by more than 2 authors, the citation should restricted to the first one followed by et al. e.g. Indotristichatirunelveliana Sharma, karthikeyan& Shetty cited as Sharma et al.

3) Use of 'ex' : The names of 2 authors are linked by 'ex' when the first author proposed a name but the name was validly published by the second author. e.g. Cleome aspera Koenig ex DC.

4) Use of 'in': When a name with a description supplied by one author is published in another author's work, the word 'in' should be used to connect the names of 2 authors. e.g. Carexkashmirensis Clark in Hook. f. Clark published the new species in the "Flora of British India"whose author was was Sir J.D. Hooker.

5) Use of parenthesis ( ): When a genus or taxon of lower rank is altered but retains its name or epithet, the author of the basionym bringing synonym must be cited in parenthesis.e.g. Cyanodondactylon (L.) Pers. from Panicum dactylon L

6) Use of 'emend': (emendavit): The names of 2 authors are linked using 'emend' when the second author makes some change in the diagnosis or in circumscription of a taxon without altering the type. e.g. *Phyllanthus Linn*. emend Mull

7) Use of square brackets ([ ]): These are used to indicate pre- starting point of author. e.g. The generic name of Lupinus was defectively published by Tournefort in 1719, but since it happens to be earlier than 1753, the appropriate citation for the genus is Lupinus [Tourne. ] L.

8) Use of 'hort'. (hortulanorum): If a taxon is of garden origin, then while citing the name, it should be ascribed to 'hort' and connected to the name of the author who published it by an e.g. Geanariadwarklarii hort. ex Hook.

9) While naming an infraspecific taxon, the authority is cited for both specific epithet and infraspecific epithet. e.g. *Acacia nilotica* (L.) Del. sp*indica* (Benth.) Brenan.

But in case of in autonym, the infraspecific epithet does not bears the author's name as it is based on the same type. e.g. Acacia nilotica (L.) Del. ssp. Nilotica

**General Recommendations on Citation:**

The important ones include:

1) In the citation of a name published as a synonym, the words "as synonym" or "prosynonym" should be added. e.g. *Myrtus serratus* Koenig ex Steudel, prosyn.
2) In the citation of a nomen nudum (published without a diagnosis), its status should be indicated by adding the words 'nomen nudum' or 'nom.nud. e.g. *Convolvulus adpressus* Wall. nom. nud.
3) A misapplied name is indicated by the words auct. non followed by the name of the original author. e.g. *Phyllanthus fraternus* Webster, 1955 *Phyllanthus niruri*auct. non L.1753
4) If a generic name is conserved (nomenconservandum) the words nom.cons. should be added to the citation. e.g. *Tectona* L. f. suppl.20,151. 1781 nom.cons.

## 4.7 REJECTION OF NAMES (ART. 51-59): CHAPTER VII:

The illegitimate names are generally rejected. A legitimate name must not be rejected

The types of names fall under category of illegitimate names are:

1) Tautonym: A binary name in which the specific epithet exactly repeats the generic name. e.g. *Malus malus*
2) Autonym: An automatically created tautonym for infrageneric or infraspecific taxa. e.g. *Abutilon indicum* sp. *indicum*
3) Synonym: A different name used for the same taxonomi group or taxon. e.g. *Lannea coromandelica*=Odina wodier
4) Homonym: Identical names to 2 different taxa. e.g. *Jatropha heterophylla* Steudel for 1 plant. *Jatropha heterophylla Heyne* ex Hook f. is for second plant. The second one becomes homonym and it was named as Jatropha heynei by Balakrishnan.
5) Basinym: It is the original name of a taxon subsequently replaced by another name as a result of change in rank citation of a taxon. e.g. *Euphorbia hirta* is transferred to *Chamaesycehirta*, the first name becomes a basionym.
6) Isonym: The same name, based on the same type has been published independently at different times by different authors, the earliest has nomenclatural status. Other reasons for rejection include.
    a) Name not properly formulated, not effectively published, lacking typification or without a Latin diagnosis.
    b) Name without description.
    c) Tautonym: Malus malus *exception for infraspecific epithets.

d) Later homonyms: Use of same names for 2 different species given at a later date.

e) Nomen superfluum (nom.superfl.): A name published appearing nomenclaturally superfluous.e.g. *Physkium natans* transferred to *Vallisnaria*, the epithet natans should be retained. But, *Vallisnariaphyskium* is a superfluous name.

f) Nomen ambiguum (nom. ambig.): If a name used in different sense by different Authors is rejected.

g) Nomen confusum (nom.confus.): A confusion name.

h) Nomen dubium (nom.dub.): A dubious name.

i) Name based on monostrosity: A plant showing an abnormal structural condition.

## 4.8 ORTHOGRAPHY AND GENDER OF NAMES (ART. 60-61): CHAPTER VIII:

**A) Orthography:**

The original spelling of a name or epithetisto be retained except for the correction of typographic or orthographic errors. * The original spelling means the spelling used when a new taxon was published.

**B) Gender:**

According to Principle V of this code, botanical names are treated as Latin. All Latin words have a gender. Gender determination is usually confined to the names at the rank of genus or below.

**Chapter F. Names of Fungi:**

This chapter deals solely with names of organisms treated as fungi. Content of this chapter may be modified by action of the Nomenclatural session of an International Mycological Congress (IMC).Valid publication of names for non-fossil fungi is treated as beginning at 1 May 1753. The name of a fungus published on or after January2019 is illegitimate if it is a later homonym of a prokaryotic or protozoan name.

**Chapter H. Names of Hybrids:**

Hybridity is indicated by the use of the multiple sign (X) or by the addition of the prefixnotho to the term denoting the rank of the taxon. e.g. nothogenus, nothospecies.

**Interspecific Hybrid**:

A hybrid between 2 species of Salix (S. aurita x S. caprea) Bigeneric hybrids are designated by a condensed formula X Asplenophyllites (a hybrid between species of 2 genera viz., Asplenium and Phyllites).

## 4.9 SUMMARY:

The International Code of Nomenclature (ICN) is a set of rules and recommendations that govern the scientific naming of organisms traditionally considered as algae, fungi, and plants,

ensuring consistency and clarity in botanical taxonomy by dictating how to properly name and classify these groups, including the use of a single correct name for each taxonomic group, based on priority principles where the first published name takes precedence; previously known as the International Code of Botanical Nomenclature (ICBN).

## 4.10 SELF-ASSESSMENT QUESTIONS:

1) Give a detailed account on ICN
2) What is genus epithet
3) What is species epithet
4) What are the rules of ICN

## 4.11 REFERENCES:

1) International Code of Nomenclature for algae, fungi, and plants (Schenzhen Code), 2018 online version) adopted by the Nineteenth International Botanical Congress, Chenzehen, China.
2) Angiosperm Phylogeny Group, 2016. An update of the Angiosperm Phylogeny Group Classification for the Orders and Families of Flowering Plants: APG IV. Botanical Journal of the Linnaean Society 181: 1-20.
3) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J.2016. Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.
4) Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, Canada.
5) Sambamurthy, A.V.S.S. 2005. Taxonomy of Angiosperms. I.K. International Pvt. Ltd, New Delhi.

**Dr. P. Sathya Narayana Raju**

# LESSON-5

# TAKHTAJAN'S SYSTEM OF CLASSIFICATION

**STRUCTURE:**



**Armen Takhtajan** (1910-2009) was a Russian taxonomist and a leading authority on phytogeography and origin and phylogeny of flowering plants. He was the President of the 12th International Botanical Congress held in Leningrad in 1975.

His classification was first published in 1954 in Russian language and later, it was translated into English and published in 1958. His comprehensive system was published in 1997 in "Diversity and Classification of Flowering Plants". Later, in 2009, his greatly revised and expanded classification was published in the 2nd Edition of "Flowering Plants".

## 5.1 SALIENT FEATURES:

1) He belonged to Besseyanschool.
2) He believed in the monophyletic origin of angiosperms, having evolved from seed ferns, "Lyginopteridophyta".
3) He considered Amborellaceae as the primitive family and placed it under the order: Amborellales.
4) He considered the Poaceae as an advanced family placed under the order: Poales.
5) He placed angiosperms in the Phylum: Magnoliophyta. He classified Phylum: Magnoliophyta into two classes viz. Magnoliopsida and Liliopsida.
6) The classes were further subdivided into subclasses (ending in-idae), super orders (ending in 'anae'), orders and families.
7) He considered Magnoliopsida as primitive and Liliopsida derived from it.

8) He placed the Family: 'Haptanthaceae' as dicotyledonous family of incertae position.

9) He described 560 families.

10) He used a number of criteria for his classification popularly known as "Takhtajan's Principles".

## 5.2 TAKHTAJAN'S PRINCIPLES:

1) **Growth Habit:** Small woody trees are primitive than herbaceous plants. Sparingly branched trees are primitive than trees with numerous slender branches, evergreen plants are primitive than deciduous woody plants.

2) **Leaves:** simple leaves are primitive than compound leaves, alternate leaves are primitive than opposite leaves and pinnate leaves are primitive than palmate leaves and reticulate venation is primitive than parallel venation.

3) **Stomata**: Stomata with subsidiary cells are primitive than stomata without subsidiary cells.

4) **Nodal Structure**: Tripentalacunar type is primitive than unilacunar type.

5) **Wood Anatomy**: Vessels with scalariform perforations are primitive than simple perforations.

6) **Inflorescence**: Cymose inflorescence is primitive than racemose inflorescence.

7) **Floral Structure**: Spiral arrangement of floral parts is primitive than cyclic arrangement of floral parts.

8) **Androecium**: Broad laminar type of stamens are primitive than stamens with filament and connective

9) **Pollen Grains**: Monocolpate(single furrow) pollengrains are primitive than tricolpate (three furrows) pollen grains. Triporatepolycolpate pollen grains are most advanced ones.

10) **Gynoecium**: Apocarpous condition is primitive than syncarpous condition. Axile placentation is primitive than parietal placentation.

11) **Ovules**: Bitegmic ovules are primitive than unitegmic ovules. Crassinucellate condition is primitive than tenuenucellate condition

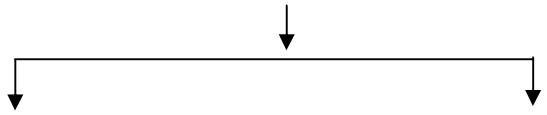
12) **Pollination**: Entomophily (by insects) is primitive than Anemophily (by wind)

13) **Gametophyte**: Monosporic gametophyte is primitive than tetrasporic gametophyte.

14) **Fruits:** Many seeded follicle is primitive than others.

## 5.3 SYSTEM OF CLASSIFICATION (2009):

**Phylum: Magnoliophyta** (Flowering Plants)



| Class: **Magnoliopsida** (Dicotyledons) | Class: **Liliopsida** (Monocotyledons) |
|---|---|
| 8 Subclasses | 4 Subclasses |
| 32 Superorders | 12 Superorders |
| 126 orders | 31 Orders |
| 440 Families | 120 Families |
| 10,500 Genera | More than 3,000 Genera |

***Dicotyledonous Family of Incertae Position is Haptanthaceae**

**Class: Magnoliopsida:** It comprises 8 subclasses.

Subclass I. **Magnoliidae**: It includes 5 superorders.

Superorder: Nymphaeanae-Amborellales, Nymphaeales, Chloranthales, Ceratophyllales

Superorder: Magnolianae-Magnoliales. Annonales etc.

Superorder: Lauranae-Laurales

Superorder: Piperanae-Piperales etc.

Superorder: Rafflesianae- Rafflesiales etc.

Subclass II. **Ranunculidae**: It includes 2 superorders.

Superorder: Proteanae-Proteales, Nelumbonales

Superorder: Ranunculanae-Menispermales, Ranunculales, Papaverales

Subclass III. **Hamamelididae**: It includes 4 superorders

Superorder: Trochodendranae-Trochodendrales

Superorder: Myrothamnanae-Myrothamnales

Superorder; Hamamelidanae-Hamamelidales, Casuarinales

Superorder: Juglandanae-Juglandales

Subclass IV**. Caryophyllidae**: It includes 3 superorders.

Superorder: Caryophyllanae-Caryophyllales

Superorder: Polygonanae-Polygonales, Plumbaginales, Tamaricales

Superorder: Nepenthanae-Nepenthales

Subclass V**. Dillenidae**: It includes 7 superorders.

Superorder: Dillenianae-Dilleniales

Superorder: Ericanae-Theales, Balsaminales, Polemoniales etc.

Superorder: Primulanae-Sapotales, Primulales etc.

Superorder: Violanae-Violales (Passiflorales), Elaeocarpales, Cucurbitales etc.

Superorder: Capparanae-Caricales, Moringales, Capparales etc.

Superorder: Malvanae-Malvales, Urticales

Superorde: Euphorbianae-Euphorbiales

Subclass VI. **Rosidae**: It includes 7 superorders.

Superorder: Rosanae-Saxifragales, Vitales, Rosales etc.

Superorder: Myrtanae-Myrtales

Superorder: Fabanae-Fabales, Polygalales

Superorder: Rutanae-Oxalidales, Sapindales, Rutales etc.

Superorder: Celastranae-Celastrales

Superorder: Santalanae-Santalales, Balanophorales

Superorder: Rhamnanae-Rhamnales

Subclass VII**. Asteridae**: It includes 2 superorders.

Superorder: Cornanae-Apiales

Superorder: Asteranae-Asterales

Subclass VIII. **Lamiidae**: It includes only 1 superorder.

Superorder: Lamianae-Rubiales, Solanales, Boraginales, Lamiales etc.

**Class: Liliopsida**: It includes4 subclasses.

Subclass I**. Alismatidae**: It includes 3 superorders.

Superorder: Pterosavianae- Pterosaviales

Superorder: Alismatanae-Hydrocharitales, Alismatales, Potamogetonales

Superorder: Aranae-Arales

Subclass II. **Liliidae**: It includes 3 superorders.

Superorder: Lilianae-Liliales, Orchidales, Amaryllidales, Asparagales etc.

Superorder: Pandananae-Pandanales

Superorder: Dioscoreanae-Dioscoreales

Subclass III**. Arecidae**: It includes only 1 superorder.

Superorder: Arecanae-Arecales

Subclass IV.**Commelinidae**: It includes 5 superorders.

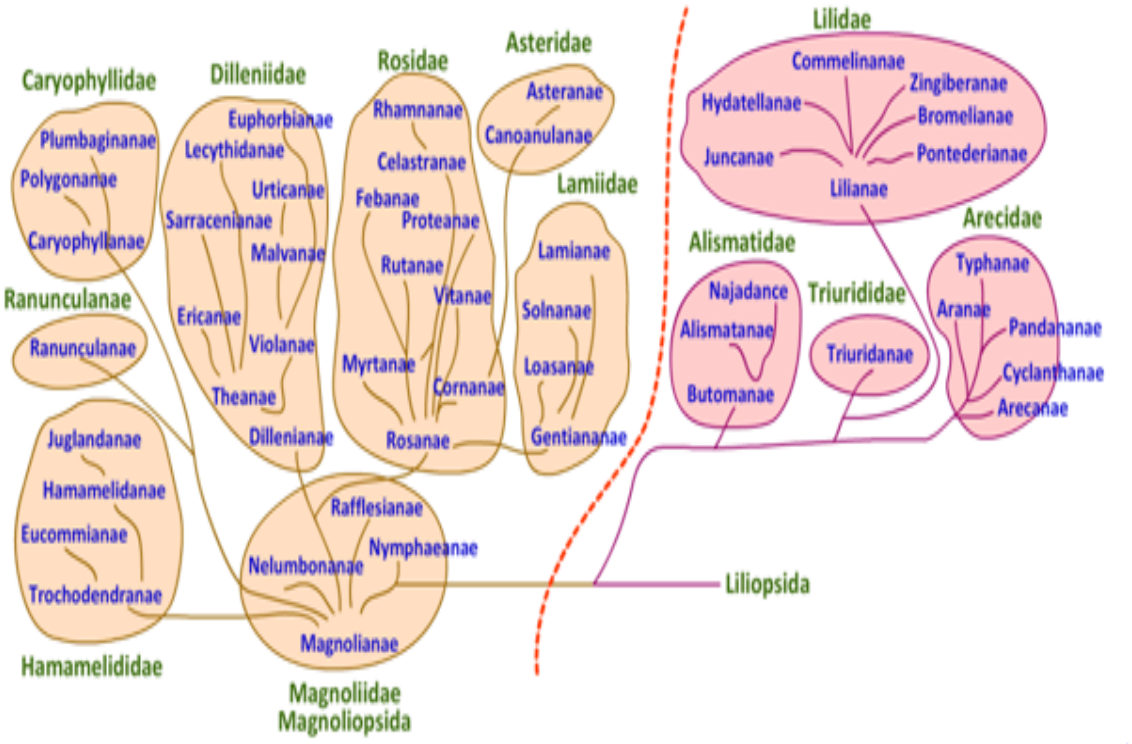
Superorder: Bromelianae-Bromeliales

Superorder: Zingiberanae-Zingiberales

Superorder: Commelinanae-Commelinales

Superorder: Juncanae-Juncales

Superorder :Poanae-Typhales, Poalesetc




**5.3.1 Merits:**

1) This system is more phylogenetic than earlier systems as it is based on widely accepted phylogenetic principles.
2) He incorporated phylogenetic as well as phenetic information for improvement.
3) The evolution/derivation of monocots from terrestrial hypothetical group of Magnolidae is supported.

4) Abolition of artificial groups such as Lignosae, Herbaceaeetc,
5) The nomenclature is in accordance with ICBN.
6) The placement of Magnoliidae as the primitive group.
7) He splittedAsteridae into Asteridae and Lamiidae.
8) He separated Urticales from Hamamelididae and placed in Dillenidae between Malvales and Euphorbiales
9) Depiction of the relationships with the help of bubble diagram (Phylogram).

**5.3.2 Demerits:**

1) This system, although highly phylogenetic, is not helpful for identification.
2) The numerical analysis shows that Arales are closer to Liliales. But, he placed Arales under subclass Alismatidaeand Liliales under subclass Liliidae.
3) Further, the splitting of families has resulted in a very narrow circumscription by creation of numerous monotypic families.
4) Many botanists regard the vesselless family Winteraceae as the most primitive among living angiosperms.

## 5.4 SUMMARY:

Armen Takhtajan's system of classification is a way to categorize flowering plants (angiosperms). It's based on evolutionary principles and multiple fields of evidence. It includes (1) Classes Takhtajan's system divides flowering plants into two classes: Magnoliopsida (dicots) and Liliopsida (monocots). (2) Subdivisions (3) The classes are further divided into subclasses, superorders, orders, and families. Takhtajan used criteria like growth habit, leaves, and pollen grains to determine the placement of groups. Takhtajan believed that angiosperms evolved from seed ferns. He favored smaller orders and families to make it easier to understand evolutionary relationships and character. Takhtajan's system is considered one of the most widely accepted phylogenetic systems. The Takhtajan system is still influential and is used by the Montréal Botanical Garden.

## 5.5 SELF-ASSESSMENT QUESTIONS:

1) Brief the salient features of Taktajan”s classification ?
2) Write about Takhtajan Principles ?
3) Give a detailed account on Takthajan’s System of Classification ?

## 5.6 SUGGESTED READINGS:

1) Crawford, D.J.2003. Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.

2) Gurcharan Singh.1999. Plant Systematics: Theory and Practice. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

3) Radford, A.E. 1986. Fundamentals of Plant Systematics. Harper & Row Publisher, New York.

4) Davis, P.H. and Heywood, V. M.1973. Principles of Angiosperm Taxonomy. Robert. Kereiger

**Prof. A. Amrutha Valli**

# LESSON-6

# ANGIOSPERM PHYLOGENY GROUP (APG)

**STRUCTURE:**



## 6.1 INTRODUCTION:

The Angiosperm phylogeny Group (APG) refers to an International group of systematic botanists. They came together to try to establish a consensus view of the taxonomy of flowering plants based on phylogenetic studies utilizing molecular data or a combination of morphological and molecular data. This led to the development of the classifications of **APG-I** (1998), **APG-II**( 2003), **APG-III** (2009) and **APG-IV** (2016).

**APG-I:**

The first classification APG I was the effort of 29 systematic botanists (Bremer, Chase, Backlund, Briggs, Judd, Stevens etc.). This system is based on 2 chloroplast genes and 1 gene coding for ribosomes. In this system, 40 putative (supposed) monophyletic orders are divided into 462 families.

**APG-II:**

It was compiled by B. Bremer, K. Bremer, Soltis and Stevens. In this system, only monophyletic families were recognized and redefined. They are separated into separate groups (Liliaceae and Scrophulariaceae) or united into one family **(**Bombacaceae, Tiliaceae and Sterculiaceae are merged into a single family: Malvaceae).

**APG-III:**

1) It recognized 14 new orders (total 59). The newly recognized orders are: Amborellales, Nymphaeales, Chloranthales, Petrosaviales, Trochodendrales, Buxales, Vitales, Zygophyllales, Pycramniales, Huerteales, Berberidopsidales, Escalloneales, Bruneales and Paracryphiales.
2) The order Ceratophyllales was erroneously marked as a new order.
3) The designation of alternative 'Bracketed families" abandoned in this system. The discontinued bracketed families were Illiaceae, Alliaceae, Agavaceae, Fumariaceae etc.
4) 20 new families such as Petermanniaceae, Limeaceae, Talinaceae, Calophyllaceae, Capparidaceae, Cleomaceae etc. were accepted in this system.
5) The number of families not placed in any order was reduced from 39 to 10. Apodanthaceae and Cynomoriaceae were placed among Angiosperms, incertae sedis (= not in any group within the angiosperms).
6) 3 genera such as Gumillea, Nicobariodendronand Petenaea were placed within the Angiosperms ,incertae sedis. Nicobariodendronand Petenaea were newly added to the list.

**APG-IV:**

1) It was given in the article entitled *'An update of the Angiosperm Phylogeny Group Classification for the Ordersand Families of Flowering Plants: APG IV'* compiled by James Chase, Douglas, Soltis et al.,
2) It is the fourth version of a modern, mostly molecular based system and published in **"**Botanical Journal of the Linnean Society" in 2016.
3) This system recognizes five new orders such as Boraginales, Dilleniales, Icacinales, Metteniusales and Vahliales. This system also recognizes some new families. Totally, 64 angiosperm orders and 416 families have been recognized.

## 6.2 BROAD OUTLINE OF APG IV (PUBLISHED IN 2016):

The 'Angiospermae' has been divided into clades (Informal groups) in this system.

**Clade I** **BasalAngiosperms - It includes 3 orders.**

Order 1. Amborellales-Amborellaceae

Order 2. Nymphaeales-Cabombaceae, Nymphaeaceae etc.

Order 3. Austrobileyales-Austrobileaceae, Schizandraceae

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Mesangiosperms (Core angiosperms)

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**Clade II Magnoliids (Magnoliid complex)-It comprises 4 orders.**

Order 1. Canellales-Canellaceae, Winteraceae

Order 2. Piperales-Aristolochiaceae, Piperaceae etc.

Order 3. Magnoliales-Annonaceae, Magnoliaceae, Myristicaceae

Order 4. Laurales-Calycanthaceae, Hernandiaceae, Lauraceae etc.

**Independent lineage to more inclusive clade**

*Chloranthales -Chloranthaceae

**Clade III Monocots -It includes 11 orders.**

Order 1. Acorales - Acoraceae

Order 2. Alismatales – Alismataceae, Araceae, Hydrocharitaceae etc.

Order 3. Petrosaviales – Petrosaviaceae

Order 4. Dioscoreales – Dioscoreaceae etc.

Order 5. Pandanales – Pandanaceae etc.

Order 6. Liliales – Liliaceae, Smilacaceae, Colchicaceae etc.

Order 7. Asparagales – Amaryllidaceae, Asparagaceae ,Orchidaceae etc.

Order 8. Arecales – Arecaceae,

Order 9. Commelinales – Commelinaceae, Pontederiaceae etc.

Order 10. Zingiberales – Cannaceae, Costaceae, Heliconiaceae, Marantaceae, Musaceae, Strelitziaceae, Zingibearaceae etc.

Order 11. Poales – Bromeliaceae, Cyperaceae, Poaceae, Typhaceae etc.

**Probable Sister to Eudicots:**

*Ceratophyllales-Ceratophyllaceae. The molecular evidence shows that it is sister to eudicots is becoming clearer.

**Clade IV Eudicots -It includes 4 orders.**

Order 1. Ranunculales-Menispermaceae, Papaveraceae, Ranumculaceae etc.

Order 2. Proteales – Nelumbonaceae, Proteaceae etc.

Order 3. Trochodendrales – Trochodendraceae

Order 4. Buxales – Buxaceae

**Clade V** **Core eudicots-It comprises 2 orders.**

Order 1. Gunnerales – Gunneraceae

Order 2. Dilleniales – Dilleniaceae

**Clade VI** **Superrosids**: It includes a single order.

Order 1. Saxifragales-Crassulaceae, Hamamelidaceae, Paeonaceae

**Clade VII** **Rosids** This clade has 17 orders in this clade.

Order 1. Vitales-Vitaceae

Order 2. Zygophyllales - Zygophyllaceae etc.

Order 3. Fabales – Fabaceae, Polygalaceae etc.

Order 4. Rosales – Cannabaceae, Moraceae, Rhamnaceae, Rosaceae etc

Order 5. Fagales – Casuarinaceae, Fagaceae etc.

Order 6. Cucurbitales – Bigoniaceae, Cucurbitaceae etc.

**COM Clade: Placement uncertain**

Order 7. Celastrales – Celastraceae etc.

Order 8. Oxalidales – Elaeocarpaceae, Oxalidaceae etc.

Order 9. Malpighiales – Euphorbiaceae, Malpighiaceae, Violaceae etc.

Order 10. Geraniales - Geraniaceae

Order 11. Myrtales – Combretaceae, Lythraceae, Myrtaceae etc.

Order 12. Crossosomatales - Crossosomataceae

Order 13. Picramniales - Picramniaceae

Order 14. Huerteales – Gerradinaceae

Order 15. Sapindales – Anacardiaceae, Bursaraceae, Meliaceae, Rutaceae, Sapindaceae

Order 16. Malvales – Bixaceae, Cochlospermaceae, Malvaceae,

Order 17.Brassicales-Brassicaceae, Capparaceae, Caricaceae, Cleomaceae etc.

**Clade VIII Superasterids. 3 orders**

Order 1. Berberidopsidales – Berberidopsidaceae

Order 2. Santalales – Santalaceae, Balanophoraceae, Loranthaceae

Order 3. Caryophyllales - Tamaricaceae, Plumbaginaceae, Amaranthaceae etc.

**Clade IX. Asterids. There are 17 orders in this clade.**

Order 1. Cornales – Cornaceae, Hydrangeaceae etc.

Order 2. Ericales – Balsaminaceae, Ebenaceae, Ericaceae, Sapotaceae etc.

Order 3. Icacinales – Icacinaceae etc.

Order 4. Metteniusales - Metteniusaceae

Order 5. Garryales -Garryaceae

Order 6. Gentianales – Apocynaceae,Gentianaceae, Rubiaceae

Order 7. Boraginales - Boraginaceae

Order 8 .Vahliales – Vahliliaceae

Order 9. Solanales – Covolvulaceae, Hydroleaceae, Solanaceae

Order 10. Lamiales – Acanthaceae, Bignoniaceae, Lamiaceae, Oleaceae, Verbenaceae etc.

Order 11. Aquifoliales - Aquifoliaceae

Order 12. Asterales – Asteraceae, Campanulaceae

Order 13. Escalloniales - Escalloniaceae

Order 14. Bruniales - Bruniaceae

Order 15. Paracryphiales – Paracryphiaceae

Order 16. Dipsacales – Adoxaceae

Order 17. Apiales – Apiaceae, Araliaceae, Pittosporaceae, Aralidaceae

**INCERTAE SEDIS** (Taxa of uncertain position) :

*Atrichodendron, Gumillea, Hirania, Rumphia* etc**.**

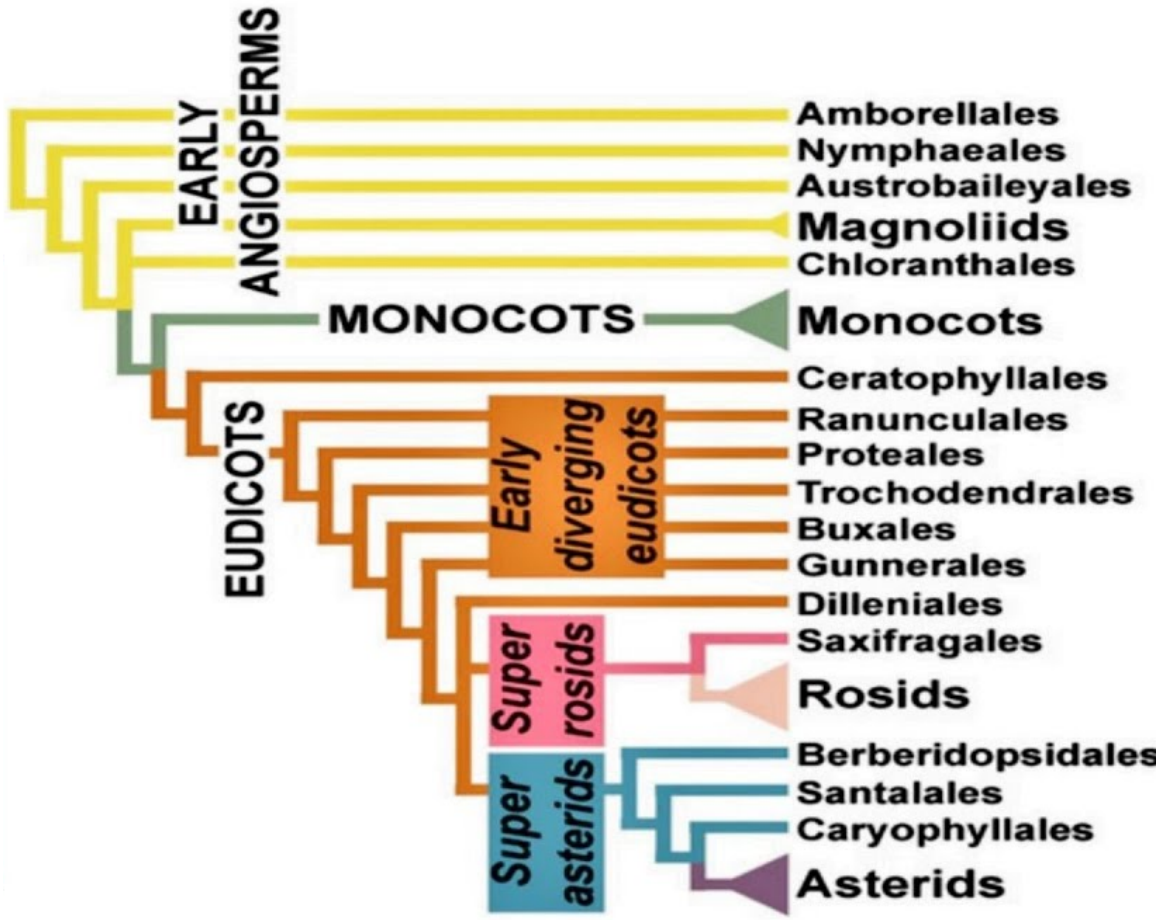



**Fig. 6.1 Simplified version of APG IV**

(Source: Plant Gateway`s The Global Flora, Vol. I, January 2018)

### 6.2.1 MERITS:

1) This system is based on sound phylogenetic principle of constructing taxa only where monophyly is established.
2) This system is based mainly on morphology, anatomy, embryology, phytochemistry and more strongly molecular studies.
3) The traditional division of angiosperms into monocots and dicots has been abandoned.
4) Various monocot taxa have been placed in between primitive angiosperms and eudicots.
5) A number of cladograms are presented in order to show the general affinities between various groups of angiosperms based on molecular data and data from other field.
6) The families with primitive features are placed in the begining of the angiosperms.
7) Winteraceae and Canellaceae are brought together under the same order (Canellales) based on multigene analysis and morphological studies.

8) Capparaceae and Brassicaceae have been separated and Cleomaceae has been established on the basis of Chloroplast DNA studies.
9) The Liliaceae family of earlier workers has been splitted into Liliaceae, Asparagaceae etc.
10) The merger of Asclepiadaceae with Apocynaceaehas been supported by molecular evidences.
11) The circumscription of Malvaceae has been broadened to include Tiliaceae, Sterculiaceae and Bombacaceae based on molecular and morphological studies.

### 6.2.2 DEMERITS:

As APG classification is still evolving and continuously improving, it will take considerable time before it is stabilised.

1) This system is not proceeded below the family level. So, it is not useful in practice in herbaria and flora.
2) No formal names have been given to informal groups as per the ICN.
3) This system provides angiosperms the rank of a division, but there are no formal taxa between the rank of an order and division.
4) A number of families and few unplaced genera still remain to be placed suitably.

## 6.3 SUMMARY:

The APG IV classification, which stands for Angiosperm Phylogeny Group IV, is the latest version of a widely accepted system for classifying flowering plants (angiosperms) based primarily on molecular evidence, dividing them into major clades like monocots and eudicots and further subdivided into orders and families, with the key feature being its reliance on DNA analysis to determine evolutionary relationships between plant groups; it is considered a consensus among botanists regarding the most accurate representation of flowering plant phylogeny. Unlike older systems, APG IV heavily relies on DNA sequence data to determine relationships between plant groups, providing a more accurate picture of evolutionary history. .The system recognizes major clades like monocots and eudicots, which are further divided into smaller groups like "Magnoliids" and "Rosids". The APG is a group of botanists from around the world who work together to develop and refine the classification system.

## 6.4 SELF- ASSESSMENT QUESTIONS:

1) Write about broad outlines of APG?
2) Five a detailed account on APG-IV?
3) Brief the merits of APG-IV?
4) Brief the Demerits of APG-IV?

## 6.5 SUGGESTED READINGS:

1) Angiosperm Phylogeny group, 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG-IV. Botanical Journal of the Linnaean Society 181: 1-20.

2) Judd, W.S. Campbell, C.S., Kellogg, E.A., S Tevens, P.A. and Donoghue, M.J.2016.

3) Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.

**Prof. A. Amrutha Valli**

# LESSON-7

# ANGIOSPERM PHYLOGENY GROUP (APG)

**STRUCTURE:**



## 7.1 INTRODUCTION:

The **basal angiosperms** are a broad group of the most primitive flowering plants. They do not belong to either the monocots or eudicots. The basal angiosperms are mostly woody plants that produce seeds and flowers.

They diverged from the lineage leading to most flowering plants. There is roughly 9000 basal angiosperm species currently existing on the earth that can be separated into two categories:

I) ANA grade basal angiosperms
(A-Amborellales; N-Nymphaeales; A-Austrobaileyales.)

II) Magnoliids

## 7.2 CHARACTERISTICS OF BASAL ANGIOSPERMS:

Basal angiosperms have a number of characteristics that show their primitive evolution.

The basal angiosperms will have both monocot and dicot characteristics.

1) For a long time, the basal angiosperms and eudicots were grouped together as dicots due to both groups having two embryonic leaves (seedling leaves).
2) They also tend to have reticulate vein patterns in their leaves as in eudicots.
3) Basal angiosperms also have a less advanced vascular system than other angiosperms.

4) *Amborella* and the members of Nymphaeales lack vessel elements like gymnosperms.
5) The leaves are alternate and arranged spirally.
6) They lack any real differentiation between their sepals and their petals (tepals).
7) They have numerous flattened (laminar) stamens with wide filaments.
8) Their pollen has one pore or groove as in monocots. So, the pollen grains are monocolpate or monoaperturate (3 colpi in eudicots).
9) They have many separate carpels (Apocarpous condition)
10) The fruits are typically single chambered and dry.
11) They also lack the etherealoils (essential oils).

**Distribution of Basal Angiosperms**

Basal angiosperms are found all around the world, except in extreme climates such as Antarctica and the Saharan desert. They are successfully growing in tropical and warm-temperate rainforests.

A number of ANA basal angiosperms are confined to Australia, Asia and Oceania. In comparison, Magnoliid species tend to have much more variable distributions.

**Relationships:**

The exact relationships between *Amborella,* Nymphaeales and Austrobaileyales are not yet clear. Although most studies show that *Amborella* and Nymphaeales are more basal than Austrobaileyales, and all three are more basal than the mesangiosperms, there is significant molecular evidence in favour of two different trees, one in which is *Amborella* sister to the rest of the angiosperms, and one in which a clade of *Amborella* and Nymphaeales is in this position.

Recent studies showed that (2014) *Amborella* plus Nymphaeales together represent the earliest diverging lineage of extant angiosperms. A number of other studies identify *Amborella* the most basal of all angiosperms.

## 7.3 ANA BASAL ANGIOSPERMS:

The ANA grade basal angiosperms include three orders viz. Amborellales, Nymphaeales and Austrobileyales

**AMBORELLALES:** This order has only a single species, *Amborellatrichopoda*. It is an evergreen shrub that is found only in New Caledonia in the South Pacific (today`s Scotland).

**Characters:**

1) It is a vessel less evergreen shrub.
2) The flowers are unisexual with spiral perianth
3) The androecium with numerous laminar stamens
4) The gynoecium is with apocarpous, apically open, 1 ovule

**NYMPHAEALES:** This order comprises a number of aquatic herbs including the water lilies and is the second oldest lineage of basal angiosperms after the order Amborellales. They have a much wider distribution than any other ANA basal angiosperm and is distributed throughout the world except in deserts and the polar regions of Antarctica and the Arctic.

**Nymphaeaceae (**water lily.family)

**Characters:**

Aquatic herbs

Spiral floral parts

Laminar stamens

e.g., *Nymphaeanouchali*(= *Nymphaea stellata*)-Indian water lily, Star lotus

*Nymphaea alba*-White lotus, European water lily

*Nymphaea rubra*-Red Indian water lily

*Victoria amazonica*-Giant water lily, Amazon water lily, Royal water lily, Victoria lily

**Cabombaceae:** (Fanwort family)

**Characters:**

Aquatic submerged herbs

Atactostelic stem (Vascular bundles are dispersed, not in a ring)

*e.g., Cabombacaroliniana*

**AUSTROBILEYALES:** This order includes a number of shrubs and vines that are found in parts of Asia, eastern North America, a small spot in northern Australia and in the Caribbean.

**Austrobaileaceae**

e.g., *Austrobaileya scandens*-It grows only in the wet Tropics rain forests of Queensland, Australia.

### 7.3.1 MAGNOLIIDS:

The Magnoliids are a large group containing more than 8,500 species of related basal angiosperms. They include trees, shrubs, herb and vines, and are most common in tropical and warm temperate regions.

They are typically referred to as "Basal or Primitive Angiosperms."

**Characteristics:**

1) Most of the species have long, broad net-veined leaves.
2) Large trimerous flowers with numerous spirally arranged tepals, stamens and carpels.
3) Some species have laminar stamens.
4) Pollen with only one pore (Monoaperturate).

Magnoliids are arranged in 4 orders viz. Canellales, Piperales, Magnoliales and Laurales.

**CANELLALES:** Canellaceae, Winteraceae

This comprises fragrant trees and shrubs

**PIPERALES:** Aristolochiaceae, Piperaceae, Saururaceae.

**Aristolochiaceae** (Birthwort/Dutchman's pipe family)

(Aristos=best; lochia=child birth)

Climbing plants

Enlarged petaloid calyx

Corolla reduced or absent

*e.g., Aristolochiabracteolata*-Worm killer

*Aristolochia indica*-Indian birthwort, Serpent root plant, Eswaran's root

*Aristolochia littoralis*-Calico flower, Pipe vine, Elegant Dutch man`s pipe

*Aristolochia grandiflora*-Pelicon flower.

**Piperaceae** (Pepper family)

*e.g. Piper betle* - Betle leaf plant, Betel pepper

*Piper longum* - Long pepper

*Piper nigrum* - Black pepper, Common pepper, Pepper

*Piper trioicum* - Snake pepper

**Saururaceae** (Lizards tail family)

*e.g. Sarurus chinensis*

*Saururus cernuus*

**MAGNOLIALES:** Annonaceae, Magnoliaceae, Myristicaceae

**Annonaceae** (Custard apple family)

1) Trimerous perianth
2) Tepals
3) Numerous spiral stamens and pistils on elongated receptacle.

**e.g.,** *Annona squamosa* -Custard apple, sugar apple

*Annona reticulata* – Bullock's heart, Ox- heart, Bull's heart

*Annona muricata* – Soursop, Prickly custard apple

*Annona cherimola* – Cherimoya, Cherimola

*Artabotryshexapetalus* – Climbing Ylang ylang,

*Polyalthia longifolia* - Indian mast tree, False ashoka

*Cananga odorata* - Ylang- ylang tree, Cananga tree,

**Magnoliaceae:**

1) They have stipulate leaves.
2) Tepals in multiples of three (6 to many). The outer 3 are sepaloid.
3) Solitary flowers.
4) Numerous stamens and pistils arranged spirally

e.g. *Magnolia grandiflora* L.-Magnolia

*Magnolia (Michelia) champaka* L.-Champaka

**Myristicaceae:**

e.g., *Myristica fragrans (Nutmeg= seed/ kernel; mace= aril)*

**LAURALES:**

Most of the species are tropical and subtropical. The important families are Hernandiaceae, Lauraceae

***Hernandiaceae:*** *Gyrocarpus asiaticus*-Helicopter tree

*The white wood is soft and light

*It is used for making toys and boxes.

e.g. Kondapalli toys

**Lauraceae:**

***e.g.,*** *Cassytha filiformis*-Green thread creeper, Moss creeper (a parasitic vine)

*Cinnamomum camphora*-Camphor: Camphor is a white crystalline substance.

It is a component of incense, medicine and alsoan insect repellent.

*C. tamala*-Indian bay leaf

*C. verum* (= *C. zeylanicum*)-Cinnamon-The bark is used as spice.

### 7.3.2 MONOCOTS:

They are one of the two groups of flowering plants. According to IUCN (International Union for Conservation of Nature), there are 59,600 species of monocots.

Monocots are distinguishable from other angiosperms both in terms of their uniformity and diversity. The organization of the shoots, leaf structure and floral configuration are more uniform than in other angiosperms.

**Features:**

1) They have a single cotyledon.
2) Roots fibrous or adventitious.
3) Most have parallel venation except in Araceae, Dioscoreaceae and Smilacaceae.
4) Floral parts are in multiples of 3.
5) All have an atactostele.
6) All monocots have sieve tube plastids with cuneate proteinaceous inclusions of P2 type.
7) Majority are lacking a petiole.
8) Many do not show secondary growth so that they are herbaceous.

**Monocots include several important orders. They include:**

**ACORALES:** It comprises a single Acoraceae family.

***Acoraceae***

1) Marsh plants.
2) Stem rhizomatous.
3) Spadix inflorescence
4) Stamens 3+ 3, free.
5) Laminar stamens.

*e.g., Acorus calamus* (Sweet Flag)-Rhizomes used to improve memory & speech (brain tonic), rejuvenator.

**ALISMATALES:**

This group is characterized by the presence of trichomes in the axils of sheathing leaves known as 'Intravaginal squamules'. It includes the families like Araceae, Hydrocharitaceae etc.

***Araceae:***

*e.g.,* *Alocasiamacrorrhizos* – Gaint elephant ear

*Amorphophallus paeoniifolius* – Elephant foot yam

*Colocasia esculenta* – Taro arum

*Caladium bicolor* – Heart of Jesus

*Epipremnumaureum* – Money plant

*Monstera deliciosa*- Cut leaf Philodendron

*Syngonium podophyllum* – Arrow head vine

***Hydrocharitaceae:*** All plans are hydrophytes

*e.g.,* *Hydrilla verticillata* – Hydrilla ,Water thyme

*Ottelia alismoides* – Duck lettuce

*Vallisnaria natans* – Tape grass

**DIOSCOREALES:** It includesDioscoreaceae etc.

***Dioscoreaceae–***Perennial rhizomatous herbs.

*e.g.,* *Dioscorea alata* – Yam

*D. pentaphylla* – Five- leaved yam

*D. bulbifera* – Dog yam, Potato yam (Air potato)

**PANDANALES:** It comprises Pandanaceae etc.

***Pandanaceae:***

Sympodial branched

Woody plants with prop roots

*e.g.,* *Pandanustectorius* – Screw pine.

**LILIALES:** It includes Liliaceae, Colchicaceaeetc

***Liliaceae:***

Bulbous roots

Lacking onion like odour

Basal or cauline leaves

e.g. *Aloe vera*-The Barbados aloes

Leaf juice is used for beauty aid, dandruff. It contains 18 amino acids & 12 Vitamins.

*Chlorophytum comosum*-Spider plant, Ribbon plant

**Colchicaceae:**

*e.g.,* *Colchicumautumnale*-Colchicin inducing chromosome doubling

*Gloriosa superb*-Flame flower, Flame lily

**ASPARAGALES:** It comprisesAmaryllidaceae, Asparagaceae, Orchidaceae etc.

Seeds having a seed coat containing a black substance called 'Phytomelan'.

***Amaryllidaceae:***

Perennial bulbous herbs with umbellate inflorescence, superior ovary

*e.g.,* *Crinum asiaticum* – Crinum lily

*Hymenocallis littoralis* – The beech spider lily

*Allium cepa* – Onion

*A. sativum* – Garlic

***Asparagaceae*** (incl. Agavaceae )

*e.g,* *Asparagus racemosus* – Climbing asparagus

*Agave Americana* – Century plant

*Dracaena reflexa* – Song of India

*Dracaena sanderiana* – Lucky bamboo

*Furcraeafoetida* – Mauritius hemp

*Polianthus tuberosa* – Tuberose

*Sansevieria trifasciata* – Snake plant, mother-in-laws tongue

*Yucca gloriosa* – Adam`s needle

*Beucarnearecurvata*- Pony tail, Elephant foot plant

***Orchidaceae:***

Mycorrhizal, perennial epiphytes

Flowers with a labellum

Pollinia with stalk called 'Pollinarium'

*e.g.* *Vanda tessellata – Vanda orchid*

*Spathoglottis plicata – Palm orchid, ground orchid*

**ARECALES:** It has a single family Arecaceae

***Arecaceae***: The members are popularly known as palms.

Rhizomatous, lianous or arborescent stem.

Large sheathing leaves.

A fleshy drupaceous fruit.

*e.g.,* *Areca catechu* – Areca nut, Betel nut

*Borassus flabellifer* – palmyrah palm, Toddy palm

*Caryotaurens* – Fish tail palm

*Cocos nucifera* – Coconut

*Elaeis guineensis* – Oil palm

*Roystonea regia* – Royal palm

*Wodyetiabifurcata* – Fox tail palm

**COMMELINALES:** It includes Commelinaceae.

***Commelinacee*** (Spider worts):

*e.g.,* *Commelina benghalensis*-Bengal day flower

*Tradescantia spathacea* (=*Rhoeo discolor*) - Boat lily

**ZINGIBERALES:** It has Cannaceae, Musaceae, Zingiberceae etc.

***Cannaceae:***

e.g. *Canna indica*- Indian shot

***Musaceae:***

*e.g.* *Musa* x*paradisiaca*-Banana, Plantain

***Zingiberaceae:***

*e.g.,* *Zingiber officinale*-Ginger

*Curcuma longa*-Turmeric

*C. aromatic*-Wild turmeric

*C. amada*-mango ginger

*Elettaria cardamomum*-Cardamon

*Chelocostusigneus*-Insulin plant

**Strelitziaceae:**

*e.g.,* *Ravenala madagascariensis* - Travellor's palm

**POALES:** It comprises the important families like Cyperaceae, Poaceae

***Cyperaceae*:** The members are commoinly known as sedges.

*e.g.,* *Cyperus rotundus* – Nut sedge

*C. alterifolius* – Umbrella sedge

*Cyperus triceps*- Purple glume flat sedg

***Poaceae*:** The members are known as Grasses.

*e.g.* *Aristida funiculata* – Aristida

*Arundo donax* – Giant cane

*Bambusa arundinacea* – Thorny bamboo

*B. ventricosa* – Buddha belly bamboo

*Chloris barbata* – Swollen finger grass

*Cymbopogon citratus* – Lemon grass

*Cynodondactylon* – Bermuda grass, Dhoob grass

*Imperata cylindrica* – Cogon grass, Cotton grass

*Oryza sativa* – Paddy

*Spinifex littoreus* – Littoral spine grass, Ravana's moustache

*** COMMELINIDS (Commelinoids):**

They are a monophyletic assemblage of monocots. APG III named this clade within the monocots. There are 4 orders in this clade. They include Arecales, Commelinales, Zingiberales and Poales

They are characterized by the presence of a class of organic acids viz., Coumaric acid, Ferulic acid and Deferulic acid.

# LESSON-8

# SELECTIVE CLADES-EUDICOTS, ROSIDS, ASTERIDS

**STRUCTURE:**



## 8.1 EUDICOTS:

This term “Eudicots” derives from dicotyledons. The eudicots are also known as ‘Tricolapates’ or ‘Non-magnoliid dicots’ . They are a large, monophyletic assemblage of angiosperms comprising roughly 1,90,000 described species (3 quarters of flowering plants) .

**8.1.1 CHARACTERISTICS:** The are showing the following.

1) The seeds have two cotyledons (seed leaves).
2) They produce seeds from flowers.
3) Leaves with reticulate venation.
4) Flowers are pentamerous or tetramerous.
5) Pollen grains are three colpate (3 grooved pores)
6) Secondary growth occurs.

They can be categorized into Basal eudicots and Core eudicots.

**BASAL EUDICOTS:** They are a paraphyletic group. They are grouped into 4 orders viz. Ranunculales, Proteales, Trochodendrales and Buxales.

**Ranunculales:** It includes the families like Menispermaceae, Papaveraceae, Ranunculaceae etc.

***Menispermaceae*** (Moon seed family)

*e.g.,* *Tinospora cordifolia*-Guduchi

***Papaveraceae*** (Poppy family): The important characters of this family are:

Perianth triseriate (corolla biseriate)

Numerous stamens

Parietal placentation

Capsule fruit

*e.g.,* *Papaver somniferum* - Opium poppy

*Argemone Mexicana*- Mexican poppy

***Ranunculaceae*** (Butter cup family):

*e.g.,* *Clematis gouriana* – Indian travellor` joy, Old man`s beard

*Naravalia zeylanica*

**Proteales:** It comprises the families like Nelumbonaceae, Proteaceae etc.

**Nelumbonaceae:**

Aquatic herbs emergent concave peltate leaves

Solitary flowers with numerous tepels

Apocarpous

*e.g.,* *Nelumbo nucifera*-Indian Lotus, sacred Lotus: Seeds may remain viable for many years (1,300 years)

### 8.1.2 CORE EUDICOTS:

They are a monophyletic group. They are extremely large diverse assemblage of flowering plants. The include the clades like Superrosids, rosids, Superasterids and Asterids.

**Characteristics:**

They are characterized by

1) Floral parts in fives or multiples of fives
2) Sepals and petals are differentiated.

3) A gynoecium with 3 to 5 typically fused (partially fused) carpels.
4) Production of ellagic and gallic acids.

There are 2 orders in this clade viz. Gunnerales and Dilleniales

**Gunnerales:** It includes the family Gunneraceae.

**Gunneraceae:** Only two genera viz., *Gunnera*and*Myrothamnus*are present.

**Dilleniales:** It comprises the family Dilleniaceae.

**Dilleniaceae**-only one family

***e.g.*** *Dilleniaindica (Elephant apple)*-Planted for its scented flowers and lemon flavoured fruits used in jellies and curries.

*Dilleniapentagyna*: Fruits are used as vegetables.

## 8.2 ROSIDS:

### 8.2.1 Rosids Characteristics:

They are members of a large clade of flowering plants containing more than 70,000 species. Most They are characterized by

1) Bitegmic and crassinucellate ovules.
2) Nuclear endosperm developed.
3) Reticulate pollen exine.
4) Simple perforations of vessel end walls alternate intervessel fitting.
5) Mucilaginous leaf epidermis.
6) 2 or more whorls of stamens
7) + ellagic acid.

### 8.2.2 ORDERS OF ROSIDS:

This clade is divided into 17 orders. The important groups are:

**VITALES:** It comprises a single family.

**Vitaceae** (Grape family)

**Vitaceae:**

1) Lianes
2) Leaf opposed tendrils.
3) Fruit berry

*e.g.,* ***Vitis vinifera* –Grape plant**

***Cissus quadrangularis* - Bone setter, Admant creeper**

**ZYGOPHYLLALES:** The important family is Zygophyllaceae

**Zygophyllaceae:**

e.g., *Tribulus terrestris*– Puncture vine, Goat head

**FABALES**: It comprises Fabaceae, Polygalaceae etc.

**Fabaceae:** It is popularly known as the 'legume family'. The members are easily recognized by their legume fruit. There are 19,000 legume species. It is divided into 3 subfamilies viz. Faboideae, Caesalpinoideae and Mimosoideae.

**a. Faboideae**:

*e. g.,* *Abrusprecatorius* – Indian liquorice, Crabs eye

*Aeschynomene indica* – Pith plant

*Butea Montana* - Flame of the Forest

*Dalbergia latifolia* – Indian Rose wood

*Gliricidia sepium* - Mother of cocoa

*Indigofera tinctoria* – Indigo plant

*Lablab purpurerus* – Hyacinth bean

*Pterocarpus santalinus* – Red sanders.

*Sesbania grandiflora* - Sesban

*Vigna unguiculata* – Cowpea

**b. Caesalpinoideae:**

e.g., *Bauhinia purpurea* - Camel foot tree

*B. variegata*- Orchid tree

*Caesalpinia pulcherrima* – Peacock flower, Paradise flower

*Cassia fistula*- Indian laburnum

*Delonix regia* – Flame boyant

*Peltophorumpterocarpum*- Copper pod tree, Rusty shield bearer

*Saracaasoka* – Sita ashok tree

**c. Mimosoideae:**

e.g. *Acacia nilotica* – Black babul

*A. leucophloea* – White babul

*A. sinuata* - Soap pod tree

*Adenantherapavonina* - Iron tablet tree

*Albizia lebbeck* - East Indian walnut, Silk flower

*Mimosa pudica* - Touch me not

*Pithecellobium dulce* - Manila tamarind

*Prosopis chilensis* - Mesquite

*P. cineraria* – King of desert

*Samanea saman* – Rain tree, Monkey pod

**ROSALES**: It comprises the families like Rosaceae, Rhamnaceae, Moraceae etc.

**Rosaceae:** The Rose family.

***e.g.*** *Rosa centifolia* – Rose plant.

**Rhamnaceae:**

*e.g.* *Zizyphusmauritiana* – Indian jujub tree

**Moraceae:**

*e.g.,* *Morus alba* - Mulberry

*Ficus benghalensis*- Banayan tree

*F. religiosa* – Indian peeple tree

*F. benjamina* – Benjamin fig.

*F. elastica – Indian rubber plant*

*F. racemosa* - Cluster fig

**CUCURBITALES**: It includes Cucurbitaceae, Bigoniaceae etc.

**Cucurbitaceae** (Gourd family): The members are called cucurbits. It consists of about 965 species. They yield fruity vegetables of nutritional value. They are of most agricultural and commercial members.

*e.g.* *Benincasa hispida* –Ash gourd.

*Citrullus lanatus* – Water melon

*Corollocarpusepigaeus* – Indian bryonia

*Cucumis sativus* – Cucumber

*Cucurbita maxima* – Red gourd

*Lagenaria siceraria* – Bottle gourd

*Luffa acutangula* – Ridge gourd

*Luffa cylindrica* – Dish cloth gourd

*Momordica charantia* – Bitter gourd

*Trichosanthescucumerina* – Snake gourd

**CELASTRALES**: It consists of Celastarceae family.

**Celastraceae:**

*e.g.* *Elaeodendron glaucum* – Ceylon tea

*Celastrus paniculatus*- Intellect tree

**OXALIDALES:** It comprises the families like Elaeocarpaceae, Oxalidaceae.

**Elaeocarpaceae:**

e.g. *Elaeocarpus ganitrus* – Bead tree, Rudraksha

*Mutungiacalabura* – China cherry

**Oxalidaceae:**

*e.g.* *Oxalis corniculata* – Creeping wood sorel

*Biophytumsensivuim* – Sensitive plant

**MALPIGHIALES:** It includes Euphorbiaceae, Violaceae, Phyllanthaceae etc.

**Euphorbiaceae:**

*e.g.* *Acalypha indica*- Indian acalypha

*Acalypha wilkesiana* – Garden acalypha

*Acalypha hispida* – Cat`s tail, Red cat`s hot tail

*Euphorbia hirta* – Asthma herb

*Jatropha curcas* - Barbados nut

*Manihot esculenta* – Cassava, tapioca

*Tragiainvolucrata*- Indian stinging nettle, Foget me not

**Phyllanthaceae:**

*e.g.* *Phyllanthus amarus* – Seed under leaf

*Phyllanthus emblica* – Indian gooseberry

*Phyllanthus acidus* – Star gooseberry

**MYRTALES:**

Combretaceae, Lythraceae, Myrtaceae

**Combretaceae:**

*e.g.* *Combretum indicum* – Rangoon creeper

*Terminalia arjuna* - Arjuna tree

*Terminalia alata* – Crocodile bark tree

*Terminalia bellerica* – Bellereic myrobalan

*Terminalia catappa* – Indian almond tree

*Terminalia chebula* – Chebulic myrobalan

**Myrtaceae:**

*e.g.,* *Callistemon lanceolatus* - Bottle brush

*Eucalyptus globules* – Blue gum tree

*Psidium guajava* – Guava

*Syzygiumcumini* – Jambu, Black plum

*Syzigiumjambos* – Rose apple

*Syzygium aromaticum* – Cloves

**SAPINDALES:** It comprisesAnacardiaceae, Meliaceae, Rutaceae, Sapindaceae etc.

**Anacardiaceae:**

*e.g.* *Anacardium occidentale* – Cashew nut

*Lannea coromandelica* – Indian ash tree

*Mangifera indica* – Mango

**Meliaceae:**

*e.g.,* *Azadirachta indica* – Neem, Margosa

*Melia azadirach* – Persian Lilac

**Rutaceae:**

*e.g.,* *Aegle marmelos* – Bael fruit

*Citrus aurantiifolia* – Lemon

*Citrus aurantium*– Sour orange

*C. maxima (C. grandis)*– Paradise apple

*C. medica* – Citrus apple, Persian apple

*C. reticulata*- Seedless orange, Kamala fruit

*C. sinensis* – Sweet orange

**MALVALES:** It comprisesMalvaceae, Bixaceae etc.

**Malvaceae:**

e.g. *Abelmoschus esculentus* – Ladies finger, Okra

*A. moschatus* – Musk mallow

*Gossypium arboreum* -Tree cotton

*Gossypium herbaceum* – Indian cotton

*Hibiscus rosa-siinensis* – China rose

*Hibiscus caanabinus* – Deccan hemp (red)

*Hibiscus sabdariffa* -Jamaican sorrel (white)

*Sidaacuta* – Common wire weed

*Thepesiapopulnea* – Umbrella tree

**BRASSICALES**: It includesBrassicaceae, Caricaceae etc.

**Brassicaceae:**

*e.g.* *Brassica juncea* – White mustard

*Brassica nigra* – Black mustard

*Brassica oleracea var. botrytis* – Cauliflower

*Brassica oleracea var. capitata* – Cabbage

*Raphanus sativus* – Radish

**Caricaceae:**

e.g. *Carica papaya* **–** Papaya, Papa tree

* **COM clade:** It is a clade within the Rosids. In nature, this clade is an unranked group that contains 3 phyto-terrestrial orders of flowering plants.

The COM clade includes

1) Celastrales
2) Oxalidales
3) Malpighiale

## 8.3 ASTERIDS:

Asterids is the largest group of flowering plants, with more than 80,000 species, about a third of the total flowering plant species.

They are generally united by 3 major characters.

1) Presence of iridoid compounds.
2) Most have a sympetalous corolla.
3) Unitegmic and tenuenucellate ovules.

**8.3.1 ORDERS OFASTERIDS:**

This clade comprises 13 orders. The important orders include:

**CORNALES:** It comprises Cornaceae, Hydrangeaceae etc.

**Cornaceae:**

*e.g.,* *Cornus officinalis* - Japanese cornelian cherry

*Cornuscanadensis* - Creeping dogweed

*Alangiumsalvifolium* –Ankolam, Sage leaved Alangium

**ERICALES**: Balsaminaceae, Ebenaceae, Sapotaceae, Theaceae etc.

**Balsaminaceae:**

*e.g.,* *Impatiens balsamina* – Balsam plant

**Ebenaceae:**

*e.g.,* *Diospyros melanoxylon* - Beedi leaf

**Sapotaceae:**

Trees with laticiferous vessels and all parts are hairy.

*e.g.,* *Manilkara zapota (=Achras zapota)* - Sapota

*Manilkara hexandra* – Milk tree, Ceylon iron wood

*Madhuca longifolia* - Indian butter tree, Mahua tree

*Mimusopselengi L.* - Bullet wood, Spanish cherry

**Theaceae:**

*e.g.,* *Camellia sinensis* - Tea plant

**GENTIANALES**: Apocynaceae, Rubiaceae

**Apocynaceae**(incl. Asclepiadaceae): It is chacterized by the presence of connate stigmas (gynostegium) and pollinia.

*e.g.* *Allamanda cathartica* – Allamanda vine

*Alstoniascholaris* – Black board tree, Shaitan wood, Devil`s tree

*Cascabelathevitia* - Yellow oleander

*Plumeria rubra* – Frangipani, Red frangipani, Pagoda tree

*Rauwolfia serpentina* - Rauwolfia , Snake root, Serpent root

*Tabernaemontanadivaricata* – Adam`s apple, Crape jasmine

*Wrightia tinctoria* – Ivory wood, Easter tree, Pala indigo plant

*Calotropis gigantea* – Gigantic swallow wort, Giant milk weed

*Calotropis procera* – Swallow wort, Sodom apple, Akund

*Pergulariadaemia* – Trellis vine, Pergularia

**Rubiaceae**: It consists of trees, shrubs, lianes or herbs that are recognized by opposite leaves with interpetiolar stipules.

*e.g.,* *Ixora coccinia* - Jungle flame, Flame of the woods,

*Mussaendaerythrophylla* – Red Mussaenda, Red flag bush,

*Neolamarckiacadamba* - Parvathi's tree, Kadam

**BORAGINALES**: It includes the family Boraginaceae.

**Boraginaceae:** The members are characterized by the presence of simple spiral leaves, monochasial cymes, deeply 4- lobed ovary and gynobasic style.

*e.g.,* *Heliotropium indicum* **–** Heliotrop, Scorpion weed

*Cordia dichotoma* – Indian cherry, Dog`s teak

*C. sebestena* – Scarlet cordia

**SOLANALES:** It comprises several families like Covolvulaceae, Solanaceae etc.

**Convolvulaceae (**Morning glory family): The members have infundibular corolla and involute aestivation.

e.g. Argyreia nervosa – Wooly morning glory, Elephant climber.

*Cressa critica* – Littoral bind weed

*Evolvulusalsinoides*- Dwarf Morning glory

*Ipomoea aquatica (=I. reptans*)

*I.pomoeacairica* - Railway creeper

*Ipomoea batatas* – Sweet potato

*Ipomoea carnea* – Pink Morning glory

*Ipomoea quamoclit* – Cypress vine

*Merremiaemarginata* – Kidney leaf Morning glory

*Operculinaturpethum* - Indian jalap

**Solanaceae:** They haveinvolutecorolla

*e.g.,* *Capsicum fruitescens* – Red pepper

*Capsicum annum* – Green pepper

*Cestrum nocturnum* – Night queen

*Datura metel* – Black Datura, Devil`s trumpet

*D. stromonium* – White Datura, Thorn apple

*Lycopersicon esculentum* – Tomato

*Nicotiana tabaco* – Tobacco

*Physalis minima* – Sun berry

*Solanum melongena* – Egg plant, Brinjal

*Withaniasomnifera* – Aswagandha

**LAMIALES**: It includes several important families like Acanthaceae, Bignoniaceae, Lamiaceae, Oleaceae, Pedaliaceae, Verbenaceae, Scrophulariaceae etc.

**Acanthaceae:** The members are characterized by the presence of opposite leaves, bracteate and zygomorphicflowers with bilabiate corolla

*e.g.,* *Andrographispaniculata* – King of bitters

*Barleria cristata* – Barleria, December flowers

*Crossandrainfundibuliformis* – Fire cracker flower

*Justicia adhatoda* – Malabar nut tree

*Ruellia tuberosa* – Menow weed, Cracker plant

**Bignoniaceae:** They have didynamous stamens, axile/ parietal placentation and capsule fruit.

*e.g.* *Campsis radicans* – Trumpet vine

*Jacaranda acutifolia* – Mimosa leaved Jacaranda

*Kigelia Africana* – Africal calabash tree

*Millingtonia hortensis* – Tree jasmine

*Pyrostegia venusta* – Flaming trumpet

*Spathodeacampanulata* – Scarlet bell tree

*Tecoma stans* – Yellow bells tree

**Lamiaceae:** They areherbs/ shrubs, the plant parts have aromatic with ethereal oils, quadrangular stems opposite/ whorled leaves, verticillaster/ thyrsus inflorescence, zygomorphic and bilabiate flowers with superior ovary

*e.g.,* *Anisomeles indica* – Indian catmint

*Coleus amboinicus* – Indian borage

*Leucas aspera* – Common Leucas

*Majorana hortensis* – Majorum

*Ocimum basilicum* – Basil

*Ocimum. gratissimum*- Large basil, Lemon basil

*Ocimum kilmandscharicum* – Camphor basil

*Ocimum tenuiflorum* – Sacred basil, Holobasil

**Verbenaceae:**

*e.g.,* *Clerodendrum inermae*- Glory tree

*Duranta repens* – Golden dew drop

*Lantana camara* – Lantana weed, Wild sage

*Tectona grandis* – Teak

**ASTERALES**: It includes families like Asteraceae and Campanulaceae.

**Asteraceae (**Sun flower family): The members are herbs, shrubs, vines or treesThey have head inflorescence, pappus calyx

*e.g.,* *Artemisia nilagirica* – Indian warm weed, Mother wort

*Chrysanthemum indicum* – Chrysanthemum

*Ecliptaprostrata* – Trailing Eclipta

*Helianthus anuus* - Sun flower

*Parthenium hysterocarpus* – Parthenium weed

*Tagetuserecta* – Mexican marigold, African marigold

*T. patula* – French marigold

*Vernonia cinerea* - Little iron weed

*Zinnia elegans*

**APIALES**: It comprises families like Apiaceae, Araliaceae etc.

**Apiaceae:** The plants are aromatic with hollow stems and umbel inflorescence.

*e.g.* *Centella asiatica* – Indian penniwort

*Coriandrum sativum* – Coriander

*Cuminum cyminum* – Cumin

*Daucus carota* – Carrot

*Foeniculum vulgare* – Fennel

*Ferulaasafoetida* – Asafoetida, Food of the Gods

## 8.5 SUMMARY:

Eudicots are a large group of flowering plants where the major clades are "Rosids" and "Asterids," both representing highly diverse groups within the core eudicots, characterized by their distinct floral structures and often containing a large number of species; while Rosids tend to have simpler flowers, Asterids often exhibit fused petals forming a corolla tube, with many species displaying specialized pollination mechanisms and adaptations to insect pollinators.

## 8.6 SELF-ASSESSMENT QUESTIONS:

1) Brief account on Eudicots characteristics?
2) Give a detailed account on Core Eudicots?
3) Brief account on Rosids?
4) Give a detailed account on Orders of Rosids?
5) Give a detailed account on Orders of Astirids?

## 8.7 SUGGESTED READINGS:

1) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J.2016. Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.
2) Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, Canada.
3) Sambamurthy, A.V.S.S. 2005. Taxonomy of Angiosperms. I.K. International Pvt. Ltd, New Delhi.

**Prof. A. Amrutha Valli**

# LESSON-9

# MORPHOLOGY IN RELATION TO TAXONOMY

**STRUCTURE:**



## 9.1 MORPHOLOGY IN RELATION TO TAXONOMY:

**Morphology** (Gk. Morph means shape/ form) is the study of structure and form of plants usually dealing with the organism and its component organs. Most of the taxonomic evidence is coming from the external morphology. Morphololgical data at all levels is useful in taxonomic studies. Morphological features have been extensively studied by taxonomists.

There are two types of morphological characters used in taxonomic studies viz., vegetative and reproductive characters.

**A. Vegetative Features:**

I. **Growth habit**: Hutchinson considered habit as an important character and classified the plants into Herbaceae and Lignosae. e.g., Members of Brassicaceae and Orchidaceae are herbaceous, members of Fagaceae are woody and members of Asteraceae are both herbaceous and woody.

II. **Growth pattern:** On the basis of the growth patterns of leaves which are arranged distichously and parallel to the rhizome, it was suggested that *Zingiber*is more closely related to Hedychieae and Zingibereae, than to Alpineae where the leaves are transverse to the rhizome.

III. **Underground parts**: The structure and morphology of bulb, rhizome, stolon, root tuber, root system etc. have taxonomic significance.

Bulb structure is an important taxonomic criteria in *Allium*. In this, the bulb is solitary or clustered. Rhizome characters are useful for identification of various species in *Iris.* Stolon characters are useful in *Fragaria.* In *Dioscorea*, the structure and morphology of root tubers are used as a taxonomical character.

The root system is tap root in dicots and fibrous in monocots. David has divided the genus *Ranunculus*based on root stock. In *Polygala*, fresh roots are scented.

IV. **Seedling characters:** Type of germination, cotyledonary characters and leaf dimorphism have systematic value and taxonomic significance in Brassicaceae, Convolvulaceae etc.

V. **Leaf characters:** Leaf structure**,** size, shape, arrangement**,** type, form**,** venation have taxonomic importance.

***Stipules:*** Stipule character is fairly constant within a species. Interpetiolar stipules are present in Rubiaceae.

***Leaf base:*** Leaf base is pulvinous in legumes. Sheathing leaf base is closed in Cyperaceae and sheathing leaf base is open in Poaceae.

***Type of leaves:*** Unipinnate in *Azadirachta* and bipinnate in *Melia.*

***Leaf size, shape and arrangement*** on the rachis is useful in the delimitation of *Dalbergia latifolia, D. sissoo and D. sympathetica*

***Leaf venation:*** Reticulate in dicots and parallel in monocots. Intramarginal venation is present in Myrtaceae.

***Leaf modifications*****:** Pitcher shaped insectivorous leaves in *Nepenthes* andtentacular leaves in *Drosera, Salix, Populus.*

**B. FLORAL FEATURES:**

Floral characters are extensively used in delimitation of taxa. Flora characters such as the type and position of inflorescence, flowers and associated structures like structure of perianth, floral symmetry, the number, size, shape and union and types of floral parts such as sepals, petals, stamens and carpels in each whorl, types of ovules, the characters of bracts, bracteoles and pedicels are very important in taxonomy.

I. **Inflorescence type:** The inflorescence is ament in Betuliaceae, umbel in Apiaceae, head (capitulum) in Asteraceae, cyathium in Euphorbiaceae, verticillaster in Lamiaceae and hypanthodium in Moraceae. Epicalyx is present in Malvaceae

The flowers are pentamerous or tetramerous in dicots and trimerous in monocots. Calyx is tubular or bilipped in *Ocimum, Salvia etc.* Corolla is papilionaceous in Faboideae of Fabaceae. Stamens in Mimosaceae, Lamiaceae etc. and carpel number in Caryophyllaceae are of taxonomic significance. The style is gynobasic in Lamiaceae

and lateral in Mango. The presence of gynostegium in Asclepiadaceae and appendicular stamens in *Viola* are also have taxonomic value.

**II. Fruits:** Fruit characters are widely used in identification.

e.g.,

1) Coole used only fruit characters in dividing species of *Valerianella.*
2) Singh *et. al*. used fruit morphology in Asteraceae. e.g., shape of cypsela, presence / absence of pappus.
3) Number of capsule valves in Caryophyllaceae. e.g. *Silene, Melandrium, Cerastium*are separated on the number of valves in capsule.

**III. Seeds:** Seeds have been successfully used particularly at the specific level. The number of seeds per fruit, colour of seeds, shape of seeds and sculpturing of seeds have systematic value.

e.g.

1) ***Anthericum***and ***Chlorophytum*** have been distinguished on the basis of number and shape of seeds.
2) Length and colour of hairy outgrowths on the testa of seed in Acanthaceae, Asclepiadaceae, Convolvulaceae, Malvaceaeetc have taxonomic value.

## 9.2 ANATOMY IN RELATION TO PLANT TAXONOMY:

**Anatomy** (Gk. Anatome means dissection) is the study of the structure of organisms and their parts or it deals with the study of structural organization of living organisms.

Anatomical characters of vegetative and floral parts of plants have been successfully employed in solving many taxonomic problems and to elucidate phylogenetic relationships.

**Boureau** (1864) published a monograph on Bignoniaceae in which he used anatomical characters for separating taxa at various levels for the first time in plant classification and published. Later, **Solereder** (1899) published a book entitled "SystematischAnatomie der Dicotyledonen' (Systematics and Anatomy of the Dicotyledons) by which the importance of anatomy in taxonomy was greatly realized.During $20^{th}$ Century, Baily, Esau, Eames, Swamy, Pant etc. published a number of papers regarding the importance of anatomy in taxonomy.

A number of anatomical characters are used for taxonomic studies. These characters can be studied under different heads.

I. Epidermal features II. Wood anatomy III. Nodal anatomy
IV. Leaf anatomy V. Floral anatomy VI. Seed coat anatomy
VII. Fruit wall anatomy

**I. EPIDERMAL FEATURES:**

**1) Trichomes**: These are the surface hair like structures/ outgrowths protectingthe plant. Trichomes include hairs, scales and papillae..

There are two types of trichomes in plants on the basis of presence or absence of glands.

a) Glandular trichomes b) Non- glandular trichomes.

**a) Hairs:** On the basis ofnumber of cells, the hairs may be unicellular or multicellular. The unicellular hairs may be unbranched (e.g., *Cannabis)* or branched *(e.g., Lobularia). The multicellular hairs may be present in* a single row of cells (e.g., *Chenopodium, Nicotiana)*or in several layers *(e.g., Portulaca).* In some multicellular hairs, they may be branched in dendroid manner (e.g., *Platanus*) or the ranches oriented in one plane (e.g., *Sida).*

**b) Scales** (Peltate hairs): Peltate hair is a discoid plate of cells borne on a stalk in *Hedera napalensis,* while stellate trichomes in *Hedera helix.*

**c) Papillae** – These are the raised thickenings on the surface of the epidermis.

*Secretary trichomes are present in Rubiaceae

Many families like Asteraceae, Lamiaceae, Solanaceae etc. possess characteristic trichomes useful in taxonomy. **Cowan (1950)** utilized the trichome character in distinguishing subgenera and species of *Rhododendron.*

2) **Leaf epidermis:** The importance of epidermal characters of leaves in angiosperm taxonomy has been reviewed by Stace (1965).

**The important epidermal features are**

1) Shape of epidermal cells
2) Type of sculpturing of their walls, and
3) Cell inclusions provide useful information

**Prat (1960) showed 2 types of epidermal cells in grasses.**

**1) Panicoid type:** In this complicated silica cells and bicellular hairs are present e.g. *Panicum*

**2) Festucoid type:** In this, only simple silica cells are present. Bicellular hairs absent.. e.g. *Festuca*

**3) Stomata:** Stomatal study is very useful in taxonomy. They have been classified according to the position of subsidiary cells, and guard cells in relation to the aperture.

About, 35 types of stomata have been described in Vascular plants. The important ones are:

a) Anomocytic (Ranunculaceous/Irregular celled): A limited number of epidermal cell like subsdiary cells surrounding the stomata. e.g. Ranunculaceae, Papaveraceae, Malvaceae.

b) Anisocytic (Cruciferous/Unequal celled): 3 subsidiary cells of unequal size surrounding the stomata. e.g. Brassicaceae, Solanaceae

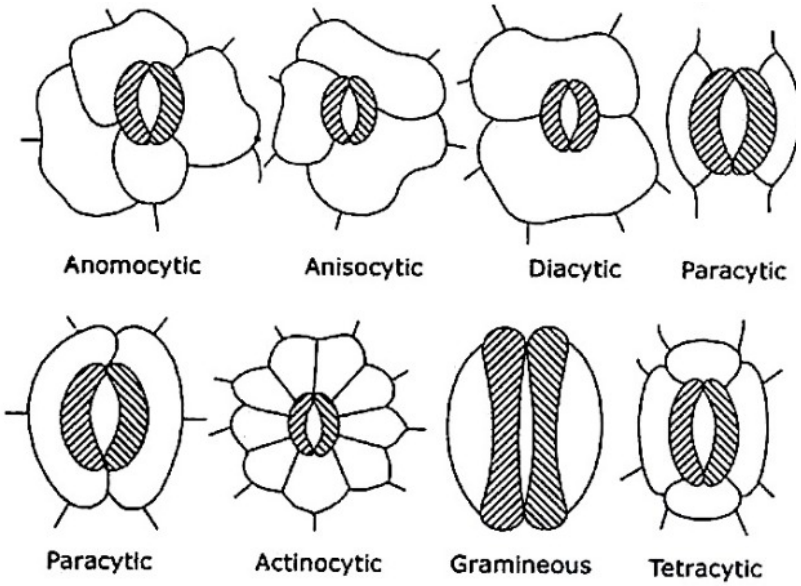
c) Diacytic (Caryophyllaceous/ cross celled): 2 subsidiary cells at right angles to the guard cells. e.g. Caryophyllaceae, Acanthaceae.

d) Paracytic (Rubiaceous/ parallel celled): 2 susidiary cells more parallel to guard cells. e.g. Rubiaceae, Magnoliaceae.

e) Actinocytic (Symmetric): Stomata surrounded by a ring of radiating cells. e.g. Commelinaceae, Musaceae

f) Graminaceous type: Guard cells dump-bell shaped. e.g. Poaceae, Cyperaceae. *Sunken stomata indicate xerophytic habit.

g) Cyclocytic: cyclic manner.e.g. Arecaeae, Pandanaceae.




**4) Silica bodies:** Silica bodies present in epidermal cells of some families are useful in taxonomy at generic and specific levels.They are present only in Rosaceae of dicots and Zingiberaceae, Musaceae and Arecaceae of monocots.

According to Mehra and Sharma (1965), the distribution and shape of epidermal silica cells can be used in Cyperaceae

**III. WOOD ANATOMY:** The wood (secondary xylem) primarily consists of tracheids and vessels. Vessels are absent in gymnosperms and primitive angiosperms like Winteraceae. The importance of wood anatomy in taxonomy is well known. This has been used at all levels due to conservative nature of anatomical features of wood.

**IV.** The wood characters of taxonomic importance are:

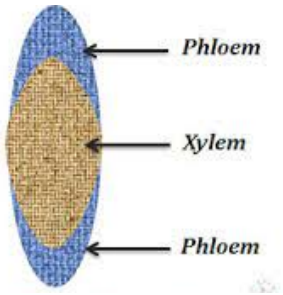
1) Types of vascular bundles.
2) Type of secondary growth.
3) Different features of xylem and phloem.

In Monocots, vascular bundles are scattered and in dicots they are present in a ring.

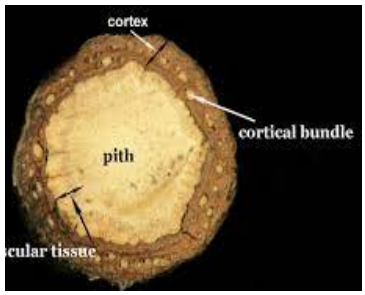
Bicolleteral vascular bundles (Phloem occurs on either side of the xylem) are present in Cucurbitaceae, Gentianaceae etc. In Araliaceae, Cactaceae, Oleaceae, Asteraceae etc. cortical bundles allows the passage of water and nutrients through the voluminous cortex.

Medullary (Intraxylary/ Supernumerary) phloem in which the phloem is present on the inner side of the vascular bundles, occurs in Amaranthaceae, Crassulaceae, Euphorbiaceae. Interxylaryphloem in which the phloem is embedded in the secondary xylem, occurs in Combretaceae, Acanthaceae.

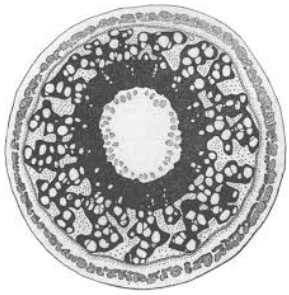
Wood anatomy helped to establish the systematic position of primitive vesseless angiosperms like Winteraceae, Trochodendraceae.It is also helpful in separating *Paeonia* from Ranunculaceae.




**Bicolleteral bundle**




**Cortical bundle**



**Intraxylary phloem**

The studies of Baily et. al. (1943) established a number of trends of evolution in stelar structure. These studies helped to establish the Magnolia type (Magnoliaceae, Winteraceae and Deneriaceae).

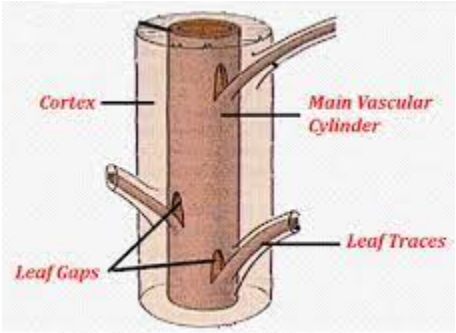
Wood features like vessels, wood parenchyma, ray system and storied structures are useful in taxonomic studies. The structure, abundance and distribution of vessels have taxonomic importance.

Solitary vessels is a primitive character while vessels in groups is an advanced character. Sculpturing on vessel walls is also useful. Presence or absence of latex vessels, resins, crystals in the wood are also useful. Absence of wood parenchyma in Winteraceae is a primitive character.

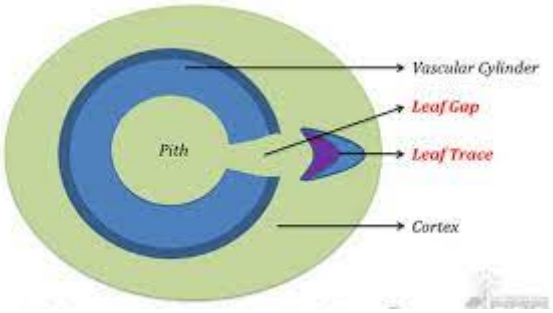
Many cellular contents likec alcium oxalate crystals in *Allium,* cystoliths in Moraceae, albuminoids in *Laportea,* starch grains in *Solanum tuberosum,* andprotein bodies in Cactaceae are also important.

## III. NODAL ANATOMY (PETIOLAR VASCULARIZATION):

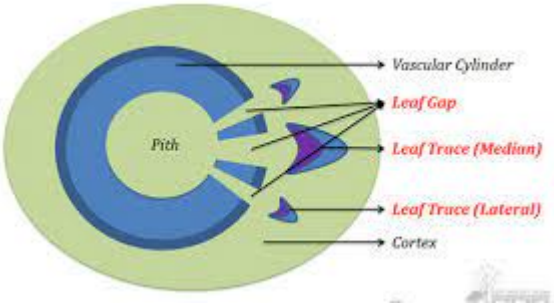
It is important in taxonomic studies. The number of vascular traces (leaf traces) and their associated gaps (leaf gaps) are of taxonomic importance.



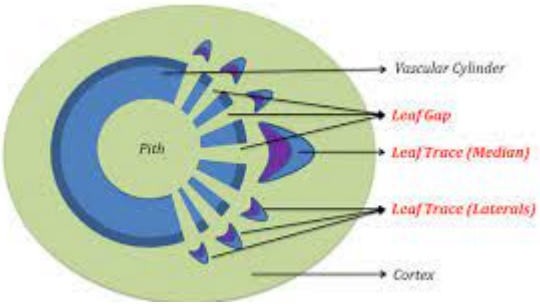

**Leaf traces and leaf gaps**




**Unilacunar node**




**Trilacunar node**




**Multilacunar node**

1) Unilacunar type: In this one leaf gap and one leaf trace are present.

   e.g. Laurales, Caryophyllales, Ericales, Myrtales etc.

2) Trilacunar type: It consists of 3 leaf gaps and 3 leaf traces.

   e.g. Majority of Dicots.

3) Multilacunar type: They are present in primitive orders like Magnoliales, Piperales etc. and in advanced orders like Umbellales and Asterales.

## IV. LEAF ANATOMY:

Leaf characters like leaf venation, leaf internal structure, and foliar sclereids are useful in taxonomic studies.

1) **Leaf venation:** The basic parallel and reticulate venation show variation. The number of primary and secondary veins, angles of secondary veins in relation to primary veins and the nature of tertiary and higher order venation provide valuable characters for classification.

2) **Leaf internal structure:** The chloroplast structure and other morphological features helped in delimiting the genus *Chamaesyce* from *Euphorbia*. Metcalfe (1968) listed several anatomical features to separate Poaceae and Cyperaceae. The classification of several genera of Poaceae has been revised on the basis of Kranz (dense thick walledchlorenchymatous bundle sheath) anatomy. Petiole anatomy of 64 species of *Baphia* (Fabaceae) is used for intrageneric classification.

3) **Foliar sclereids:** Sclerenchyma consists of fibres and sclereids (Stone cells).Rao et al. (**1951**) classified the sclereids as follows.

   **a) Epidermal sclereids:** They are formed by transformation of epidermal cells.

   e.g., *Maerua arenaria*

   **b) Palisade cell sclereids:** They are formed by transformation ofpalisade cells.

   e.g., *Mimusopselengi.*

   **c) Spongy mesophyll cell sclereids:** They are formed by transformation of spongy mesophyll cells.,

   e.g. *Diospyros discolor*

   **d) Terminal sclereids:** They are found in vein and veinlet endings.

   e.g., *Memycylon*

**V. FLORAL ANATOMY:**

This was extremely studied by Eames, Puri, Murty etc. As the reproductive organs show a high degree of conservation, they have been widely used in the classifications. The vascular supply to these floral organs is also conservative.

The distribution and course of vascular bundles within the receptacle and floral parts have proved to be of systematic significance, particularly in ranking of taxa of higher order suchas genera and families.

Murthy and Puri (1980) reported more important variations.

a) Reduction in the number of vascular bundles in a flower/ floral organs.

b) Amplification (increase) in the number of vascular traces to floral organs.

c) Cohesion: The fusion of traces.

d) Adnation: The fusion of nearby traces.

**Contributions:**

1) Earlier Cyperaceae and Poaceae were placed in a single order. Later, they were separated by Hutchinson and placed in separate orders, Cyperales and Poales, respectively. This was confirmed by floral anatomical characters.

2) Inclusion of Solanaceae and Scrophulariaceae due to uniformity in floral vasculature.

3) On the basis of the vascular supply of the ovary of *Trapa,* it was removedf rom the Onagraceae.

4) The separation of *Hydrocotyle asiatica* as *Centella asiatica* has been confirmed on the basis of floral anatomy.

**VI. SEED COAT ANATOMY:**

Corner (1976) in his book "**The Seeds of Dicotyledons**" discussed the importance of seed coat anatomy in systematics. Chowdhury and Buth (1976) formulated a key to identify some important pulses in India.

**VII. FRUIT WALL ANATOMY:**

Leewen (1971) studied the fruit wall characters in 2 genera, *Ammania*and *Rotala*. In *Ammania,* the orientation of 2 layers of pericarp are similar. In *Rotala,* the cells in the inner layer are linear and strongly lignified and transverse to the outer layer.

**VIII. ULTRASTRUCTURAL SYSTEMAICS OF ANATOMY:**

Heywood and Dakhshini have demonstrated the benefits of SEM to plant systematics. Similarly, TEM have also proved a powerful tool in studying anatomical aspects of taxonomic significance.

**Examples:**

a) Dilated Cisternae (DC): They commonly occur in Brassicaceae and Capparaceae.

b) Sieve tube plastids: Depending on their accumulation of starch and protein they are of several types.

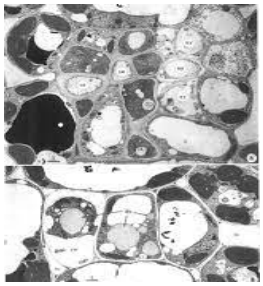
   i) S-type: They accumulate starch. About 65% of the flowering plants have such plastids. They are present in Dillenidae, Hamamelididae, Rosidae, Caryophyllidae etc.

   ii) P- type: They accumulate protein. They are present in the Pinaceae of gymnosperms and 21 families of the monocots and in few families of dicots like Vitaceae, Leeaceae etc.

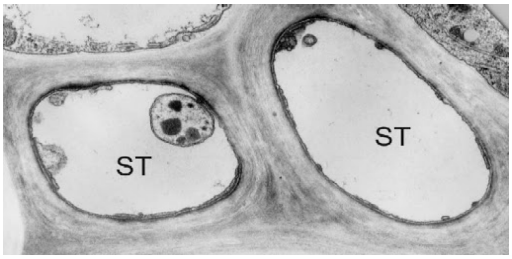
   iii) So -type: They are the plastid elements and have neither starch nor protein.

   e.g. Crassulaceae, Rafflesiaceae, Moraceae etc.

*P- type is considered to be ancestral, while S-type is derived from P- type.



**Dilated cisternae of ER**




**Sieve tube plastid**

## 9.3 EMBRYOLOGY IN RELATION TO TAXONOMY:

**Embyology** (Gk.Embryon means unborn, embryo) is the study of the prenatal development of gametes, fertilization, and development of embryos.

The use of embryological characters in taxonomic studies was first indicated by Hoffmeister and Strasburger by the end of 19th Century. Later, Mauritzon (1939), Maheswari (1950, 64), Johri (1963), Davis (1966), Bhojwani and Bhatnagar (1979), Kapil and Bhatnagar (1980) published excellent articles on the role of embryology.

The use of embryology in taxonomy becomes more useful because embryological characters do not display much ecotypic variation. Maheswari, Kapil and Bhatnagar have listed various embryological features of taxonomic significance. They are:

### 1. ANTHER AND POLLEN:

a) Number of microsporangia (pollen sacs)

b) Type of anther wall development: The anther wall may be of basic, dicotyledonous, monocotyledenous or reduced types.

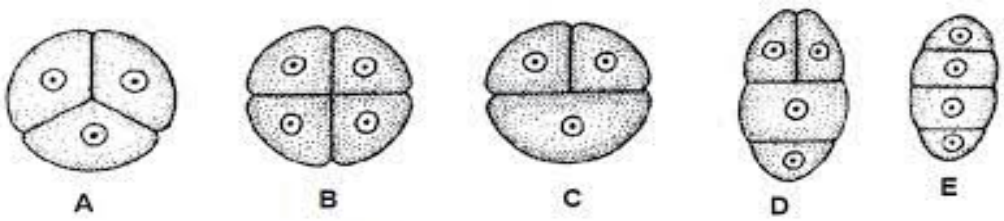
c) Origin and behavior of tapetum (nutritive tissue): It may be parietal (lining around the sporogenous tissue), glandular or plasmodial.

d) Delimitation of microspores: The delimitation may be simultaneous, successive or heterotypic.

e) Orientation of microspore tetrads: They may be tetrahedral (4 triangular faces), decussate, isobilateral and linear/T shaped.

f) Form of pollen grains: The pollen grains are present in different forms like monads, pseudomonads, dyads, tetrads and massulae/pollinium

g) Characters of pollen grains: The size, shape, apertures and sculpturing provide valuable information.




Different types of microspores
A. Tetrahedral, B. Isobilateral, C. Decussate, D. T-shaped, E. Linear

**2. OVULE:**

a) **Placentation**

b) **Orientation:** The ovules may be orthotrophous, anatrophous, amphylotrophous etc. on the basis of the orientation of microphyle and chalaza regions.

c) **Nuclear development:** It may be crassinucellate, pseudonucellate, and tenuinucellate

d) **Initiation and ontogeny of integuments**

e) **Number of integuments:** The ovules may bebitegmic with two integuments or unitegmic with only one integument.

f) **Megasporogenesis and Megagametogenesis**

g) **Fertilization**

h) **Endosperm:** The endosperm may be nuclear, cellular or helobial. The presence or absence of haustoria is also of taxonomic importance.

**3. EMBRYO:** The type of development of embryo.

**4. SEED:** Seed coat, presence or absence or endosperm, presence or absence of seed appendages like aril, caruncle, Jaculator etc. also yield taxonomic information.

**5. FRUIT:** Histogenic differentiation of fruit is useful in taxonomic studies.

**6. Abnormalities** like Parthenogenesis, Apogamy, Polyembryony etc. also have taxonomic importance.

**APPLICATIONS:**

**I. Use of embryological characters among major taxa:**

a) Delimitation of angiosperms from other groups is based on embryological characters like enclosed ovules, double fertilization and triple fusion and post fertilized triploid endosperm. These characters are supporting their monophyletic origin.

b) Delimitation of monocots and dicots is based on the number of cotyledons and other characters.

| | **Monocots** | **Dicots** |
|---|---|---|
| 1 | Amoeboid tapetum | Glandular/ Secreting tapetum |
| 2 | Successive cytokinensis in microspore mother cell | Cytokinensis is simultaneous |
| 3 | Helobial endosperm | Cellular / Nuclear endosperm |
| 4 | Absence of endothelium | Presence of endothelium |

**II. Above the family level:**

There are certain orders which exhibit a set of uniform embryological features.

1) Caryophyllales: It is widely known as "Centrospermae". It is characterized by trinucleate pollen. bitegmic, crassinucellate ovules, seed with a curved and peripheral embryo with perisperm (a mass of nutritive material outside the embryo sac)
2) Ericales: It is characterized by undifferentiated endothelium, glandular tapetum with multinucleate cells, pollen in permanent tetrads, poral dehiscence, unitegmic, tenuinucellate ovules, hollow style with elongated zygote and cellular endosperm.
3) Helobiae: It is characterized by helobial endosperm.
4) Orchidales: It is characterized by undifferentiated embryo with little or no endosperm.
5) Gentianales: It is characterized by lack of integumentary tapetum and nuclear endosperm.

**III. At the family level:**

The embryological evidences have strongly supported the placement of certain disputed families.

1) Cactaceae: Earlier this family was kept under different orders like Ficoidales, Opuntiales, Cactales etc. Studies of Maheswari, Chopra etc. confirmed its centrospermian affinities. This family shares some characters like Glandular tapetum, simultaneous division and campylotrophous ovules etc.
2) Cyperaceae: Formation of only one microspore from microspore mother cell.
3) Loranthaceae: It comprises subfamilies Loranthoideae and Viscoideae.

| | **Loranthoideae** | **Viscoideae** |
|---|---|---|
| a) | Triradiate pollen grains. | Spherical pollen grains |
| b) | ***Polygonum*** type of embryo sac | ***Allium*** type embryo sac |

So, Maheswari suggested to establish 2 families Loranthaceae and Viscaceaeon the basis of above differences between them.

4) Onagraceae: Oenothera type of embryosac is present in all the members of ***Oenothera lamarckiana.***
5) Podostemaceae: It is characterized by presence of pseudo-embryo sac formed by the disintegration of nucellus and no endosperm, bisporic type of embryo sac, paired pollen grains and the large basal cell of the pro-embryo gives rise to prominent haustoria.

**IV. AT GENERIC LEVEL:**

1) ***Trapa:*** Earlier, it was placed under Onagraceae and later in Trapaceae due to the following differences between Trapa and Onagraceae.

| | Trapa | Onagraceae |
|---|---|---|
| 1 | Pollen grains pyramidal | Triangular |
| 2 | Ovary bilocular with a single pendulous ovule | Many ovules |
| 3 | Embryo sac Polygonum type | Oenothera type |
| 4 | Endosperm absent. | Endosperm present |
| 5 | Embryo is ofSolanad type | Onagrad type |
| 6 | Suspensor well developed | Suspensor short. |

2) **Paeonia**: Earlier, it was placed in Ranunculaceae, later in Paeonaceae due to the following differences.

| | Paeonia | Ranunculaceae |
|---|---|---|
| a) | Endothelium multilayered | 1 layered |
| b) | Tapetum 2 layered | 1 layered |
| c) | Pollen exine pitted | Granular |
| d) | Female archisporiummulticelled | Unicelled |

3. *Exocarpus:* Earlier, it was placed in Exocarpaceae in gymnosperms near Taxaceae due to presence of nakedovule, articulate pedicel like *Podocarpus* and pollen chamber

However, Ram`s (1959) embryological studies have clearly shown that

a) The flowers are angiospermous.
b) The anthers have fibrous endothecium.
c) Pollen grains are 2 celled.
d) Ovules enclosed in ovary
e) The mature embryosac is 8 nucleate.

So, he suggested its placement in Santalaceae and later supported by others.

## 9.4 PALYNOLOGY IN RELATION TO TAXONOMY:

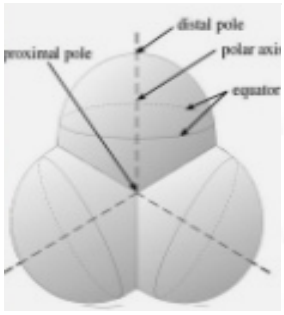
The palynology (Gk. Palynein means to spread) is the study of structure and development of pollen grains. The term ‘Palynology’ was coined by Hyde and Williams (1945).

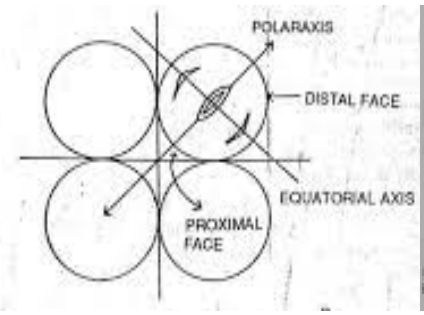
The role of palynology in solving taxonomic problems was first indicated by Erdman (1952) in his book “Pollen Morphology and Taxonomy”.

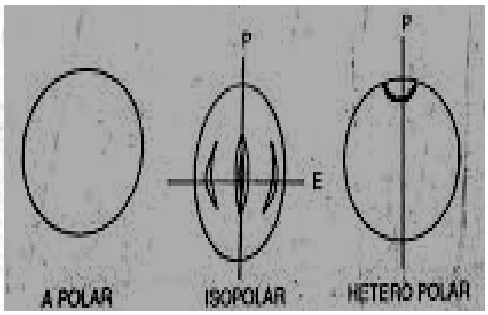
**Various characters of pollen grains are used in taxonomic studies.**

1. Polarity
2. Symmetry
3. Apertures
4. Size
5. Number of pollen grains
6. Wall layers
7. Exine ornamentation
8. Nucleate condition
9. N-P-C formula

**1) Polarity:** The pollen grains are produced in the anther. This anther consists of sporogenous tissue in which spore mother cells are produced. After meiosis, these cells produce pollen tetrads. In tetrads, one end of a grain is directed towards the centre of tetrad which is called 'proximal (nearest) pole'. The other end is called 'distal (far away) pole'. A hypothetical line connecting the 2 poles is called 'polar axis'. It is crossed by another line called an 'equatorial axis' (middle line of the grain). The equatorial axis demarcates the proximal and distal faces which may be of equal size (Isopolar) or dissimilar (Heteropolar).




**2) Summetry:** The pollen grains are symmetrical (either bilateral or radial) or asymmetrical

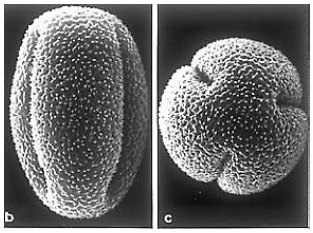
**3) Apertures:** The exine of the grains is provided with apertures which are thin and formed only of a hyaline membrane. This aperture is either long, short/ rounded. Long aperture is called 'colpi' (sing. colpus) and short ones are called 'pores'.

a) The pollen grains may bea. Monocolpate: A single colpus is present. e.g., Gymnosperms, Monocots and certain Dicots.

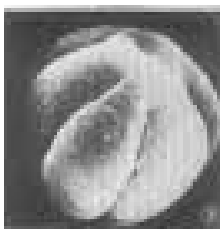
b) Tricolpate : Three colpi are present. e.g., Most Dicots.

c) Pancolpate (Multicolpate): More than 3 colpi are present.

**Monocolpate**



**Tricolpate**



**Pancolpate**

In monocots and monocotyledonous dicots, the aperture is distal. There is an evolutionary trend from proximal (primitive) to distal position. However, the apertures are uniformly spread over the entire surface. e.g., Chenopodiaceae.

4) **Size:** The size varies from 2 to 5 µ in *Myosotis* (Boraginaceae) to about 200 µ in some cucurbits and Nyctaginaceae.

5) **Number of pollen grains:** The output of pollen grains per stamen is also useful in taxonomic studies. e.g. In *Rumex acetosa,* 30,000 pollen grains are produced per stamen. In *Secale cereale,* 19,000 and in *Acer platanoids,* 10,000 pollen grains are formed per stamen.

6) **Wall layers:** The wall of pollen grain consists of an inner thinner layer called 'intine' and an outer thicker layer called 'exine'.

   The wall layer of Amaryllidaceae, Cannaceae, Iridaceae, Musaceae, Zingiberaceae, Costaceae, Marantaceae, Strelitziaceae, Heliconiaceae have a highly reduced exine and an elaborated intine.

7) **Exine ornamentation:** The exine may be smooth or is provided with ornamentation.

   Psilate – smooth

   Granulate – with minute granules

   Gemmate – constricted

   Verrucate – unconstricted

   Undulate – with wavy surface

   Spinate – with spine like short tip

   Spinulate – short spinous

   Baculate – rod shaped

   Clavate – club shaped

8) **Nucleate condition of pollen grains at the time of anthesis**( the period during which the flower is fully open and functional). Dufou (1961) found that among flowering plants, the monocots and polypetalous or apetalous members of dicots are often 2 nucleate. The gamopetalous dicots are 3 nucleate. The ancestral dicotyledonous families are characterized by 2 nucleate pollen. In Euphorbiaceae, 2 nucleate in *Acalypha* and *Phyllanthus* and 3 nucleate in *Croton, Manihot* etc.

9) **N-P-C formula:**

   Where

   N = Number of apertures divided into 9 classes (No=No aperture; N8 with irregular apertures =)

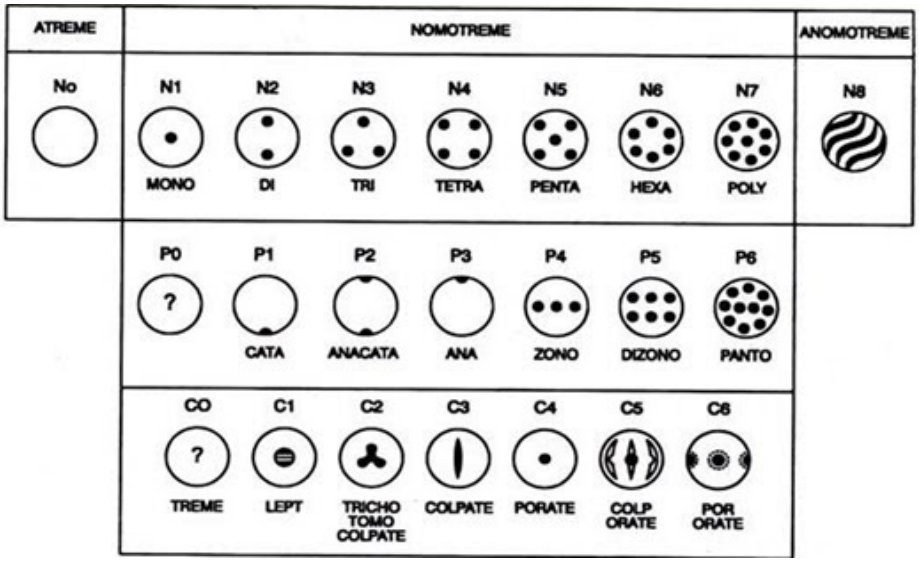
P = Position of apertures divided into 7 classes (Po – P6) distal, proximal etc.

C = Characters divided into 7 classes (Co – C6)

N classification is one dimensional

N+P classification is two dimensional

N+ P+C classification is three dimensional




**Applications:** They can be studied under different heads.

**I.** Applications among higher taxa

**II.** Applications at family level

**III.** Applications at generic level

**IV.** Applications at specific level

**I. Applications Among Higher Taxa:**

Cronquist (1968) divided Magnolidae into Magnoliales, Piperales, Aristolochiales, Nymphaeales, Ranales and Papaverales. The orders Magnoliales, Piperales and Aristolochiales have trichotomocolpate, monocolpate and inaperturate pollen grains. In Nymphaeaceae also the pollen grains are monocolpate. But in Nelumbonaceae, the pollen grains are tricolpate.

**V. Applications at Family Level:**

Depending on variability of pollen grains, pollen grains may be

i) *Stenopalynous( Unipalynous*): Pollen characters are constant in the family.

e.g., Pollen tetrads in all the members of Ericaceae.

ii) Tricolpate and reticulate in all the members of Brassicaceae.

*Eurypalynous*: Pollen vary in sizes, aperture and exine ornamentation.

The exine ornamentation patterns have been of great help in delimitation and classification of various taxa.

1) In Malvaceae, the exine is spiny**.** In *Bombax***,** *Ceiba*and*Adansonia*, exine is Psilate (smooth).
2) In the Asclepiadaceae, the subfamily Periplocoideae is nowraised to the level of Periplocaceae. In Asclepiadaceae, the pollengrains are aggregated into pollinium. But in Periplocaceaethey remain united in tetrads.
3) *Trapa*, once placed in the family Onagraceae, was separated from that family and placed in separate family Trapaceae due to presence of characteristic meridonial crest in pollen of *Trapa.*
4) Stalked pollinia are present in Orchidaceae.

**III. Applications at Generic Level:**

The genus *Polygonum* shows a range of variation in floral and vegetative characters. Thus, Hedburg suggested to separate this genus into a number of genera like *Koenigia, Persicaria* etc. Davis suggested the pollen for identification of annual species of *Ranunculus.*

**IV. Applications at specific level**

The variation in apertual characters are used in delimitation at specific level.

e.g., 1. *Sesamum indicum* - 11 colpi

*Sesamum prostratum* – 9 colpi

*Sesamum leciniatum* – 8 colpi

2. *Bauhinia acuminata* – exine is psilate(smooth)

*Bauhinia malabarica* – exine is spinate

*Bauhinia retusa* – verrucate (unconstructed)

3. *Nymphaea stellata* – pollen grains spinate

*Nymphaea alba* – pollen grains psilate (smooth)

## 9.5 CYTOLOGY IN RELATION TO TAXONOMY:

**Cytology** (Gk. kytos=container) deals with the study of structure, function, multiplication and life history of cells.

The importance of cytology in taxonomy came into light with the introduction of “Biosystematics” or “Experimental Taxonomy” (The study of variation and evolution of a population of organisms in relation to taxonomy or taxonomy based on Cytogenetics and Genetics).

Cytology has made an outstanding contribution in solving many taxonomic problems. The study of the cell, more particularly the study of the chromosomes, has a significant role in plant taxonomy.

**Cytology has contributed to taxonomy in two ways.**

1) It has added a new category of characters for taxonomic studies.
2) It provides valuable information regarding the origin of species.

The chromosomes are best seen at mitotic metaphase and phenotypic appearance of chromosomes at this stage is known as 'karyo type'. Karyo type shows the number, size and form of somatic chromosomes. This concept was first formulated by Delauman (1926). Idiogram is the diagrammatic representation of Karyo type.

An account of chromosome data in taxonomy was given by Moore (1968). Ehredorfer (1976) has reviewed chromosome evidence in angiosperm origin and phylogeny.

**The cytological characters of taxonomic importance are:**

1) Chromosome number.
2) Chromosome morphology (size and structure).
3) Chromosome behavior at meiosis and in crosses.
4) Heterochromatin.

**I. Chromosome Number:**

All individuals in a species have the same number of chromosomes. Darlington and Janaki Ammal (1945) published "*Chromosome Atlas of Cultivated Plants***"** in which extensive records of chromosome numbers are available.

The chromosome number is reported as diploid number (2n/ 2x) from mitosis of sporophytic tissue while the gametophytic (haploid) number of diploid species is reported as base number (n/x).

The chromosome number is varied from one species to another.

The lowest number of chromosomes is reported in *Haplopappusgracilis* (n=2). The highest number of chromosomes is reported in *Poa littorosa* (n=132). Highest number of chromosomes in vascular plants is reported from *Ophioglossumreticulatum* (Adder's tongue fern, 2n=1260). The original chromosome number of the Angiosperm is considered to be n=7.

**Darlington** (1963) provided a diagram showing the use of basic numbers for suggesting relationships among families of woody plants. (e.g., Caryophyllidae n=9; Ericales n=6; Ranuculaceae-n=8; Poaceae – Bambusoideae n=12 and Poaideae n=7).

**II. Chromosome morphology (Size and Structure):**

The morphology of chromosomes used in taxonomy can be studied under two heads.

**a. Size:** The size of chromosomes of karyo type is fairly constant for a species.

e.g. In Liliaceae, the genus *Trillium* has 100 times larger chromosomes than allied genus

*Mediola*. In general, monocotyledons have lager sized chromosomes than dicotyledons.

e.g.

1) The genus *Paeonia* has larger chromosomes than other members of Ranunculaceae.

In *Paeonia* n = 5. In others n = 6-10.

The number and size of chromosomes supported by other studies suggested that the separation *Paeonia* from Ranunculaceae.

2) Earlier *Yucca* was placed in the family Liliaceae of Coronarieae (ovary is superior). *Agave* was placed in Amaryllidaceae of Epigynae (Ovary is inferior). Cytological investigations revealed that these genera have 5 large+25 very short chromosomes (n = 5 +25). This karyotype is called "Bimodal karyotype". Due to this, they were placed in Agavaceae family. Similarly, *Camassia* (Liliaceae) and *Chlorogalum* (Hyacinthaceae) were transferred to Agavaceae.

**b. Structure:** Different forms of chromosomes occur. Relative length of arms, position of centromere and presence of satellites have taxonomic significance. They may be

1. 'V' shaped/ Metacentric with median centromere and two equal arms-Symmetric.
2. 'J' shaped/ acrocentric with one long arm and other short arm-Asymmetric.
3. 'I' shaped or Rod shaped/ Telocentric with a subterminal centromere.

In general, a correlation exists between asymmetry in the karyotype and evolutionary trends. In the Helleboreae tribe of Ranunculaceae, advanced genera like *Delphinium* and *Aconitum* have asymmetrical chromosomes (j shaped). These are regarded as advanced ones. *Anemone* has V shaped chromosome. This is regarded as primitive character.

**III. Chromosome Behavior at Meiosis and in Crosses:**

The behavior of chromosomes at meiosis yield valuable information regarding their affinities. Garber (1958) used chiasma frequency for grouping of species of *Collinsia* (Scrophulariaceae). He found that species with sessile flowers possess low mean number of chiasmata, while those with pedicellate flowers had a high number of chiasmata.

Based on genomic analysis, it has been confirmed that the hexaploid *Senecio cambrensis* is allohexaploid between *Senecio vulgaris* (Tetraploid- m 4n) x *Senecio sqalidus* (Dipoid-2n)

The hexaploid *Triticum aestivum* (common bread wheat) is with a genome **AABBDD.**

**A** is derived from *Triticum monococcum* (diploid)

**B** is derived from *Aegilops speltoides* (diploid)

**D** is derived from *Aegilops squamosa* (diploid)

**IV. Heterochromatin:**

Most of the chromosomes are characterized by a banding pattern. i.e. they show certain bands when they are stained with certain stains such as Geimsa stain and leishman stain**.** The darker regions are called Heterochomatin. The bands are rich in heterochromatin where histone-DNA interaction is more.

Heterochromatin forms 'H' spectrum', which is characteristic of species. Similar H' spectrums are found in related species. Distantly related species may show little or no similarity.

**APPLICATIONS:**

The cytological characters are useful at all the taxonomic levels.

**I. At Family Level:**

**Examples:**

1) **Euphorbiaceae:** According to Hans (1973) there are two basic numbers of chromosomes. n=7 and n=13.

The later is probably derived from the former by doubling and aneuploidy. The other base numbers are 6, 8, 9, 10, 11, 12, 14, 16 and 18. According to Webster, the original base number is 10 and other numbers originated in descending aneuploid series.

2) **Umbelliferae:** The haploid number ranges from 4 - 84. The role of chromosome data is useful in species delimitation in the genus *Bupleurum.*

3) **Loranthaceae:** It is divided into 2 subfamilies: Loranthoideae and Viscoideae. The members of Loranthaceae have uniform basic number of chromosomes (n=9) while Viscaceae are characterized by aneuploid numbers 10-14.

**Other examples are:**

1) *Yucca* (earlier placed in Liliaceae) and *Agave* (Earlier Amaryllidaceae were placed in the same family: Agavaceae based on the presence of Bimodal Karyotype (25 small +5 large)

2) Gramineae-Bambusoideae-n= 12

   Poideae–n= 7

**II. At Genus Level and Below:**

1) The onion is variously recognized as *Allium cepa* var. *viviparum / A. fistulosum* var**.** *proliferum*or *A. cepa* & A. *fistulosum***.** The top onion was subjected to Giemsa banding and it revealed that some chromosomes resemble *A. cepa* and while others resemble *A. fistulosum*. So, top onion is recognized as Pseudodiploid. It is concluded that it is a hybrid between *A.cepa* & *A. fistulosum*.
2) The use of chromosome number and size has been useful to delimit *Crepis* from such related genera like *Cymboseris* and *Youngia.*
3) A difference in chromosome number is helpful in separation of much varied and confused *Violatricolor* and *Viola arvensis.*
4) Palm species with pinnate leaves have n= 16 while palm species with palmatae leaves have n=18.
5) Stebbins (1971) distinguished grasses on the basis of size and number of chromosomes.
6) Bambusoid grasses have small and many chromosomes.
7) Chloridoid grasses have small and few chromosomes.
8) Festucoidgrasses have large chromosomes.
9) Panicoid grasses-medium sized chromosomes.

## 9.6 SELF-ASSESSMENT QUESTIONS:

1) Write an essay on Morphology in Relation to Taxonomy?
2) Write an essay on Anatomy in Relation to Plant Taxonomy?
3) Write an essay on Embryology in relation to taxonomy?
4) Write an essay on Palynology in relation to taxonomy?
5) Write an essay on Cytology in relation to taxonomy?

**Dr. Madhuri Vajha**

# LESSON-10

# DATA INFORMATION SYSTEMS (DATABASE SYSTEMS)

**STRUCTURE:**



## 10.1 INTRODUCTION:

Data are the material for obtaining information. Information systems use data stored in computer databases to provide needed information. Information systems can be defined as an integration of components for collection, storage and processing of data, comprising digital products that process data to facilitate decision making and the data being used to provide information and contribute to knowledge.

## 10.2 COMPONENTS OF INFORMATION SYSTEMS:

An information system consists of six general components. They include:

1) Hardware: The term hardware refers to machinery and equipment. In a modern information system, this category includes the computer itself and all of its support equipment. The support equipment includes input and output devices, storage devices and communications devices.
2) Software: The term software refers to computer programs and the manuals (if any) that support them. Computer programs are machine-readable instructions that direct the circuitry within the hardware parts of the system to function in ways that produce useful information from data.
3) Programs are generally stored on some input/output medium, often a disk or tape.

4) Data: Data are facts/ material that are used by systems to produce useful information. In modern information systems, data are generally stored in machine-readable form on disk or tape until the computer needs them.

5) Procedures: Procedures are the policies that govern the operation of an information system.

6) People: Every system needs people if it is to be useful. Often the most overlooked element of the system is the people, probably the component that most influences the success or failure of information systems. This includes not only the users, but those who operate and service the computers, those who maintain the data, and those who support the network of computers.

7) Internet: The internet is a combination of data and people (Although this component is not necessary for functionality).

A Data Information System or Database System (DBS) refers to the organization, inputting, and accessing of information. The accumulation of separate pieces of data is known as a database. Databases are organized collections of interrelated data used by applications software. Databases are managed by systems software known as database management systems (DBMS) and shared by multiple applications. The databases may be manipulated to address the general or specific questions in plant taxonomy. It is important that students must be trained in the basics of accessing and manipulating information available from these systems.

## 10.3 APPLICATION OF DATA INFORMATION SYSTEMS IN HERBARIA:

All data information systems utilize computer hardware and software to record information. The data are organized as separate/ discrete units, generally known as **fields**. For example, for information in an herbarium collection, typical fields (separate/ distinct units) might be:

| | | | |
|---|---|---|---|
| Taxonomic number | Group | Latitude | Morphology |
| Genus | Family | Longitude | Phenology |
| Specific epithet | Country | Topography type | Habitat description |
| Species author | State | Date of collection | Additional information |
| Infraspecific name | District | Collection number | Accession number |
| Infraspecific author | Locality | Collector | |
| Infraspecific rank | Elevation | Associate collector (s) | |

Basically all of the discrete items recorded at the time of collection or as part of accessioning or identifying the plant. These items may be entered into the database. In addition, a digitized image (photograph) of the plant specimen may be recorded for future access.

The great advantage of computerized data management systems lies in the ability to summarize information about the plant collection. For example, one may call up a listing of all plant specimens collected at a specific locality or within a certain geographic range, defined by latitude and longitude coordinates. One may request a list of all species collected on particular soil or all species that flower in a particular season or month etc. Sophisticated systems may be able to generate a dot distribution map (it uses a point symbol to visualize the geographic distribution of large number) of all the collections of a given taxon.

One critical problem with data information systems is the collection of data. Many, herbarium specimens lack much of the critical information needed. For example, information about plant characteristics, phenology, ecology or latitude / longitude is often not recorded on labels. In fact, on many older herbarium specimens, locality information is not available.. Thus, depending on the quality of the collection, the amount of useful information obtained from herbarium specimens may be quite limited.

Data management systems may also help in the day-to-day organization of herbarium operations. For example, accession numbers (which may be scanned with barcodes) may automatically keep track of both outgoing and incoming returns. Many of the major herbaria have an *on-line* connection that allows others to access this information over the internet, including searchable web pages.

The data management of natural collections has become valuable in biodiversity studies. The data information system allows for the tabulation of presence, range, and distribution of taxa especially important for studying rare, endemic or endangered species or sensitive habitats.

## 10.4 IMPORTANCE OF TAXONOMIC DATABASE IN PLANT SYSTEMATICS:

A **taxonomic database** is a database created to hold information on biological taxa. For example, groups of organisms organized by species name or other taxonomic identifier for efficient data management and information retrieval (getting back).

**Taxonomic databases are used for the following.**

1) For the automated construction of biological checklists such as floras, both for print publication and online
2) To strengthen the web-based species information systems, as a part of biological collection management (for example in museums and herbaria)
3) To provide the taxon management component of broader science or biology information systems.

They are also a fundamental contribution to the discipline of biodiversity informatics. Taxonomic databases digitize scientific biodiversity data and provide access to taxonomic data for research.

Some databases, such as the Global Biodiversity Information Facility (GBIF) database and the Barcode of Life Data System, store the DNA barcode of a taxon if one exists (also called the Barcode Index Number (BIN) which may be assigned, for example, by the International Barcode of Life project (iBOL) or UNITE, a database for fungal DNA barcoding).

A taxonomic database aims to accurately model the characteristics of interest that are relevant to the organisms which are in scope for the intended coverage and usage of the system. For example, databases of fungi, algae, bryophytes and vascular plants ("higher plants") encode conventions from the International Code of Botanical Nomenclature.

## 10.5 IMPORTANT DATABASES OF PLANT SYSTEMATICS:

The following selected databases provide access to data and resources for plant systematics.

1) **Algabase**: a database of information on algae.
2) **Angiosperm Phylogeny Website** (APWeb) is a biological information resource. The content is reflecting up-to-date research in the evolutionary relationships of flowering plants.
3) **Biodiversity Heritage Library:** The world`s best open access digital Library for biodiversity literature.
4) **Botanicus:** A Web-based encyclopedia of digitized historic botanical literature.

5) **Global Plants:** It provides the information of more than two million high- resolution digitized plant type specimens with their references, primary sources, collectors paintings, drawings and photographs.

6) **International Plant Names Index** (IPNI): It is the product of a collaboration of the "The Royal Botanical Gardens, Kew", "The Harward University Herbaria" and "The Australian National Herbarium".

7) **The Plant List:** It provides the working list of the scientific names of all known plants

8) **Tropicos:** It is an online database and contains images and taxonomical and bibiliographical data on more than 4.2 million herbarium specimens and data on over 49,000 scientific publications. It is maintained by the Missouri Botanical Garden, USA.

**Dr. Madhuri Vajha**

# LESSON-11

# BOTANICAL SURVEY OF INDIA (BSI)

**STRUCTURE:**



## 11.1 INTRODUCTION:

**Botanical Survey of India** (**BSI**), the apex taxonomic research organization of the country, is located in Kolkata, West Bengal, India. It is under the Ministry of Environment, Forest and Climate Change, Government of India, It was founded on 13$^{th}$ February 1890, for survey, research and conservation of plant wealth, flora and endangered species and vulnerable plant species of India.

## 11.2 OBJECTIVES:

1) Survey of plant resources of the country for preparing an inventory of the plant wealth in the form of National, Regional and District Floras.
2) Development of the Central National Herbarium and the various Regional Herbaria as repositories of the Types and other authentic specimens.
3) Development of the Indian Botanic Garden, the Regional Experimental Gardens and the National Orchidaria, for the study, introduction and conservation of flora.
4) Development of the Central Botanical Laboratory and Botanical Section of the Indian Museum for experimental studies on plants and popularizing their role in our lives.
5) Assessment and care of threatened plants and studies on little known or new plants particularly among rural and tribal societies.

## 11.3 ACTIVITIES:

1) Sustained utilization of our plant resources. Practical steps are taking to regulate trade of threatened and endangered species .Areas of rich biological diversity are studied at Silent Valley (Kerala), Namdapha (Arunachal Pradesh), Similipal (Orissa), Nanda Devi (Uttar Pradesh), Dechigam (Kashmir), Valley of Flowers (Uttar Pradesh) etc. and steps taken for their conservation.

2) Preserving the diversity of flora and fauna and conservation of individual species of flora which are facing threat or danger of extinction in a major area of interest to the Survey.

3) Sanctuaries have been set up in forest areas for selected plants like the curious carnivorous pitcher plant (*Nepenthes khasiana* Hook. F.) in Meghalaya, and beautiful Rhododendrons and Orchids in Sikkim and Darjeeling Himalayas.

4) Botanical gardens play a very important role in conservation, education, research and recreation.

   The Indian Botanic Garden at Sibpur, largest in the country, is maintained and developed by this organization. In addition, a number of smaller gardens have been established at Pauri (Uttar Pradesh), Allahabad, Mundwa near Pune, Yercaud (Shevaroy Hills, Tamil Nadu), Barapani (Meghalaya) and Dhani Kari near Port Blair. All these gardens give special emphasis to the conservation of rare plants.

5) The Survey assists in teaching and research activities in the country by identifying selected botanical specimens, and also by supplying samples of authentic materials.

6) The Survey maintains close collaboration with Universities, Research Organizations, such as Council of Scientific and Industrial Research (CSIR), Indian council of Agricultural Research (ICAR), Forest Research Institute (FRI), Forest Departments of the states and several Herbari and botanical gardens of the world.

## 11.4 ORGANIZATION:

The Directorate of BSI is located at the Indian Botanic Garden, Howrah, and is headed by a Director. He is assisted by a Joint Director, a Deputy Director, a Senior Administrative Officer and Senior Scientists in charge of various divisions.

There are three important units of Directorate.

1) **Scientific Unit:** It is concerned with Flora, Ecology, Cryptogams, Plant chemistry, Pharmacognosy.

2) **Technical Unit:** It looks after Publication, Documentation and Library, Drawing and Photography.

3) **Administrative Unit:** It contains Establishment, Accounts, Administration, Stores, Security sections. Besides the Directorate, there are the Central Botanical Laboratory, Central National Herbarium and Indian Botanic Garden at Howrah. Industrial Section and Indian Museum.

There are nine circles of BSI which are under the charge of a Senior Scientist.

1) **Southern Circle**, **Coimbatore:** This Circle comprises the states of Andhra Pradesh, Kerala and Tamil Nadu.
2) **Northern Circle, Dehra Dun:** It includes the States of Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Delhi and 24 districts of Uttar Pradesh covering the hilly areas.
3) **Eastern Circle, Shillong:** This circle covers the states of Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.
4) **Western Circle, Pune:** It covers the states of Maharashtra, Karnataka, Union territories of Goa, Laccadive and Minicoy islands.
5) **5.Central Circle, Allahabad:** Central Circle was established in 1962 at Allahabad. This covers the states of Madhya Pradesh and the plain districts of Uttar Pradesh.
6) **Arid zone circle, Jodhpur:** It includes the entire State of Rajasthan, Districts of Bhatinda and Firozpur of Punjab, districts of Hissar, Mahendergarh and Gurgaon of Haryana, Delhi Ridge, districts of Mathura, Agra and Jhansi of Uttar Pradesh, districts of Morena, Bhind, Gwalior, Datia, Sivapuri, Guna, Mandasor, Ratlam and Jhabua of Madhya Pradesh and districts of Kutch, Banas Kantha, Mehsana, Sabar Kantha, Ahmedabad and all the districts of Saurastra from Gujrat.
7) **Andaman and Nicobar Circle, Port Blair:** It coveres different islands of the Andaman, Car Nicobar, Kamorta, Nancowry and Great Nicobar islands of the Nicobars
8) **Sikkim-Himalayas Circle, Gangtok**: It coveres Sikkim and adjacent areas.
9) **Arunachal Field Station, New Itanagar:** It covers the north-eastern India.

## 11.5 PUBLICATIONS:

**Flora of India:**

**Series 1:** National Flora in the form of fascicles.

**Series 2: State Flora** i.e.,

Flora of Tamil Nadu

Flora of Himachal Pradesh

Flora of Karnataka

Flora of Andaman and Nicobar Islands.

Flora of Goa, Diu, Daman, Dadra and Nagarhavelli

Flora of Jammu and Kashmir

Flora of Kerala-Grasses

Flora of Kerala

Flora of Madhya Pradesh

Flora of Maharashtra State (Monocot; Dicots)

Flora of Manipur

Flora of Mizoram

Flora of Rajasthan

Flora of Saurashtra

Flora of West Bangal

Flora of Bihar

Flora of Sikkim

**Series 3: District Flora:**

e.g., Flora of Guntur District

Flora of East Godavari District

Flora of Nalgonda District etc.

## 11.6 SUMMARY:

The Botanical Survey of India (BSI) is a premier research organization under the Ministry of Environment, Forest and Climate Change, established in 1890 to study and document the wild plant resources of India, including identifying plant species with economic value, conducting taxonomic research, and creating an inventory of the country's flora through extensive surveys across diverse ecosystems, from coastal regions to the Himalayas; its primary goal is to explore and understand India's plant diversity for conservation and sustainable use. BSI is Focusing in conducting taxonomic and floristic studies on wild plants in India. Established on February 13, 1890 with an Objective to explore and identify plant species with potential economic benefits. BSI Activities are Conducting field surveys, collecting plant specimens, identifying new species, creating regional floras, and promoting environmental awareness. Its Headquarters at Kolkata under the Ministry of Environment, Forest and Climate Change

## 11.7 SELF ASSESSMENT OBJECTIVES:

1) Give a detailed account on BSI
2) Write short notes on (a) Activities of BSI; (b) Publications of BSI

## 11.8 SUGGESTED READINGS:

1) Radford, A.E. 1986. Fundamentals of Plant Systematics. Harper & Row Publisher, New York.
2) Davis, P.H. and Heywood, V.M.1973. Principles of Angiosperm Taxonomy. Robert. Kereiger Publishers, New York.
3) Gamble, J.S. and Fisher, C.E.C. 1915-35. Flora of Presidency of Madras. 3 Volumes. BSMS, Dehradun.

**Dr. Madhuri Vajha**

# LESSON-12

# PROCESS OF IDENTIFICATION

**STRUCTURE:**



## 12.1 METHODS OF IDENTIFICATION:

Identification of plants is one of the basic components of the taxonomy. Recognizing an unknown plant is important in taxonomic activity. In the biological sense, identification is the determination of the group to which a specimen/ an organism belongs.

**The process of plant identification usually includes several methods.**

1) **Comparison**: A direct comparison of an unknown specimen with the already named and classified taxa in a herbarium.
2) **Taxonomic Keys**: The direct comparison of the features of a plant with those in taxonomic keys on the basis of similarities and differences between two specimens.
3) **Taxonomic literature:** Various forms of literature are useful for proper identification of unknown plants. These printed forms include:
   a) **Floras:** A flora is a systematic enumeration of plant species occurring in a given area. It contains keys, descriptions and often illustrations. The latest flora is utilized and the list of the plants present in that particular region is recorded. In any flora, the plants are arranged according to the available standard system of classification. Based on the area covered, the floras may be categorized as Local flora, Regional flora, Continental flora etc.

**b) Monographs:** A monograph is a detailed taxonomic study of all species and intraspecific taxa of a given taxonomic group, generally a genus or family. It deals with the compilation of worldwide available significant information concerning the taxon.

**c) Manuals and Journals:** They provide a continuous update on additional taxa described or reported from a region. A manual is a more exhaustive treatment than a flora and covering specialized groups of plants. Journals provide information on the results of ongoing research.

**d) Catalogues:** They account for the books of special libraries in taxonomic studies. The data regarding the full name of an author, exact title of a work, period of publication etc. are available from these catalogues.

4**. Computers in identification:** The main approaches used in computer identification are computer stored keys, computer constructed keys etc. Descriptions, photographs and illustrations are also available for help in identification.

## 12.2 TAXONOMIC KEYS:

Taxonomic keys are aids for rapid identification of unknown plants. They are the important components of floras, monographs and other taxonomic literature.

*"A key is an artificial arrangement or analytical device whereby a choice is provided between two contradictory statements resulting in the acceptance of one and the rejection of another"*

A single pair of contradictory statements is called a **couplet.** Each statement of couplet is called a **lead**. Leads are usually the best contrasting characters.

Based on the arrangement of the characters and their utilization, taxonomic keys are of 2 major types.

1) Single access/Dichotomous/ Sequential/Diagnostic Keys.
2) Multi access keys/Polyclaves

### 12.2.1. Single Access/Dichotomous/Sequential/Diagnostic Keys:

These were first introduced by Lamarck. These are based on diagnostic characters. Thus, they are known as diagnostic keys. They are based on pairs of characters. Hence, they are called dichotomous keys. For characters, sequence of alternate choices are provided. So, they are called sequential keys. They are used in floras, manuals, monographs etc.

**Based on the arrangement of couplets and their leads, the dichotomous keys are of 3 types.**

a) Indented / Yolked keys

b) Bracketed/ Parallel keys

c) Serial / Numbered keys

**a) Indented / Yolked keys:** These are commonly used in floras and manuals when the keys are smaller in size. The leads and taxa are arranged in groups (Yolks). The subordinate couplets are indented below at a fixed distance from the margin In this, each of the couplets is indented at a fixed distance from the left margin of the page. The distance is increasing with each subordinate couplet. There is a wastage of space. e.g. *Flora Europea*.

1. Fruit an achene

2. Calyx differentiated from corolla

3. Petal with basal nectary…… *Ranunculus*

3. Petal without basal nectar…….....*Adonis*

2. Calyx not differentiated from corolla

4. Plants woody…….....*Clematis*

4. Plants herbaceous……...*Anemone*

1. Fruit follicle

5. Spur present

6. Number of spurs 1……...*Delphinium*

6. Number of spurs 5……..*Aquilegia*

5. Spur absent……..*Caltha*

**b) Bracketed/ Parallel keys:** These are used in larger floras. In this type, the two leads of a couplet are always together and the distance from the margin is always the same. Thus, there is saving of the page. At end of each line in the key, there is either a number / a name of the plant.

e.g. *Flora of the USSR, Plants of Central Asia.*

1. Fruit an achene……2

1. Fruit follicle……5

2. Calyx differentiated from corolla……...3

2. Calyx not differentiated from corolla….4

3. Petal with basal nectary……..*Ranunculus*

3. Petal without basal nectar……..*Adonis*

4. Plants woody…….....*Clematis*

4. Plants herbaceous……..*Anemone*

5. Spur present……6

5. Spur absent……*Caltha*

6. Number of spurs 1……..*Delphinium*

6. Number of spurs 5…….*Aquilegia*

**c) Serial / Numbered keys:** In this, Indented key arrangement is retained but there is no indentation. So, the distance from the margin is same. The location of alternate leads is done by serial numbering of couplets. The serial number of the alternate leads is indicated within the parenthesis. There is no wastage of space.

1. (6) Fruit an achene

2. (4) Calyx differentiated from corolla

3. Petal with basal nectary……..*Ranunculus*

3. Petal without basal nectar…….....*Adonis*

4. (2) Calyx not differentiated from corolla

5. Plants woody…….....*Clematis*

5. Plants herbaceous……...*Anemone*

6. (1) Fruit follicle

7. (9) Spur present

8. Number of spurs 1……...*Delphinium*

8. Number of spurs 5……..*Aquilegia*

9. (7) Spur absent…….*Caltha*

The above all sequential keys are called `**Monothetic sequential keys**` as they have single character included in a couplet with two contrasting characters.

The common forms of keys used in flora shave at least some couplets with several statements about different characters in each lead. These are called **`Polythetic sequential keys (Synoptic keys)`.**

These are particularly used for identification of higher categories of plants like orders, families etc..

e. g. Plants rarely woody, mostly herbaceous….Order: Companales

1. Flowers not in a dense head like spike

2. Not succulent…….Campanulaceae

2. Succulent……..Goodeniaceae

1. Flowers in a dense head……...Calyceraceae

**12.2.2. Multi Access (Multi entry)/Polyclaves:**

These are multi-entry keys with many choices of sequence of characters. They have a tremendous advantage over dichotomous keys. They are becoming increasingly popular, especially because of the ease of computerizing them. The advantage of these keys is that they allow the user to enter the key at any point.

**In this, the user is free to select appropriate characters for unknown species.**

1) **Punch cards:** Two basic types of punch cards are commonly used.
   a) Body punched cards
   b) Edge punched cards

**a) Body punched cards (Window cards/ Peak-a- boo cards):** These cards have holes in the body of the card. One card is used for one character. On each card, holes are punched corresponding to the taxa in which that character is present. The procedure of identification includes several steps.

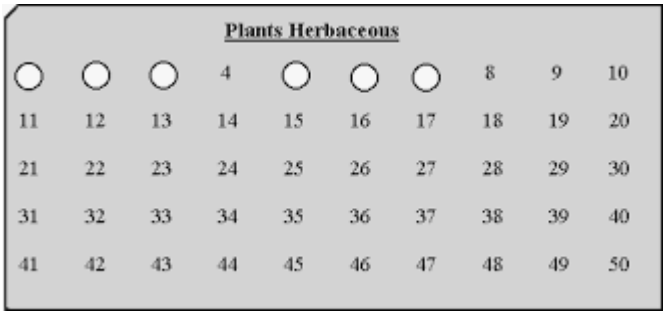
i) The plant is first examined and its characters are to be noted.

ii) The cards corresponding to the characters found in the plant are selected.

iii) These cards are put on the top of one another in a stack. This process is repeated with additional card until finally only one hole is visible. The taxon not perforated in this new card are excluded.

iv) Taxa having all observed characters are indicated by holes or windows which are seen easily when the cards are held in front of light.

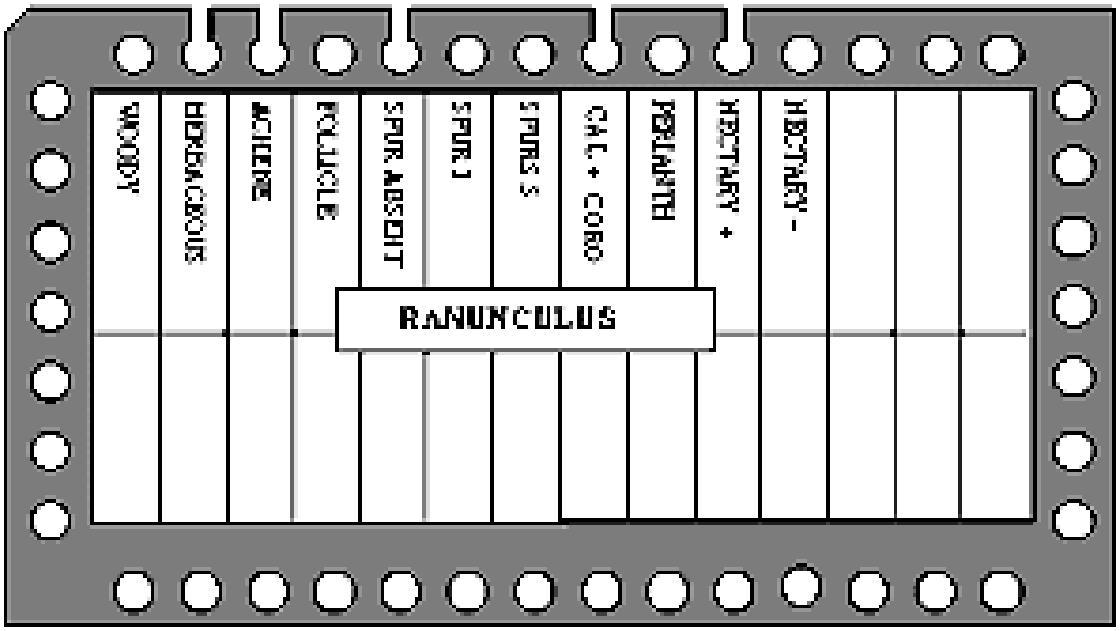
v) The taxon to which this hole corresponds is the identification of the unknown plant.




**A body punched card for herbaceous habit for the genera of Ranunculaceae**

**b) Edge punched cards:** An edge punched card differs from the body punched card in that only one card is used for each taxon. The holes are punched along the edge of the card, one for each character. The holes are normally closed along the edge.

For each character, present in the taxon the hole is clipped out to form an open notch. All cards are held together as a pack. A needle is inserted in the hole corresponding the first attribute of the unknown plant. As the needle is lifted up the taxa containing this character would fall down. The cards falling down are again arranged in a pack. The process is repeated until finally a single card falls down. The taxon, which this card represents, is the identification of the unknown plant.




**2) Tabular keys:** They are very easy to use. The data are incorporated in tables with taxa along the rows and attributes along the columns. The corresponding characters are pictured with the help of appropriate symbols or drawings. The characters not represented in a taxon show a blank space in the column. Hence, the table will have as many rows as taxa and as many columns as number of characters for which information is available.

| Attributes / Taxa | Woody | Herbaceous | Achene | Follicle | Calyx+Cor. | Perianth | Spur 0 | Spur 1 | Spurs 5 | Nectary + | Nectary - | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ranunculus | | ▬ | ▬ | | ▬ | | ▬ | | | ▬ | | | | | | |
| Adonis | | ▬ | ▬ | | ▬ | | ▬ | | | | ▬ | | | | | |
| Anemone | | ▬ | ▬ | | | ▬ | ▬ | | | | ▬ | | | | | |
| Clematis | ▬ | | ▬ | | | ▬ | ▬ | | | | ▬ | | | | | |
| Caltha | | ▬ | | ▬ | | ▬ | ▬ | | | | ▬ | | | | | |
| Delphinium | | ▬ | | ▬ | | ▬ | | ▬ | | ▬ | | | | | | |
| Aquilegia | | ▬ | | ▬ | | ▬ | | | ▬ | | ▬ | | | | | |
| | | | | | | | | | | | | | | | | |

**3) Taxonomic formulae:**

A taxonomic formula is an alphabetic formula based on a specific combination of alphabets. Various characters (attributes) are coded with different alphabets, Thus, each taxon gets a unique alphabetic formula. Based on the characters of the unknown plant its taxonomic formula is constructed. The formula is located in the alphabetic list and its identification read against the formula.

e.g.,

**In Ranunculaceae, the alphabets are assigned for different characters as follows:**

| | |
|---|---|
| A-Woody | H-Calyx differentiated from corolla |
| B-Herbaceous | I-Calyx not differentiated from corolla |
| C-Achene | J-Nectary present |
| D-Follicle | K-Nectary absent |
| E-Spur absent | |
| F-Spurs 1 | |
| G-Spurs 5 | |

**The genera of the family have the formula as given below.**

ACEIK-*Clematis*

BCEHJ-*Ranunculus*

BCEHK-*Adonis*

## 12.3 ROLE OF COMPUTERS IN IDENTIFICATION (COMPUTERISED IDENTIFICATION):

The rapid use of computers in data collection made plant identification an easier and quicker method. In the computerized identification of plants, the major efforts are grouped into 4 major approaches.

**a) Computer constructed keys:** The constructed dichotomous keys are fed into a computer and run using a suitable program**.**

b) **Computer stored dichotomous keys:** Appropriate programs may be developed to construct the keys in the computers based on the taxonomic information about the taxa.

**c) Automated pattern recognition systems:** The computer fitted with optical scanners can observe and record characters, compare these characters with those already known.

d) **Simultaneous character- set methods:** The comparison with the detailed description of the unknown taxon with the description of all taxa of the group can be achieved through a computer in a matter of seconds.

In recent years, information exchange through internet (online) providing illustrations (images) of the plants and their parts from various parts of the world has made the plant identification easy.

## 12.4 CONSTRUCTION OF TAXONOMIC KEYS:

Before plant identification, the plant should be carefully studied, described and a list of characters is prepared. When creating a key, both the qualitative and quantitative characters are considered. The initial identification is to be at the family level and subsequently up to genus, species, subspecies, variety and forma.

1) The dichotomous keys should be strictly dichotomous, consisting of couplets with only two possible choices.
2) Keys should be constructed using constant contrasting characters.
3) Distinct and readily observable characters are used. Variable ones should not be used.
4) Proper measurements rather than terms like “large” and “small” should be used
5) The two leads of a couplet should be mutually exclusive, so that the acceptance of one should automatically lead to the rejection of another.
6) The first word of each lead of the couplet should be identical. e.g. Fruit is berry / Fruit is Follicle.
7) If sufficient number of characters are contrasted, the number of possibility eventually reduced to one.
8) It is important to have two keys based on male and female flowers separately for dioecious plants.
9) Couplets of a key may be numbered or lettered.

Keys are traditional method of identification in taxonomy. If keys are well written with adequate specimens and carefully, the specimen can be successfully identified.

## 12.5 SUMMARY:

Plant identification, using a taxonomic key, is a method to determine the exact species of a plant by systematically comparing its observable characteristics to a series of paired statements (called couplets) in a key, where you choose the statement that best matches the plant, progressively narrowing down options until you reach the correct species name; essentially, it's a structured decision-making process based on visible features like leaf shape, flower structure, and stem type to identify an unknown plant.Key points about plant identification and taxonomic keys: Taxonomic keys act as a tool to identify unknown plants by presenting a series of choices based on visible features, allowing users to pinpoint the correct species.

## 12.6 SELF ASSESSMENT QUESSTIONS:

1) Write about different methods of Identification?
2) Describe different types of Taxonomic Keys?
3) Give a brief account on Single Access/ Dichotomous/ Sequential/ Diagnostic Keys?
4) Give a brief account on MULTI ACCESS (Multi entry)/ POLYCLAVES?
5) Explain the Construction Of Taxonomic Keys?

## 12.7 SUGGESTED READINGS:

1) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J. 2016. Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.
2) Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, Canada.
3) Sambamurthy, A.V.S.S. 2005. Taxonomy of Angiosperms. I.K. International Pvt. Ltd, New Delhi.

**Dr. C.V.S. Bhaskar**

# LESSON-13

# HERBARIUM METHODOLOGY

**STRUCTURE:**



Herbarium Methodology is the fundamental aspect of study, training and research in taxonomy. *"A collection of dried and pressed plants (plant specimens) mounted on sheets, bearing a label, arranged according to a classification system and available for reference or study is known as Herbarium"*.

In practice, herbarium is a name given to a place owned by an Institution, which maintains orderly collecting plant specimens. An Italian botanist **Luca Ghini** (1551) was the first initiator of the art of Herbarium. The word 'Herbarium' was first used by **de Tournefort.**

## 13.1 EQUIPMENT FOR HERBARIUM PROCESS:

For field collections and the preparation of herbarium specimens, some equipment are needed.

a) **For collection:** The equipment for field work involves:

   1) **Digger/ Trowel:** For the collection of whole herbaceous plant, its deep root parts/ rhizomes are required to be taken out with the help of these tools.

   2) **Pruning shears and knives/ Secateurs**: For sharp pruning and cutting, they are needed especially for twigs, branches etc. of shrubs or trees.

   3) **Vasculum**: It is a container and made of a tin or aluminium sheet. It is with a tightly fitted lid and a shoulder strap. It is painted with white to reflect the sun rays in order to protect specimens from heat and locate it quickly in greenery or recyclable polybags are also used and they are readily made airtight using a rubber band.

4) **String tags:** These are made of water proof material used for labeling plants.

5) **Field note book (Field diary):** It contains a well designed and numbered sheets with printed proforma for entering field notes such as

**Scientific Name :**

**Local Name :**

**Family :**

**Locality :**

**Altitude :**

**Date of Collection:**

**Collection No. :**

**Additional Data :**

6) **Camera:** It is essential for taking photographs of the plants and plant parts in the field.

7) **Hand lens**: It is used for observation of characters and identification. A 10X hand lens is used for quick observation.

**b) For pressing and drying:**

8) **Plant press**: It consists of two wooden, plywood / wire mesh planks, each of 30/ 45 cm size.

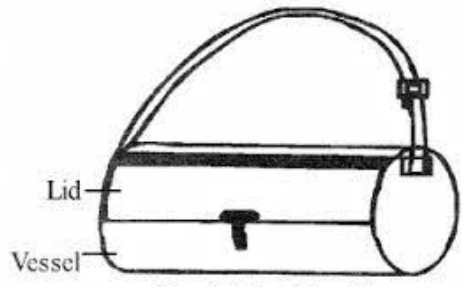
Between these planks/ frames, papers / old news papers are placed for absorbing water quickly.

In between these papers, corrugated sheets (ventilators) are placed. Two chains/ belts are used two tighten the press. Depending on moisture content, the blotters are replaced by new one.

9) **Driers:** Blotting papers, old news papers.

**Digger/ Trowel**

**Pruning shear/ Secateur**




**Vasculum**

**Plant press**

## 13.2 METHODOLOGY:

A specimen for an herbarium needs to be carefully collected, pressed, dried, mounted, labeled, incorporated and preserved properly.

**Broadly, there are 3 steps in Herbarium Methodology.**

I. Collection

II. Processing

III. Preservation

### I. COLLECTION:

Some points should be kept in mind during plant collection.

1) The plant specimens should bear leaves, flowers and fruits, if present.
2) Herbaceous small specimens should be collected completely in flowering condition along with leaves and roots..
3) For woody plants, a twig of about 25 cm with leaves and flowers should be collected.
4) To avoid any chance of loss/ damage at least 4 specimens should be collected.
5) All information about the plant should be recorded in the field note book and the tag from the sheet attached to the concerned specimen.
6) Specimens should be pressed in the field itself or immediately.

### II. PROCESSING:

This processing involves a series of operations such as

1. Pressing
2. Drying
3. Poisoning
4. Mounting and Stitching
5. Labelling
6. Filling/incorporation

**1) PRESSING:** The specimens after collection should be pressed immediately. It is the process of placing specimens between the absorbents under heavy pressure. Herbaceous specimens should be washed to remove mud from roots. The specimens should be placed properly on a pressing sheet (news paper/ blotter).

A specimen shorter than 15 inches (38 cm) should be kept directly in the folded news papers after loosely spreading the leaves and branches to avoid overlapping. If the specimens are larger, can be folded in the form of a V, N or W ensuring that the terminal part of the plant with leaves, flowers and fruits is erect.

As the grasses show elasticity, the specimens can be managed by using strips. Water plants, readily collapsed due to the absence of cuticle, are collected in bags and floated in a tray filled with water, at the bottom of which a white sheet of paper is placed. Then the specimen is placed in a blotter and pressed. It is difficult in making herbarium specimens of succulent plants like Cacti, Euphorbia etc. Their thick succulent tissues take very long time to dry and so they require special attention. Hence, either the tissues should be killed by dipping in boiling water or excess of tissues removed by hollowing out the thick organs. Treating with alcohol or strong Formalin can also kill the tissue.

Once the plant specimens are arranged, the press is tightly bound with ropes/ straps. The press is now ready for drying.

**2) DRYING:** Specimens should be dried as rapidly as possible. Drying of pressed specimens is a slow process if no artificial heat is used. If the drying is quicker, the plant parts will not lose much of their colour. The drying is of two types.

a) Natural drying

b) Artificial drying

**a) Natural drying:** In this drying, freshly collected specimens, placed in a press, are left for 24 hours. During this sweating period, plants lost some moisture and become flaccid. They are transferred to another folded fresh blotting paper/ news paper. This is repeated until the specimens are completely dried. If sheets are infected, they must be discarded immediately. For one week, there must be daily changes of the sheets. The plants must be carefully transferred.

Solar power driers are also used in the press and they are placed in the sun.

**b) Artificial drying:** Artificial heat may also be usedfor drying process. The specimens should not be dried in an oven. Drying with artificial heat may take 12 hours to 2 days. The specimens after the initial sweating period in the press are transferred to a drier.

The drier is made in the form of a wooden box made up of thick boards. In this cabinet, the light bulbs are fitted inside for producing heat. Small openings are made for the entry of air which gets heated and will dry the plants.

**3) POISONING:** The dried specimen is then poisoned. The specimens are usually poisoned with a saturated solution of Mercuric Chloride (Hg Cl2) in alcohol/ spirit. The specimen is either dipped in the solution by holding with tong or applying by

means of a brush. Dipping fingers in the solution should be avoided and rubber gloves should be used while poisoning. All parts of the plant are dipped in the solution and left there for 15-20 seconds, depending up on the thickness of the plants. Lauryl pentachlorophenate (LPCP) is used in some herbaria as substitute for mercuric chloride and it is reported to be very effective and comparatively safer in handling.

4) **MOUNTING AND STITCHING:** In this, pressed and dried specimens are mounted on herbarium sheets. The standard size of a herbarium sheet is 29 x 41.5 cm (11 ½ x 16 ½ inches). The aim of mounting is that the specimens should be neatly and uniformly spread and fixed on the sheet and all parts of the plant should be easily visible for study. A good quality glue/ paste is applied to the back of the specimen and then affix on to the herbarium sheets. Some of the good quality glues are WILHOLD-128, ELMER'S GLUE-All, SWIFTS Z-5032 or NICOBON B.

Narrow strips of gummed paper/ cellophane tapes are used as an additional aid to hold heavy and woody specimens. Sometimes, stem, branches and petioles are stitched. Loose and dissected parts are placed in paper packets and pasted on the some herbarium sheet.

5) **LABELLING:** A label usually of 6.5 x 10.5 cm (Jones & Luchsinger, 1987) dimension, is pasted/ printed on the lower right side of the herbarium sheet. The label contains the information like

**Heading**-Name of Institution/ Person along with the name of the state and country.

**e. g.**

**ACHARYA NAGARJUNA UNIVERSITY**

**NAGARJUNA NAGAR-522 510, GUNTUR DISTRICT, ANDHRA PRADESH, INDIA**

**Botanical Name (Along With Authority):**

**Local/vernacular name:**

**Family:**

**Locality-Place of collection:**

**Habitat-Vegetation type, moisture and soil:**

**Date of Collection:**

**Collection No.:**

**Name of the Collector:**

**Field Notes:**

**Additional Information:**

Voucher herbarium specimens of a research study often have authentic information about the specimens recorded in the form of a **Voucher label**.

6) **FILLING/ INCORPORATION:** Mounted, labeled and treated specimens are finally incorporated in a herbarium, where they properly stored and looked after.

   Small herbaria arrange specimens alphabetically according to family, genus and species. However. larger herbaria follow a particular system of classification. Most herbaria usually follow Bentham& Hooker system. In few European herbaria the families are arranged according to the recent classification, APG (Angiosperm Phylogeny Group).

   The specimens belonging to a species are placed in a folder made of thin strong paper, called **Species cover**. The species covers belonging to a particular genus are arranged alphabetically and placed inside a **genus cover** made of a thicker cover. The genus covers of a family are arranged according to the system of classification, the demarcation between the two families is done using a sheet of paper with a **front-hanging label**. The herbarium sheets are arranged in wooden or steel Almirahs with pigeonhole compartments. Type specimens are kept separately in separate herbarium cases/ rooms for better care and safety.

## 13.4 PRESERVATION:

Herbarium specimens are generally sufficiently dry and as such they are not attacked by fungi and bacteria. But, they are easily attacked by pests like silverfish, beetles etc. The permanent specimens require proper protection and care against damages by insects There are several control measures and they include:

1) **Treating incoming specimens:** Specimens have to be pest free before they can be incorporated into a herbarium. It can be achieved in three ways:
   - i) **Heating** at temperatures up to 60C for 4-8-hours in a heating cabinet.
   - ii) **Deep- freezing methods** are being adapted in some herbaria to prevent infections of fungi, insects etc. in place of harmful chemicals.
   - iii) **Microwave ovens** have been used by some herbaria.
   - iv) **Portable refrigerators/ Freezers** are used in recent years for preserving the seeds and cuttings of plants.
2) **Use of repellents:** To keep the pests away from the specimens, Naphthalene and Para dichlorobenzene are commonly used repellents.
3) **Fumigation**: A periodical fumigation with chemicals (DDT, CuSO4 etc.) is essential for management. Fumigation involves exposing specimens to the vapours of certain chemicals like a mixture of ethylene dichloride and carbon tetrachloride, Copper sulphate etc. Vapona resin strips, Dowfume-75 are useful.

## 13.5 SUMMARY:

Herbarium methodology refers to the process of collecting, preserving, and organizing plant specimens by pressing, drying, mounting them on sheets of paper, and labeling them with detailed information about their location and identification, creating a reference collection for botanical study and research, often used for taxonomic classification and documenting plant biodiversity across regions. Key steps in herbarium methodology are collection, Fieldannotation, Pressing, Drying, Poisoning, Mounting Identification, Determining the scientific name of the plant using taxonomic keys and consulting expert knowledge and Storage.

## 13.6 SELF ASESSMENT QUESTIONS:

1) Give a detailed account on Herbarium preparation.
2) Write about Methodology of herbarium.
3) Write about Processing.
4) Write about Preservation.

## 13.6 SUGGESTED READINGS:

1) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J.2016. Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.
2) Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, Canada.
3) Sambamurthy, A.V.S.S. 2005. Taxonomy of Angiosperms. I.K. International Pvt. Ltd, New Delhi.

**Dr. C.V.S. Bhaskar**

# LESSON-14

# IMPORTANT WORLD AND INDIAN HERBARIA

**STRUCTURE:**



## 14.1 INTRODUCTION:

An herbarium (plural herbaria) is a storehouse of dried plant specimens collected from far and wide, mounted on appropriate herbarium sheets, arranged according to some known system of classification and kept in pigeonholes of steel or wooden cup-boards and are generally associated with botanic gardens and educational or research organizations.

## 14.2 TYPES OF HERBARIA:

Herbarium ranges from small personal collections, mostly of a few hundred specimens to large collections of Colleges, Universities, Private foundations and Government agencies. There are different types of herbaria and they are being used for various activities and generally the following types of herbaria are categorized.

1) International herbaria e.g., Royal Botanic Gardens, Kew.
2) National herbaria e.g., Central National Herbarium, Howrah.
3) Regional herbaria e.g., Andaman and Nicobar Regional Centre, BSI, Port Blair.

4) University herbaria e.g., Calcutta University Herbarium, Kolkata).
5) Medicinal plant herbaria e.g. Central Institute of Medicinal and Aromatic Plants, Lucknow.
6) Economically important plant herbaria e.g. Industrial section Indian Museum, Kolkata.
7) Local herbaria e.g., Malabar Botanical Herbarium, Calicut
8) Agricultural herbaria e.g. Tamil Nadu Agricultural University Herbarium, Coimbatore.

According to FOSBERG (1946), a modern herbarium is a great filling system for information about plant in the form of actual specimens of the plants and 2 in the form of published information, pictures and recorded notes.

According to RADFORD (1986), a modern herbarium is a research, training and service Institution that serves as a reference centre, documentation facility and data store house.

**IMPORTANCE/ ROLE OF HERBARIA:**

Herbarium is a conservatory of material and data.

1) **Repository (Store house) of plant specimens:** The primary role of the herbaria is to store dried plant specimens.
2) **Safe custody of type specimens:** Type specimens are the principle proof of the existence of a species. They are kept in safe custody in the herbaria.
3) **Compilation of floras, manuals and monographs:** The knowledge of taxonomy evolution and distribution are depending on the herbaria.
4) **Training centre for herbarium methodology:** The herbarium serves as an aid in teaching botany to graduates and undergraduates. Many herbaria carry facilities for training in herbarium practices.
5) **Identification of unknown specimens:** The herbaria have a wide ranging collection of specimens and facility for identification of unknown specimen.
6) **Information on geographical distribution:** Herbaria have collections from different parts thus they can provide information on geographic distribution.
7) **Preservation of voucher specimens:** Voucher specimens provide an index of specimens on which the studies on chromosomes, phytochemistry, ultra structure have been undertaken.

## 14.3 MAJOR HERBARIA OF THE WORLD:

A large number of herbaria nearly 850 Institutions have been established throughout the world. Herbaria in different parts of the countries remain associated with Colleges, Universities, Scientific Institutes and Botanical Gardens.

Over 1,600 world's most important herbaria are listed in "INDEX HERBARIORUM" of Holmgren et al. (1981). Missouri Botanical Garden publishes a valuable monthly news letterentitled "HERBARIUM NEWS". The major herbaria of the world are:

| | Location | Acronym | No. of Specimens |
|---|---|---|---|
| 1 | Museum of Natural History, Paris, France | P | 9.377 millions |
| 2 | Royal Botanic Gardens, Kew, UK | K | 7 millions |
| 3 | British Museum of Natural History, London, UK | BM | 7 millions |
| 4 | New York Botanical Garden, New York, USA | NY | 6.5 millions |
| 5 | Conservatory and Botanical Garden, Geneva, Switzerland | G | 6 millions |
| 6 | Missouri Botanical Garden, St. Louis, Missouri, USA | MO | 5.25 millions |
| 7 | VL Komarov Botanical Institute of Azerbaizan (Former Leningrad), Russia | LE | 5.7 millions |
| 8 | Combined Herbaria, Harward University, Cambridge | GH | 5 millions |
| 9 | US National Herbarium, Washington | | 4.1 millions |
| 10 | Botanical Survey of India, Kolkata | | 1.3 millions |

## 14.4 MAJOR INDIAN HERBARIA:

| | | | |
|---|---|---|---|
| 1 | The Central National Herbarium, Kolkata | CAL | 2,50,000 |
| 2 | Herbarium of Forest Research Institute, Dehradun | DD | 3,50,000 |
| 3 | Blatter Herbarium, St. Xavier`s College, Fort Bombay | BLAT | 2,00,000 |
| 4 | Herbarium of National Botanic Gartdens, Lucknow | LWG | 2,60,000 |
| 5 | Herbarium of Botanical Survey of India (BSI) | | |
| | • Central circle, Allahabad | BSA | 50,000 |
| | • Eastern Circle, Shillong | ASSAM | 1,15,000 |
| | • Western Circle, Pune | BSI | 1,25,000 |
| | • Northern Circle, Dehradu006E | BSD | 65,000 |
| | • Southern Circle, Coimbatore | MH | 2,80,000 |
| | • Deccan Circle, Hyderabad | BSID | 10,000 |

## 14.5 BOTANICAL GARDENS (BOTANIC GARDENS):

"A **Botanical Garden** is the institution or place that maintains the living plant collections of different varieties of plants including the ornamental, cultivated, wild, medicinal plants and, plants of economic importance of different geographical regions for study, aesthetics, conservation, economic, educational, recreational and scientific purposes".

Modern Botanical gardens serve as centers for documentation, research, reference, data storage, education, conservation etc. Botanical Gardens that specialize in trees are referred to as 'Arboretums'.

**Botanical gardens contain different sections such as**

1. Herbarium
2. Library
3. Documentation
4. Photographic studies
5. Lecture pavilion
6. Conservation
7. Nursery
8. Extension of services

### 14.5.1 ROLE / IMPORTANCE OF BOTANICAL GARDENS

1) **Aesthetic appeal:** They attract a large number of visitors. They provide aesthetically pleasant environment and sound mental health.
2) **Material for botanical research:** They supply seeds, living resources and material for research in different fields.
3) **On-site teaching:** Collection of plants are displayed according to families, genera/ habitats and used for demonstration.
4) **Conservation:** They are used for conservation of genetic diversity especially rare and endangered plants.
5) **Herbarium & Library:** Major gardens have herbaria and library and they provide information of flora.
6) **Public services:** They provide general information to the public on identification of indigenous and exotic plants, methods of propagation and for home gardening.

### 14.5.2 MAJOR BOTANICAL GARDENS OF THE WORLD:

Thousands of Botanical gardens are present worldwide. The "Hanging Gardens of Babylon" of Iraq (Hillah, Babil province) are the wonders of the ancient world. Of these, nearly 800 important gardens are documented in the "*International Directory of Botanical Gardens*" published by Henderson (1983).

**1) ROYAL BOTANIC GARDEN, KEW , ENGLAND, UK:** It is also called **'KEW GARDENS:**

It is the largest botanical garden in the world and established in 1759 by Princess Augusta. It is located at the Kew. Sir William Hooker was the first Director of this garden. Sir J D Hooker also worked as Director. It covers an area of 330 *ha*.

It includes varieties of plants and fungi. It is called the global centre of excellence in the world. It supports environmental conservation and species identifications. It provides the research facilities for Cytology, Anatomy, Genetics, Physiology etc. So, it is called the "Botanical Capital of the World.

At present, the herbarium contains over 7 million specimens. The arboretum has over 7,000 species and its glass houses have over 13,000 species. Other remarkable features of this garden are Victorian Glasshouse with 10,000 plant species, Palm House, Rose Garden, Chelsia physic garden and world`s best Rock garden. A beautiful Alpine house, Bamboo garden and a Lily pond are also attached..

**2) NEW YORK BOTANICAL GARDEN, NEW YORK, USA:**

It is located at Bronx Park in the Bronx, New York city. It was founded in 1801 and covers 250 acres of land at present. There are 15,000 species distributed in the demonstrated gardens. The Conifer collection, *Rhododendron* and *Azalea* collection, Lily garden, Rhododendrons, Rock garden, Herb garden, Rose garden, Arboretum etc. are the main attractions of this garden.

**3) PADUA BOTANICAL GARDEN, ITALY:**

It is the first university and world's oldest botanical garden developed in Padua in 1545. Nearly 6,000 plants including the collections of insectivorous plants, medicinal plants, poisonous plants, orchids, aquatic plants, alpine plants and Mediterranean plants are growing in this garden.

**4) MISSOURI BOTANIC GARDEN, USA:**

It was founded in1859 in the city of St. Louis. It is one of the oldest national garden in USA. It coveres 79 *acres* of land. It is centre for botanical research, education and horticultural display. It is a home for world' largest collections of rare and endangered orchids.

This garden shows information via Website "Tropicos", the world`s largest database containing more than 9,20,000 scientific plant names. It operates world`s most active "Tropical Botanical Research Programme"

**5) BERLIN BOTANIC GARDEN AND MUSEUM, GERMANY:**

It covers an area of 126 acres. It was developed from 1897 to 1910 under the guidance of Adolf Engler. Nearly, 20,000 species are growing. The Botanical Museum, Herbarium with 3.5 million preserved specimens are the main attractions of the garden.

"**Tropical Green House**" is the biggest in the world.

**6) MONTREAL BOTANIC GARDEN, CANADA:**

It is a large botanical garden in Motreal, Canada. It covers an area of 190 acres of land. Nearly 22,000 *species of plants* are growing. Physic garden is the collection of medicinal plants. The water garden has 10 water pools. In addition, 10 green houses and over 30 outdoor themed gardens are other attractions.

**7) MOSCOW BOTANIC GARDEN, USSR:**

It covers an area of 900 *acres* of land. Economically used plants and ornamental plants are growing. Nearly, 1,800 species of trees, 3,000 herbs, 6,000 ornamental plants, 2,000 crop plants are present.

**8) CAMBRIDGE UNIVERSITY BOTANICAL GARDEN, UK:**

It was founded in 1762. It covers an area of 40 *acres* of land. Artistically landscaped with systematic plantings, Alpine garden, tropical houses are the important attractions.

**14.5.3 MAJOR BOTANICAL GARDENS OF INDIA:**

**1) ACHARYA JAGADISH CHANDRA BOSE INDIAN BOTANIC GARDEN, KOLKATA, WEST BENGAL:**

It is the biggest and oldest botanical garden in India. Earlier, it was named as Royal Botanical Garden. It covers an area of 273 *acres* of land. It was established in 1787 by Lt. Col. **Robert Kid** for the beneficial to the inhabitants. **William Roxburgh**, "The Father of Indian Botany" was its second Director and founded the world famous herbarium. It is now under the control of BSI. Dr**. K. Biswas** was the first Indian superintendent.

*The main attraction of this garden is "**Big Banyan Tree**", one of the largest tree in size in the world and mentioned also in the **GuineesBook of World Records.** It appears like a **miniature forest** itself. Over, **2,880** prop roots are rooted in the ground. The circumference of the canopy is more than **404** m. It is considered to be over 250 years of age.

This garden is now noted for potato cultivation. Cultivation of *Aloe*, Coffee, Indian rubber, *Cardamom* are some of the achievements. There are over **15,000***spp.* of plants collected from several countries are growing. Some other attractions are Palm house, Orchid house, Pinetum, Cacti, *Porana paniculata*, Branching palm (*Hyphaenethebaca),* Double coconut (*Lodoiceamaldivica)* etc.

**2) LLOYD BOTANIC GARDEN, DARJEELING, WEST BENGAL:**

It covers an area of 40 *acres*. The land was donated by William Lloyd. A.G. Jeffrey was the first Curator. It has a rich collection of indigenous and exotic plants.

**Orchid house** consists of 47 spp., **Cactus house** contains 40 spp. and **Herbarium** contains 3,230 spp. It is the major Institution for the distribution of seeds, bulbs, and plants of temperate Himalayas to different parts of the world.

The other attractions of this garden are the presence of Maiden hair tree (*Ginkgo biloba),* and Serpentine woody climber (*Wisteria chinensis).*

**3) LAL BAGH (THE MYSORE STATE) BOTANICAL GARDEN, BANGALORE , KARNATAKA:**

It covers an area of 240 *acres.* It is best in South India for its layout, maintenance, seen beauty and scientific interest.

Because of roses and red coloured flowers, it was named as "Lalbagh" by **Sultan Hyder Ali** (1760). His son **Tipu Sultan** also developed this garden. **Major Waugh** was its first Director. He introduced a number of exotic plants.

It is now a big centre of horticultural activities. It has well equipped laboratories for seed testing and soil testing labs and also grape orchard, tree nursery, fruit nursery, pot garden and a herbal garden.

**4) NATIONAL BOTANICAL GARDEN, LUCKNOW, UTTAR PRADESH:**

It was established in 25 ha on the bank of river Gomati. It is popularly known as **Sikandar Bagh Garden,** a name given by Nawag WaJid Ali Shawin remembrance of his wife Begum Sikandar Mahal. Now, it is called **National Botanical Research Institute** (NBRI).

The major attractions of this garden are Orchards of mango, Citrus and guava, Rosarium Palm house, Cactus house, Fern house and Orchid house. It has well equipped laboratories of Morphology, Aromatics, Cytogenetics, Plant breeding, Tissue culture, Virology and Palynology etc.

**5) BOTANICAL GARDEN OF FOREST RESEARCH INSTITUTE, DEHRADUN**

It was established in 20 *acres* by **Parkinson.** It is the major centre of research in Plant Introduction. There are about 700 plants belonging to 400 genera and about 100 families. Most of them have been introduced from different of the world.

This garden has a green house, Cactus house etc. It has biggest herbarium with 30,000 specimens.

**6) GOVERNMENT BOTANICAL GARDEN, OOTACAMAND (TAMIL NADU):**

It was established in 1847 on the slopes of Nilgiri hills at an elevation of 7,250 *m* feet.

**Melver** introduced *Cinchona, Eucalyptus* with 36 varieties, Essential oil yielding plants like *Lippia, Mentha, Rosmarinus*etc.

**7) BOTANIC GARDEN OF INDIAN REPUBLIC (BGIR), NOIDA, UTTAR PRADESH:**

It was established by the Ministry of the Environment, Forest and Climate change to serve as a national repository of threatened plants of a country. It was opened in 2002.

## 14.6 SUMMARY:

A key world herbarium is the Herbarium of the Royal Botanic Gardens, Kew in England, while in India, the most important herbarium is the Central National Herbarium (CAL) located in Howrah, which is considered the largest and oldest in the country;. Major botanical gardens globally include the Singapore Botanic Gardens and the Brooklyn Botanic Garden, while in India, prominent gardens are the Acharya Jagadish Chandra Bose Indian Botanic Garden in Kolkata, the National Botanic Garden in Lucknow, and Lalbagh Botanical Garden in Bangalore

## 14.7 SELF ASSESSMENT QUESTIONS:

1) Different types of Herbaria.
2) Explain major Herbaria of The World.
3) Explain major Herbaria of India.
4) Write about Botanical Gardens (Botanic Gardens).
5) Write about major Botanical Gardens of The World.
6) Write about major Botanical Gardens of India.

## 14.8 SUGGESTED READINGS:

1) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J.2016. Plant Systematics: A.
2) Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.
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4) Sambamurthy, A.V.S.S. 2005. Taxonomy of Angiosperms. I.K. International Pvt. Ltd, New Delhi.

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# LESSON-15

# DNA BARCODING IN PLANTS

**STRUCTURE:**



## 15.1 INTODUCTION:

In the past 20 years, a novel approach based on the use of DNA markers has been developed. DNA barcoding provides a reliable and rapid method for the identification of organisms. The DNA is stable and not effected by external factors. Each species has a specific sequence of DNA.

DNA barcoding is a molecular method of species identification using a short, standardized segments of DNA from a specific gene or genes. By comparing with the DNA sections (also called "DNA Sequences"), an individual sequence can be used to identify an organism.

Different gene regions are used to identify the different organisms and their groups using barcoding.

1) A portion of the cytochrome *c* oxidase I (COI or COX1) gene, found in mitochondrial DNA, is used for barcoding in animals and some protists.
2) The internal transcribed spacer (ITS) r RNA often used for fungi.
3) *rbcL* (Large sub unit of RUBISCO) used for plants.
4) The 16 S rRNA gene is widely used in identification of prokaryotes, whereas the 18 S rRNA gene is mostly used for detecting microbial eukaryotes.

These gene regions are chosen because they have less intraspecific (within species) variation than interspecific (between species) variation, which is known as the "Barcoding Gap".

**Some Applications of DNA Barcoding include:**

1) Identifying plant leaves even when flowers or fruits are not available.
2) Identifying pollen collected on the bodies of pollinating animals.

When barcoding is used to identify organisms from a sample containing DNA from more than one organism, the term DNA Metabarcoding is used,

e.g. DNA metabarcoding of diatom communities in rivers and streams, which is used to assess water quality. This Metabarcoding is useful in biodiversity (**Ruppert Krista*et al.*, 2019).**

**HISTORY:**

In 2003, specific methods and terminology of modern DNA barcoding were proposed as a standardized method for identifying species.

**Hebert** *et al.,* 2004) demonstrated the utility of the cytochrome *c* oxidase I (COI) gene, first utilized by **Folmer** et al., 1994) using their published DNA primers as a tool for phylogenetic analyses at the species levels.

## 15.2 SAMPLING AND PRESERVATION:

The tissue collected from a target specimen, from a mixture of organisms (**bulk sample**) is used for barcoding. Environmental samples are also used for barcoding.

The methods for sampling, preservation or analysis differ between different types of samples. To avoid contamination, it is necessary to sterilize tools used for sampling. It is recommended to collect two samples from one specimen, one to archive (record providing information), and one for the barcoding process. Sample preservation is crucial to overcome the DNA degradation.

Two types of samples are generally used viz., bulk samples and eDNA samples

**Bulk Samples:**

A bulk sample is a type of environmental sample containing several organisms from the taxonomic group. The difference between bulk samples and other environmental samples is that the bulk sample usually provides a large quantity of good-quality DNA.

**eDNA Samples:**

The **environmental DNA** (eDNA) method is a non-invasive approach to detect and identify species from cellular debris or extracellular DNA present in environmental samples (e.g. water or soil) through barcoding or metabarcoding.

The approach is based on the fact that every living organism leaves DNA in the environment, and this environmental DNA can be detected even for organisms that are at very low abundance. An eDNA sample always includes the DNA of whole-cell, living microorganisms, which are often present in large quantities.

## 15.3 PROCESS OF DNA BARCODING:

Markers (selected segments of DNA of a specific region) used for DNA barcoding are called **barcodes.** In order to successfully characterize species based on DNA barcodes, selection of informative DNA regions is important. Ideally, one gene sequence would be used for all taxonomic groups, from viruses to plants. Different barcodes are used for different groups of organisms.

In **plants**, however, mitochondrial genes are not appropriate for DNA barcoding because they exhibit low mutation rates. A few genes have been found in the chloroplast genome, the most promising being maturase K gene (*matK*) by Multi-locus markers such as ribosomal internal transcribed spacers (ITS DNA) along with *mat K*, *rbcL* etc. have also been used for species identification. The best discrimination between plant species has been achieved when using two or more chloroplast barcodes.

Various barcoding tools have been developed for the species identification of plants, fungi etc. DNA barcoding involves several steps. These include:

1) **Sample Collection:** A small sample of tissue is taken from the organism to identified.
2) **DNA Extraction:** DNA is extracted from the tissue sample by using different extraction methods are used.
3) **DNA Amplification:** It is an essential step in DNA barcoding. When DNA from organisms or eDNA samples is amplified using Polymerase Chain Reaction (**PCR**), the inhibitor molecules contained in the sample are affecting this reaction. Removal of these inhibitors is crucial to ensure that high quality DNA is available for subsequent analysis.
4) **DNA Sequencing:** The amplified DNA is sequenced. DNA sequencing is a method of reading the order of nucleotides in a DNA molecule. Typically, only a small fragment of the total DNA material is sequenced (typically 400-800 base pairs) to obtain the DNA barcode.
5) **DNA Sequence Analysis:** The DNA sequence is compared to a reference library, then the organism is identified. If the DNA sequence matches a barcode in the reference library, then the organism is identified.

**Reference Libraries and Bioinformatics:**

Reference Libraries are used for the taxonomic identification. These databases contain the DNA barcodes assigned to previously identified taxa. New entries are continually created.

However, such standards are fulfilled for only a small number of species. The process also requires the storage of voucher specimens in museum collections, herbaria and other collaborating institutions.

The **Barcode of Life Data System** (**BOLD**) is launched in 2007. It is one of the biggest databases, containing more than 4,50,000 BINs (Barcode Index Numbers) in 2019. It is a freely accessible repository for the specimen and sequence records for barcode studies, and it is also a workbench aiding the management, quality assurance and analysis of barcode data.

## 15.4 SPECIES IDENTIFICATION AND TAXONOMIC ASSIGNMENT:

The taxonomic assignment of the OTUs (operational taxonomic units) to species is achieved by matching of sequences to reference libraries. The Basic Local Alignment Search Tool (**BLAST**) is commonly used to identify regions of similarity between sequences by comparing sequence reads from the sample to sequences in reference databases. If the reference database contains sequences of the relevant species, then the sample sequences can be identified to species level. If a sequence cannot be matched to an existing reference library entry, DNA barcoding can be used to create a new entry.

**Significance of DNA Barcoding:**

1) It is an accurate method of identification of unknown species.
2) It can be used to build phylogenetic trees.
3) It helps to evaluate the authenticity of herbal products.

**APPLICATIONS:**

There are many applications of DNA barcoding. They include:

1) **Identification of Species/ Species discovery:** Specific short DNA sequences or markers can provide a DNA barcode for identifying species. It is primarily used for the discovery of all multicellular life on the earth.
2) **Ecological assessment for conservation:** It helps in understanding biodiversity and changes for in the species survival. It can be used to assess the presence of endangered species or threatened species for conservation efforts, or the presence of indicator species reflective to specific ecological conditions, for example excess nutrients or low oxygen levels.
3) **Detection of invasive species:** It can be used to identify invasive species that may not be native to an area, which can help prevent the spread of these pests and limit their impact on crops.
4) **Delimiting cryptic species:** This method enables the identification and recognition of cryptic species which are morphologically indistinguishable organisms that are incapable of interbreeding

5) **Barcoding for food safety:** DNA barcoding represents an essential tool to evaluate the quality of food products. The purpose is to guarantee food traceability, to minimize food piracy, and to valuate local and typical agro-food production.

6) **Time and Cost:** DNA barcoding is faster than traditional morphological methods all the way from training through to taxonomic assignment. It takes less time to gain expertise in DNA methods than becoming an expert in taxonomy.

## 15.5 PRACTICAL IMPLICATIONS:

There is considerable controversy regarding the taxonomic perspective of molecular data, including DNA barcoding (Meier, 2008). It should be noted that DNA barcoding can not detect all members of undescribed species, especially for recently divergent groups. The main problem is the possibility of erroneous results when DNA is degraded.

Traditional taxonomy mainly depends on morphological diagnosis, and it should be collaborated by other sources of data, such as geographical, ecological, reproductive and DNA sequence information. However, constructing a robust (strong) taxonomy for recently diverged plant taxa is more difficult, because they often show little difference in their morphological and genetic profiles. In addition, many other aspects could also cause the failure of DNA barcoding, such as imperfect taxonomy, interspecific hybridization, paralogy (Genes are homologous that result from a gene duplication) and incomplete lineage sorting.

DNA barcoding, although effective in species identification, may not be sufficient to determine the country of origin in case of illegal wild plant trade.

This method is not suitable for identifying hybrid species. This is because DNA barcoding is based on a single region, and hybrids or closely related species may have different sequences for this region. Overlap can be caused by several factors, including large genetic diversity in a species (De Salle et *al.,* 2005).

Another great challenge for barcoding plant species is linked to hybridization events. Natural or artificial hybrids in *Primula* have been reported recently, and these may cause a failure in barcoding *Primula* species

By surveying the non-monophyletic taxa at species level and examining genetic distance, we filtered out barcoding failures in several species probably caused by incomplete lineage sorting.

## 15.6 SELF ASSESSMENT QUESTIONS:

1) Describe the Process of DNA Barcoding.
2) Explain Species Identification and Taxonomic Assignment.
3) Give a brief account on Practical Implicatioins.

## 15.7 SUGGESTED READINGS:

1) Judd, W.S. Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J.2016. Plant Systematics: A Phylogetic Approach. Sinauer Associates, Inc., Massachusetts.

2) Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, Canada.

3) Sambamurthy, A.V.S.S. 2005. Taxonomy of Angiosperms. I.K. International Pvt. Ltd, New Delhi.

**Dr. C.V.S. Bhaskar**

# LESSON-16

# CHEMO SYSTEMATICS

**STRUCTURE:**



## 16.1 INTRODUCTION:

A wide range of chemical compounds are found in plants. In addition, various chemicals are produced in different metabolic pathways. The occurrence and the distribution of various types of chemical substances present in plants are useful in plant systematics. Chemical data are used at all levels of taxa.

**"***The approach of systematics in which chemical features of plants are used in developing classifications or in solving taxonomic problems is called chemosystematics"*.

The chemical compounds present in the plants are divided into 2 major groups (Jones and Luchsinger, 1987).

I. Micromolecules: Compounds with low molecular weight. (less than 1000).

II. Macromolecules: Compounds with high molecular weight. (1000 or more).

**I. Micromolecules:**

**a) Primary metabolites**: They are involved in vital metabolic pathways.

e.g. Citric acid, Aconitic acid.

**b) Secondary metabolites**: They are the byproducts of metabolism. They perform non-vital functions.

e.g. Non-proteinic amino acids.

**II. Macromolecules:**

**a) Non-Semantides:** They are not involved in information transfer.

e.g. Starch, cellulose.

**b) Semantides:** They are involved in information transfer (Information carriers).

i) Primary Semantides: DNA

ii) Secondary Semantides: RNA

iii) Tertiary Semantides: Proteins

The chemosystematics can be studied under different heads

A. Primary Metabolites

B. Secondary Metabolites

C. Non-Semantides

D. Semantides

E. Additional Chemical Compounds

## 16.2. PRIMARY METABOLITES:

These compounds are involved in vital metabolic pathways. Most of them are universal in plants.

**Thus, they have Little Taxonomic Significance.**

eg. In Glycolysis, Phosphoenol pyruvate (PEP), Phosphoglycerate (PGA) are the primary metabolites.

In Krebs cycle, Citrate, Oxalacetate (OAA), Ketogluterate are the primary metabolites.

However, the quantitative variations of these metabolites may be of taxonomic significance.

e.g. *Gilgiochloaindurata*(Poaceae). In this plant, Alanine is the main amino acid in leaf extract,

Proline is the main amino acid in the seed extract. Aspergine is the main amino acid in the flower extract. The family Rosaceae is rich in Arginine.

## 16.3 SECONDARY METABOLITES:

They are the byproducts of metabolism. They perform non- vital functions. They are not involved in metabolism. They are important in chemical defense against predators, pathogens etc. and help in pollination and dispersal.

**The Important Secondary Metabolites of Taxonomic Significance are:**

1) Non-proteinic amino acids
2) Phenolics
3) Alkaloids
4) Glucosinolates
5) Terpenes

**1) NON-PROTEINIC (NON- PROTEINOGENIC) AMINO ACIDS**

There are **22** proteinic amino acids which are encoded in the Genetic code and associated with proteins. They are called proteinic amino acids, But, a large number of amino acids (more than 300) which are not associated with proteins. They are called non-proteinic/ non-proteinogenic amino acids. They are not encoded in the Genetic Code. Their distribution is not universal and they have taxonomic significance.

e.g.: **Lathyrine** is present only in *Lathyrus.*

**Canavanine** is present only in Fabaceae (* It protects against insect larvae)

**Azetidine-2 carboxylic acid** is found only in Agavaceae, Liliaceae and Amaryllidaceae.

**Acetyl ornithine** is present only in Fumarioideae.

**2) PHENOLICS (PHENOLIC COMPOUNDS):**

These are based on a Phenol (C6H5OH). They are present in plants in considerable number, diversity and quantity.

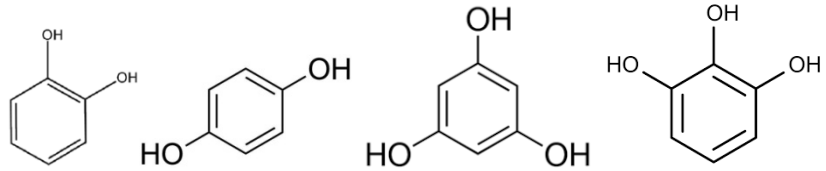
**a) Simple phenols:** They are made up of a single ring and differ in position and number of OH groups. They are widely distributed in the plant kingdom.

e.g.: Catechol - 2 OH groups side by side

Hydroquinone – 2 OH groups on alternate position

Phloroglucinol – 3 OH groups on alternate positions

Pyragallol – 3 OH groups




**Catechol** **Hydroquinone** **Phloroglucinol** **Pyrogallol**

**b) Coumarins:** They are a group of natural phenolics. They have a characteristic smell.

e.g**.** The crushed leaves of *Anthoxanthumodoratum* can be identified by this smell.

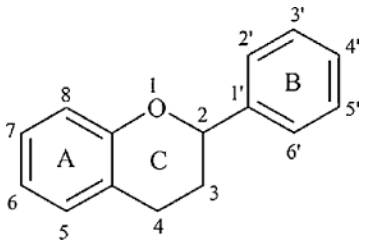
**c) Flavonoids:** They are based on a flavonoid nucleus consisting of two Benzene rings jointed by a C3 open/closed structure.

e.g.. Flavonols

Isoflavones

Malvadins

Anthocyanins




A Flavonoid nucleus structure

Flavonoids from vegetative parts and seeds provide more reliable taxonomic evidence.

**d) Anthocyanins and Anthocyanins:** They are important pigments in the cell sap of petals and other structures. Anthocyanins givingred colour/ blue colour/ other related colours and anthoxanthins giving light colours like yellow colour/ colourless in a large number of families.

**e) Betalains:** Betacyanins (red pigments) and Betaxanthins (yellow pigments) together known as Betalains. They differ from flavonoids and other phenolic compounds owing to the presence of Nitrogen in them. However, they are equivalent to phenolics functionally.

Betalains are present in the traditional group "Centrospermae" (now called Caryophyllales).

All the 10 families of the order Centrospermae (Aizoaceae, Amaranthaceae, Basellaceae, Caryophyllaceae, Chenopodiaceae, Didieraceae, Molluginaceae, Nyctaginaceae, Phytolaccaceae and Portulacaceae) produce Betalains so that they are placed together in a single order Caryophyllales in modern classifications). Betalains are also reported in Cactaceae andSapindaceae.

**3) ALKALOIDS :**

These are basic nitrogen containing organic compounds, usually with a heterocyclic ring. They are toxic substances but are used medicinally in small quantities.

In plants, these are synthesized from amino acids or their immediate derivatives. More than a **thousand alkaloids** are known from vascular plants. They are of three types.

1) Protoalkaloids: They are lacking a heterocyclic nitrogen ring e.g., Ephidrine, Hordinine
2) Indole alkaloids: Rauwolfine, Protopine
3) Pyradine alkaloids: e.g., Nicotine, Recinine
4) Isoquinoline alkaloids e.g., Papaverine

One of the best examples where alkaloids have proved to be useful in taxonomic studies is of Papaveraceae and Fumariaceae. The members of Papaveraceae contain several alkaloids like Protopine, Coptisine and Sanguinarin. Similarly, all members of Fumariaceae. So, they have close relationship.

**Other examples:**

**Morphine** is produced only in *Papaver somniferum*

**Strychnine** is produced only in Strychnos

**Protopine** is produced in Papaveraceae and Fumariaceae

**Nicotin** is produced in *Nicotiana tabacum*

**Lupinine** is produced in *Lupinus*

**Quinine** is produced in *Cinchona*

**Ephidrin** is produced in *Ephidra*

**Histrin** is produced only in 3 genera of Fabaceae such as *Genista, Adenocarpus*etc.

**Matrine** is produced in *Adenocarpus and Genista*

**Tropane** is produced in Solanaceae and Convolvulaceae

**4) GLUCOSINOLATES (MUSTARD OIL GLUCOSIDES):**

Glucosinolates is a group of about 85 thioglucosides. On hydrolysis, they form glucose and a corresponding isothiocyanate. They are also called Mustard oil glucosides.

The recent findings support the view that Glucosinolate producing families Brassicaceae Cruciferae) and Capparaceae should be placed under separate order Capparales.

**5) TERPENES:**

It is a largest group of compounds derived from the mevalonic acid precursor and they are mostly polymerized isopropane derivatives.

e.g. **Camphor** is from *Cinnamomum camphora* (Lauraceae)

**Menthol** is from *Mentha arvensis* (Laminaceae)

The important terpenes are: terpenoids and Iridoids.

**a) Terpenoids:** They are a common group of terpenes. They have been largely used in distinguishing specific and subspecific variations.

According to the number of isoprene units present in a terpenoid molecule, there are 5 categories.

1) Hemiterpenes (C5H24) -Tiglic acid
2) Monoterpenes (C10 H16) - Mycene
3) Sesquiterpenoids (C15H24)- Parnesol
4) Diterpenoids (C20H32) – Phytol
5) Triterpenoids (C30H48) – Squaline

They have used extensively in the chemotaxonomy of mints, Umbellifers, Citrus plants.

Some applications are:

*Origin of certain ***Citrus*** cultivars were determined by studying their rind terpenoid pattern.

*In **Asteraceae**, and **Fabaceae** (Tribe Genesteae), the petal carotenoids which form a prominent group of terpenoids prove to be useful.

*Some specific terpenoids are found in certain families.

e.g. **Cucurbitacins** in Cucurbitaceae

**Asperuloside**in Rubiaceae

**Sesquiterpene** lactones - Asteraceae

**b) Iridoids:** They are mostlymonoterpene lactones. They are present in over 50 families. Their presence is correlated with sympetalous corolla, unitegmic and tenuinucellate ovules, cellular endosperm, endosperm haustoria etc.

## 16.4 NON-SEMANTIDES:

They include complex polysaccharides such as starch, cellulose etc. Starches are insoluble carbohydrates deposited in the form of grains by the leucoplasts.

**The grains may be:**

**1. Concentric:** The organic centre Hilum is present at the centre. e.g. *Triticum, Zea.*

**2. Eccentric:** The Hilum is present at one side. e.g. *Solanum tuberosum.*

## 16.6 SEMANTIDES:

They are primary constituents of living organisms. e.g., nucleic acids like DNA and RNA, and proteins. They are popular sources of taxonomic information. Because of their complex structure, special techniques are essential for isolation, study and comparison. They include:

1) **DNA hybridization**: Boulton and Mc Carthy developed a relative and effective method to measure the homology of DNA and RNA of various groups.

   Two single strands of different organisms are allowed to hybridized *in vitro*. The degree of reassociation (annealing) expresses the degree of similarities in the sequence of nucleotides. By using this techniques , it was shown that *Triticum* is more closely related to *Secale.*

2) **DNA sequencing:** The rapidly expanding DNA sequences especially plastid generbcL (Large unit of ribulose biphosphate carboxylase/ oxygenase) provided new information.

3) **Serology** (Immunological Reactions): It is concerned with the interaction of antigen and antibody. Each kind of living organism has its own set of proteins. The proteins of related species are alike.

   e.g. *Illiceum* of Magnoliaceae family was now placed in a separate family: Illeciaceae.

   In addition, Biosynthetic pathways and additional chemical compounds are also useful in taxonomic studies.

**(i) Biosynthetic pathways**

**C3 / Cavin cycle** is found in 300 families

**C4 / Hatch & Slack cycle** is found in 943 species of 18 families.

**C3 & C4** is found in 18 genera *(Aerva, Alternanthera, Boerhavia, Euphorbia, Cyperus etc.)*

**CAM** in succulents.

**(ii) Additional Chemical Compounds:**

1) **Steroids**: They usually possess 2 methyl groups. They are mostly alcohols or esters. They are located in plant cutins. They perform the function of Water proofing. Their distribution is helpful in the taxonomy of the genera of Liliaceae.

2) **Lipids and Waxes**: Lipids are the esters of fatty acids with Glycerol while the waxes are esters of long chain alcohols with long chain fatty acids.

   e.g. **Erucic acid** in Brassicaceae.

   **Xymenyric acid** in Santalaceae

   **Malvalic acid** in Malvaceae

   **Capric acid** in Lauraceae

3) **Cyanogenic Compounds:**

   Some plants release poisonous compounds. These are found in Araceae, Poaceae, Juncaceae etc.,

   e.g. Hydrocyanic acid, Amygdalin.

## 16.7 SUMMARY:

Chemosystematics, within plant systematics, refers to the practice of classifying plants based on their chemical composition, primarily by analyzing the presence and structure of specific secondary metabolites like alkaloids, flavonoids, and terpenoids, which can help identify evolutionary relationships between different plant species and aid in taxonomic classification when morphological features are inconclusive; essentially, it uses chemistry to understand plant relationships. Unlike primary metabolites essential for basic plant functions, secondary metabolites are often unique to specific plant groups and are used for defense mechanisms, making them valuable for chemotaxonomic studies. Chemosystematics can help resolve taxonomic ambiguities, confirm species boundaries, and identify new taxa by comparing chemical profiles of different plant specimens. Advanced analytical methods like chromatography and mass spectrometry are crucial for identifying and quantifying plant chemicals, enabling detailed chemical profiling. The distribution of specific chemical compounds across different plant groups can provide insights into evolutionary relationships and ancestral lineages. Chemosystematic applications are Identifying plant families: The presence of specific alkaloids like quinine in Cinchona species can be used to confirm their placement within the Rubiaceae family.

## 16.8 SELF-ASSESSMENT QUESTIONS:

1) Write about Primary Metabolites.
2) Write about Secondary metabolites.
3) Write about Non-semantides.
4) Write about Semantides.

## 16.9 SUGGESTED READINGS:

1) Crawford, D.J.2003. Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.
2) Gurcharan Singh.1999. Plant Systematics-Theory and Practice. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
3) Radford, A.E. 1986. Fundamentals of Plant Systematics. Harper & Row Publisher, New York.
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5) Gamble, J.S. and Fisher, C.E.C. 1915-35. Flora of Presidency of Madras. 3 Volumes. BSMS, Dehradun.

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# LESSON-17

# SERO SYSTEMATICS

**STRUCTURE:**



## 17.1 INTRODUCTION:

*"The application or utility of serology in solving taxonomic problems is called Serosystematics or Serotaxonomy".*

Serology is defined as the branch of biology that deals with the study of antigen and antibody reactions/ interactions. Smith (1976) defined it as the study of the origins and properties of antisera. A substance (protein) capable of the formation of an antibody is called an antigen (agglutinogen / serum). The highly specific protein molecule produced by plasma cells in the immune system in response to the antigen is called an antibody (agglutinin / antiserum).They participate in agglutination process. Agglutination is a type of antigen and antibody reaction that results in visible clumps of organisms or other materials.

The classification of plants by means of differences in their proteins is valuable in Plant Systematics. It uses the specific properties of antisera produced by animals against plant proteins as characters to assess plant relationships. Serotaxonomy developed and became popular in Germany, which has been an active center since the beginning of this century.

**HISTORY:**

Nuttal (1901) was the first biologist to compare the serum for systematics. Dunbar (1910) showed that proteins from pollen, seeds and leaves of rice were serologically distinct. Gohlke (1914) founded a School of Serology in Germany and in the later years Germany became the centre of serological studies.

K.C. Mez (1926) and Moritz (1934) of Germany and Boyden of America developed the technique of serology. Based largely on serological studies, Mez and Ziegenspeck produced a family tree for the whole plant kingdom.

Notable contributions of application of serology to taxonomy are made by Rives (1923), Hawkes and Lester (1966), Smith (1968-1972), Kloz (1971), Fairbrothers (1967-1983), Crawford and Giannasi (1982) etc.

## 17.2 METHODOLOGY:

1) The protein extract of a plant is collected mainly from pollen and seeds. This extract is called antigen/serum.
2) This antigen (protein extract) is injected into the blood of an experimental animal (Rabbits).
3) In response to a specific protein (antigen/ serum), a specific protein (antiserum) is produced.
4) This antibody is then made to react *invitro* with the protein as well as with proteins of other plants in order determine their relations.

When the antiserum is allowed to react with the original extract, a total coagulation (agglutination/ precipitation reaction) takes place. Kraus (1897) showed that this reaction indicates similarity of antigens. The amount of coagulation shows the degree of similarity (homology). This degree of protein homology is determined and is taken as a phylogenetic marker and taxonomic character.

**Techniques:**

Several serological methods are available for serosystematic studies.

1) Double-Diffusion Serology
2) Immunoelectrophoresis
3) Absorption
4) Radioimmunoassay (RIA)
5) Enzyme Linked Immunosorbent Assay (ELISA)

**1) Double-Diffusion Serology:**

The protein (antigen) and antiserum are allowed to diffuse towards one another in a gel. Different proteins travel at different rates and thus reactions occur at different places. This method is useful in comparing precipitation reactions of several antigen mixtures from several taxa on the same gel simultaneously.

**2) Immunoelectrophoresis:**

It involves both electrophoresis and immunological reactions. It is used for the analysis of complex mixtures of antigens and antibodies.

The antigen proteins are subjected to electrophoresis and separated unidirectionally in a gel. Then, they are allowed to travel towards the antiserum. Only one antigen mixture can be handled on a single gel.

**3) Absorption :**It involves the diffusion into the interior of the material.Protein mixtures from different species often contain a large number of common proteins especially those involved in common metabolic processes.

The antibodies for these common proteins (antigens) are removed from the antiserum so that there is an accurate comparison of precipitation reactions.

**4) Radioimmunoassay (RIA):**

It combines the principles of radioactivity of isotopes and immunological reactions of antigen and antibody. In this technique, the antibodies/ antigens are labeled with radioactive molecules enabling their detection even when present in minute quantities.

**5) Enzyme Linked Immunosorbent Assay (ELISA):**

It is a non-isotopic immunoassay. An enzyme is used as a label in ELISA in place of radioactive isotope as in RIA. Either the antibodies /antigens are labeled / linked with enzymes.

## 17.3 APPLICATIONS IN PLANT SYSTEMATICS:

Serology is useful in taxonomy in different ways. Serological studies using clued plant protein extracts have been widely used in elucidating the taxonomy of a wide variety of higher level taxa and in estimating phylogenetic relationships.

1) It expresses similarities and dissimilarities among different taxa. It determines the degree of similarity between species, genera, families etc. Single proteins from different plant taxa are also compared by serological techniques.
2) This method is used for the construction of phylogenetic trees of families.

**EXAMPLES:**

1) A close relationship among the Magnoliidae, Hamamalididae etc. of the angiosperms has been found based on comparative serological studies of their major seed protein studies. This has rejected their independent evolution.
2) Pickering and Fairbrothers (1970), on the basis of serological studies, proposed the classification of Umbelliferae into Hydrocotyledeae, Saniculoideae and Apioideae.
3) Johnson and Fairbrothers (1965) suggested that the genera *Magnolia* and *Michelia* show the closest affinity whereas *Liriodendron* is distinct from other members on the basis of serological studies.

4) Jensen (1967) confirmed that the serological characters in Ranunculaceae show a similarity between *Aconitum- Delphinium, Actia - Cimicifuga, Anemone - Clematis* etc.

5) Simon (1971) showed that the serological analysis has been useful in eliminating the generic relationship between the Nymphaeceae and Nelumbonaceae.

6) Fairbrothers (1983) used the serological data in the classification of orders and assignment of families in Apiales, Caryophyllales, Capparales, Fagales, Rubiales, Magnoliales, Papaverales, Rubiales etc.

*7)* Hawkes and Tucker (1968) observed a strong relationship between *Solanum, Nicotiana, Hyocyamus, Datura* etc.

*8)* Crispels and Gartner (1978) gave evidence to confirm the assignment of *Phaseolus aureus* and *Phaseolus mungo* to the genus *Vigna*on the basis of serological studies.

*9)* Fairbrothers (1975) supported the separation of *Illicium* from Magnoliaceae to Illeciaceae and *Scizandra* to Schizandraceae.

10) Kloz (1971) applied the serological techniques in the classification of Leguminosae.

## 17.4 SUMMARY:

Biosystematics in plant systematics refers to the study of plant evolutionary relationships by integrating data from various disciplines like morphology, anatomy, cytology, genetics, and ecology, aiming to understand the diversification of plant species and their classifications based on their evolutionary history, not just physical characteristics alone; essentially, it's a holistic approach to plant taxonomy that incorporates evolutionary insights to accurately classify plants.

## 17.5 SELF-ASSESSMENT QUESTIONS:

1) Give a detailed account on Sero systematics
2) Applications of Sero systematics

## 17.6 SUGGESTED READINGS:

1) Crawford, D.J.2003. Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.
2) Gurcharan Singh.1999. Plant Systematics-Theory and Practice. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
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5) Gamble, J.S. and Fisher, C.E.C. 1915-35. Flora of Presidency of Madras. 3 Volumes. BSMS, Dehradun.

**Dr. K. Babu**

# LESSON-18

# MOLECULAR SYSTEMATICS

**OBJECTIVE:**

This chapter attempts to present the Phylogenetic Systematics, Assumptions of Cladistics and its application and Molecular Systematics.

**STRUCTURE:**



## 18.1 PHYLOGENETIC SYSTEMATICS:

*Phylogenetic Systematics is the field of biology that reconstructs the evolutionary history and studies the patterns of phylogenetic relationships among organisms.*

Willi Hennig (1950-57), a German Biologist, founded the subject of Phylogenetic Systematics. Its goal is to group species in ways that reflect a common ancestry. The methodology of phylogenetic systematics is called “Cladistics”.

“Cladistics is an approach of biological classification in which organisms are categorized on the basis of shared derived characters or an approach of classification based on phylogenetic relationships and evolutionary history of groups of organisms”.

Phylogeny is commonly represented in the form of a branched diagram called “Cladogram” (Phylogenetic tree). The lines are called lineages/clades. The term ‘clade’ was first introduced by Huxley (1958). These lines represent the sequence of ancestral- descendant populations through time (descendant= deriving from ancestor).

Branching of cladogram represents Lineage divergence/ diversification. Two separate lineages are formed from one common ancestor through speciation. The point of divergence of one clade into two clades is called a node. The region between two nodes is called an internode.

Evolution may occur within lineages over time. The evolution is recognized as change from ancestral condition to derived condition.

**Plesiomorphy**: Ancestral/primitive character state.

**Apomorphy**: Derived or advanced character state.

**Symplesiomorphy**: Shared common ancestral character states.

**Autoapomorphy**: Derived characters not share

## 18.2 ASSUMPTIONSOF CLADISTICS:

There are 3 assumptions in cladistics.

1) *Change in characteristics occurs in lineages over time.*

   Original/ ancestral character states are called Plesiomorphic while changed states are called Apomorphic.

2) *Any group of organisms is related by descent from a common ancestor.*

   All life on earth today is by descent from a common ancestor and the derived ones are related to the ancestor.

3) *There is bifurcating / branching pattern of lineage-splitting.*

   When a lineage splits, it divides into 2 groups due to lineage divergence.

## 18.3 METHODOLOGY:

The cladistics is the methodology that attempts to analyse phylogenetic data. Cladistic methods are largely based on the '***Principle of Parsimony'***. According to this principle, the evolutionary route is the shortest hypothetical way of changes that explains the pattern under observation.

**The methodology involves different steps.**

I) Selection of taxa (Selection of operational evolutionary units - OEUs)

II) Character analysis (Selection of characters, characterstates and coding)

III) Preparation of data matrix

IV) Measurement of Distance

V) Construction of cladograms (Phylogenies/ Phylogenetic tree)

**I. SELECTION OF TAXA:** It involves the selection of operational evolutionary units **(OEUs)**

The study of phylogeny begins with the selection OEUs. These may include living or fossil organisms. The OEUs may be genes, individuals, populations, species, genera etc.

Taxon selection includes both the group as a whole called “Ingroup” (study group) or one or more “Outgroup”. Ingroup is a group of total OEUs of a taxon while outgroupis a taxon that is closely related but not a member of ingroup. It represents the ancestral group.

Both OEUs and total group must be assessed for monophyly before the analysis is begun.

**II. CHARACTER ANALYSIS:** In involves the selection of characters, character states, character compatibility, polarity and coding of character states.

i) **Character and character state selection:** The description is fundamental in phylogeny. A list of characters of a taxon / taxa is prepared and plesiomorphic state and apomorphic state of each character are distinguished.

ii) **Character Compatibility**: It is a preliminary (first) step in character analysis. Character compatibility isa property assigned to splits of ataxon.

In this character compatibility study, each character is examined to determine the proper sequence of character states changes that takes place as the evolution progresses. Majority of characters are two character states (**Binary)**. Sometimes, they are multistate characters.

In binary characters, only one **morphocline** (transformation series) is possible.

**0 ⟷ 1**

In **multistate characters**, more than one morphoclines are possible.

**0 ↔ 1 ↔ 2**

**0 ↔ 2 ↔ 1**

iii) **Polarity:** Next step is polarity.Polarity is an evolutionary ordering of character states in which the relative ancestry of the character state is to be determined. The designation of polarity is often difficult and uncertain aspect of phylogenetic analysis.

For this, the comparison may be within the concerned group called “Ingroup comparison” or relatives outside the group called “Outgroup comparison”. The outgroup comaparison provides useful information.

iv) **Coding of characters:** In case, the character has 2 character states.

**0**-represents plesiomorphic character state.

**1**-represents apomorphic character state.

In case, the character has three character states.

e.g. Leaves simple

Leaves pinnately lobed

Leaves pinnately compound

**The coding may be**

**0**- Most primitive character state

**1**- Intermediate character state

**2**- Advanced state

## III. PREPARATION OF DATA MATRIX

Once the data relating to plesiomorphic and apomorphic character states has been collected for all OEUs, a data matrix *t* (OEUs) x*n* (characters) is prepared. In this, 0 represents the plesiomorphic character state and 1 the apomorphic character state.

| **Characters (n)** / **OEUs(t)** | **Habit** 0=Woody 1=Herbaceous | **Fruit** 0=Follicle 1=Achene | **Spur** 0=Spur present 1=Spur absent |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

## IV) MEASUREMENT OF DISTANCE:

The data matrix in which character states are coded for each OEU, can be used for calculating the distance between every pair of OEUs including the hypothetical ancestor.

The distance is calculated as the total number of character state differences between two concerned OEUs., often represented as Manhattan distance and the data presented as ***t*** x***t*** matrix.

The distance can be calculated as follows.

$$d(X1\ Y) = \sum_{i=1}^{n} | Xi - Yyi |$$

Where,

*d (X1 Y)* is the distance between taxa *X* and *Y*

*n is the total number of characters*

*V Xi*is the character state value of EU X for character *I* and

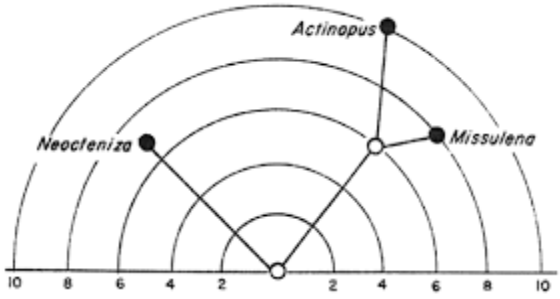
*Vyi is the character state value of EU Y* for character *i*

## V. CONSTRUCTION OF CLADOGRAMS (PHYLOGENIES)

Several methods are used for the construction of cladograms. The important methods are:

1) The rooted phylogenetic tree method.
2) Unrooted tree method/ Netted method.

### 1. The Rooted Phylogenetic Tree Method:




**Wagner Ground Plan Divergence Method**

In this, an hypothetical ancestral taxon is the basal member of tree.

e.g. ***Wagner ground plan divergence method* :**This method was developed by **Wagner**.

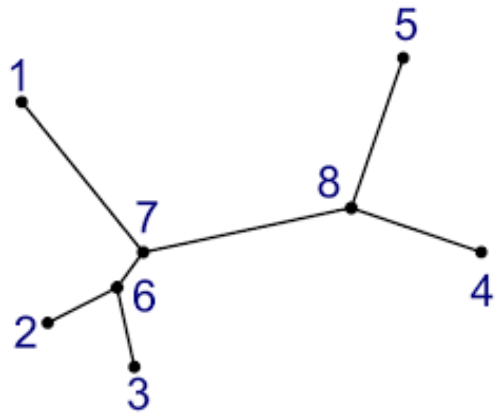
This method includes various steps.

a) The plesiomorphic and apomorphic character states are determined in a series of character transformation.
b) The plesiomorphic character state is coded as ‘0’ and apomorphic character is coded as ‘1’.
c) A table of taxa and coded character states (matrix) is constructed.
d) The divergence index for each taxon is calculated by totaling the values.
e) The taxa is plotted on a graph. Each taxon is placed on a concentric semicircle. The lines connecting the taxa are determined by shared synmorphies.

### 2. Unrooted tree method/ Netted Method:

a) It is a branching diagram that minimizes the total number of character state changes between taxa.
b) They are constructed by grouping taxa from a matrix in which polarity is not indicated.

c) The character state changes are noted on the unrooted tree. Evolutionary changes are simply denoted.




## 18.5 APPLICATIONS / ADVANTAGES:

Cladistics has many applications in various fields of biology.

1) **Taxonomy and Systematics**: Cladistics has revolutionized the field of taxonomy by providing a classification of organisms based on evolutionary relationships. Taxonomists now use cladistic analysis to develop phylogenetic systems.
2) **Molecular phylogenetics**: The integration of molecular data into cladistic analyses has allowed scientists to construct phylogenetic trees based on genetic sequences.
3) **Conservation biology**: Cladistics plays an important role in conservation by helping identify evolutionary distinct and threantenedlineagesthat the related organisms are grouped
4) **Biogeography**: Cladistics helps to understand how organisms have dispersed and diversified across different geographic regions over time.
5) **Evolution**: Cladistics helps to elucidate mechanisms of evolution and to understand the history of life on earth.

## 18.6 MOLECULAR SYSTEMATICS:

*"Molecular Systematics is the application of molecular data in inferring phylogenetic relationships of plants and in developing phylogenetic systems of classification".*

Evolution is based on genetic changes. These changes reflect true phylogeny better than morphological and other data. So, the molecular data at the level of gene is essential. The closely related species have greater similarity in their genetic makeup than the distantly related species.

**The molecular data is usually obtained from**:

a) DNA sequences (Gene sequences)

b) DNA Restriction sites by Restriction Fragment Length Polymorphism (RFLP) method.

c) Allozymes

d) Microsatellite DNA

e) Random Amplified Polymorphic DNA (RAPD)

f) Amplified Fragment Length Polymorphism (AFLP)

Molecular data are obtained from nucleus, chloroplast and mitochondria. Among them, Chloroplast genome is the smallest.

**1) Nuclear DNA** (*n* DNA) is obtained from the nucleus.

**2) Chloroplast DNA** (*cp* DNA) is obtained from the chloroplast genome.

a) *atp*B (Beta subunit of ATP)

b) *rbc*L (Large subunit of RUBISCO)

c) *mat*K (Maturase)

d) *ndh*F (Subunit of chloroplast NADH dehydrogenase)

**3) Mitochondrial DNA** (*m* DNA) is obtained from the mitochondria.

The *m* DNA is unstable because it undergoes lot of rearrangements as it is of little importance in systematics, whereas *n* DNA and *cp* DNA are highly stable and used as taxonomic tools.

**I. GENE SEQUENCES (DNA SEQUENCES):**

In majority of the molecular taxonomic studies, the most common approach is the comparison of sequences for genes to identify the similarity among organisms.

DNA sequence data is basically the sequence of nucleotides/nitrogen bases such as Adenine (A), Guinine (G), Cytosine (C) and Thymine (T) in a particular region of DNA. Comparison of homologous regions (having same relative positions) of DNA among taxa provides the characters and character states.

**a) ACQUISITION OF MOLECULAR DATA:**

A specimen is collected and mounted on herbarium. It serves as documentation for molecular study. For DNA methods, pieces of leaves are removed from the living plants and dried immediately in a container of silica gel.

Polymerase Chain Reaction (PCR): It was developed by Kary Mullis (1983). It is a laboratory technique for replicating thousands of DNA copies. The DNA from plant sample is first isolated and purified by various chemical procedures. After this, the DNA sequences of interest are amplified (enlarged) by using PCR.

The essential requirements for PCR are

a) The target DNA

b) 2 Primer (A short length of DNA Oligonuleotide of 17-30 nucleotides length)

c) 4 Deoxyribonucleotides (free nucleotides)

- d ATP for adenine
- d CTP for cytosine
- d GTP forGuinine
- d TTP for Thymine

d) DNA Polymerase that can withstand at a temperature up to 95°C.

The technique of PCR involves repeated cycles for amplification. Each cycle has 3 stages

1) *Denaturation:* The solution is heated at 95°C until the DNA sample is denatured.

2) *Renaturation (Annealing):* After separation of two strands, the DNA is cooled. The complementary regions of the primer base pair are flanking (binding) target DNA strands.

3) *Synthesis:* The initiation of DNA synthesis occurs at 3´(Three prime end) end of each primer. The primers are extended by joining the bases complementary to DNA strands by the enzyme DNA Polymerase.

The PCR produces more than million copies of DNA within 2 hours. After DNA replication, it is sequenced by using a machine. This reads fluorescent dyes with a laser detector.

**b) ANALYSIS OF DNA SEQUENCE DATA:**

The sequences of a given length of DNA are aligned (to bring into line) in which homologous nucleotide positions are arranged in corresponding columns.

For some genes, all taxa have the same number of nucleotides per gene.

**Taxon 1**-GCCTAGCA

**Taxon 2**-GCCTAGCA

**Taxon 3**-GCCTAGCA

For other genes, the other taxa may have one or more additions, deletions, inversions or translocations.

Generally, a character is equal to the nucleotide position and a character state is the specific nucleotide at that position. Four character statesare possible corresponding to the nucleotides.

A major addition, deletion, inversion or translocation can be identified as an apomorphy. It is used in grouping of lineages.

## 18.7 RESTRICTION SITE ANALYSIS:

Restriction Fragment Length Polymorphism (RFLP), commonly pronounced as "rif-lip", is a technique used for the study of variations in homologous DNA sequences. In this analysis, the DNA sample is broken into pieces.

**RESTRICTION SITES** (**RESTRICTION RECOGNITION SITES**):

Restriction is a process in which a restriction fragment is resulted from the cutting of a DNA strand by a restriction enzyme. Restriction sites are locations on a DNA molecule containing specific sequences (4-8 base pairs/nucleotide length) which are recognized by restriction enzymes. Each enzyme is highly specific in recognizing a particular restriction site (short DNA sequence) and cutting both strands at specific points. Most restriction sites are Palindromic (The sequence of nucleotides is same on both strands when read in the 5´ to 3´ direction).The restriction enzymes cleave/ split nucleotides by hydrolyzing the phosphodiester bonds between them.

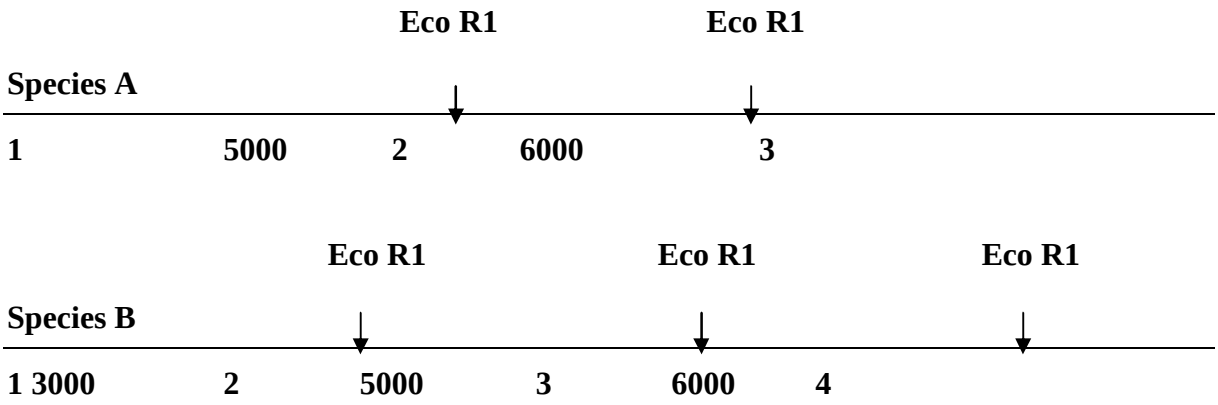
The restriction enzymes are endonucleases which are the bacterial enzymes. These endonucleases can split or cut DNA at specific recognition sites (restriction sites). The pieces are called Restriction fragments or Polymorphs.

**The endonucleases include:**

1) **Ecor R1** (from *E.coli*) recognizes the palindromic sequence of GAATTC and cuts between the G and A on both strnds (top and bottom) .
2) **Bam H1**( from*Bacillus amyloliquefaciens* )
3) **Hae III** (from *Haemophilusaegyptius*)
4) **Hind III** (from *Haemophilus influenzae*)
5) **Not 1**( from *Nocardia otitidis*)

Two methods are in use for the detection of RFLPs.

1) **Southern hybridization**: The DNA is digested with enzyme and separated by electrophoresis.
2) **Polymerase chain Reaction**( PCR):




**A** & **B** are hypothetical species.

The amplified DNA lengths of 10,000 bp are subjected to Eco R1 enzymes.

After enzymatic reaction, **A** is cleaved (splitted) into **3** fragments corresponding to **2** restriction sites and **B** is cleaved (splitted) into **4** fragments corresponding to **3** restriction sites.

The relative locations of the restriction sites on the DNA can be mapped. The data can be coded as characters and character states.

## 18.8 ALLOZYMES:

Different molecular forms of an enzyme that are coded by different alleles at the same locus are called "**Allozymes**".

For enzyme analysis, fresh material should be used, as enzymes degrade very rapidly. Allozymes are detected by using **Electrophoresis**. The enzymes are extracted and placed on a Starch medium. An electric current runs through this starch medium. The sample migrate toward one pole or the other pole depending on its charge. So, different allozymes migrate differently because they differ slightly in their amino acid composition. These are identified with specific stains. The bands are marked by their relative positions.

There are several ways for coding the polymorphic allozyme data. Each allele is coded as a character and the presence or absence of that allele as the character states.

Allozymes are used to study the genetic variation within a population of a species. They are also used as data in phylogetic analysis of closely related species.

### I. MICROSATELLITE DNA (SIMPLE TANDOM REPEATS):

Microsatellites are the regions of DNA that contain short repeats of nucleotides.

e.g. **TGTGTG** -Two base pairs are repeated.

These regions, called tandem repeats, are located all across the genome. The species / individuals within or between populations may vary in the number of tandem repeats at a given locus. This variable number can be used as a genetic marker.

**II. RANDOM AMPLIFIED POLYMORPHIC DNA (RAPDs)**

It is pronounced as 'rapid'. It is a PCR based molecular marker. PCR is used for amplifications.

It is a type of reaction, but the segments of DNA that are amplified are random. It is used to identify polymorphic DNA regions of different individuals.

It is used in genetic studies.

**III. AMPLIFIED FRAGMENT LENGTH POLYMORPHISM (AFLP):**

This method is similar to RFLPs and restriction enzyme is used to cut DNA into pieces. Each piece terminates in a characteristic nucleotide sequence. These DNA pieces are then modified by binding to each end (using DNA Ligase) into a synthesized, double stranded piece of DNA called Primary Adapter. Primers are then bind to the primer adapters and amplify the DNA fragments using PCR. Electrophoresis separates the amplified DNA fragments that exhibit length polymorphism, enabling the recognition of numerous genetic markers.

It is used to identify genetic differences among individuals.

**Applications:**

Molecular systematics provides powerful taxonomic tools.

The molecular data is used

1) To establish the relationships of different plant groups at DNA level.
2) To study the evolutionary history of plant groups.
3) To construct the phylogenetic trees by using relationships and evolutionary history in cladistics.
4) In genome mapping, phytodiversity and biodiversity conservation.

**Examples:**

1) Jansen and Palmer (1987) reported a large single copy region of cp DNA in Asteraceae. But it is absent in others.
2) Bayer et al. (1999), based on DNA sequence analysis of the chloroplast atp B (Beta subunit of atp) and rbcL (Large subunit of RUBISCO) DNA proposed to merge Tiliaceae, Sterculiacee and Bombacaceae in Malvaceae.
3) Recently, Hussain et.al. (2008) studied molecular basis of Dicot- Monocot split and relationships among major angiosperm groups.

## 18.9 SUMMARY:

Molecular systematics in plant systematics refers to the use of molecular techniques like DNA sequencing to analyze genetic variations within plants, allowing for a more accurate and detailed understanding of evolutionary relationships between different plant species, providing a deeper insight into plant classification beyond just physical characteristics; essentially, it uses genetic data torefine plant taxonomy and phylogeny. Key points about molecular systematics in plant systematics are improved accuracy: Targeted DNA regions: Phylogenetic analysis and its applications:

## 18.10 SELF-ASSESSMENT QUESTIONS:

1) Give a detailed account on Phylogenetic Systematics
2) Describe the Molecular Systematics
3) Give a brief account on Restriction site analysis
4) Give a brief account on Allozymes

## 18.11 SUGGESTED READINGS:

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4) Davis, P.H. and Heywood, V. M.1973. Principles of Angiosperm Taxonomy. Robert. Kereiger Publishers, New York.
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