

A TEXTBOOK ON PLANT TAXONOMY

(VOL-1)

DR. SUJOY KUMAR SEN



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My acknowledgment would be incomplete without mentioning the name of my dearest older brother Late Ajoy Sen, former Assistant Professor in Mathematics at P.D. Womens' College, Jalpaiguri, West Bengal and my teacher Late Dr. Palash Mandal, former Associate Professor in Botany at University of North Bengal. They always provided me with incredible support and will always remain incised somewhere deep within me for my entire life.

Last but not the least I want to express my gratitude to all of my well-wishers, students, and co-workers, for their support, encouragement, and invaluable feedback.

As it is not possible here to mention everyone who has directly or indirectly supported me, I thank all of them who have been, somehow, a part of this work.

Dr. Sujoy Kumar Sen

March 2026

PREFACE

Plant Taxonomy is the art of comprehending the underlying order, beauty, and evolutionary links in the green world around us; it is not just a science of naming. It is more important than ever to accurately identify and classify every species, from the tiniest bryophyte to the tallest angiosperm, in a time when biodiversity is facing hitherto unheard-of difficulties. By going beyond dry morphology to include molecular insights and ecological context, this book seeks to provide students, researchers, and botanical enthusiasts a contemporary, approachable introduction to the fundamentals of plant systematics.

The book is written in an approachable style for students, taking into account the most recent (NEP) curriculum offered by various colleges and universities. Additional material is also offered for the benefit of scholars and prospective students, taking competitive exams into account. I hope that anyone getting ready for the Plant Taxonomy (Botany) examination will find this book to be a useful resource. The writer conveys his heartfelt gratitude to the publisher.

Any positive suggestions to improve the book are greatly welcomed.

Dr. Sujoy Kumar Sen

March 2026

Dedicated to
Late Dr. Palash Mandal
(My Teacher)
&
Late Sri Ajoy Sen
(Elder Brother)

***“There are special people in our lives who never leave us,
even after they are gone” — D. Morgan***



GOLDEN RULES TO GET HIGH MARKS IN EXAMINATIONS

The key to achieving high scores on examinations is to study intelligently, not simply hard, by combining efficient planning, active learning, and practicing healthy lifestyle. The "golden rules" for success are as follows:

1. Understand the Topic rather than Mugging Up: Focus on Conceptual Understanding, Don't just memorize, Connect different topics
2. Master the art of consistency
3. Revise Regularly & consistently
4. Follow a healthy routine
5. Breakdown the syllabus
6. Build a winning study strategy
7. Build a comfortable study area
8. Understand the syllabus and exam pattern
9. Don't be overconfident: Understand the exam pattern
10. Make study notes in your own words: Use mnemonics, Summarize key points for memorizing & quick revision before the exam
11. Identify your weak points & overcome them to boost confidence
12. Maintain a Healthy Lifestyle: Get adequate sleep, eat a balanced diet, drink plenty of water & sustain your body clock.
13. Take care of your health (physical and mental) & Manage stress
14. Seek Help from teachers, classmates, or online resources whenever needed: Teach others & form study groups
15. Use Active learning techniques: Solve previous years' papers
16. Practice Sample Papers and Mock Tests
17. Create a realistic study plan/schedule
18. Identify & Focus on scoring areas

"Arise, awake, and stop not till the goal is reached" – Swami Vivekananda

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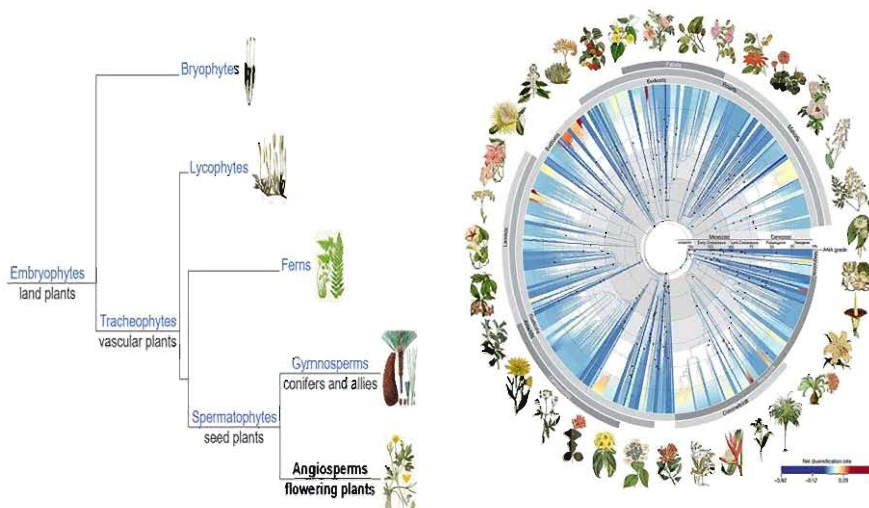
CHAPTER 1

Introduction

Chapter Contents:

- When was Taxonomy founded?
- Brief History of plant Taxonomy
- Initial Developments (Antiquity - 17th Century)
- The Linnaean Revolution of the 18th Century
- Post-Linnaean Advancements (18th - 19th Century)
- Evolutionary and Contemporary Period (Late 19th Century - Present)
- Plant Taxonomy and Systematics
- Relationship between Plant Taxonomy and Systematics
- *Alpha, Beta, Gamma, and Omega Taxonomy*
- Objectives of modern Taxonomy
- Steps in Taxonomy
- Relationship between Plant Taxonomy and Botanical Nomenclature
- Why Taxonomy is important?

Angiosperms (Synonyms: Anthophyta Cronquist, Angiospermae Lindl., Magnoliophyta Cronquist, Takht. & W.Zimm, Magnoliceae Takht.) are the largest and most diverse group of plants on Earth right now. From the tiniest *Wolffia arrhiza*, a rootless floating freshwater plant that is less than 2 mm (0.08 in) across, to the tallest *Eucalyptus regnans*, which may reach heights of about 100 meters, angiosperms exhibit enormous diversity. There are over 13,000 identified genera, 300,000 known species, 64 orders, and 416 families in the Angiosperms (Christenhusz and Byng, 2016). The Greek terms "angeion" (meaning "container, vessel") and "sperma" (meaning "seed") are the origin of the term "angiosperm," which refers to a fruit that contains seeds. Flowering plants, which belong to the group Angiospermae, are plants that produce both flowers and fruits. They are more common than any other group of plants in a wide range of environments, from the snow-covered Himalayas to the salty or sandy deserts of Asia and Africa, or in freshwater or marine environments. This is because they have evolved to be very flexible and able to adapt to different conditions.



Angiosperms were reconstructed into their evolutionary context using a molecular phylogeny of plants
(Leebens-Mack et al., 2019).

Tree of Angiosperm phylogeny
(Zuntini et al., 2014).

As there are so many different kinds of plants and there are so many of them, it is hard to learn enough about them without putting them in order according to some standard rules. Plant Taxonomy is the part of Botany that studies how to name, identify, describe, and group plants.

When was Taxonomy founded?

The origins of modern scientific Taxonomy date back to the 1730s and 1750s, when Carl Linnaeus introduced consistent binomial nomenclature (Genus species) and hierarchical ranks (Kingdom, Class, Order, Genus, Species) in his work *Systema Naturae*. The 10th edition of *Systema Naturae*, published in 1758, marked the beginning of valid zoological names. A.P. de Candolle later came up with the term "Taxonomy" itself in 1813.

Brief History of Plant Taxonomy

Plant Taxonomy is one of the earliest fields of botany. It began as "Folk Taxonomy" in the early 15th century, but over the past 500 years, it has expanded and come a very long way. Taxonomy's purpose and scope have significantly changed. Plant Taxonomy has evolved from initial practical classifications (edible, medicinal) by ancient scholars such as Theophrastus (trees, shrubs, herbs) to formalized systems, significantly transformed by Carolus Linnaeus in the 18th century through binomial nomenclature and the sexual system. It subsequently transitioned from artificial to more natural classifications rooted in overall similarity, ultimately using evolutionary (phylogenetic) principles that integrate genetics and DNA analysis for

authentic relationship-based systems. *Pedanius Dioscorides*, *Bauhin*, *Tournefort*, *de Candolle*, *Bentham & Hooker*, *Hennig*, and contemporary geneticists and their progression from basic morphology to intricate molecular phylogenies are important figures.



Pedanius Dioscorides



Gaspard Bauhin



Joseph Pitton de Tournefort

Initial Developments (Antiquity - 17th Century):

Historical Origins: Initial classifications concentrated on utility (culinary, medicinal) or fundamental structure (herbaceous plants, arboreal species).

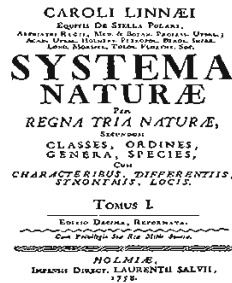
Theophrastus (c. 371 – c. 287 BC), known as the "**Father of Botany**," classified plants into trees, shrubs, undershrubs, and herbs, and distinguished between monocots and dicots.

Pedanius Dioscorides (c. 40 AD to 90 AD) cataloged 600 therapeutic plants in his work, *De Materia Medica*. During the Medieval and Renaissance periods, herbalists maintained knowledge; nonetheless, methods remained rudimentary until the advent of the printing press and the establishment of botanic gardens catalyzed advancement.

Gaspard Bauhin or Caspar Bauhin and Tournefort (17th Century): Swiss botanist Gaspard Bauhin's 1623 work, *Pinax theatri botanici*, defined and categorized thousands of plants in a way that is comparable to Linnaeus's later binomial nomenclature. He also focused on human anatomical nomenclature and was a student of renowned Italian physician Girolamo Mercuriale. *Gaspard Bauhin* created the notion of genus, whereas *Joseph Pitton de Tournefort* delineated genera based on floral and inflorescence characteristics. The first person to clearly define the term "genus" for plants was the French botanist Joseph Pitton de Tournefort, who lived from June 5, 1656, to December 28, 1708. Charles Plumier, a botanist, studied under him and travelled with him.

The Linnaean Revolution of the 18th Century:

Carolus Linnaeus (1707–1778): Pioneer of contemporary Taxonomy; established binomial nomenclature (genus + species) in *Species Plantarum* (1753) and employed a straightforward, artificial classification scheme based on floral structures (stamens/pistils).



Carl Linnaeus & his *Systema Naturae*

Post-Linnaean Advancements (18th - 19th Century):

Transitioning from Artificial to Natural: Botanists pursued "natural" systems that represent overarching similarities rather than focusing solely on a singular attribute. *De Candolle* established regulations for botanical nomenclature, resulting in the inaugural *International Code of Botanical Nomenclature* (ICBN).

Bentham and Hooker developed an extensive natural classification system for angiosperms.

Evolutionary and Contemporary Period (Late 19th Century - Present):

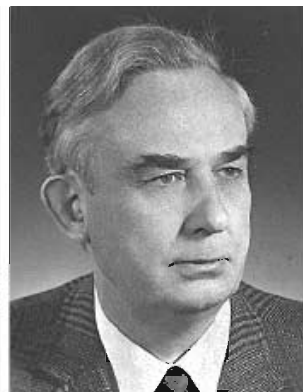
Darwin (12 February 1809 – 19 April 1882) and *Wallace* (8 January 1823 – 7 November 1913) proposed that evolutionary theory necessitates classification to mirror evolutionary relationships (phylogeny).



Charles Darwin



Alfred Russel Wallace



Willi Hennig

Phylogeny: Classification transitioned to illustrating the "tree of life," categorizing species according to shared ancestry.

Cladistics (Hennig): Introduced objective methodologies (clades, shared derived traits) for constructing phylogenetic trees.

The Molecular Revolution: DNA sequencing and barcoding serve as potent instruments for classification based on genetic code, enhancing the comprehension of evolution.

Plant Taxonomy and Systematics



Augustin Pyramus de Candolle

The word "Taxonomy" was first used in 1813 by Swiss botanist A. P. de Candolle. It is an irregular composite of the Greek words "taxis" (meaning "order") and "nomos" (meaning "law"), joined by the French suffix -o-. The term "Taxonomy" is primarily used in biology to describe the classification and arrangement of living things in accordance with their similarities. *Taxonomy is the theory and practice of classifying living things* (Mayr, 1982). An incomplete inventory of the world's flora, particularly in the tropics, is aided by plant

Taxonomy. It is essential to have a thorough understanding of plant Taxonomy in order to create a comprehensive classification scheme for plants. The study of the evolutionary implications of plant diversity makes use of the field of plant Taxonomy.

"**Systematics**" was a term first used by Linnaeus. Plant classification and hierarchical order are the foundation of systematics. When examining or describing differences between organisms to create a classification scheme, the term systematics is used as the general term. By grouping organisms in this way, a large population can be categorized and comprehended. The systematic study of plants and their evolutionary development is a field of science. Systematic biology is the study of Taxonomy and systematics.

Relationship between Plant Taxonomy and Systematics

Interconnected yet separate disciplines: Plant Taxonomy and systematics are interconnected yet separate disciplines in botany. Taxonomy largely concerns the identification, description, nomenclature, and classification of plants according to their attributes. Systematics is a larger field that includes Taxonomy and also examines the evolutionary links and variety of plants. Taxonomy establishes the framework for the organization and classification of plants, whereas systematics investigates their evolutionary history and interrelationships.

Systematics is founded on Taxonomy:

Systematics employs the data from Taxonomy to explore evolutionary links and the diversification of plant life.

Evolving: The amalgamation of DNA data and other innovations has obscured the distinctions between Taxonomy and systematics, resulting in more cohesive methodologies for analyzing plant diversity.

<i>Plant Taxonomy</i>	<i>Plant Systematics</i>
Focus: Identification, description, naming, and classification of plants based on their observable characteristics.	Studying the evolutionary relationships and diversity of plants, including their origins, divergence, and adaptation.
Goal: To create a hierarchical system of plant classification, from species to higher taxonomic groups like genus, family, and order.	To reconstruct the evolutionary history of plants and understand how their different traits and adaptations have arisen.
Methods: Morphology, anatomy, embryology, and increasingly, molecular data to determine similarities and differences between plants.	Combines taxonomic information with data from various fields, including genetics, paleontology, and ecology, to infer evolutionary relationships.
Example: Identifying an unknown plant by comparing its features to those of known species, assigning it a scientific name, and placing it within a specific classification group like the order Liliales, family Liliaceae, and genus Liliales.	Using molecular data to determine the phylogenetic relationships between different plant groups, such as understanding how the Liliaceae family evolved from a common ancestor.

The *Systematics* or *Taxonomy* of plants has been studied using four *main methodologies*. These could be summed up as follows:

- 1) ***Pioneer or Alpha:*** These were the early times when there were explorations and plant discoveries. William Bertram first uses the term Alpha Taxonomy in a collection of papers that were published between 1935 and 1937.
- 2) ***Consolidation:*** In this phase, the large amount of data collected was organized to understand classification. The phase is identified by the appearance of several landmarks works on plant classification:
 - I. The *Linnaeus system* was modified by De Candolle (1778–1841).
 - ii. *Genera Plantarum*, published by Bentham and Hooker in 1864, contains a natural system of classification that is still very useful in daily life.

- iii. In "*On the Origin of Species*", published by Charles Darwin in 1859, the idea of natural selection and the evolution of species was put forth.
 - iv. "*Biological Species Concept*" was published by Dobzhansky in 1937. A species is defined as "a group of interbreeding populations reproductively isolated from any other such populations" by the biological concept.
- 3) **Synthesis:** During this phase, the consolidated data and adequate plant material collected were classified principally based on morphological characters. It attained its peak by the late 1800s and to some extent still continues. The development of biosystematics over the past fifty years has led to a qualitative improvement in the field of taxonomic concepts and applications. The objective of "*holo-taxonomy*" is to be attained by the "New Systematics". Huxley (1940) for the first time coined the phrase "New systematics". Then, the term "Biosystematics" was introduced to the new systematics by Camp and Gilly in 1943. Cytotaxonomists regarded chromosome size, number, and shape as very reliable taxa.
- 4) **Experimental:** Using different scientific tools and modern technology, the vast amount of collected data interpreted in evolutionary or phylogenetic terms is being currently analyzed. This phase is still evolving.
- a) "*Chemotaxonomy*" was developed as a result of the development of techniques like two-dimensional paper chromatography and the identification of chemical substances in plants as secondary metabolites.
 - b) The new methods can provide information such as the amino acid sequence and the nucleotide sequence of DNA and RNA.
- 5) **Encyclopedic or Holotaxonomic Phase:** To comprehend phylogeny, data are gathered, analyzed, and a meaningful inference is made:
- (i) Numerical Taxonomy, a separate field of *Taxonomy*, is responsible for data collection, analysis, and synthesis.
 - (ii) Quantitative Taxonomy, also known as numerical Taxonomy, is based on a numerical evaluation of how closely related different groups of organisms are to one another and the classification of these groups into higher-ranking taxa in accordance with these comparisons.

Alpha, Beta, Gamma, and Omega Taxonomy

The British botanist *William Bertram Turrill*, who was made a Fellow of the Royal Society for his contributions, is credited with the introduction of the terminologies in Taxonomy like *alpha, beta, and gamma*. For the purpose of identifying, categorizing, and researching various plant species, there are following levels of the Taxonomy:

- (i) **Alpha (α) Taxonomy:** The analytical process of discovering, identifying, describing, and naming species is known as the alpha (α) Taxonomy. The term "*Orthodox Taxonomy*" is

another name for classical Taxonomy. Typically, classical Taxonomy deals with operational processes like species identification, nomenclature, and classification. Traditional Taxonomy bases its classification on morphological traits, anatomical information, the geographic distribution of species, and data gathered from the herbarium. At this level, newly discovered species are given names based on the Linnaean Taxonomy of the binomial nomenclature. Priority is given to the author whose work is published first. Here, a variety of issues are addressed. It all began with Tournefort, de Jussieu, and Linnaeus' work.

- (ii) **Beta (β) Taxonomy:** It is the hierarchical categorization of species in accordance with the natural system of classification. It emerged during the 20th century. This is based on an analysis of numerous features that are plainly visible and common structural features. The pursuit of a natural classification system is, therefore, the focus of the beta Taxonomy.
- (iii) **Gamma (γ) Taxonomy:** The analysis of intra-specific variability and the study of evolution are two topics covered by the **Gamma (γ) Taxonomy**. The study of speciation and the causal interpretation of organic diversity have received a lot of attention. But in reality, they blend together and overlap, making it very challenging to distinguish between the two. Few animal groups have classifications that go as far as gamma levels. Otherwise, most groups are still working at alpha and beta levels. Consequently, each taxon serves a unique diagnostic purpose.
- (iv) **Omega (uppercase Ω , lowercase: ω) Taxonomy:** It is the most ideal classification scheme based on all characters. The idea of Alpha-Omega Taxonomy is the best. While alpha Taxonomy serves as the foundation for biology, Omega Taxonomy ultimately incorporates all of the data.

Points to remember:

Alpha Taxonomy is about identifying and naming. *Beta Taxonomy* is about organizing and classifying. **Gamma Taxonomy** is about understanding evolution and speciation. *Omega Taxonomy* is about integrating diverse data for a holistic understanding.

The *three main goals of Taxonomy* are identification, nomenclature, and classification.

However, the following are some further significant objectives that relate to plant Taxonomy:

- i) to produce a practical method for identification and communication;
- ii) to create a comprehensive and universal system of classification; and
- iii) to give each plant and group of plants in the world, both living and fossil, a single Latin "scientific" name.
- iv) to keep track of the global flora, and
- v) to illustrate how plant diversity affects evolution;

There are two primary strategies:

- (a) *Empirical Approach:*** It is based on real-world experiences, character observation, etc.
- (b) *Interpretive Approach:*** The classification is based on how a taxon, such as a phylogenetic system, is interpreted and how it has evolved over time.

The **objectives** of modern Taxonomy, which combines both methods, are as follows:

- (i) To offer a simple means of communication and identification.
- (ii) To the extent possible, to offer classification that is based on the natural affinities of organisms.
- (iii) To use flora to provide a list of plant taxa.
- (iv) To observe evolution in action and learn how it interprets its results.
- (v) To play an integrating and unifying role in educating biology students about how various biological disciplines relate to data collection science.

Steps in Taxonomy: There are four important *steps in Taxonomy*, viz., CHARACTERISATION, IDENTIFICATION, CLASSIFICATION and NOMENCLATURE. These are the primary activities of a taxonomist.

Characterization is the basic requirement for understanding the different parts of the organism. It is thus a description of the characters. By comparing the characters of two or more organisms, it becomes possible to differentiate them. This leads to identification.

Identification is required once two or more organisms have been distinguished (recognized) by their characteristics. When taxonomists categorize organisms, they basically do this. This is essentially what taxonomists do when they classify organisms. Once the identified organisms have been classified, it becomes necessary to name them. Thus, the process of Taxonomy is a logical sequence of knowing (1) the characters of the organisms; (2) identifying them on the basis of an understanding of their characters; (3) classifying them into groups; and (4) providing them names.

Classification is the arrangement of organisms into groups having common characteristics. These groups are then arranged according to a system. For example, similar species of flowering plants are placed into a genus (plural, genera); similar genera are grouped into families; families with common features are arranged into orders, orders into classes and classes into divisions. Classification results in the placing of organisms into a hierarchy of ranks or categories such as species, genera, and families and so on.

In practical terms classification deals more with the placing of a plant group with a selected scheme than the placing of an individual plant in one of several minor categories. Thus, a system of classification is necessary to allow us to identify plants and to communicate

scientifically with others. Indeed, classification is both, an information storage and retrieval system without which scientific communication would be impossible. Classification thus enables us to summarise our knowledge about the organisms, and that is one of the most important functions of Taxonomy. The saving of time and effort is thus one way in which we can define the utility and purpose of classification.

Nomenclature is a very important constituent of plant Taxonomy. It can be defined as the system of naming an object particularly that of biological origin. We are aware that man has been interested in plants since prehistoric times. The plants have been given names by tribes in their own languages. These are called common or vernacular names. Unfortunately, there is no uniformity in such names. Often the same plant is known by different common names in different places or even different plants belonging to different places are referred by similar names. Thus, the common names are many, different, indefinite and restricted to the people of one language or even one region of a country.

For instance, a plant's name is the key that unlocks the door to its total biology. Ecologists, horticulturists, biochemists, agriculturists and others must have a reference system for the plants, they use in their research. However, the name of plant is not meant only for the scientist, it may be used by other people with varied interests and training, those who are interested in the natural history of plants. The scientific name of a plant communicates the species and genus, and from that the family may be easily determined.

Relationship Between Plant Taxonomy and Botanical Nomenclature

Plant Taxonomy and botanical nomenclature are interrelated yet different disciplines. Taxonomy pertains to the classification and categorization of plants, whereas nomenclature concentrates on the scientific designation of such categories. Nomenclature assigns names to taxa established by Taxonomy, ensuring a uniform and globally recognized system for referencing plants. Taxonomy and nomenclature are interlinked. Taxonomy delineates the categories (taxa), whereas nomenclature assigns the names to those groups. A taxonomist may identify a novel plant species and delineate its attributes. A botanist would apply the principles of botanical nomenclature to assign a scientific name to the new species. In a nutshell, Taxonomy establishes a plant's identity, whereas nomenclature establishes its name. Remember that Taxonomy comes before nomenclature.

Why Taxonomy is important?

Humans are destroying species worldwide at unprecedented rates. This tendency must cease now. But if people don't know what they're saving, how can they decide where to put protected areas?

Identifying Species: Taxonomy helps scientists identify and describe endangered and threatened species. Less than 15% of Earth's 8.7 million eukaryotic species have been identified after generations of investigation. This implies that most life remains unidentified and numerous species may become extinct before being discovered.

Habitat protection: Conservationists can prioritize habitats by species distribution and ecological needs. Taxonomy has labeled biodiversity hotspots like the Amazon rainforest and coral reefs for protection.

Biodiversity Conservation: Deforestation, pollution, and climate change are eliminating biodiversity at an unprecedented rate. Solving this requires accurate species information. Using taxonomy, these species may be recognized, classified, and understood for successful conservation.

Fighting with Invasive Species: Taxonomy helps scientists identify native and foreign species, thus reducing ecosystem-threatening pests.

Uses in Medicine and Agriculture: Many of our everyday tools are based on taxonomy. So there is a very immediate, direct applicability. Taxonomy affects health, food security, and technology.

Identifying Pathogens: In medicine, Taxonomy assists in identifying bacterial, viral, and fungal infections. For instance, the correct classification of SARS-CoV-2 allowed speedy vaccine development during the COVID-19 epidemic. Similarly, the discovery of Plasmodium species, which cause malaria, has led to designed targeted treatments. Pathogen identification relies on taxonomy.

Pest Control: In Agriculture, Taxonomy identifies pest species and develops biological controls. Cabbage white butterfly control by the parasitic wasp (*Cotesia glomerata*) reduces pesticide consumption!

Crop Improvement: In Agriculture, scientists can improve crop variety by knowing plant genetics. Taxonomy has improved wheat and rice yields through selective breeding.

Economic impact and resource sustainability: Taxonomy affects art, culture, and industry.

Bioprospecting: It involves discovering Nature's Potential which requires taxonomy. Classifying species helps scientists find plants and animals that may produce novel drugs, enzymes, or biofuels.

Green energies: Offshore wind farms are environmentally and economically beneficial. Understanding how these initiatives affect local ecosystems is crucial to their sustainability. Taxonomy helps identify terrestrial & marine species enabling environment friendly and long-term building techniques.

Economic Value: Through sustainable practices, taxonomy drives economic progress.

Cultural Importance (Traditional information): Taxonomy discovers, documents, and preserves plant and animal information utilized in medicine, food, industry, and ceremonies. By identifying the remnants of dye plants like *Reseda luteola*, *Rubia tinctorum*, and *Isatis tinctoria* medieval textile industry expertise was preserved.

Evolutionary Biology and Taxonomy: Taxonomy helps scientists recreate the tree of life by revealing species evolution. In Phylogenetics, genetic and morphological data are used to investigate species evolution. Taxonomists use it to create “family trees” showing species' common ancestors. Unexpected settings can lead to discover new species.

Climate Change Research: Climate change effect understanding depends on taxonomy. Taxonomy helps scientists study species adaptations to changing surroundings. Coral species' responses to rising water temperatures are being studied.

Environment Monitoring: Air and water quality are measured using bioindicators like lichens and freshwater mussels. Their existence or absence provides environmental health data. Cataloging species in diverse habitats lets scientists track biodiversity changes due by pollution, habitat degradation, and climate change.

Education & Citizen Science: Education and public engagement via taxonomy foster curiosity and environmental responsibility. Taxonomy teaches pupils about biodiversity and conservation. School/college initiatives like recognizing local flora and fauna build a connection to nature gives scientific literacy improving observational skills needed for scientific investigation. Taxonomy encourages citizens to assist in scientific research.

Foundational Role of Taxonomy:

Taxonomy is the bedrock of biology, serving the fundamental framework for all other plant sciences, from genetics to ethnobotany, enabling coherent research and informed decision-making about plant life on Earth.

"Taxonomy: The perfect mix of art and science." - Mollee Marcus.

"Only when one's data is all over the place is it discovered that a taxonomist is necessary." - Rebecca Custis.

CHAPTER 2

Botanical Nomenclature & ICN

Chapter Contents:

- *International Code of Nomenclature for algae, fungi, and plants (ICN)*
- *What is IBC?*
- *History of IBC*
- *The Nomenclature Committee for Fungi (NCF)*
- *Five different codes of Nomenclature*
- *Names of different Taxa*
- *Latin diagnosis: Objective of the Latin Diagnosis*
- *Choice of names*
- *Main features of taxonomic synonyms: Procedure for Rejection*
- *Examples of Rejected Names (Metonymy/Superfluity)*
- *Nomina Conservanda*
- *Nomina specifica Conservanda & its Significance*
- *Names of Hybrids*
- *The Principle of Priority & its Limitations*
- *Author citation: Basic Examples, Complex Examples, Authorship*
- *Effective and valid publication with Examples*
- *Publication of names*
- *Typification: Types of Types: Primary Types, Example Scenario*
- *Taxonomic Ranks & Suffixes: Hierarchical system of ranks of a Taxon*
- *Paris Code (1867) & Rochester Code (1892)*
- *Chief achievements of Vienna code (1905)*
- *BioCode (Draft) & PhyloCode*

Principles and Rules of the International Code of Nomenclature for algae, fungi, and plants (ICN)

In place of the previous ICBN, currently botanical nomenclature is a formal, scientific method for naming plants, algae, and fungi that ensures universal, stable, and unambiguous names utilizing guidelines from the ICN (International Code of Nomenclature for Algae, Fungi, and Plants). Using Carl Linnaeus's *Species Plantarum* (1753) as a starting point, it mainly employs

binomial nomenclature (Genus species), which provides unique identifiers, separates scientific names from confusing common names, and is guided by principles like priority (earliest valid name wins) and correct *Latinization*. The Key Aspects of botanical nomenclature are summarized below:

Goal: to eliminate misunderstanding with regional common names by offering a naming system that is uniform, universal, and scientifically accurate.

Governing Body: The International Association for Plant Taxonomy (IAPT) publishes the ICN, which sets the rules.

Starting Point: Species Plantarum by Carl Linnaeus (1753) serves as the starting point.

Binomial System: A two-part Latinized name, such as *Solanum nigrum*, consists of the lowercase species and the capitalized genus.

Author Citation: The name of the first legitimate publisher of the name is frequently included (e.g., *Mangifera indica* L., where 'L.' stands for Linnaeus).

Priority: A taxon's initial legitimately published name supersedes subsequent names for the same organism.

Ranks: Depending on the rank (family, genus, etc.), names have distinct Latinized endings.

ICN is a set of guidelines and rules governing the formal botanical names given to plants, fungi, and a few other types of organisms that are "traditionally treated as algae, fungi, or plants." The Melbourne Code, which replaces the Vienna Code of 2005, was adopted at the International Botanical Congress in Melbourne in July 2011. It was formerly known as the International Code of Botanical Nomenclature (ICBN). As with previous codes, it goes into effect as soon as it is approved by the congress (on Saturday, July 23, 2011), but it takes some time to prepare the documentation of the code in its final form. Some of the articles with the biggest changes have had their preliminary wording published as of September 2011. Part of the Code's name is capitalized, but part of it is not. Algae, fungi, and plants are all written in lowercase to denote groups of organisms that have historically gone by these names and were traditionally studied by phycologists, mycologists, and botanists rather than being formal names of clades. This includes photosynthetic protists and taxonomically related non-photosynthetic groups, such as blue-green algae (Cyanobacteria), fungi, such as chytrids, oomycetes, and slime moulds, and other organisms. For some of these groups, the ICN includes special provisions, just like there are for fossils.

Outline of the code: It includes 3 Divisions:

a) Division I comprises six Basic and fundamental Principles.

b) Division II comprises Rules & Recommendations, divided into chapters covering ranks, typification, priority, etc., including special provisions for fungi and hybrids)

Articles 1–5: *Taxa and their Ranks* -Defines the hierarchical ranks (Kingdom to Variety), with species being the basic rank.

Articles 6–15: Status, Typification, and Priority of Names - covers name establishment, type specimens (holotypes, etc.), and publishing priority from 1753.

Articles 16–28: Status, Typification, and Priority of Names - Specific rules for naming different ranks, including families, genera, species, and cultivated plants.

Articles 29–31: *Nomenclature of Taxa* - Defines the requirements for publishing a name so it is recognized (e.g., printed, distributed).

Articles 32–45: *Valid Publication* - Sets conditions for making a name validly accepted (description/diagnosis, designation of type, and registration).

Articles 46–50: *Citation of Names* - Guidelines on how to properly cite the author(s) who first published the name.

Articles 51–59: *Rejection of Names* - Rules on how to handle illegal or confusing names (homonyms, superfluous names).

Articles 60–62: *Orthography and Gender of Names* - Governs the spelling, Latinization, and grammatical gender of names.

Rules F.1–F.9: *Names of Organisms Treated as Fungi* - Special, additional rules specifically for fungal nomenclature, including provisions for pleomorphic (multiple-stage) lifecycles.

Rules H.1–H.12: *Names of Hybrids* - Rules for designating and naming hybrid organisms.

c) Division III comprises Provisions for Governance (Controls the Nomenclature Section and permanent committees, as well as how the Code is handled and updated)

The Code also includes a Preamble, a Glossary, and Appendices.

To Remember: The XXI International Botanical Congress (IBC) will take place in Cape Town, South Africa, from July 21-28, 2029. Last updated in 2024, the Madrid Code succeeded the Shenzhen Code (2018).

DIVISION I: PRINCIPLES

Principle I

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

Principle II

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

Principle III

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

Principle IV

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

Principle V

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

Principle VI

The rules of nomenclature are retroactive unless expressly limited.

What is International Botanical Congress (IBC)?

The IBC is a global assemblage of botanists across several fields of science, sanctioned by the International Association of Botanical and Mycological Societies (IABMS) and convened every six years, with its venue alternating among various continents. The existing numbering scheme for congresses began in the year 1900; the XX IBC held in Madrid, Spain, in July 2024. The XXI IBC is scheduled to be held in Cape Town, South Africa, in July 2029.

The IBC holds the authority to modify the ICN, which was renamed from the ICBN during the XVIII IBC (2011), held in Melbourne, Australia. The authority formally lies with the Plenary Session; but, in practice, it ratifies the decisions made by the Nomenclature Section. The

Nomenclature Section convenes prior to the Congress to address all requests for amending the Code, including the ratification of recommendations by subcommittees on conservation. The Nomenclature Section mandates a 60% majority for any alterations not previously endorsed by a committee to mitigate the likelihood of impulsive decisions.

History of IBC

The regulations pertaining to zoological nomenclature came into effect in 1843. However, there has been considerable controversy regarding those regulations throughout the history of botanical nomenclature. The *Lois de la nomenclature Botanique* ("Laws of Botanical Nomenclature") was the first international set of rules, and it was chosen as the "best guide to follow for Botanical Nomenclature" at an "International Botanical Congress" held in Paris in 1867. It was not enforced, unlike contemporary codes. Six sections and 68 articles made up the entire thing.

Several competing codes were created as a result of numerous attempts to make botanical nomenclature more "expedient" or more equitable, which ultimately led to a compromise with the 1930 congress. The Vienna Congress in 1905 was followed by the publication of the second edition of the international rules. The *Regles Internationales de la Nomenclature Botanique* adopted by the Congress International de Botanique de Vienne 1905 were the official name of these regulations (or in English, International rules of Botanical Nomenclature adopted by the International Botanical Conference of Vienna 1905). They are known as the Vienna Rules informally (not to be confused with the Vienna Code of 2006). The International Code of Botanical Nomenclature (ICBN), which was later produced by some but not all subsequent meetings of the International Botanical Congress (IBC), contains revised versions of these Rules.

<i>Year</i>	<i>IBC held in the City / Informal name</i>	<i>Remarks</i>
<i>1900</i>	<i>Paris (France)</i>	<i>Nomenclature decisions were postponed.</i>
<i>1905</i>	<i>Vienna (Austria)</i>	First binding regulations of nomenclature; French was designated as the official language of the assembly; requirement for Latin plant descriptions from 1908 onward (not enforced); conclusion of the Kew Rule.
<i>1910</i>	<i>Brussels</i>	Distinct commencement dates for fungal nomenclature have been established.
<i>1926</i>	<i>Ithaca (USA)</i>	<i>Nomenclature decisions postponed.</i>
<i>1930</i>	<i>Cambridge</i>	The type method included: Latin requirement postponed until

		1932; acceptance of the "absolute homonym rule," or "once a later homonym, always illegitimate (unless conserved)," which modified the status of numerous names, including those that had previously been conserved. The Cambridge Code was published in 1935. This code was endorsed by earlier advocates of the American Code, concluding a phase of division.
1935	<i>Amsterdam</i>	French was superseded by English as the Congress's official language. The Code was not made public.
1950	<i>Stockholm</i>	The first International Code of Nomenclature for Cultivated Plants was put into effect; arbitrary dates were set for several foundational works; and it was decided to hold future congresses every five years (with the exception of the next congress, which will take place in four years). For ancient plants, organ and form genera were developed.
1954	<i>Paris (France)</i>	Two more principles, II and III, addressing types and priority, have been incorporated. Proposals to conserve or reject particular names were dismissed; nonetheless, a committee was formed to explore methods for enhancing the stability of names.
1959	<i>Montreal (Canada)</i>	A presentation of a thoroughly revised list of conserved and rejected names, prompted by amendments made during the 1930 congress, was not accepted for species. The determination that priority rules are inapplicable above the familial rank. The initial reference for family names is Antoine Laurent de Jussieu's <i>Genera Plantarum</i> , published in 1789. Selection among French, English, and German official codes of English as the standard in instances of dispute.
1964	<i>Edinburgh (USA)</i>	<i>No significant alterations to the code.</i>
1969	<i>Seattle (USA)</i>	Founded the International Association of Bryologist.
1975	<i>Leningrad (soviet Union)</i>	Authorized editions of the code are available in English, French, and German, with the English version prevailing in instances of inconsistency; the rejection of species names is permitted under certain exceptional circumstances. Organ-genera for fossil plants are supplanted by form-genera.
1981	<i>Sydney (Australia)</i>	Official versions of the code are available in English, French, and German, with the English version prevailing in cases of discrepancy; the conservation procedure (and rejection) has been expanded to include species names of significant economic importance; the starting date for fungi has been reverted to 1753, with sanctioned name status conferred; the

		types of genera and higher categories are now regarded as the types of species, meaning that the taxa themselves are no longer considered types, only specimens or illustrations are.
1987	<i>Berlin (Germany)</i>	The official version of the code is solely in British English, with further translations available in French, German, and Japanese; conservation has been expanded to species names that indicate the type of a conserved generic name.
1993	<i>Tokyo (Japan)</i>	Initiatives for the registration of plant names; comprehensive reorganization of the nomenclature code; The official version of the code is exclusively in British English, with subsequent translations available in Chinese, French, German, Italian, Japanese, Russian, and Slovak. Conservation applies to all species names, and rejection is allowed for any name that would result in a detrimental nomenclatural alteration. The concept of epitype has been introduced.
1999	<i>St Louis (USA)</i>	The Black Code; Clarification of type requirements; pictures as types predominantly prohibited since 1958; morphotaxa for fossils. Rejected proposals comprised the BioCode and the registration of plant nomenclature.
2005	<i>Vienna (Austria)</i>	Fossil morphotaxa and standard taxa; photos as types are mostly forbidden since 2007; a glossary was included.
2011	<i>Melbourne (Australia)</i>	Authorized electronic publication; fungal nomenclature registration; descriptions (or diagnoses) in Latin or English starting in 2012; elimination of the concepts of morphotaxa (for fossils) and anamorph and teleomorph (for fungi).
2017 (in July)	<i>Shenzhen (China)</i>	<i>The Blue Code</i> - It emphasized electronic publication, simplified taxonomic ranks, and required fungal name registration.
2024 (July 21-27)	<i>Madrid (Spain)</i>	It's the 20th & most recent IBC. The 2023 IBC in Brazil was canceled due to the COVID-19 epidemic, along with its severe economic repercussions and societal unrest. The XX IBC has been rescheduled for Madrid in 2024. Hundreds of species names associated with "kaffir" were chosen for modification.
2029 (XXI) IBC	<i>Cape Town (South Africa)</i>	<i>Yet to be held</i>

The Nomenclature Committee for Fungi (NCF): is a permanent committee of the IBC designated to deliberate on the international regulations governing fungi, particularly their Taxonomy. The NCF members are elected every six years. International Botanical Congresses

(IBCs) are held every six years (e.g., Shenzhen 2017, Madrid 2024—the latter delayed to seven years owing to COVID-19).

Names of different Taxa:

- Genera & higher ranks should be monomials, eg., *Aesculus* L., *Rosa* L., Rosaceae Juss.
- Species should be binomials, eg., *Gossypium tomentosum* Nutt.
- Subspecies should be trinomials, e.g., *Hibiscus moscheutos* ssp. *palustris* (L.) Clausen.
- Varieties should be quadrimomials, e.g., *Lilium catesbaei* Walter ssp. *catesbaei* var. *longii* Fernald.

Latin diagnosis: The diagnosis, details & description of new taxa published before 1st January, 1995 were accepted by ICBN as valid, irrespective of the language after this date the description of any new taxa would be considered valid only if accompanied by Latin diagnosis.

Objective of the Latin Diagnosis:

Unambiguity: Unlike current languages that change over time, Latin has set meanings that prevent misunderstandings.

Universality: Despite being a dead language, Latin provides botanists all around the world with a shared scientific language.

Precision: It serves as a filter, eliminating poorly characterized taxa by demanding careful consideration and highlighting important distinctions.

Historical Standard: The International Code of Nomenclature for Algae, Fungi, and Plants (ICN) established this long-standing practice for legitimate publication.

The Rule's Evolution:

Prior to 1935, Latin diagnoses and descriptions were advised but not strictly necessary.
Post-1935: Became mandatory for valid publication (except for algae/fossils).
2012 Change: In recognition of contemporary practices and the challenge of excellent Latin for all taxonomists, the criteria were relaxed to permit an English description or diagnosis.

Debate on the need of Latin diagnosis:

- ✓ Arguments for its elimination: Some contend that since detailed descriptions in contemporary languages provide clarity and the type specimen frequently clarifies identity, it is an antiquated barrier that slows down science.

- ✓ Arguments for its Retention/Change: Some consider it as an essential safeguard against subpar science, but they also recognize that flexibility is necessary, which leads to the English option.

❖ **Choice of names:**

Botanical nomenclature choice emphasizes unique, Latinized names that comply with binomial nomenclature (Genus + specific epithet), highlighting publication priority (oldest valid name is chosen), clarity (avoiding lengthy or difficult names, hybrid phrases), relevance (reflecting affinities if feasible), separate from zoological norms, and strict application of ICN (International Code of Nomenclature) for universal, stable scientific naming, applying type specimens as foundations.

- ✓ When the rank of a taxon is changed for example, a species becomes a genus (or vice-versa) the earliest legitimate name in its new rank is its correct name.
- ✓ When 2 or more taxa of the same rank are united into one, for e.g., 2 or more genera are united, the oldest legitimate name of these taxa should be retained as the name of the united taxon.
- ✓ *When a genus or a species is divided into 2 or more genera or species, the original name of the genus or species must be retained.*
- ✓ When a species is transferred to another genus without the change of rank, the original name must be retained. e.g., *Hydrocotyle asiatica* L., on transference to genus *Centella*, must be named as *Centella asiatica* (L) Urban. (Retention of Names of divided Taxa on transference)
- ✓ Let's explain with examples: When Ranks Change, since *Aesculus* is the oldest valid name for the merged group, it must be kept when a group formerly classified as a genus (*Macrothyrsus*) merges with an older genus (*Aesculus*).
- ✓ *Species Level Example:* Even if the epithet was originally a component of a varietal name (*Medicago polymorpha* var. *orbicularis*), the appropriate name for groups below genus is the combination of the genus name and the oldest specific epithet (e.g., *Medicago orbicularis*).
- ✓ *Priority & Conservation:* The basic idea is to utilize the first legitimately published name at the recognized rank for stability, unless there are restrictions such as conservation (Article 14) or any particular ICN criteria that limit priority.

❖ **Rejection of Names –**

- (A) If a name is illegitimate, it is rejected:

- i) Superfluous nomenclature
 - ii) If published in violation of certain regulations (indiscriminately or dublicately published)
 - iii) If the generic name is denied.
 - iv) If tautonym.
- (B) It is a source of misunderstanding if it is used with another meaning. For instance, *Quercus rubra* L. for American oak, *Quercus falcata* Michx. for Spanish oak, and *Quercus borealis* Michx. f. for Red oak. So, Reder proposed *Quercus rubra* L. as nomen ambigua and rejected *Quercus falcata* while *Quercus borealis* is the valid name.
- (C) If a taxon's name is derived from two or more completely discordant elements, it must be rejected unless one of these elements can be chosen as the site factory type of the name. For instance, Oliver created *Actinotinus* in 1888 after rejecting a specimen that came from *Viburnum* and *Aesculus*.

The guidelines for rejecting names are-

- (i) ***Nomen nudum (nom. nud)***: A name is rejected if it lacks a description, typification, Latin diagnosis, etc. A Latin name that has been published without a proper & complete description (considered a naked name) is called *Nomen nudum*. In fact it is a name that does not fulfill the criteria set by the ICN as a legally described scientific name & therefore cannot be used unless it is subsequently proposed correctly. *e.g.*, *Convolvulus adpressus* Wall. Cat. No. 1424.1828, *nom.nud.* Wallich (1824-1849) in his catalogue published new names without description or reference to an earlier published description. Hence, these names are not considered to be valid.

Few more examples:

Egeria is a nomen nudum since Néraud published it (in Gaudichaud, 1826) without providing a description or a diagnosis. Later genus *Egeria* in Hydrocharitaceae family was validly published by Jules Émile Planchon in 1849 (Art. 38, Ex. 1). German botanist Wilhelm Schimper named *Loranthus macrosolen* on his herbarium sheets in 1843. But he did not provide a description or diagnosis for this species. So, it was considered a nomen nudum. Later in 1848, Ernst Steudel correctly described *Loranthus macrosolen* Steud. ex A. Rich. using Schimper's material. This species is now assigned to *Phragmanthera macrosolen* (Steud. ex A.Rich.) M.G.Gilbert. For *Carex bebbii* (Olney, 1871), no description or diagnosis was provided. *Cerasus Cornuta* Wall. Another plant, such as *Cerasus cornuta* Wall. ex Royle, was a nom. nud. in Wallich's Catalogue until it was later validated. *Quercus dilatata* Wall. ex A.DC. was cited in Wallich's Catalogue (Wall. Cat.) in 1812 without a description; other authors later validated it, but the original nom. nud. is not the legally recognized

name. *Veronica sutherlandii* is a *nomen nudum*, used in horticulture but never formally described (occasionally used as the basis for a cultivar name, like *Hebe pinguifolia* 'Sutherlandii'); Nathaniel Wallich numerated thousands of Indian specimens. Many names were published without botanical descriptions and are called *nom.nud.* Similarly, many names listed in earlier, unvalidated botanical catalogs or expedition lists are examples of *nomen nudum*.

(ii) **Tautonyms:** These are names where the specific epithet exactly repeats the generic names with or without transcribed symbol. Such names are legitimate under ICZN but illegitimate under ICBN [e.g., *Naja naja*, *Bison bison*, *Catla catla*]; Names like *cajanus cajan* or *Sesbania sesban* are not tautonyms as they are not exactly identical.

a) Prohibited True Tautonyms (Historical Examples): Following names are no longer valid but show what tautonyms were like before rules changed: *Larix larix* (originally *Pinus larix*, moved to *Larix* creating a tautonym, now *Larix decidua*), *Lablab lablab* (A synonym for *Lablab purpureus*), *Opuntia opuntia* (A synonym for *O. humifusa*)

b) Permitted Near-Tautonyms (Similar but Not Identical): *Roridomyces roridus*, *Arctostaphylos uva-ursi*, *Cajanus cajan* (Pigeon pea), *Cuminum cyminum*: (Cumin), *Ziziphus zizyphus* are allowed as they don't perfectly repeat the genus name.

(iii) **Later homonym:** A later homonym is rejected if an existing name is used to different taxa once again. Examples: *Tapeinanthus* Boiss. ex Benth. (1848, Labiatae) vs. *Tapeinanthus* Herb. (1837, Amaryllidaceae) and *Torreya* Arn. (1838) vs. *Torreya* Raf. (1818). Genus *Amblyanthera* Müll. Arg. (1860) is a later homonym of *Amblyanthera* Blume (1849). Species *Zingiber truncatum* S.Q. Tong (1987) is a later homonym of *Zingiber truncatum* Stokes (1812). Species *Cryptantha foliosa* Reiche (1907) is a later homonym of *Cryptantha foliosa* Greene (1887). Genus *Bradleja* Banks ex Gaertn. (1790) is a homonym of *Bradlea* Adans. (1763). Species *Astragalus rhizanthus* Boiss. (1843) is a later homonym of *Astragalus rhizanthus* Royle (1835).

(iv) **Nomen ambiguum (nom. Ambig.):** A name used by various authors in different senses becomes a source of error is called *nomen ambiguum* (plural: *nomina ambigua*). Such names are rejected to ensure clarity. e.g., *Rosa villosa* L., *Bruea bengalensis* Gaud., *Phyllanthus clausenii* Müll. Arg. Under ICN, to avoid confusion & maintain consistency, these names are typically replaced with a conserved name (*nomen conservandum*) or disregarded in current botanical literature.

(v) **Nomen confusum (nom. confus):** A name based on heterogenous elements from which it is impossible to select a lectotype. Such names are rejected. There should be

no confusion in the name. e.g., *Uropedium* Lindl. (1846), *Trifolium infamia-ponertii* Greuter, *Rhinanthus crista-galli* L. (1753)

❖ **Why are *Nomen confusum* problematic?**

Instability: Makes it difficult to consistently identify and classify plants.
Ambiguity: A plant may have various names (some *nomina confusa*), or a single name may refer to multiple species.

Conceptual examples include:

Consider a name like "Common Daisy" in English, which may refer to *Bellis perennis* in Europe but also *Erigeron* or *Chrysanthemum* species in other regions (though these are common names, the principle applies to scientific names too). However, specific textbook examples are frequently historical and complex.

Historical Usage: Until a type specimen (a particular plant sample) was chosen to correct its meaning, early botanists may have applied a name (e.g., *Anemone* spp.) to a wide variety of unrelated species, rendering the original *Anemone* a ***nomen confusum***. Despite being an example from entomology, *Tribolium confusum* (Confused Flour Beetle) serves as an example of how a name can convey confusion, according to certain authorities. In botany, names such as *Cochlearia officinalis* were historically ambiguous since, prior to clarification; the idea encompassed numerous species of scurvy-grass.

(vi) **Nomen dubium** (plural: *nomina dubia*; abbreviated *nom. dub.*): A name that is doubtful, meaning it has an unclear application, is likewise disapproved of. e.g., *Actinotinus* Oliv. (1892), *Uropedium* Lindl. (1846), *Sida acuta* L. (a potential *nom. dub.* - Older *Sida* synonyms without a type specimen have ambiguous descriptions that make it difficult to distinguish between related species).

(D) **Nomenclatural synonyms or homotypic synonyms:** Synonyms based on the same nomenclatural types are called *nomenclatural synonyms* or *homotypic synonyms*. Such synonyms are also called obligate or objective synonyms.

Examples:

- Picea abies* (L.) H. Karst. (current) and *Pinus abies* L. (older, now a synonym).
- Achnanthidium minutissimum* and *Achnanthes minutissima* (same type).
- Punctelia reddenda* (Stirt.) Krog. and *Parmelia reddenda* Stirt. (species moved to a new genus).
- Coelocaulon aculeatum* (L.) Link and *Cetraria aculeata* (Ach.) Fr. (epithet adjusted for gender, same type).

Main features of Nomenclatural Synonyms:

- ✓ **Same Type:** Always share the same name-carrying type specimen.
- ✓ **Formal:** Established through formal nomenclatural acts (publication, transfer).
- ✓ **Goal:** Based on rules of priority or type locality, not merely opinion.
- ✓ **Symbol:** Often reflected by "≡" in taxonomic literature, means "is identical with".

(E) ***Taxonomic synonyms or heterotypic synonyms:*** Synonyms based on the different nomenclatural types are called *taxonomic synonyms or heterotypic synonyms*; also known as subjective synonyms. **Examples:**

- a) *Taraxacum officinale* (F. H. Wigg.) (the accepted name for the common dandelion) has names like *Leontodon taraxacum* or other specific dandelion names as its heterotypic synonyms.
- b) *Gomphonema louisiananum* (Kalinsky) and *Gomphonema patrickii* (Kocielek & Stoermer) are heterotypic diatom synonyms since they were based on different type specimens, but are now considered the same **organism**.
- c) When a taxonomist describes a new species (e.g., *NewSpecies novum*) and later decides its type specimen belongs to an already named species (e.g., *OldSpecies*), *NewSpecies novum* becomes a heterotypic synonym of *OldSpecies*.

Main features of taxonomic synonyms or heterotypic synonyms:

- ✓ **Various Types:** Every name has a distinct type specimen, which is the actual specimen on which the name is based.
- ✓ **Subjective:** Their synonymy, which frequently involves combining smaller species into larger ones, is based on taxonomic judgment or opinion rather than rigid criteria.
- ✓ **Shown by "=":** They are frequently displayed with an equals symbol in botanical literature (e.g., Species A = Species B).

(F) **Homonyms** – are names spelt in identical manner but based on different types. The one published at an early date is called earlier homonym & that at a later date as the later homonym. The code therefore rule that of the 2 or more homonym all except the oldest are excluded from use if the earlier homonym is illegitimate. e.g., *Cryptantha foliosa* Reiche (1907) against *Cryptantha foliosa* Greene (1887). *Carex musartiana* Kük. ex V.I. Krecz. against *Carex musartiana* Kük. & V.I. Krecz.

The rule is "first come, first served": the earliest validly published name takes precedence, and any later identical name for a different taxon is an illegitimate homonym, making it invalid for future use in botany.

(G) **Autonyms** – It is an automatically created tautonym for infra-generic or infra-specific taxa; e.g., for the genus *Rubus* (raspberries, blackberries), if a subgenus contains the type species *Rubus idaeus*, the subgenus is simply named *Rubus* subgen. *Rubus*. Similarly, *Acacia nilotica* (Babul) has subspecies like *A. nilotica* subsp. *nilotica*, that represents the type specimen (called an autonym) & its variant is *A. nilotica ssp. indica*.

(H) **Typonyms** - A name is rejected if there is an older valid name based on the same type.

e.g., An earlier name for the same type (a typonym/homonym) is *Ziziphus jujuba* Mill. (1768). Because of this older typonym, the subsequent name *Z. jujuba* Lam. is rejected. *Unona cochinchinensis* DC is a typonym (later synonym) of *Desmos cochinchinensis* as it was proposed later based on the same type. Similarly, *Unona Desmos* Dunal is another typonym based on the same type specimen as the above names. (*Desmos cochinchinensis* Lour. is the legitimate name).

(I) **Metonyms** - A name is rejected when there is an older valid name based on another member of the same group. e.g., The rejection of *Chrysophyllum sericeum* Salisb. (1796) as a "superfluous name" is a form of metonymic rejection. It was used for *Chrysophyllum cainito* L. (1753), a plant that already had a legally recognized name.

(J) **Hyponyms** - A name is rejected when natural group to which it applies is undetermined. e.g., Linnaeus initially used the name *Rhinanthus crista-galli* L. (1753) to refer to a collection of numerous different types, leaving the natural group unclear. It was classed as nomen dubium (doubtful name) and eventually discarded since later authors used it for a variety of unclear situations.

(K) **Nomen superfluum** - A name nomenclaturally superfluous when published if the taxon to which it was applied as circumscribed by its author, included the type of another name which ought to have been adopted under the rules. Such names are illegitimate & must be rejected. e.g., Adanson explicitly cited *Chrysophyllum* in synonymy when renaming the genus *Chrysophyllum* L. (1753). *Cainito* is a superfluous and invalid name as *Chrysophyllum* was already the legal name.

More Examples of Rejected Names (Metonymy/Superfluity)

Picea excelsa Link (1841): Rejected because it was based on *Pinus excelsa* Lam. (1778), which was a superfluous name for *Pinus abies* L. (1753). The correct name is now *Picea abies* (L.) H. Karst.

Chloris radiata Sw. (1788): Rejected when it was discovered that the older name *Andropogon fasciculatus* L. (1753) already existed for the same taxon. The priority belongs to the older name, making the later one superfluous.

***Uropedium* Lindl. (1846):** Rejected because it was based on a "monstrosity" (a physical deformity) of a member of the existing genus *Phragmidium*.

Nomina Conservanda (nom.cons.) (Art-14):

A generic or a family name that is retained by authorization by an ICN, although it strictly contravenes one or more provisions of the code. When a generic name is conserved, the words **nom. cons.** are added to the citation;

Examples of Conserved Genus Names (Nomina Generica Conservanda):

Carya (1818) is a conserved name against *Hicoria* (1817); similarly, *Sesbania* Scop. (1777) against *Sesban* Adans. (1763) and *Agati* Adans. (1763). *Desmodium* Desv. (1813) against *Pleurobolus* (1812) & *Meiobomia* (1959); *Cajanus* DC. (1818) against *Cajan* (1763); *Protea* L. (1771) against *Leadbeatera* Duhamel (1755), *Bambusa* Schreb. (1789) against *Bambos* Retz. (1789) and so on.

Examples of Conserved Species Names (Nomina Specifica Conservanda):

Triticum aestivum L. (Bread Wheat) is conserved to prevent confusion and to maintain stability for this crucial crop in literature. *Triticum aestivum* L., 1753 (=) *Triticum hybernum* L., 1753 [Conserved at Berlin congress in 1987 & published in subsequent code in 1988]

Though technically *Solanum lycopersicum* is valid, *Lycopersicon esculentum* has been proposed/used as a conserved name for tomato to avoid confusion in literature. *Lycopersicon esculentum* Mill. 1768 (=) *Lycopersicon lycopersicum* (L.) H. Karsten. 1882 [Conserved at Berlin congress in 1987 & published in subsequent code in 1988]

***Bromus sterilis* L. (Barren Brome):** A specific example of a conserved name against an earlier synonym. *Carex filicina* Nees. 1834 (=) *Cyperus caricinus* D. Don, 1825.

Examples of Conserved Genera (NGC) Frequently Associated with Species Preservation:

Although *Nomina specifica conservanda* are for species, the idea is also demonstrated by numerous conserved genera (*Nomina generica conservanda*, NGC), which frequently fix species within them. e.g., *Protea* L. (King Protea) is maintained in spite of previous names that were in dispute, such as *Protea cynaroides*. The genus *Ficus* and its common species remain retained because of its extensive use.

❖ **Names of Hybrids:**

A multiplication sign (×) is used in botanical nomenclature to indicate parental lineage in hybrid names. The Latin name of the plant can also be used. e.g., *Salix aurita* X *Salix caprea*.

Interspecific Hybrids: These are named using the genus followed by a multiplication sign and the epithet (Genus X epithet). e.g., *Magnolia x soulangeana* is a hybrid between *Magnolia denudata* & *Magnolia liliiflora*.

Intergeneric hybrids: These are designated by using a new nothogenus name from the parent genera' names preceded by a multiplication symbol (X). e.g., *Triticosecale* (commonly *Triticale*) is a hybrid of *Triticum* (wheat) and *Secale* (rye).

Intraspecific Hybrids: These names use prefix "notho-" to indicate rank, such as nothosubspecies or nothovariety. e.g., *Polypodium vulgare* nothosubsp. *mantoniae* is a hybrid between two subspecies of *Polypodium vulgare*.

Naming Conventions & Key Symbols

Multiplication sign (×): Placed before the name to indicate a hybrid.

Hybrid formula: Parents listed alphabetically with the sign: Parent1 × Parent2 (e.g., *Hebe elliptica* × *H. speciosa*).

Nothogenus: A hybrid genus name (e.g., × *Fatschedera*).

Cultivars: Often added to hybrid names (e.g., *Hamamelis* × *intermedia* 'Arnold Promise').

THE PRINCIPLE OF PRIORITY

The Principle of Priority addresses the use of a single accurate taxonomic group name. Illegitimate names should be rejected, and only legitimate names should be kept. Article 11-12 establishes the following standards for priority:

- (i) Every lower-ranking family or taxon with a specific circumscription, position, and rank may only have one valid name (Art 11).
- (ii) The oldest valid name that has been published with the same rank is the correct name for any taxon, from family to genus (Article 11).
- (iii) Unless a taxon's name is legitimately published, it has no legal standing under this law (Article 12).
- (iv) Nomenclatural type dictates the use of both conserved and rejected names (Art-14).
- (v) Botanists are permitted to keep a name that has been tentatively approved for protection by the general committee until a later international Botanical Congress makes a decision.

True The publication of names is typically seen as having started in May 1753, when Linnaeus published *Species Plantarum*, volume I. When a taxon has multiple names, the

earliest name that is considered correct will be considered valid. The Rule of Priority gives this name consistency.

The Principle of Priority is the idea that seniority is determined by the date of valid publication. For instance, the names of the same species are *Nymphaea nouchali* Burro f. 1768, *N. pubescence* Willd 1799, and *N. torus* Hook f. et. T., 1872; but, if the rule of Priority is followed, the first name is the proper one and the other two are synonyms.

Another interesting example:

In 1790, Loureiro described a plant and gave it the name *Physikum nataus*. In 1828, A.L. de Jussieu moved it to the genus *Vallisneria*. He gave the precise name as *V. physikum* rather than *Natans*. It is an unnecessary name. The same plant was identified as *V. gigantea* by Graebner (1912) and as *V. asiatica* by Miki (1934). Harg verified that all of these names are interchangeable while researching Asiatic species. No valid combination based on *Physikum natans* (Leru) has yet been found. In 1974, he created *V. natans* Hara. Although it is based on the earliest basionym, the specimen's accurate name is now the most recent one; the others will be synonyms. We will refer to *V. gigantea* and *V. asiatica* as **homotypic or nomenclatural synonyms**. The names *V. gigantea* and *V. asiatica* are derived from different kinds. These synonyms are referred to as **heterotypic or taxonomic synonyms**. Each plant taxon can only have one accurate name, with a few exceptions where different names are allowed. The correct name is the earliest one that has been legally published, unless conservation has limited priority. However, there are numerous exceptions, such as algae, fungi, and musci. Publication dates for algae only start to appear quite late in history; for example, Hirm's monographs *Iconographic der Oedogoniaceen* were published in 1900 for the Oedogoniaceae. Fossil plant groupings begin on December 31, 1820. Tautonyms, such as *Malus malus*, occur when a specific name is repeated without changing the general name. When we come across names like *Corvus corvus*, this approach is recognized in zoological nomenclature. According to the rule of nomenclature, each taxon with a specific circumscription, taxonomic location, and rank may only have one legitimate name. All later published names will be discarded, and credit will be awarded to the first person to publish the name in a legitimate and effective manner.

The rule of priority states that if a plant name was published by Linnaeus in 1753 and two or more authors later published it in a different way without realizing it was already published, say in 1780 or 1790, the name published by Linnaeus in 1753 will be accepted as the official name and all other names published after that will be rejected.

LIMITATIONS OF THE PRINCIPLE OF PRIORITY

1. Starting dates: Principle of Priority starts with the publication date of *Species Plantarum* of Linnaeus, i.e., on 1-5-1753 for Vascular Plants (Spermatophyta & Pteridophyta),

Bryophytes (except for mosses, which used 1801, but the ICN currently recognizes 1 May 1753 for all), Fungi (now mostly covered under the 1753 rule, along with "one fungus, one name" provisions), Algae (but specific groups have varied, later starting dates e.g., 1848 for Nostocaceae). Fossil Plants have starting date of 31st December 1820 (Sternberg, Flora der Vorwelt).

2. Restricted only up to family ranks: It is not applicable beyond the family rank.
3. The correct name shouldn't be outside of the rank. Combinations with other ranks are permitted only when the taxon's correct name is unavailable.
4. Its application resulted in changes in many names. To avoid it, a list of conserved generic and family names has been created and published in the code with certain modifications. Such *Nomina conservanda* (nom. Cons.) are to be used as the valid names replacing previous valid names, e.g., *Sesbania* scop, 1777 is the conserved genus as against *Sesban* adam 1763 and *Agati* adam 1763.

IMPORTANT NOMENCLATURAL MILESTONES:

1 May 1753: Start of botanical nomenclature.

1867: First International Code of Botanical Nomenclature (Lois de la nomenclature botanique).

1 January 1932: Latin diagnosis mandatory for new taxa.

1 January 1990: Type of the name must be specified (holotype).

1 January 2000: Registration of new names required.

1 January 2012: Electronic publication allowed, English accepted instead of Latin (Melbourne Code).

AUTHOR CITATION

In botanical nomenclature, author citation means citing the person or group of individuals who legitimately published a botanical name, i.e., who first published the name while satisfying the formal requirements as outlined by ICN.

Basic Examples

Single Author: The author's name follows the species name. e.g., *Mangifera indica* L. (Linnaeus); *Solanum nigrum* L..

Multiple Authors: Names are linked by "et" or "&". e.g., *Delphinium viscosum* Hook. f. et Thomson.; *Rubus ursinus* Cham. & Schldl. (Chamisso & Schlechtendal).

Complex Examples

Validation of an Earlier Name ("ex"): When one author proposed a name but failed to publish it & another author later validly published it. e.g., *Cerasus cornuta* Wall. ex Royle

Name Transfer (Basionym): When a species is moved to a new genus, original author is kept in parentheses. e.g., *Mohavea confertiflora* (Bentham) Heller (Bentham first described it, Heller transferred it). *Helianthemum conquense* (Borja & Rivas Goday ex G. López) Mateo & V.J. Arán Resó.

Authorship Ascribed in another's Publication ("in"):

If an author acknowledges another's manuscript (mss.). Examples: *Calyptridium* Nutt. (Nuttall's manuscript, published by someone else); *Brachystelma* R. Br. (Published by Sims, but attributed to R. Brown); *Carex kashmirensis* Clarke in Hook. f.

Pre-Starting Point Authors (Square Brackets): Sometimes used to acknowledge authors who published names before official starting date of botanical nomenclature (May 1, 1753). Example: *Lupinus* [Tourn.] L.

Infraspecific Taxa: Multiple authorities are frequently cited for subspecies or variations (e.g., *Acacia nilotica* (L.) Del. ssp. *indica* (Benth.) Brenan).

To remember: According to code author names are often abbreviated (e.g., L. for Linnaeus, Hook. f. for Hooker filius). Its purpose is to clarify the name's origin and ensure accuracy and verifiability.

❖ **Effective and valid publication**

Requirements for effective publication

- ✓ It must be published in a printed matter
- ✓ Scientific Book or Journal or Periodical
- ✓ Sale, loan, exchange or gift of the book
- ✓ Available in Library or Distributed to general public or at least to 10 botanical institutions
- ✓ Accessible to public or botanists
- ✓ PDF copy- must have ISBN (International Standard Book Number) & ISSN (International Standard Serial Number) [01.01.2012]
- ✓ Before 01.01.1953: Any hand-written material that is indelible autograph can be effectively published
- ✓ If printed before 01.01.1973: Trade catalogue, non-scientific newspapers & seed exchange list
- ✓ Communication of new names at public meeting or by placing of names in collections or gardens open to public or by issuing microfilm made from manuscripts, typescripts or other unpublished material.

- ✓ The date of effective publication is the date on which the printed matter became available.

Requirements for valid publication

- ✓ It must be effective
- ✓ Name should be confirmed
- ✓ Latin description [on or after 1.1.1935]
- ✓ One detailed description (any language)
- ✓ Author citation
- ✓ Type specimen details (collection time, place, collector, serial no. etc)
- ✓ Name of the Herbarium where the type specimen deposited- Acronym may be used
- ✓ Selection of medium / journal (Scientific Book or Journal or Periodical)
- ✓ Proper title of the article mentioning the rank of new taxon
- ✓ Taxonomic hierarchy must be mentioned in Latin language e.g., nov. (Order novum), Fam. Nov. (Family novum), Gen. nov. (Genus novum), Sp. Nov. (Species novum)
- ✓ **Use of comb. nov. (*Combina novum*) for change of name:** Basionym must be mentioned along with year, book name, vol., page no. e.g., *Catharanthus roseus* (L.) G.Don comb. nov. (Gen. Syst. 4:95, 1837) Basionym: *Vinca rosea* L., Syst. Ed.10: 944. 1759
- ✓ **Status novum** (stat. nov.) *Urena lobata* L. subsp. *sinuata* (L.) Borss., comb. Nov. et stat. nov. *Urena sinuata* L., Sp. Pl. ed. 1:692. 1753
- ✓ If any name published before 01.01.1908 without description but drawings & diagnostic characters mentioned, (valid)

Examples of Effective Publication

A scientific paper in The Plant Journal: When a botanist publishes a new species in a widely distributed scientific journal, it is considered effectively published because it's printed and available to other botanists and institutions.

A thesis submitted to a university library: If a thesis is physically distributed to the library and available for public access, it can constitute effective publication.

Examples of Valid Publication

Simple Valid Publication: *Rosa gallica* L.: Linnaeus effectively and validly published *Rosa* and *R. gallica* by distributing his *Species Plantarum* (1753), which contained descriptions and met all other rules.

Publication with Author Citation: *Viburnum ternatum* Rehder: Published in Sargent's Trees & Shrubs, the name is ascribed to "Rehd." (Rehder) because he authored the description, making it validly published as *V. ternatum* Rehder.

Double Citation (Basionym Transfer): *Cynodon dactylon* (Linn.) Pers.: Linnaeus named the species *Panicum dactylon*, but Persoon later transferred it to the genus *Cynodon*. The name is validly published with both authors cited (Linn. as the basionym author, Pers. as the author of the combination).

"ex" Citation (Proposed but not published by first author): *Gossypium tomentosum* Nutt ex Seem.: Nuttall proposed the name, but Seemann effectively and validly published it later, linking them with "ex".

"in" Citation (Published within another author's work): *Carex kashmirensis* Clarke in Hook. f.: Clarke published this species within Hooker's Flora of British India, so the name is cited as *C. kashmirensis* Clarke in Hook. f..

Emended Diagnosis: *Phyllanthus* Linn. emend. Mull.: Müller changed the circumscription or diagnosis of a genus named by Linnaeus but kept the same type, indicated by "emend." (emendavit).

Examples of Publication that is NOT Valid

Unpublished names in a personal letter: A name mentioned only in a letter isn't distributed and thus isn't effective or valid.

A new name published without a Latin diagnosis (before 1935): Names published before Jan 1, 1935, are valid if effectively published; however, names after this date require a Latin diagnosis to be validly published.

A name published in a work not accessible to botanists: If a publication is sold out and not available in libraries, it fails the effective publication test.

Publication of names:

The name of a Taxon should fulfill certain requirements before its effective publication as:

- (i) **Formulation:** It should indicate
 - (a) sp. nov. (species novum) for a new species
 - (b) Comb. nov. (combination novum) for change in the epithet of basionym. The name of the original author should be kept in Parentheses.
 - (c) nom. nov. (Nomen novum) when the original name is completely replaced.

- (ii) English or **Latin diagnosis**: As per ICN (The Melbourne Code) the requirement of Latin diagnosis for Names of New Taxa has been changed. As per this code the description of new names should be in English or Latin.
- (iii) Typification: Holotype should be designated. The name of new Taxon is valid only when the type of the name is mentioned after January 1, 1990. The name of the taxon whose type is a specimen or unpublished illustration; the herbarium or institution in which the type is conserved must be specified.
- (iv) After January 1, 1996 the name of new taxon of fossil should be accompanied by a Latin or English description of character.

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

Typification: Types of Types

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

According to Principle II, “***The application of names of taxonomic groups is determined by means of nomenclatural types***”. This means that when a species is described as new, the author must indicate the type-specimen on which the new species is based.

A type specimen is a herbarium sheet (or rarely a drawing or a photograph) of a specimen which was used by the author to provide its authentic description. According to the article 9 of ICBN the type of a genus is a species [e.g., the type of genus *Vernonia* is *V.noveboracensis* (L.) Michx.] & the type of a family is a genus (e.g., *Aster* is a type genus of Asteraceae).

- **Type culture** - the culture derived from a holotype, lectotype or neotype.
 - **Type locality** - the exact geographical site from where the type of a species or subspecies was collected.
 - **Type genus** - the type of a family group taxon.
- a) **Holotype** – It is a specimen used by the author in the original publication as the nomenclatural type. e.g., *Phyllanthus mukherjeanus* Mitra et Bennet in Bull. Botan. Soc. Bengal 19 (2); 145-146. 1966. Holotype Bennet 621A (CAL);
 - b) **Isotype** – It is a duplicate specimen of the holotype, i.e., from the same collection, with the same locality, date & number as the holotype. e.g., *Phyllanthus mukherjeanus* Mitra et Bennet in Bull. Botan. Soc. Bengal 19 (2); 145-146. 1966. Isotype Bennet 621 B-C (CAL);
 - c) **Paratype** – It is a specimen cited in the protologue with the original description other than the holotype or Isotype [any specimen from the type series remaining after the designation of the holotype or isotype]. Thus there can be only 1 sheet of holotype but there can be a

number of sheets of isotypes or paratypes. Allotype is a paratype of opposite sex to the holotype & originally designated by the author. Parallelotype is a paratype of the same sex as the allotype. e.g., *Polygala jacobii* Chandr. In Bull Bot. surv. India 9 (1-4):288-289.1967. Paratype Rangachari s.n. (Acc no. 2444, MH);

- d) **Neotype** – It is a specimen selected to serve as a substitute for the holotype when all material, on which the name of the taxon was based, is missing.
- e) **Topotype** – It is a specimen collected from the same locality from where the holotype was collected.
- f) **Epitype** [interpretative type]- It is a specimen or illustration selected to serve as an interpretative type when the holotype, lectotype, or previously designated neotype, or all original material associated with a validly published name, is demonstrably ambiguous and cannot be critically identified for purposes of the precise application of the name of a taxon. When an epitype is designated, the holotype, lectotype, or neotype that the epitype supports must be explicitly cited (Art. 9.18).

Ex. 2. The holotype of *Vitellaria paradoxa* C. F. Gaertn. (1807) is a seed of unknown provenance (P), clearly belonging to the species currently known as *Butyrospermum paradoxum* (C. F. Gaertn.) Hepper. However, the two subspecies recognized within that species can only be distinguished by characters of foliage or inflorescence. Hall & Hurdle (in Taxon 44: 410. 1995) designated an epitype with foliage, *Mungo Park* (BM). It belongs to the western subspecies, now to be known as *B. paradoxum* subsp. *paradoxum*.

- g) **Iconotype**: A diagram or camera-lucida drawing or an illustration based on the original specimens is called iconotype. It is sometimes required to represent delicate specimen.

Summary of Primary Types (Designated by Author)

- **Holotype (Holo-)**: The single specimen (or illustration) to which a name is permanently attached, selected by the original author.
- **Isotype (Iso-)**: A duplicate specimen of the holotype, collected at the same time and place.
- **Syntype (Syn-)**: Any one of several specimens cited by the author when no single holotype was designated.
- **Paratype (Para-)**: Specimens cited in the original publication but not designated as types (e.g., not isotypes or syntypes).

Secondary Types (Selected by Later Taxonomists)

- **Lectotype (Lecto-)**: A specimen chosen from the original material (isotypes, syntypes, etc.) to serve as the type when the holotype is lost or missing.

- **Neotype (Neo-):** A new specimen selected to be the type when all original material is lost or destroyed, requiring justification.
- **Epitype (Epi-):** A specimen (or illustration) selected to provide an unambiguous interpretation of an ambiguous or poor-quality original type.

Example Scenario:

If a botanist describes a new flower (*e.g.*, *Flora novae*):

- They might designate one specific pressed flower as the *Holotype*.
- Other flowers from the same collection trip become *Isotypes*.
- If the holotype is lost, another scientist might select one of the *Isotypes* as the *Lectotype*.
- If the original description was vague, a third person could choose a representative specimen as an *Epitype* to clarify the species' identity.

Important Points to Remember

- Paratypes are supporting types, whereas holotypes, lectotypes, and neotypes are major, name-bearing types.
- A lectotype or neotype has to be identified in the event that a holotype is lost.
- Even if a species is transferred to a new genus, the original type specimen is still used as a reference.
- The geographic area where the holotype was discovered is known as the type locality.
- In case of Higher Taxonomic Types: Species group names are based on a type specimen; Genus group names are based on a Type Species; & Family group names are based on a Type Genus.

Taxonomic Ranks & Suffixes

- ❖ -aceae: Standard suffix for botanical families (*e.g.*, Rosaceae).
- ❖ -ales: Standard suffix for botanical orders.
- ❖ -idae: Standard suffix for zoological families (*e.g.*, Felidae).
- ❖ Sub-: Prefix indicating a lower rank (*e.g.*, subspecies, subfamily).

Hierarchical system of ranks of a taxon:

A common mnemonic for hierarchical system of ranks is "*Dear King Philip Came Over For Good Spaghetti*". (*e.g.*, Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species).

- Domain: The highest taxonomic rank, consisting of Bacteria, Archaea, and Eukarya.

- Kingdom: Major groups such as Animalia, Plantae, Fungi, and Protista.
- Phylum (or Division): A group of related classes; "Division" is more commonly used in botany.
- Class: A group of related orders.
- Order: A group of related families.
- Family: A group of related genera, [e.g., Poaceae (Grass) family.]
- Genus: The first part of an organism's scientific name (e.g., *Oryza* in *Oryza sativa*).
- Species: The most specific rank; individuals that can interbreed and produce fertile offspring.

What is Paris code?

The **Paris Code** (1867), or *Lois de la nomenclature botanique*, was the first, foundational international set of regulations for plant nomenclature, established at the International Botanical Congress in Paris. Alphonse de Candolle had a significant role in stabilizing names, creating legitimate publication guidelines, and emphasizing Linnaeus as the beginning point.

Key Aspects of the Paris Code (1867)

- a) The aim: It was created to replace confusing polynomial, or multi-word, plant names with a standardized, generally understood binomial system.
- b) Background: Approximately 150 European and American botanists came together to adopt it in August 1867 in order to control plant nomenclature.
- c) Guidelines: It established the principle of priority, according to which a plant species should be given its oldest valid name.
- d) Author Citation: highlighted the need to cite the person who originally validly published the botanical name.
- e) Evolution: While considered the basis, it was later modified and replaced by successive codes, including the Vienna Code (1905) and the contemporary International Code of Nomenclature for algae, fungi, and plants (ICN).
- f) The Paris Code is recognized as the cornerstone of current plant Taxonomy, providing the stage for regular and organized botanical naming.

What is Rochester code?

American botanists led by **N.L. Britton** in Rochester, New York, created the Rochester Code (1892) as a set of botanical nomenclature guidelines to amend the 1867 Paris Code. It introduced the concept of nomenclatural kinds, severely maintained the principle of priority, and accepted tautonyms (e.g., *Malus malus*).

Key details regarding the Rochester Code:

Aim: It was intended to address concerns in plant nomenclature and assure more stability, principally backed by American botanists as an alternative to the European-favored codes.

Key Principles:

- a) **Type Concept:** Introduced the idea of employing a specific specimen (type) to fix the application of a name.
- b) **Strict Priority:** Emphasized that the earliest published name is the valid one.
- c) **Tautonyms:** Accepted names where the specific epithet repeats the genus name.

Impact: The severe regulations of the Rochester Code, together with the later 1907 American Code, created a schism between American and European botanists (who followed the Vienna Code) regarding botanical nomenclature. It was a major, though controversial, forerunner to the present-day International Code of Nomenclature for algae, fungus, and plants (ICN).

Vienna code (1905)

The Vienna Code of 1905, enacted at the Second International Botanical Congress, was a landmark in plant Taxonomy that established formal, internationally acknowledged rules to replace inconsistent, local, or contradictory systems.

Notable milestones of Vienna Code (1905) are:

- a) **Establishment of the Starting Point:** To ensure a consistent baseline, the Code officially recognized Linnaeus's *Species Plantarum* (1753) as the official beginning point for the nomenclature of the majority of plant groups.
- b) **Generic Name Conservation (Nomina generica conservanda):** It introduced the idea of retaining extensively used, renowned generic names, even if they violated the principle of priority, defending them against older but vague names.
- c) **Mandatory Latin Diagnosis:** The requirement that new plant taxa be accompanied by a description in Latin in order to be legitimately published was a significant accomplishment.
- d) **Rejection of Tautonyms:** The Code explicitly prohibits the use of tautonyms, which are names like *Linaria linaria* that have the same genus and specific epithet. **Standardization of Ranks:** The Code introduced standard, rank-specific endings for suprageneric names, increasing the coherence of taxonomic hierarchies.
- e) **Improved Botanical Nomenclature Structure:** It established a clear, organized set of rules (68 articles) that progressed beyond the simple "recommendations" of prior, less organized initiatives.

Although the 1905 Code was a significant advancement, it is crucial to remember that it did not fully embrace the "type method" for naming, which was developed in later congresses and involved utilizing a particular herbarium specimen as a reference.

PhyloCode (International Code of Phylogenetic Nomenclature) & BioCode (Draft):

They are two separate, evolving biological nomenclature systems that aim to improve Linnaean, rank-based codes (zoological, botanical). Unlike the PhyloCode (International Code of Phylogenetic Nomenclature), the Draft BioCode (2011) aims to unify and rank existing codes.

Draft BioCode (DBC): The first draft was presented in 1996 (ICSEB V in Budapest), revised in 1997 (Draft BioCode 1997), and updated in 2011.

PhyloCode: The first formal workshop at Harvard University was held in August 1998 for PhyloCode, which began in autumn 1997. A draft was posted online in April 2000. Final version, connected to Phylonyms, was published in 2020.

Fundamental Distinctions Between PhyloCode and Biocode

1. A Basic Definition of Taxa

BioCode: Describes taxa according to Linnaean taxonomic ranks (e.g., Family, Genus, Species) and types (a defined specimen or picture).

PhyloCode: This system defines taxa not by ranks or particular type specimens, but by phylogenetic connections (nodes or branches on a tree). Clades, not ranks, are named.

2. Role of Taxonomic Ranks

BioCode: Maintains the use of mandatory, hierarchical ranks for all organisms.

PhyloCode: Is rank-independent. A group is named because it is a clade, not because it deserves a specific rank.

3. Purpose and Scope

BioCode: Aims to harmonize, unify, and simplify the existing, disparate codes of nomenclature (zoological, botanical, etc.) into one.

PhyloCode: Aims to provide an alternative system specifically designed for naming clades, especially in the context of "tree-thinking".

4. Naming Principles

BioCode: Relies on priority (the first validly published name is accepted).

PhyloCode: Focuses on explicit phylogenetic definitions (e.g., "the clade stemming from the most recent common ancestor of A and B").

5. Species Representation

BioCode: Uses binomial nomenclature (Genus + species).

PhyloCode: Does not control the names of species in the traditional sense; it mainly focuses on naming clades (which can include species, but the code doesn't manage the species rank itself).

Brief Comparison of BioCode & PhyloCode

<i>Features</i>	<i>BioCode (Draft)</i>	<i>PhyloCode</i>
<i>Approach</i>	<i>Evolution (unifies existing rules)</i>	<i>Revolution (new approach)</i>
<i>Foundation</i>	<i>Type-based/Linnaean ranks</i>	<i>Phylogeny-based (Clades)</i>
<i>Ranks</i>	<i>Obligatory</i>	<i>Irrelevant/Optional</i>
<i>Goal</i>	<i>Simplify, harmonize codes</i>	<i>Naming evolutionary lineages</i>
<i>Scope</i>	<i>All organisms (except viruses/cultivated plants)</i>	<i>Clades (can be used alongside traditional, or exclusively)</i>

Rules are for the obedience of fools and the guidance of wise men" and "The golden rule is that there are no golden rules".

CHAPTER 3

Systems of Classification in Plant Taxonomy

Chapter Contents:

- Botanical Classification & its types
- Difference between Artificial, Natural & Phylogenetic systems of classification
- Major contributions of Theophrastus, Bauhin, Tournefort, Linnaeus, Adanson, de Candolle, Bessey, Hutchinson, Takhtajan, and Cronquist
- Classification systems of Bentham and Hooker (up to series)
- Engler and Prantl's system of classification (up to series)
- A critical analysis of Engler-Prantl's system:
- Brief reference of Angiosperm Phylogeny Group (APG III) classification
- History of APG
- Problems faced in the existing classification systems before APG & Objective of APG
- APG-I (1998)/APG-II (2003)/An outline of APG-III classification (2009)
- Unplaced Families & Genera in APG-III (2009)
- Subfamilies replacing APG II bracketed families
- APG IV (2016)
- Merits & Demerits of APG

Botanical Classification & its types:

Classification is the division of organisms into distinct groups (or sets) based on the similarities, dissimilarities and their natural and phylogenetic relationships. Botanical Classification types are as follows:

- (i) **Empirical Classification:** Botanists have arranged the plants in this classification in alphabetical (ABC.....) order. The system can be compared to how words are arranged in dictionaries according to alphabetical order. No character was taken into account.
- (ii) **Reasonable Classification:** The plants were grouped together in this classification based on a few natural characteristics that might connect them. The following four categories further divide this type of classification:

(a) Practical Classification: This classification is primarily based on a plant's characteristics, specifically its value or utility to the human race.

(b) Artificial Classification: This is more or less arbitrary because the plants are categorized based on one or a small number of characteristics, which don't reveal anything about the affinities or relationships between the plants. Recent research has revealed that artificial classification, also known as key classification, is a classification scheme designed for ease of use, using phenotypic traits that can be readily observed without necessarily indicating phylogenetic relationships. From 300 B.C. to around 1830, artificial systems of classification that were based on one or a few easily observable characteristics of plants, such as habit (trees, shrubs, herbs, etc.) or floral characteristics predominated (particularly the number of stamens and carpels). Artificial classifications use arbitrary or at least readily observable characteristics, frequently regardless of their affinity. The sexual system of Linnaeus is a good example of artificial classification because it groups plants into 24 Classes based solely on a single characteristic—the number of stamens—and as a result, numerous unrelated taxa that are only superficially related are grouped together under the same Class.

(c) Natural system of classification:

The classification of plants in this system is based on a number of characteristics, including those related to reproductive organs and structural relationships, as well as all other significant characteristics. It aids us in identifying a plant's name as well as its connections to and affinities with other plants. All of the classification schemes used today are natural. According to Charles Darwin's proposed theory of evolution (1859), all living plants today are related to one another in some way because they all evolved from plants that were present in the distant past through a series of adaptations in response to shifting environmental conditions.

Thus, it makes sense to group together plants that are closely related to one another. Natural classification describes this. Therefore, the more characters that different taxa share, the closer they are to one another. The modern classification system is based on this.

(d) Phylogenetic system of classification:

Plants are categorized using this kind of system based on their evolutionary and genetic connections. It enables us to identify any taxon's ancestors or derivatives. All current phylogenetic systems were created by combining natural and phylogenetic evidence because our current knowledge is insufficient to create a perfect phylogenetic classification. The terms Phylogeny, Phylogenetic and Phyletic can be explained as follows:

Phylogeny: Taxa originate from and evolve through phylogeny.

Phylogenetic: It emphasizes how taxa are related to one another historically.

Phyletic: It places a strong emphasis on having a specific line of ancestry (phyletic line).

After Darwin's idea, classification schemes are typically phylogenetic, combining evolutionary interpretations with as many taxonomic traits as feasible. Phylogenetic trees or shrubs indicate the groups' presumed evolution. Natural systems are two-dimensional (based on current facts), unlike phylogenetic classification (Vertical or Evolutionary Classification), which adds the third dimension of previous history or ancestry. But according to Radford (1986), there are four classification schemes:

- (a) **Artificial Classifications:** These systems, such as those of Theophrastus and Dioscorides, use a person's habit and importance to him as taxonomic characteristics.
- (b) **Mechanical Classifications:** These systems, such as those of Caesalpino, Bauhin, Ray, Tounefort, and Linnaeus, group taxa based on one or a few carefully chosen taxonomic characteristics.
- (c) **Natural Classifications:** Natural classification is based on more than just a small number of characters, and mostly the entire character pool is taken into account. It is founded on posteriori taxonomic character weighting. It is based on hidden or diagnostic characters that reveal connections. It is an upward classification that groups related species that are similar to one another and creates a hierarchy of higher taxa by combining taxa of lower rank that are similar to one another. This classification makes it easier to identify their shared ancestors and the missing link. It can clarify relationships between taxa, making it useful for determining phylogenies between various taxa. The most notable authors of this classification system are Ray Lankester (1847-1919), Mayr (1940, '65, '69), Simpson (1961), Mayr and Ashlock (1991), and others. It was first used in the middle of the 19th century.
- (d) **Phylogenetic Classifications:** A classification system based on an organismal group's evolutionary descent is called a phylogenetic system. A phylogenetic tree, cladogram, or phylogram is used to illustrate the relationship.

Difference between Artificial, Natural & Phylogenetic systems of classification

Artificial systems of classification	Natural systems of classification	Phylogenetic systems of classification
It classifies organisms by means of one or a few superficial characters.	It is based on several constant characters that exist in nature.	It classifies organisms according to their evolutionary sequence in addition to several constant characters.

In this type, evolutionary sequence, genetic relationships & ancestors or derivatives, if any, of any organisms or taxon are not considered.	It is not phylogenetic because plants are not grouped according to their evolutionary sequence; instead, plants are placed together on the basis of a correlation of characters in common i.e., on the basis of form-relationships.	In these, natural affinities & relationship of organisms are considered in addition to several constant morphological characters. These classifications reflect genetic relationships & enables one to determine at a glance the ancestors or derivatives (when present) of any organism or taxon.
It classifies organisms as an aid to quick identification.	It serves the practical need by functioning adequately as an aid to easy identification.	These systems are more recent. These are based on presumed phylogenetic relationships & hence widely used.

❖ Major contributions of Theophrastus, Bauhin, Tournefort, Linnaeus, Adanson, de Candolle, Bessey, Hutchinson, Takhtajan, and Cronquist

Major contributions of Theophrastus:

Theophrastus (372 BC to 287 BC) is known as the ***Father of Botany***. He was Aristotle's successor in the Peripatetic school. He was a Greek philosopher who wrote more than 200 manuscripts, most of which are only remembered as pieces or quotes in the works of other people. His work was later translated into English, namely “Inquiry into plants” (1916) and “Causes of plants” (1927). He described 500 types of plants, which were put into four main categories: trees, shrubs, subshrubs, and herbs, and published in “*Historia Plantarum*” which is known as the oldest botanical work. He recognized the differences between flowering plants and non-flowering plants. He actually pointed out the basic differences between dicot and monocot plants. Further, He recognized the superior ovary and inferior ovary, free and fused petals, and also types of fruit.

The original version of *The Enquiry into Plants* had ten books, but only nine of them still exist. The work is set up in a way that groups plants together based on how they grow, where they grow, how big they are, and what they are used for, such as foods, juices, herbs, etc. The first book is about the parts of plants. The second book is about how plants reproduce and when and how to sow seeds. The third, fourth, and fifth books are about trees, their types, where they grow, and how they can be used. The sixth book is about shrubs and spiny plants. The seventh book is about herbs. The eighth book is about plants that make edible seeds. The ninth book is about plants that make useful juices, gums, and resins. From *Kohler's Medicinal Plants*, this is *Cinnamomum verum* (1887).

On the Causes of Plants was written in eight books, but only six of them are still around today. It talks about how plants grow, what affects their fertility, when they should be planted and harvested, how to prepare the soil, how to fertilize it, and how to use tools. It also talks about the smells, tastes, and properties of many different plants. The work is mostly about how plants can be used for money, not how they can be used for medicine, though the latter is sometimes mentioned. There may have been a time when the whole work included a book about wines and a book about how plants smell.

Even though these works have a lot of strange and funny things to say, they also have some good things to say about how plants work and what they are made of. Theophrastus found out how seeds grow and understood how important climate and soil are to plants. Much of the information about Greek plants may have come from his own observations since he is known to have travelled around Greece and had his own botanical garden. But the works also benefit from what Alexander the Great's followers said about the plants of Asia. For example, he knew about the cotton plant, the banyan tree, pepper, cinnamon, myrrh, and frankincense because of what Alexander's followers said.

Theophrastus's Enquiry into Plants was first printed in Latin by Theodore Gaza at Treviso in 1483. In its original Greek, it was first printed by Aldus Manutius at Venice in 1495–98, from a third-rate manuscript that has been lost, like most manuscripts sent to printers in the fifteenth and sixteenth centuries.

Christian Wimmer found two first-rate manuscripts: the Codex Urbinas in the Vatican Library, which J. G. Schneider, who made the first modern critical edition between 1818 and 1821, did not know about, and the excerpts in the Codex Parisiensis in the Bibliothèque Nationale de France.

Summary:

1. The most important of his books are two large botanical treatises, Enquiry into Plants (1916), and On the Causes of Plants (1927), which constitute the first systemization of the botanical world and were major sources for botanical knowledge during antiquity and the Middle Ages. On the strength of these works some call him the "father of botany."
2. Authored more than 200 works most of which survive as fragments or as quotations in the work of other authors.
3. Described about 500 kinds of plants, classified into 4 major groups: the trees, shrubs, sub-shrubs and herbs.
4. Recognised the difference between flowering and non-flowering plants, superior ovary and inferior ovary, free and fused petals and also fruit types.

Major contributions of Gaspard Bauhin:

Swiss botanist Gaspard Bauhin studied plants. He was the one who came up with the idea of Binomial nomenclature. Even though he wasn't well-known for it. In his work, he often used binary nomenclature to talk about plants and made a difference between genus and species. He was the first person to use the binomial system, but he didn't do it, in the same way, every time. He made 4000 herbarium specimens all by himself. He wrote *Phytopinax* (1596), and *Prodromus theatri botanici* (1620). His book "*Pinax Theatri Botanici*" (1623) is a great botanical work and contained a list of 6000 species of plants giving synonyms. It was his last publication. *Summary:*

1. A Swiss botanist was the actual introducer of the Binomial nomenclature (Although he was not popular for the same).
2. He alone can formed 4000 herbarium specimen.
3. He published *Phytopinax*(1596), *Prodromus theatri botanici* (1620), and lastly , *Pinax theatri botanici* (1623) containing a list of 6000 species of plants giving synonyms.

Major contributions of Tournefort:

Elements de Botanique, which contained 698 genera and 10,46 species, was published by him in 1694. His book ***Institutions Rei Herbariae*** is a great botanical work. It is a Latin translation of his work with additions. It was released in 1700. He was possibly the first person to name and describe genera instead of just listing species. His classification scheme was undoubtedly well-liked in Europe in the eighteenth century.

Summary:

1. He published *Elements de Botanique* in 1694, including 698 genera and 10,46 species.
2. A latin translation of this work with additions was published as *Institutions rei herbariae* in 1700.
3. He was perhaps the first to give the names and descriptions of genera, merely listing the species.
4. His system of classification has no doubt popular in Europe during the eighteenth century.

Major contributions of Linnaeus:

Karl Von Linne (1707-1778) was a Swedish botanist. *Species Plantarum* and *Systema Naturae* are his notable works. *Systema Naturae*—published in 1735. In his lifetime, *Systema Naturae* (1st ed. 1735) had 12 editions. This study divided nature into mineral, vegetable, and animal kingdoms. Linnaeus ranked class, order, genus, species, and variety. He classified plants by reproductive elements like stamens and pistils and split those groupings until he reached the lowest set (species), at which point he couldn't divide further. Initially, he classified by class,

genus, and species. In subsequent versions, he introduced fourth-level order. Since then, numerous levels have been added. Biologists still organize creatures using this fundamental concept. His Taxonomy of minerals has dropped long since from use. The Linnaean system, devised by him, classifies species hierarchically by shared physical traits. It uses a taxonomic rank system—Kingdom, Phylum, Class, Order, Family, Genus, Species—and binomial nomenclature to give each species a two-part Latin name. In the tenth edition (1758) of the *Systema Naturae*, the Linnaean classes were:

CLASS	EXAMPLE
Class 1. MONANDRIA	Lemna, Scirpus, Salicornia, Canna
Class 2. DIANDRIA	Salvia, Veronica, lepidium, Olea
Class 3. TRIANDRIA	Many grasses, Iris, Sisyrinchium
Class 4. TETRANDRIA	Ulmus, Mentha, Galium, Prota
Class 5. PENTANDRIA	Primula, Ipomoea, Campanula
Class 6. HEXANDRIA	Alisma, Lillium, Narcissus, Rumex
Class 7. HEPTANDRIA	Aesculus, Trientalis
Class 8. OCTANDRIA	Fagopyrum, Vaccinium, Dirca
Class 9. ENNEANDRIA	Ranunculus, Rheum, laurus, Butomus
Class 10. DECANDRIA	Oxalis, Acer, Rhododendron
Class 11. DODECANDRIA	Asarum, Euphorbia, Reseda, Calla
Class 12. ICOSANDRIA	Rubus, Rosa, Siraea
Class 13. POLYANDRIA	Nymphaea, Tilia, Papaver
Class 14. DIDYNAMIA	Monarda, Linaria, Linnaea
Class 15. TETRADYNAMIA	Cruciferae
Class 16. MONADELPHIA	Members of Geraniaceae & Malvaceae
Class 17. DIADELPHIA	All legumes
Class 18. POLYADELPHIA	Theobronia, Hypericum
Class 19. SYNGENESIA	Asteraceae family, Lobelia, Viola
Class 20. GYNANDRIA	Aristolochia, Orchids
Class 21. MONOECIA	Morus, Typha, Quercus, Carex
Class 22. DIOECIA	Salix, Urtica, Juniperus
Class 23. POLYGAMIA	Many Asteraceae, Acer, Empetrum, Nyssa
Class 24. CRYPTOGAMIA	Algae, Fungi, Bryophyta, Ferns, Pteridophyta

Merit: -It helps in quick & easy identification by means of one or a few characters.

Demerits: -

- ❑ Gymnosperms were placed in the 14th class along with the angiosperm family Labiatae.
- ❑ Monocot & dicot were not considered; so, in many cases families & orders of dicot & monocot were mixed up; e.g., Class 20 (Gynandria) contains Orchids & *Pistia* of monocots & *Grewia*, *Passiflora*, etc. of dicots.
- ❑ No affinity among the families, genera, etc. is established because it is based on 1 or a few superficial characters only, with other characters being ignored.
- ❑ Plants having flowers with 1 stamen of both monocot & dicot were put together in 1 class Monandria e.g., *Globba* (Zingiberaceae-Monocot) & *Mangifera* (Anacardiaceae – Dicot).
- ❑ Benson (1957) commented: “*Certainly it did not contribute anything directly to knowledge of plant relationships but it gives a tremendous impetus to study of the plant kingdom.*”
- ❑ *Due to its simple & convenient approach, this system became very popular for more than 75 years before the publication of the Natural system by A.L.de Jussieu & A.P.de Candolle.*

Linnaeus's other big idea was the Binomial nomenclature. He used two Latin words to indicate the genus and the species. Linnaeus introduced Latin genus and species names in *Species Plantarum* (1753). The first word is capitalized, and both words are in italics. Over time, this system has named all types of living organisms. He changed his name to the Latin name of Carolus Linnaeus. He abandoned long descriptive names of classes and orders and two-word generic names (e.g., *Bursa pastoris*) with single-word names,, provided genera with detailed diagnoses (*Characteres naturales*), and reduced wide varieties to their species, saving botany from horticulturalists' new forms. He is called the “Father of Modern Botany” and “Father of Taxonomy”.

Summary:

1. In 1735 he first published *Systema Naturae* where he introduced his method of classification (sexual system) for plants.
2. He classified plants by their reproductive organs (stamen and pistils) and split them downward until the lowest set (species) was reached, at which time further division was impossible. Later editions added order to his three classification levels (class, genus, and species). Since then, more levels have been added. Biologists still classify organisms using this fundamental concept.
3. Another significant contribution of Linnaeus is the Binomial nomenclature for plant names. Latin designations for plant genuses and species were introduced in his work *Species*

Plantarum (1753). Italicize both words and capitalize the first. This fundamental approach has been used to name all biological creatures historically.

Major contributions of Adanson:

French botanist Michel Adanson lived from 1727 to 1806. He discovered the shortcomings of the Linnean system while investigating the wealth of plants in Africa, and he developed his own system of classification in the two-volume book *Families des Plantes* (1763). He most likely was the first to group genera into 58 families using his own classification, rejecting all artificial systems in favor of a new or natural one. His classifications are comparable to modern orders and families.

In his classic work "*Families des Plantes*" (1763), Michel Adanson (1727–1806) published for the first time a natural system of classification and described taxa that were roughly equivalent to modern orders and families. The concept of the present-day numerical Taxonomy came up with Adanson, which evolved into Neo-Adansonian principles. He is named as Grandfather of Numerical Taxonomy.

Summary:

1. Michel Adanson (1727-1806) in his classical work: "Families des plantes" (1763) published for the first time a natural system of classification and described taxa more or less equivalent to modern orders and families.
2. Present day Numerical Taxonomy is based on the idea conceived by Adanson and now developed into Neo-Adansonian principles.

Major contributions of de Candolle

The "*Theorie Elementaire de la Botanique*" and "*Prodrmus Systematis naturalis regni Vegetabilis*" were publications by Augustin Pyramidus de Candolle in 1813. In his lifetime, he was only able to finish 7 volumes. Later, his famous son Alphonse de Candolle (1806-1893) published the remaining works in 10 volumes of *Prodrum*, the last of which, *Theorie Elementaire*, with 213 families, was published in 1844. 58,975 dicot species and gymnosperms were described in the *Prodrum* at the time. Starting with groups that were polypetalous (*Ranunculaceae*), gamopetalous, and apetalous, the families were arranged in a linear fashion.

The de Candolle system's inclusion of vascular cryptogams among the monocots was one of its major flaws. Despite more than two dozen systems being proposed during this time (1825-1845), the Candolle system dominated plant Taxonomy until 1860. The ease and simplicity of de Candolle's system made it superior to all others.

After Prodrumus, Alphonse and then his son Anne-Casimir (1836–1919) published a monograph series. There have been about 100 of these monographs published, and they still offer a lot of information.

Major contributions of Bessey

Charles Edwin Bessey was an American botanist who was born on May 21, 1845 and lived from 1845 to 1915. He came up with the phylogenetic system for classifying plants. It was called The Phylogenetic Taxonomy of Flowering Plants when it came out in 1915 in the Annals of the Missouri Botanical Garden. In "The Phylogenetic Taxonomy of Flowering Plants," he developed what is now called the "Besseyan system." He didn't agree with the Eichler-Engler theory and stuck to Bentham and Hooker's method. He gave some new ideas about how plants have both simple and complex traits. His plan or system of classification was based on a number of dicta (a set of rules), that were used to figure out how primitive or advanced each group of plants was. Bessey thought that monocotyledons and other groups of dicotyledons evolved from the Ranales, but he also thought that all flowering plants evolved from cycads that didn't have flowers.

Botany for High Schools and Colleges (1880), The Essentials of Botany (1884), and Essentials of College Botany (1914) are all textbooks that he wrote. They were all very popular for more than 50 years and were used to teach botany in the United States. He brought the systematic study of plant shape and the experimental laboratory to college-level botany classes in the United States. Many people think that his arrangement of angiosperm (flowering plant) taxa, which focuses on how primitive forms have changed over time, is the most likely way to build a modern, complete Taxonomy of the plant kingdom. Bessey was the first person to show how evolutionary relationships look like a tree, with the most basic groups at the bottom and the most advanced at the top. This diagram, which looks like a cactus plant, is called the Besseyan Cactus.

Charles Bessey's Natural System of Plant Classification:

- A phylogenetic approach that uses genetic methods to arrange flowering plants.
- Evolution served as the foundation for Bessey's hypothesis.
- His 28 criteria, which illustrate the evolutionary patterns in angiosperms, served as the foundation for "Bessey's cactus."
- The most straightforward route depicts a group's true evolutionary history.
- It was thought that the first flower had several distinct petals, stamens, and carpels.
- As they changed, the flower sections either disappeared, shrank, or fused together.

- Rather than being primitive, the basic structures are the product of a reduction from more complicated components.
- Buttercup flowers, or *Ranunculus*, are an example of a primitive flower.
- The catkin inflorescences are a more sophisticated kind of flowering plant.

Summary:

- a) ***Phylogenetic System:*** He suggested that primitive flowers had numerous free petals and stamens, an idea that is still relevant today, and he created an evolutionary-based classification system, departing from strictly morphological methods.
- b) ***Besseyan System:*** This system identified gymnosperms as distinct from angiosperms, viewed flowers with fused parts (like catkins) as more developed, and attributed the ancestry of angiosperms to the Ranales (buttercup family).
- c) ***Evolutionary Trends:*** He identified key evolutionary trends, like the transition from simple to compound leaves, and the appearance of bisexual flowers before unisexual ones, providing frameworks that are still followed in modern Taxonomy.
- d) ***Foundational Work:*** His last significant study established the framework for contemporary genetic-based classifications.

Major contributions of Hutchinson

John Hutchinson was a British botanist who lived from 1884 until 1972. He worked at the Royal Botanic Gardens in Kew, England. He came up with a way to group plants, which was published in its final form in the third edition of the families of flowering plants (1973).

Hutchinson's earliest work was on aquatic ecosystems, especially the classification and distribution of the Heteroptera aquatic insects. He worked on different parts of evolution later.

John Hutchinson proposed a system that first appeared in Kew bulletins and then in his "*Families of Flowering Plants (1926, 34) and (1959) Vol. I Dicotyledons and Vol. II Monocotyledons.*" His plan is similar to Bessey's in some ways. The new classification by Hutchinson is based on 24 rules that are similar to **Bessey's dicta** and are as follows:

1. Evolution is both upwards and downwards.
2. Evolution does not necessarily involve all organs of the plant at a time.
3. Evolution has generally been consistent.
4. The trees and shrubs are more primitive than herbs in certain groups.
5. In one family or genus, the trees and shrubs are older than the climbers.
6. Perennials are older than biennials and from biennials, the annuals are derived.
7. Aquatic flowering plants are derived from terrestrial ones.

8. Collateral vascular bundles arranged in a ring are a primitive condition e.g., dicots.
9. Spiral arrangement of leaves is a primitive character.
10. Simple leaves are more primitive than compound leaves.
11. Bisexual flowers are more primitive than unisexual.
12. Solitary flowers are more primitive than being arranged in an inflorescence.
13. Spiral arrangement of floral parts is a primitive condition.
14. Polymorous condition is more primitive than definite numbers.
15. Apetalous flowers are derived from petaliferous flowers.
16. Polypetaly is more primitive than gamopetaly.
17. Actinomorphic condition is more primitive than zygomorphic.
18. Hypogyny is more primitive than epigyny and perigyny.
19. Apocarpous condition is more primitive than syncarpous.
20. Many carpelled conditions are more primitive than few or one carpel.
21. Endospermic seeds are primitive.
22. Indefinite number of stamens are in primitive flowers.
23. Separate stamens precede connate stamens.
24. Simple fruits are more primitive than aggregate fruits.

Some noteworthy features of his system:

1. It is phylogenetic and closer to Bentham and Hooker's system.
2. It is based on the assumption that plants with sepals and petals are primitive.
3. Classification is based on definite characters.
4. Flowering plants have been divided into 411 families are recognized.
5. Dicots are kept before Monocots.
6. Gymnosperms are placed separate from Dicots and Monocots.
7. Same as in Engler & Prantl's system.
8. Dicots are not further divided.
9. Monocots divided further into – Calyciferae, Corolliferae, and Glumiflorae.
10. Monocots start with order Butomales and end with Graminales.
11. The primitive polypetalous forms split along two lines.
12. Important publication Families of Flowering Plants (1926-1959).
13. It deals with the classification of flowering plants.
14. Angiosperms evolved monophyletically from possible gymnosperms like Bennettitales.
15. This system emphasizes similarities over differences. Magnoliaceae starts the lignosae line (tree-like habit), and Ranales starts the herbaceous line.
16. Lignosae has 54 orders, from Magnoliales to Verbenales. Magnoliaceae comes first, Verbenaceae last.

17. Herbaceae is divided into 28 orders; starts with Ranales and ends with Lamiales. The first family is Ranunculaceae and the last one is Labiatae.
18. Cucurbitaceae has been placed in Lignosae under Cucurbitales.
19. Compositae is placed under Herbaceae under the order (2nd one) Asterales.
20. Orchidaceae is given a proper position as the last family of Corolliferae.
21. Gramineae is given the highest place as the last family under Glumiflorae.
22. On the assumption that plants with sepals and petals associated with other primitive floral and anatomical characters are more ancient phylogenetically than plants with sepals and petals free floral parts are regarded as primitive and connate parts as more recent.
23. The inclusion of Lignosae and Herbaceae in his latest classification is a flaw that fragments families.
24. Many disagree with Hutchinson's basic idea that Dicots developed from herbaceous Ranales and woody Magnoliales. Insistence on a monophyletic origin from seed plants and angiosperms is another drawback.

Critical analysis of Hutchinson's System:

Hutchinson thought that the angiosperms, like Cycadoidea, might have come from a Bennettitalean stock. On one side, woody arborescent types grew, and on the other side, herbaceous non-woody types grew. They were given the names Lignosae and Herbaceae.

The monochlamydeae was thought to belong to more than one of these groups, so it was left out. The Magnoliales were the most basic of the Lignosae, while the Ranales were the most basic of the Herbaceae.

Families that were otherwise very similar were put into different groups based on whether they were woody or herbaceous. So, the Umbelliferae, which are herbaceous, and the Araliaceae or Cornaceae, which are woody, were split up, even though their flowers were very similar. In the same way, the Labiatae come from the Verbenaceae, which are woody plants, and the Bignoniaceae come from the Scrophulariaceae and Gesneriaceae.

The biggest problem with the system seems to be that it only looks at whether a plant is herbaceous or woody and ignores other features that are just as important.

But Hutchinson deserves credit for the fact that his descriptions of families are very accurate and that he gave a key that is very helpful for figuring out who belongs to a family. Hutchinson's system is not helpful for keeping a herbarium, so no herbaria have used it.

A German botany professor named Karl Christian Mez (1866–1944) came up with the idea that the protein reactions of larger groups of genetically related plants could be used to figure out how they are related to each other. This type of immunology test is called serum diagnosis.

Summary:

1. His important evolutionary classification scheme for flowering plants, detailed in *The Families of Flowering Plants*, greatly influenced plant taxonomy. It divided Dicotyledons into woody (Lignosae) and herbaceous (Herbaceae) groups, emphasizing angiosperm origins from primitive woody forms and evolutionary patterns (trees older than herbs, woody more primitive than herbaceous).
2. Hutchinson's 24 dicta on flowering plant taxonomy are well-known. His 1973 third edition focused on the fact that herbaceous plants, or Herbaceae, are phylogenetically newer than woody plants, or Lignosae.

Major contributions of Takhtajan

A Russian botanist named Armen L. Takhtajan made a system for classifying flowering plants. This system was updated over time, and the most recent update came out in 1997. Phylograms (which were not included in the 1997 version) shows the possible relationships between groups. These groups are shown by balloons or bubbles (hence the name "bubble diagram") of different sizes that show how many species are in each group. Woodland has given it the name "Takhtajan's flower garden" because of the complex bubble diagram and the way it is set up. Flowering plants' origin and dispersal is a classic book that he wrote. Armen L. Takhtajan's (1942) classification system (revised 1966, 1980, 1997) is a major evolutionary plant taxonomy system. Based on evolutionary links, it places Magnoliopsida (dicots) before Liliopsida (monocots) and emphasizes woody lifestyles and Magnoliidae as primordial. His first paper on classification was about the different kinds of gynoecium and placentation structures (1942). In which he gave a very rough phylogenetic tree of the orders of angiosperms. His actual classification system was published in 1954 as an appendix to his book about how angiosperms evolved (English translation published in 1958). Some important changes were made to his general system for classifying angiosperms, which came out in 1959. In 1966, he went into more detail than he did in 1959 about why families and orders were set up the way they were. Since 1966, there have been small changes made to the system of classification. Takhtajan used growth pattern, leaf arrangement, stomatal apparatus, nodal structure, wood anatomy, inflorescences, general floral structure (androecium, pollen grains, carpels, gynoecium and placentation, ovules, pollination, gametophytes and fertilization, seeds and fruits) as his main criteria for judging how far along flowering plants were. Takhtajan, in 1980, split the Division Magnoliophyta, which is made up of angiosperms, into two classes: Magnoliopsida, which includes dicotyledons, and Liliopsida, which includes monocotyledons. He then split Magnoliopsida into 7 sub-classes, 20 super-orders, and 71 orders. He also split Liliopsida, or monocotyledons, into 3 sub-classes, 8 super-orders, and 21 orders. He knows about 92 orders and 410 families of angiosperms in total.

Main features of Takhtajan's System of classification

- a) **Phylogenetic Emphasis:** Treats the Magnoliales as the most primitive group and is frequently acknowledged as a highly significant phylogenetic system. It focuses on the evolutionary history and linkages.
- b) **Division:** The division Magnoliophyta (angiosperms) is split into two separate classes under the system:
- c) **Class:** Magnoliopsida (Dicotyledons), with several subclasses (typically 7 in 1980, 11 in 1997). Liliopsida (Monocotyledons) is a class that has several subclasses (usually three in 1980, five in 1997).
- d) **Structure:** With more smaller, more clearly defined orders and families, it is recognized for having a higher level of complexity than other systems (such as Cronquist).
- e) **Modern Evidence:** Incorporates more than just morphology; it also includes cytology, palynology, phytochemistry, and anatomy.

Important Distinctions and Evolution of the System

- a) 1966 System: Magnoliatae (dicots) and Liliatae (monocots) were used
- b) 1980 Revision: Magnoliopsida and Liliopsida were defined and divided into subclasses, superorders, and orders.
- c) 1997 Version: Based on extensive morphological, embryological, and molecular evidence, it was refined to contain 15 total subclasses (11 dicot and 4 monocot).

Important Guidelines

- a) Woody to Herbaceous: Views herbaceous habits as sophisticated and woody habits as primitive.
- b) Floral Structure: Acknowledges that inflorescences are more advanced than solo flowers.
- c) Evolutionary Origin: Angiosperms are thought to have originated monophyletically from seed ferns (Lyginopteridophyta).

Drawbacks of Takhtajan's Classification:

- 1) **Overly Narrow Taxonomic Definitions:** Due to excessive group splitting, too many families (approximately 592 in the 1997 edition) were created, typically monotypic.
- 2) **Impractical for Identification:** While helpful for evolutionary studies, the approach lacks practical identifying keys and is difficult to utilize for herbarium work.
- 3) **Subjectivity and Cladistic Weighting:** Takhtajan occasionally prioritized theoretical cladistic (branching) knowledge above phenetic (morphological) traits.
- 4) **Debated Evolutionary Paths:** Many recent researchers disagree with his notion that monocotyledons evolved from Nymphaeales (water lilies) stocks.
- 5) **Placement Controversies:** While the 1997 revision is widely accepted, several of his placements are controversial, such as placing Winteraceae and Cancellaceae in distinct groups despite DNA data showing they are closely related.

- 6) **Outdated in Relation to Molecular Data:** The system, which was created in the middle of the 20th century, does not necessarily correspond with current molecular phylogenetic discoveries (such as the APG system).

Merits of Takhtajan's Classification:

- 1) **Strong Phylogenetic Basis:** It is considered one of the most extensively phylogenetic systems, it bases connections on evolutionary progress (e.g., woody habits are primordial, herbaceous are derived).
- 2) **Modern Understanding of Primitive Flowers:** Takhtajan recognized Magnoliidae as the most primitive group and placed dicotyledons before monocotyledons. Contemporary botanists agree with him.
- 3) **'Superorder' Rank:** He created the taxon to efficiently link large 'subclasses' to smaller 'orders,' improving intermediate classification.
- 4) **Integration of Diverse Data:** The system integrates data from anatomy, embryology, cytology, palynology, and paleobotany.
- 5) **Small, Homogeneous Units:** His system's families are small and homogenous, with closely related genera, making them easy to identify for specialists.
- 6) **Compliance with the code:** The code is strictly followed by him.
- 7) **Dicots (Magnoliopsida) are discussed before monocots (Liliopsida).**
- 8) **The Magnoliales, which are the most ancient living angiosperms, are the first group of dicot.**
- 9) **Being the most primitive living order of monocots, Alismatales is the starting point of monocots.**

Summary:

- a) **Phylogenetic System:** Created a detailed system for angiosperms reflecting evolutionary history, a major advancement over purely morphological systems.
- b) **System of Two Classes:** He divided flowering plants into Magnoliopsida (dicots, considered primitive) and Liliopsida (monocots, derived), a basic division still used.
- c) **Hierarchical Classification:** He subdivided these classes into subclasses, superorders, orders, and families, often favoring smaller, more uniform groupings.
- d) **Extensive Proof:** He inferred evolutionary paths using a variety of data, including morphology, anatomy, cytology, pollen (palynology), paleobotany, and biogeography.
- e) **Focus on Primitive Features:** Larger flowers or trees were considered subsequent developments, while primitive features such as small evergreen bushes with simple leaves and small flowers (like *Degeneria*) were identified as ancestral.
- f) **Biogeography:** understanding evolutionary patterns through integrated plant geography.
- g) **Influential Works:** He authored important books such as *Flowering Plants* (2009) and *A System and Phylogeny of the Flowering Plants* (1966).

- h) **Legacy:** Despite differences from later DNA-based systems like APG, his system is still widely used by organizations like the Montréal Botanical Garden. He greatly influenced contemporary botanical categorization by promoting the notion of monophyletic groups and stressing the significance of developmental time (neoteny) in evolution.

Major contributions of Arthur Cronquist

‘An integrated system of classification of flowering plants (1981) was written by him. Cladistics is more important to him. A phylogram in the form of a bubble diagram has been suggested, and only the major groups of angiosperms are shown on it. Cronquist (1981) made a phylogenetic classification based on a wide range of taxonomic traits that were important for phylogenetics. He put the angiosperms families into orders and subclasses all over the world by using synoptic keys and detailed charts. He thought that seed ferns, which are pteridosperms, were probably the ancestors of angiosperms. In this system, the class Magnoliopsida (Dicots) has been split into six subclasses: Magnoliidae, Hamamelidae, Caryophyllidae, Dilleniidae, Rosidae, and Asteridae. The Magnoliidae were thought to be the most basic group, and the other five subclasses were thought to have come from it in their own ways. The group of dicots called Asteridae was the most advanced. In this system, the Class Liliopsida (Monocots) has been split into five subclasses: Alismatidae, Arecidae, Commelinidae, Zingiberidae, and Lillidae. Cronquist (1981) thought that the ancestors of Liliopsida lived in water.

Summary:

The Cronquist System of Classification: His system offered a thorough, contemporary classification of flowering plants (angiosperms) based on evolutionary (phylogenetic) principles and evidence from anatomy, morphology, cytology, and phytochemistry. It was published in a number of texts, most notably *The Evolution and Classification of Flowering Plants* (1968, 2nd ed. 1988) and the seminal work *An Integrated System of Classification of Flowering Plants* (1981). It separated flowering plants into two major classes: Liliopsida (monocotyledons) and Magnoliopsida (dicotyledons). Major botanical projects like the *Flora of North America*, *Flora of China*, and the *Jepson Manual* embraced the method extensively, and many botanists began to use it as a standard reference.

Influential Publications and Floristics:

- He was a prolific writer and a primary author or co-author on several key botanical works.
- He was the primary co-author of the five-volume *Vascular Plants of the Pacific Northwest* (1955-1969).
- He co-authored *Manual of the Vascular Plants of the Northeastern United States and Adjacent Canada* (1963; 2nd ed. 1991) with Henry Gleason.

- These floristic studies provided essential tools for ecologists, foresters, and the general public to identify plants in a given geographic region.

CLASSIFICATION SYSTEM OF BENTHAM AND HOOKER

Bentham and Hooker's system of classification is the well-developed natural system. It was published in *Latin* in a 3-volume monumental work "*Genera Plantarum*" (1862-83). In this, 202 orders, which are now called families, were described. The 1st volume was published in July 1862 and the 3rd volume was published in April 1883. However, George Bentham was responsible for nearly two-thirds of the published work on the classification. It was a refinement over the systems proposed by A.P.de Candolle & Lindley, which in turn were based on that of de Jussieu. The delimitation of families & genera was based on *natural affinities* & was *pre-Darwinian* in concept.

Special features of this system: -

1. It is a classification of only the seed plants.
2. Seed plants were numbered 97,205 Species & distributed among 202 families starting with *Ranunculaceae* & ending with *Gramineae*
3. Monocots are placed after dicots.
4. Gymnosperms, the 3rd seed plant taxon, fall between dicot and monocot.
5. Creation of Disciflorae, a taxon not described by earlier taxonomists.
6. The authors did not mention anything about the Origin of angiosperm.
7. Among the Monochlamydeae, major taxa, like the series was divided on the basis of terrestrial & aquatic habits.

They divided the Seed plants (Phanerogams) into 3 *Classes*: - Dicotyledons, Gymnospermae & Monocotyledons. Dicotyledons were further subdivided into 3 *Subclasses*: - Polypetalae, Gamopetalae & Monochlamydae. These *Subclasses*, in turn, were subdivided into *Series*. Series were further divided into *Cohorts* [=Orders], Cohorts into *Natural Orders* [=Families], Natural orders (N.O.) into *Genera* & finally Genera into *Species*. In ***Polypetalae*** (15 cohorts) flowers are with 2 whorls of perianth while the inner whorl of corolla lobe is free [petals free]. It is further subdivided into 3 Series, namely Thalamiflorae, Disciflorae & Calyciflorae. The series are further subdivided into orders & families. In ***Gamopetalae*** (10 i.e., 3+3+4 cohorts) flowers are with 2 whorls of perianth, the inner whorl is gamophyllous (gamopetalous). It is further subdivided into 3 Series, namely Inferae, Heteromerae & Bicarpetatae with orders & families. In ***Monochlamydae*** (36 N.O.) flowers are mostly with a single whorl of perianth. It is further subdivided into 8 series bearing families directly. Dicotyledons consist of **61 cohorts** [Starting with *Ranales* & ending with *Unisexuales*] & **163 Natural orders** or families [starting with *Ranunculaceae* & ending with *Ceratophyllaceae*]. Monocotyledons are divided into 7

series starting with *Microspermae* & ending with *Glumaceae*. Monocots consist of 34 Natural orders starting with *Hydrocharitaceae* & ending with *Gramineae*. No cohorts were recognized within Monocotyledons & Monochlamydae, the series being directly divided into Natural orders (families). Gymnosperms are placed in between the dicots & monocots. They are divided into 3 families namely *Cycadaceae*, *Coniferae* & *Gnetaceae*.

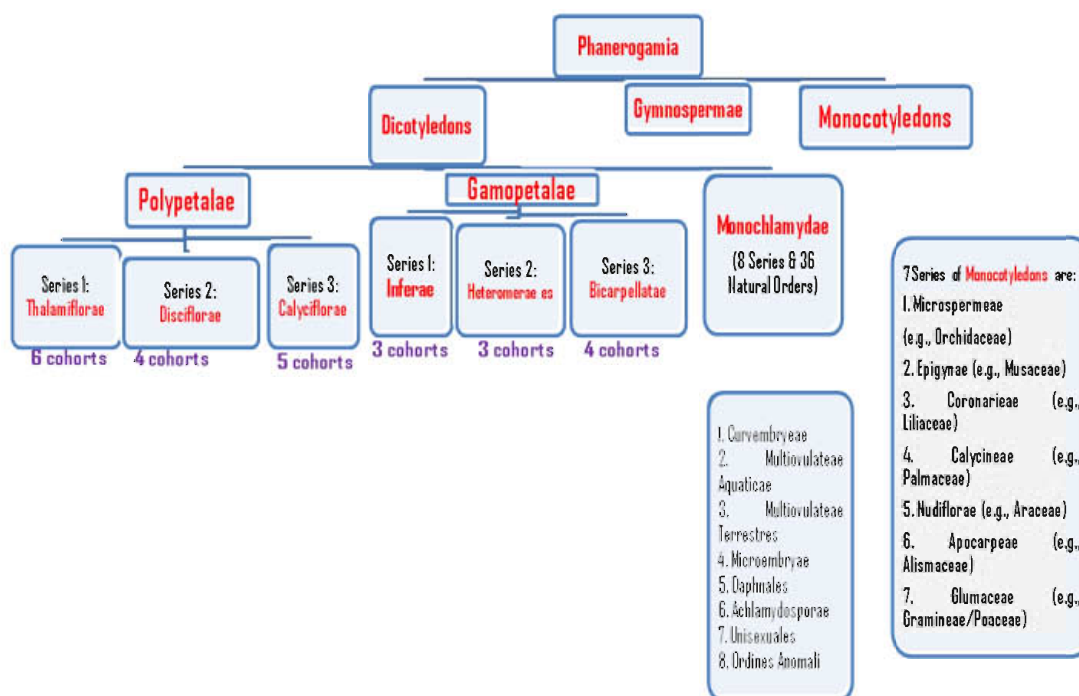


Fig: A brief Outline of Bentham & Hooker's system.

List of major families as per Bentham & Hooker's classification

In *Genera Plantarum* (1862–1883), Bentham & Hooker classified seed plants (Phanerogams) into 202 natural orders (now families) of Dicotyledons, Gymnosperms, and Monocotyledons. Here is the list of families (Natural Orders) arranged by class, subclass, and series:

1. Subclass: Polypetalae (Free petals)

Series 1: Thalamiflorae (Hypogynous flowers, petals free, stamens many)

Families: Ranunculaceae, Dilleniaceae, Magnoliaceae, Annonaceae, Menispermaceae, Berberideae, Nymphaeaceae, Cruciferae, Papaveraceae, Capparideae, Violaceae, Malvaceae, Sterculiaceae, Tiliaceae, etc.

Series 2: Disciflorae (Disc present below ovary, ovary superior)

Families: Geraniaceae, Rutaceae, Simarubeae, Meliaceae, Sapindaceae, Anacardiaceae, Rhamnaceae, etc.

Series 3: Calyciflorae (Perigynous or epigynous, flowers often with calyx tube)

Families: Leguminosae, Rosaceae, Saxifragaceae, Crassulaceae, Droseraceae, Myrtaceae, Cucurbitaceae, Umbelliferae, Araliaceae, etc.

2. Subclass: Gamopetalae (Fused petals)

Series 1: Inferae (Ovary inferior)

Families: Rubiales (Rubiaceae), Asterales (Compositae/Asteraceae), Campanales (Campanulaceae)

Series 2: Heteromerae (Ovary superior, carpels > 2)

Families: Ericales (Ericaceae), Primulales (Primulaceae), Ebenales (Sapotaceae)

Series 3: Bicarpellatae (Ovary superior, carpels = 2)

Families: Gentianales (Gentianaceae), Polemoniales (Solanaceae, Convolvulaceae), Personales (Scrophulariaceae), Lamiales (Labiatae/Lamiaceae)

3. Subclass: Monochlamydeae (Incomplete flowers, perianth single)

Series & Families: Curvembryae (Polygonaceae, Chenopodiaceae), Multiovulatae Aquaticae (Podostemaceae), Multiovulatae Terrestres (Aristolochiaceae), Daphnales (Laurineae), Achlamydosporeae (Loranthaceae), Unisexuales (Euphorbiaceae, Urticaceae), Ordines anomali.

I. Class Gymnospermae (3 Families)

Placed between Dicots and Monocots.

Families: Gnetaceae, Coniferae, Cycadaceae

II. Class Monocotyledonae (34 Families)

Characterized by one cotyledon, parallel venation, and trimerous flowers.

Series 1: Microspermae (Orchideae/Orchidaceae, Burmanniaceae)

Series 2: Epigynae (Scitamineae, Bromeliaceae, Irideae, Amaryllideae, Dioscoreaceae)

Series 3: Coronariae (Liliaceae, Pontederiaceae, Commelinaceae)

Series 4: Calycinae (Palmae/Arecaceae, Juncaceae)

Series 5: Nudiflorae (Aroideae, Typhaceae, Lemnaceae)

Series 6: Apocarpae (Alismaceae, Naiadaceae)

Series 7: Glumaceae (Gramineae/Poaceae, Cyperaceae)

Merits of Bentham & Hooker's system: -

1. It is the first great natural system of classification.
2. It has great practical value for plant identification. It is easy to use and suited for everyday identification.
3. It is widely followed for the arrangement of specimens in the herbaria of most countries including India & Britain [also in Kew herbarium] for its practical utility.
4. Every genus & species was studied from actual specimen in British & continental herbaria & descriptions were made on their detailed study & dissections etc. So, it is not a mere compilation of known facts.
5. Dicots began with Ranales. Recent taxonomic studies support it.
6. Monocots are placed after dicots.
7. Placing of Gamopetalae after polypetalae is justified.
8. In Gamopetalae, heteromae is rightly placed before Bicarpellatae.
9. The 3 series (Thalamiflorae, Disciflorae & Calyciflorae) show gradual evolutionary advance from marked hypogyny to epigyny passing through perigynous condition.
10. Addition of Disciflorae & a total new arrangement of dividing certain groups on basis of aquatic & terrestrial characteristics of plants.
11. Greater emphasis has been laid on the contrast between free & united petals e.g., dicot divided into 3 subclasses - Polypetalae, Gamopetalae & Monochlamydae.
12. Among monocots greater emphasis has been given to the relative position of the ovary & the characters of the perianth.
13. Treating Cucurbitaceae & Umbelliferae at the end of Polypetale as connecting links between poly & gamopetalous families.
14. Creation of Monochlamydeae at the end of Dicots.
15. Inclusion of disputed families among *Ordines anomaly*.
16. The Description of families & genera are precise. Keys to the identification are very useful. Larger genera have been divided into subgenera in order to facilitate identification.
17. The arrangement of taxa is based on overall natural affinities decided on the basis of morphological features, which can be easily studied with the naked eye or with a hand lens.

Demerits of Bentham & Hooker's system:

1. Origin of angiosperm is not clear.
2. It is not phylogenetic. Though it was published after the publication of Darwin's theory, it does not incorporate phylogeny.

3. Placing of Gymnosperms in between dicot & monocot is anomalous.
4. Monochlamydeae is regarded as an artificial group (recognized on the basis of 1 character, namely the presence of a single whorl of perianth). The creation of this group resulted in the separation of many closely related families. Few examples are undermentioned.
 - All the families of Series Curvembryae are related to Caryophyllaceae of series Thalamiflorae of Polypetalae.
 - Laurineae of Series Daphnales is related more to family Magnoliaceae of Ranales.
 - Nepenthaceae of Series Multiovulatae terrestres (of Monochlamydeae) is related more to family Saraceniaceae of Parietales of Thalamiflorae.
 - Chloranthaceae, Myristicaceae & Monimiaceae are related to Cyclanthaceae.
5. Retention of Polygonaceae, Nyctaginaceae, Amaranthaceae, Chenopodiaceae in Monochlamydeae is also unnatural because these are related to the orders having differentiated perianth.
6. In Gamopetalae, Inferae with an inferior ovary is placed before the other 2 series having a superior ovary. The inferior ovary is now considered to be derived from a superior ovary.
7. The entire arrangement of monocots is unnatural & unphylogenetic in this system. In the class monocotyledons –
 - Advanced families like Orchidaceae & Scitamineae were placed at the very beginning. But these should not be regarded as primitive with so many advanced characteristics.
 - Liliaceae & Amaryllidaceae were kept apart though they are closely related.
 - Iridaceae & Amaryllidaceae are more akin to Liliaceae but were placed with Scitamineae or Bromeliaceae due to epigynous flowers.
 - Juncaceae which is associated with Palmae should be placed close to Liliaceae.
 - Hydrocharitaceae was put together with Orchidaceae under Microspermae due to small seed but should be placed in Aquatic orders with non-endospermic seeds.
 - Euphorbiaceae was placed in Monochlamydeae though it is related to Malvaceae of Polypetalae.
 - Many large families e.g., Urticaceae, Euphorbiaceae, Liliaceae & Saxifragaceae are unnatural assemblages & represent polyphyletic groups. These have rightly been split by subsequent authors into smaller, natural & monophyletic families.
 - The position of series Apocarpae with free & superior carpels is unsatisfactory
 - Unisexuales is a loose assemblage of diverse families which share only 1 major character i.e., unisexual flowers. Cronquist (1988) separates these families under 2 distinct subclasses Hamamelidaceae & Rosidae and Takhtajan (1987) under Hamamelidaceae & Dilleniaceae.
 - In the use of the terminology of different taxa there is no uniformity.

- The system divides angiosperms into dicotyledons & monocotyledons, whereas the modern phylogenetic systems place paleoherb families & Magnoliids before monocotyledons & Eudicots.

Points to remember: In Bentham & Hooker's system:

- 1st & last families in Dicot are Ranunculaceae and Ceratophyllaceae respectively.
- 1st & last families in Monocot are Hydrocharitaceae and Gramineae respectively.

Engler and Prantl's system of classification (up to series):

Adolf Engler (1844-1930) was a *Professor* at the University of Berlin & Director of the Berlin Botanical Garden and Karl Prantl (1849-1893) was his close associate. They jointly published this monumental work in “*Die Natürlichen Pflanzenfamilien*” (between 1887-1915) in 20 volumes and provided keys & descriptions of all the plant families known to them at that time. They classified all the plants from algae to angiosperms. This system is largely based on the earlier little-known system of Eichler.

This scheme was continuously revised by Engler & continued by his followers after his death, the latest 12th edition appearing in 2 volumes, 1954 [ed. H. Melchior & E. Werdermann] & 1964 [ed. H. Melchior]. In this huge book, details about the appearance, anatomy, and economics of different families, as well as many illustrations and keys to the genera covered in a phylogenetic way, were given. Engler & Prantl's system has been described as a transitional phylogenetic system by Jones & Luchsinger (1987). But Radford (1986) & most other taxonomists described it as a phylogenetic system. This system often considered the beginning of phylogenetic schemes, was not strictly phylogenetic in the modern sense. It was an arrangement of linear sequence starting with the simplest groups & arranged in the order of progressing complexity. In doing so, unfortunately, Engler misread angiosperms, where in many groups; the simplicity is a result of the evolutionary reduction. In this scheme of classification, the plant kingdom was divided into 13 divisions (in the 11th edition of *Syllabus der Pflanzenfamilien* published in 1936, 14 divisions & in the 12th edition edited by Melchior 17 divisions were recognized) of which the first 11 dealt with thallophytes, the 12th Embryophyta asiphonogama (no pollen tube) included Bryophyta & Pteridophyta. The 13th & last division of Embryophyta siphonogama (pollen tube developing) included seed plants and is subdivided into two subdivisions – the Gymnospermae and Angiospermae. The subdivision Angiospermae is further divided into Monocotyledonae and Dicotyledonae.

Monocotyledonae was divided into 11 series, beginning with *Pandanales* & ending in *Microspermae* & 45 families. Dicotyledonae was divided into 2 main subclasses viz., Archichlamydeae & Metachlamydeae (*Sympetalae*); the former contains 33 series, beginning from *Verticillatae* & ending in *Umbelliflorae* with 199 families. *Metachlamydeae* contains 11 series, beginning from *Diapensiales* & ending in *Campanulatae* with 56 families. Each Series

in turn contains several families. Among the monocots the first family is *Typhaceae* & the last one is *Orchidaceae*. In *Archichlamydeae* the first family is *Casuarinaceae* & the last one is *Cornaceae*. In *Metachlamydeae* the first family is *Diapensiaceae* & the last one is *Compositae*.

Most noteworthy features of the system -

1. Placed Monocots before Dicots.
2. *Gymnosperms* were placed before *Angiosperms*.
3. *Group Monochlamydeae* was abolished & its members were distributed along families *Betulaceae*, *Fagaceae*, *Juglandaceae*, etc. in the dicots.
4. Families of higher vascular plants are arranged according to the increasing complexity.
5. *Polypetalae* & *Monochlamydeae* merged into a single sub-class *Archichlamydeae*.
6. Dicots were divided into *Archichlamydeae* consisting of apetalous & polypetalous families & *Metachlamydeae* consisting of gamopetalous families.
7. Considered apetalous & catkin-bearing dicots primitive to the dicots bearing petals & simple unisexual flowers.
8. *Fusion of petals* represented more highly evolved stage.
9. Creation of *Tubiflorae* as the 6th order of *Metachlamydeae* & creation of *Helobiales* as the 2nd order for aquatic families are the merits of this system.
10. Considered *Orchids* to be more evolved than *Grasses*.
11. Recognized (more than) 280 families of flowering plants including *Gymnosperms*.

Engler & Prantl divided the plant kingdom into 14 divisions. (In the 11th edition of *Syllabus der Pflanzenfamilien* published in 1936)

- I. Division Schizophyta
- II. Division Myxothallophyta [Class Myxomycetes]
- III. Division Flagellatae
- IV. Division Dinoflagellatae
- V. Division Bacillariophyta
- VI. Division Conjugatae
- VII. Division Heterocontae
- VIII. Division Chlorophyceae
- IX. Division Charophyta
- X. Division Phaeophyceae
- XI. Division Rhodophyceae
- XII. Division Eumycetes (Fungi)

XIII. Division Embryophyta asiphonogama (Subdivisions Bryophyta & Pteridophyta)

XIV. Division Embryophyta siphonogama (Subdivisions Gymnospermae & angiospermae)

Merits of Engler & Prantl's system: -

1. Broad treatment of the entire plant kingdom with excellent illustrations & phylogenetic arrangement.
2. Provided with exhaustive keys of families & orders.
3. Amalgamation of Polypetalae & Monochlamydeae into 1 subclass Archichlamydeae is justified.
4. Monochlamydeae is completely *abolished*.
5. Juncaceae, Iridaceae & Amaryllidaceae are placed judiciously nearer to Liliaceae.
6. Gymnosperms are treated separately unlike Bentham & Hooker's system.
7. Considering Asteraceae & Orchidaceae are the most highly evolved families & placing them at the end of dicot & monocot respectively is justified.
8. Description of each family also contains a *summary* of embryology, morphology, anatomy & geographical distribution.
9. Many large unnatural families of Bentham & Hooker have been split into smaller & natural families. The family Urticaceae is thus split into Urticaceae, Ulmaceae & Moraceae.
10. Consideration of gamopetalous condition as advanced over polypetalous condition is in line with current phyletic views.
11. The terms cohort & natural order have been replaced by the order & family of the appropriate terms, respectively.
12. The classification, being very thorough has been widely used in textbooks, Floras & herbaria around the world.

Demerits of Engler & Prantl's system:

1. The system is not a phylogenetic one in the modern sense. Many ideas of Engler are now outdated.
2. Monocots have been placed before dicots.
3. They start monocots with the unisexual apetalous Pandanales.
4. Glumiflorae was placed in 4th order among monocots.
5. Dicots derived from Gymnosperm i.e., Cycadeoidea (Bennettitales).
6. The relationship of apetalous families of angiosperms (Pandanales, Helobiae etc in monocots & Amentiferae of dicots) with Gnetales like ancestor is not fully convincing.

7. Placing of Helobiae in between 2 more advanced orders Pnadanales & Glumiflorae.
8. Amentiferae & Centrospermae have been placed at the beginning of dicots even before Ranales.
9. Araceae inserted a long way before Liliaceae from which it has been derived.
10. Derivation of bisexual flowers from unisexual ones is unsatisfactory.
11. Acceptance of the derivation of Dichlamydeous flowers from monochlamydeous ones is objectionable.
12. The derivation of free-central placentation from parietal and axile placentation contradicts floral architecture. Free-central placentation may have developed from axile placentation when septa disappeared.
13. Chalazogamy is given too much importance.
14. Fossil evidence gives little support to this system.
15. Obscure phylogenies of angiosperms families. Angiosperms were considered a polyphyletic group. Most recent evidence point towards the monophyletic origin.
16. Cucurbitaceae was treated as the last but one family among dicots & placed before Campanulatae in Sympetalae.
17. *Engler overlooked the close link between Cucurbitaceae and Passifloraceae in Sympetalae and put them in a different order, Cucurbitales, due to their continuous gamopetalous flowers. This method ignores reduction, therefore, according to Cronquist, "simple" was equated with "primitive".*

A critical analysis of Engler-Prantl's system:

Engler's system is based on what he thinks a "primitive flower" is like. It thought that the flower of an angiosperm came from a strobilus of a gymnosperm. The ancestor of strobilus was either megasporangiate or microsporangiate, and its sporophylls were also of this type. In angiosperms, which can be either staminate or pistillate, it made the catkin type of flower. This type of flower gave rise to the bisexual type. So, Engler put the Amentiferae at the beginning of the group of plants called Archichlamydeae. Here, the flowers were either without petals or had a single bract that looked like a perianth. Some people thought that the dichlamydeous and sympetalous (gamopetalous) families were more advanced. Engler considered that the gymnosperms gave rise to the Amentiferae on the one hand and the monocots on the other. So, Angiosperms had more than one ancestor. In fact, Engler never thought that evolution happened in a straight line, so he never tried to draw an evolutionary tree.

A number of botanists have criticized the idea that Amentiferae is a primitive group. They have shown that the anatomy and other features of this group are better understood as the result of reduction than as a primitive state.

So, Amentiferae would be a very specialized group made up of bisexual and dichlamydeous flowers. But Helsop-Harrison said as recently as 1957 that all unisexual angiosperms don't have to have come from bisexual types, and that it could even be an old trait. So, this point is still not clear. Richard von Wettstein (1862-1931), was an Austrian systematist. In most ways, his classification was the same as Engler's. He thought that the dicotyledons were the oldest plants and that the monocotyledons came from them through the Ranales. In general, his system of phylogenetic classification was much better than that of Engler.

Conclusion: This system became very popular like Bentham and Hooker's system & is still used in most of the non-British herbaria of the world (Europe & North America). Most continental herbaria are arranged by it and numerous floras like *Flora of Europaea* (1964-1980) followed this system. It is the first angiosperm system to take anatomical data into account.

Table: Distinctions Between Engler-Prantl & Bentham-Hooker Systems

Features	Bentham & Hooker's System	Engler & Prantl's System
<i>Type of System</i>	Natural system	Phylogenetic system based on evolutionary trends.
<i>Based on</i>	A.P de Candolle's system (1818)	Eichler's system
<i>Published book</i>	Genera plantarum (1862-1883)	Die natürlichen Pflanzen families (1887-1915)
<i>Classifying plant group</i>	Phanerogam was classified	Entire plant kingdom was classified
<i>Sequence</i>	Dicotyledons→Gymnosperms →Monocotyledons.	Gymnosperms→Monocotyledons→ Dicotyledons.
<i>Phylogeny</i>	Not considered; based on fixity of species.	Evolutionary tendencies are the foundation.
<i>Primitive Flower</i>	Bisexual with a distinct perianth (petals/sepals).	Unisexual, naked/single whorled flowers (Amentiferae).
<i>Dicot Classification</i>	Polypetalae→Gamopetalae →Monochlamydeae	Monochlamydeae→Archichlamydeae
<i>Monocots Start</i>	Microspermae (e.g., Orchidaceae).	Glumiflorae (e.g., grasses) or primitive forms.
<i>Placement of Gymnosperms</i>	Between Dicots and Monocots.	Placed before Monocotyledons.
<i>Origin of angiosperms</i>	Bennettitalean origin	Unisexual, anemophilous, flowers are considered primitive (like Amentiferae)

<i>Most primitive & Highly advanced dicot family</i>	Ranunculaceae & Labiatae (or, in some contexts, Compositae) respectively	Casuarinaceae & Compositae respectively
<i>Most primitive & Highly advanced monocot family</i>	Orchidaceae (series Microspermae) & Gramineae (Glumaceae)	Typhaceae (order Pandanales), & Orchidaceae (order Microspermae) respectively
<i>Total families</i>	202 (Flowering plants)	280 (Flowering plants) in 1964 syllabus (Engler & Diels)
<i>Application</i>	Widely used in British Commonwealth Countries (Kew Herbarium).	Widely used in Europe and America.

Brief reference of Angiosperm Phylogeny Group System

The Angiosperm Phylogeny Group system (APG System) was the first iteration of a contemporary plant Taxonomy that was largely based on molecular evidence. It was first published in 1998 under the name APG I, followed by APG II in 2003 and APG III in 2009. APG classification is primarily based on the synthesis of information about the relationships between angiosperms, which was obtained using morphological and molecular data as well as phylogenetic methods. The APG classification scheme should only acknowledge monophyletic groups. A clade is used more broadly above the level of orders and families. Only those groups where monophyly has been firmly established have been given the benefits of the APGAPG system based on the principle of monophyly, phylogenetic, anatomical, embryology, phytochemistry, and molecular formal name. The traditional division of angiosperms into monocots and dicots has been abandoned in an effort to lessen the paraphyly issue. Various monocot groups have been positioned between early dicots and modern dicots. APG classification has the drawback of being limited to taxonomic levels of only order and family. APG classification doesn't have many practitioners. Classification by Phenetics Sneath & Sokal presented the phenetic classification in 1973. Phenetic classification makes use of all phonetic relationship similarity based on information from all available sources, including morphology, ultrastructure studies, and other pertinent fields of study. The Angiosperm Phylogeny Group (APG) system is the first version of a modern system for classifying plants that are mostly based on DNA. The Angiosperm Phylogeny Group published it in 1998. It was replaced by the better APG II system in 2003, the APG III system in 2009, and the APG IV system in 2016.

History

The original APG system is unusual because it is not based on all the evidence, but on the cladistic analysis of the DNA sequences of three genes: two chloroplast genes and one ribosome gene. Even though it is only based on molecular evidence, its groups are supported by other evidence as well. For example, the difference in the shape of pollen between eudicots

and the rest of the former dicotyledons is supported by other evidence. When it comes to families, the system makes some decisions that are a bit controversial. For example, it splits up some long-standing families and merges others. It is also unusual that botanical names are not used above the level of order. In this system, an order is the highest level that has a formal botanical name. The only way to talk about higher groups is in terms of clades, which have names like monocots, eudicots, rosids, and asterids.

To remember: The APG system was changed in 2003 when the APG II system came out. In 2009, the APG III system came out, and in 2016, the APG IV system came out.

What are the problems faced in the existing classification systems before APG?

- ☐ The rapid increase in molecular evidence that led to many proposed changes,
- ☐ Stability of the previous classifications was altogether lost,
- ☐ Prior angiosperm classifications were not based on monophyletic groups
- ☐ Posed problems for all users of angiosperm classification systems.

Objectives of APG:

- To provide a widely accepted and more stable angiosperm classification.
- Their first attempt was a new system of classification published in 1998 (APG-I).
- As of 2016, 4 incremental versions of the classification system resulted.
- Published in 1998, 2003, 2009 and 2016.

Eight taxonomists have been listed as authors for the APG classification, namely:

1. Birgitta Bremer (Swedish Academy of Sciences),
2. Kåre Bremer (Uppsala University),
3. Mark W. Chase (Royal Botanic Gardens, Kew),
4. Michael F. Fay (Royal Botanic Gardens, Kew),
5. James L. Reveal (University of Maryland),
6. Douglas E. Soltis (University of Florida),
7. Pamela S. Soltis (Florida Museum of Natural History),
8. Peter F. Stevens (University of Missouri).

In addition to these 8 lead authors, 33 taxonomists are listed as contributors.

The APG system of classification is mainly based on the synthesis of knowledge, from morphological to molecular data, about the relationships of angiosperm using phylogenetic methods.

APG-I (1998)

- 462 families of Angiosperms
- 40 putative monophyletic orders
- 10 informal monophyletic higher groups (a few families without assignment to order)
- In the beginning, 11 unclassified families
- Direct 4 orders with no supraordinal groups
- At the end, additional 25 families of uncertain position

In 1999:

- Modifications of APG by Judd et al., 1999
- Total 51 orders recognized
- Some families were shifted from informal groups
- Lists only major families
- About 200 families left out

APG-II (2003)

- After 5 years of publication of APG Classification
- Updated version & further improvements
- Recognized 457 families – [5 less than APG-I (1998)]
- 45 orders [5 more than APG-I (1998)]
- Within 457 families, there are 55 optional segregates (presented in square brackets)
- 44 orders placed in 11 informal groups
- 40 unplaced families [81 in APG-I (1998)]

An outline of APG-III classification (2009)

A number of informal groups (i.e. clades) have been recognized, in which 55 orders are distributed in the latest version of APG-III classification system. These clades include:

- (1) MAGNOLIIDS
- (2) MONOCOTS
- (3) COMMELINIDS
- (4) EUDICOTS
- (5) CORE EUDICOTS
- (6) ROSIDS
- (7) FABIDS
- (8) MALVIDS (EUROSIDS-II)

(9) ASTERIDS

(10) LAMIIDS (EUASTERIDS-I)

(11) CAMPANULIDS (EUASTERIDS-II)

- Recognized 59 orders (adding 14 to APGII), 415 families (42 less than APGII),
- 4 orders (**Amborellales, Nymphaeales, Austrobaileyales, Chloranthales**) have been placed at the start of the classification without any informal clade name.
- Remaining 55 orders assigned to 11 clades or groups
- Order Ceratophyllales considered as probable sister of Eudicots
- **Taxa of Uncertain position** – Cynomoriaceae, Apodanthaceae & genera Gumillea, Petenaea & Nicobariodenron
- Concept of bracketed families (making APG II unpopular) abolished

Unplaced Families in APG-III (2009): Dasypogonaceae, Sabiaceae, Dilleniaceae, Boraginaceae, Vahliaceae, Icacinaceae, Metteniusaceae, Oncothecaceae, Apodanthaceae & Cynomoriaceae

Unplaced Genera in APG-III (2009): Gumillea, Petenaea & Nicobariodenron

LAPG & LAPG III

- Haston et al (2007) developed LAPG based on APG II classification.
- List of 479 families
- Revised LAPG for APG-III classification as LAPG III & considered 413 families
- Many European herbaria agreed to adopt LAPG.
- Accepted by RBG Kew, RBG Edinburgh, The Natural History Museum (London) etc to rearrange their herbarium collections.

Comparison

- In APG III, Families are alphabetically arranged in clades.
- In LAPG III, Families within clades are recognized.
- With respect to unplaced orers & families at the beginning, orers sequence in LAPG is similar to that of APG III but families are re-organized.
- In Magnoliid clade, Magnoliales are followed by Laurales vice versa in APG-III.
- In the clade Monocots, orders are in the same sequence as that of APG III. In Commelinids, Zingiberales are followed by Poales, vice versa in APG III.
- Unplaced Dasypogonaceae is retained in the same clade, but kept in between Zingiberales & Poales which were kept at the beginning in APG III.

- Ceratophyllales & Ceratophyllaceae position as probable sister of Eudicots is unchanged.
- Even unplaced Sabiaceae is retained same position between Ranunculales & proteales.
- There is no change in Rosid taxa.
- In Fabids & Malvids, sequence of orders is changed.
- In Asterids, sequence of orders is unchanged.
- In Lamids, sequence of orders is changed.
- In APG III, 5 unplaced families kept at the beginning, while in LAPG III 3 families are kept in the beginning & other 2 placed between Gentianales & Solanales.

A BRIEF OUTLINE OF THE APG III CLASSIFICATION

Clade Angiosperms

Order Amborellales
 Order Nymphaeales
 Order Austrobaileyales
 Order Chloranthales

Clade Magnoliids

Order Canellales
 Order Laurales
 Order Magnoliales
 Order Piperales

Clade Monocots

Order Acorales
 Order Alismatales
 Order Asparagales
 Order Dioscoreales
 Order Liliales
 Order Pandanales
 Order Petrosaviales

Clade Commelinids

Family Dasypogonaceae—unplaced in an order
 Order Arecales

Order Commelinales
Order Poales
Order Zingiberales
Probable sister of eudicots
Order Ceratophyllales

Clade Eudicots

Family Sabiaceae—unplaced in an order
Order Buxales
Order Proteales
Order Ranunculales
Order Trochodendrales

Clade core eudicots

Family Dilleniaceae—unplaced in an order
Order Gunnerales
Order Saxifragales
Clade Rosids
Order Vitales

Clade Fabids (eurosids I)

Order Celastrales
Order Cucurbitales
Order Fabales
Order Fagales
Order Malpighiales
Order Oxalidales
Order Rosales
Order Zygophyllales

Clade Malvids (eurosids II)

Order Brassicales
Order Crossosomatales
Order Geraniales
Order Huerteales
Order Malvales

Order Myrtales
order Picramniales
order Sapindales (back to core eudicots)
order Berberidopsidales
order Caryophyllales
order Santalales

Clade Asterids

Order Cornales
Order Ericales

Clade Lamiids (euasterids I)

Family Boraginaceae—unplaced in an order
Family Vahliaceae—unplaced in an order
Family Icacinaceae—unplaced in an order
Family Metteniusaceae—unplaced in an order
Family Oncothecaceae—unplaced in an order
Order Garryales
Order Gentianales
Order Lamiales
Order Solanales

Clade Campanulids (euasterids II)

Order Apiales
Order Aquifoliales
Order Asterales
Order Bruniales
Order Dipsacales
Order Escalloniales
Order Paracryphiales

Taxa of uncertain position in APG III

- Apodanthaceae Takht. (Three genera, now in Cucurbitales)
- Cynomoriaceae Endl. ex Lindl.
- Gumillea Ruiz & Pav.

- Petenaea Lundell (now in Huerteales)
- Nicobariodendron (see Simmons, 2004; probably in Celastraceae).

Phylogeny

The APG III system was based on a phylogenetic tree for angiosperms that included all 59 orders and 4 families that couldn't be put in any of the other groups. The systematic positions of the other six families that couldn't be placed were so unclear that they couldn't be put in any of the tree's polytomies. Four of them are in the group called Euasterids I, and the other two are in a group called Taxa of uncertain position.

The phylogenetic tree shown below was published with the APG III system, but without some of the labels that are shown here.

Subfamilies replacing APG II bracketed families

APG II bracketed family	APG III family: subfamily
Agapanthaceae	Amaryllidaceae: Agapanthoideae
Agavaceae	Asparagaceae: Agavoideae
Alliaceae	Amaryllidaceae: Allioideae
Amaryllidaceae	Amaryllidaceae: Amaryllidoideae
Aphyllanthaceae	Asparagaceae: Aphyllanthoideae
Asparagaceae	Asparagaceae: Asparagoideae
Asphodelaceae	Xanthorrhoeaceae: Asphodeloideae
Hemerocallidaceae	Xanthorrhoeaceae: Hemerocallidoideae
Hesperocallidaceae	Asparagaceae: Agavoideae
Hyacinthaceae	Asparagaceae: Scilloideae
Laxmanniaceae	Asparagaceae: Lomandroideae
Ruscaceae	Asparagaceae: Nolinoideae
Themidaceae	Asparagaceae: Brodiaeoideae
Xanthorrhoeaceae	Xanthorrhoeaceae: Xanthorrhoeoideae

Development of the APG system

Three additional APG classifications were released in 2003, 2009, and 2016. Each was set up by several persons. APG IV is the product of a September 2015 Kew workshop with ten compilers and 15 collaborators from six nations. An online survey helped reveal how botanists and other classification users worldwide felt about it (Christenhusz et al., 2015). APG has listed uncertain families and genera in each edition. This list included 25 families in 1998 but just seven genera in 2016. As more plants and DNA regions are investigated, our

understanding grows. Both official and informal higher-level groupings have increased. This suggests families are becoming more secure in their bonds. Based on published research, APG IV has separated Petenaea into its own family (Petenaeaceae), given Kew its own family (Kewaceae) while it was part of Hypertelis in Molluginaceae, and rearranged other problematic families. The Metteniusaceae, which had one genus before, received numerous genera from the Icacinaceae.

APG IV (2016)

- In the development of a fourth version there was some controversy over the methodology, and the development of a consensus proved more difficult than in previous iterations.
- In particular Peter Stevens questioned the validity of discussions regarding family delimitation in the absence of changes of phylogenetic relationships.
- Further progress was made by the use of large gene banks, including those of plastid, mitochondrial and nuclear ribosomal origin, such as that of Douglas Soltis and colleagues (2011).
- The fourth version was finally published in 2016. It arose from an international conference hosted at the Royal Botanical Gardens in September 2015 and also an online survey of botanists and other users.
- The system includes new orders (Boraginales, Dilleniales, Icaginales, Metteniusiales, and Vahliales), new families (Kewaceae, Macarthuriaceae, Maundiaceae, Mazaceae, Microteaceae, Nyssaceae, Peraceae, Petenaeaceae, and Petiveriaceae), and reclassification of some families.
- Due to nomenclatural issues, the family name Asphodelaceae is used instead of Xanthorrhoeaceae, and Francoaceae is used instead of Melianthaceae.
- Total 64 orders and 416 families
- Two additional informal major clades, superrosids and superasterids, that each comprise the additional orders that are included in the larger clades dominated by the rosids and asterids are also included.
- APG IV also uses the linear approach (LAPG) as advocated by Haston *et al.* (2009) In a supplemental file Byng *et al.* provide an alphabetical list of families by orders.

Updates

- ❖ Peter Stevens, one of the authors of all four of the APG papers, maintains a web site, the Angiosperm Phylogeny Website (APWeb), hosted by the Missouri Botanical Garden, which has been regularly updated since 2001, and is a useful source for the latest research in angiosperm phylogeny which follows the APG approach.

- ❖ Other sources include the Angiosperm Phylogeny Poster and The Flowering Plants Handbook

- **Summary table of APG-IV Classification (changes from APG III to APG IV)**

<i>Feature</i>	<i>APG III (2009)</i>	<i>APG IV (2016)</i>	<i>Major Change Significance</i>
<i>Total Orders</i>	59	64	<i>Added 5 new orders</i>
<i>Total Families</i>	415	416	<i>Slight increase, better resolution</i>
<i>New Orders</i>	-	<i>Boraginales, Dilleniales, Icaciniales, Metteniusales, Vahliales</i>	<i>Higher-level reorganisation</i>
<i>Parasitic Families</i>	<i>Unplaced (some)</i>	<i>Cynomoriaceae, Apodanthaceae placed</i>	<i>Resolved problematic taxa</i>
<i>Family Reorganisation</i>	<i>Icacinaceae (broad)</i>	<i>Split to Icaciniales & Metteniusaceae</i>	<i>Improved monophyly</i>
<i>Family Mergers</i>	<i>Xanthorrhoeaceae</i>	<i>Substituted for Asphodelaceae</i>	<i>Nomenclatural update</i>
<i>Family Mergers</i>	<i>Melianthaceae</i>	<i>Included in Francoaceae</i>	<i>Increased circumscription</i>
<i>New Families</i>	<i>Included in others</i>	<i>Peteneaeaceae, Kewaceae, Macarthuraceae, Microteaceae</i>	<i>Based on new data</i>
<i>Uncertain Position</i>	<i>Numerous</i>	<i>Only 7 genera listed</i>	<i>Increased stability</i>
<i>Informal Clades</i>	<i>Rosids/Asterids</i>	<i>Added Superrosids, Superasterids</i>	<i>Refined relationships</i>

Merits of APG

1. It adopts the phylogenetic principle of monophyly.
2. It has derived information from sources like morphology, embryology, anatomy, palynology, and phytochemistry & more strongly on molecular biology.
3. Formal names are given only where monophyly has been firmly established.
4. The orders, such as Amborellales, Nymphaeales, Austrobaileyales, Chloranthales, which show several primitive features, are placed at the start of the APG classification.
5. A no. of cladograms presented for general affinities between the groups.
6. The number of unplaced and uncertain families has been gradually reduced from APG-I (40) to APG-III (10).
7. The concept of bracketed families in APG II finally abandoned in APG III (2009).
8. The merger of Asclepiadaceae with Apocynaceae.
9. The merger of Buddlejaceae & Myoporaceae with Scrophulariaceae.
10. Winteraceae & Canellaceae brought together under the same order.

11. Recognition of Capparaceae as distinct family. Earlier it was merged with Brassicaceae.
12. Major changes have been carried out in the circumscription of several orders and families, which was also supported by some workers in the past.
 - (a) For instance, Liliaceae (*sensu lato*) has been split into several monophyletic families: Liliaceae (*sensu stricto*), Alliaceae, Asparagaceae, Asphodelaceae, etc.
 - (b) Similarly, circumscription of Malvaceae (*sensu stricto*) has been broadened to include Tiliaceae, Sterculiaceae and Bombacaceae, thus forming a monophyletic Malvaceae (*sensu lato*).
 - (c) Circumscription of Agavaceae (*sensu stricto*) has been strengthened to include genera like Hosta, Camassia & Chlorogalum.
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 - (c) Circumscription of Agavaceae (*sensu stricto*) has been strengthened to include genera like Hosta, Camassia & Chlorogalum.
14. It is based on the recent advances in research and is gaining authority.
15. It is well known that a classification system presents a viewpoint prevailing at a particular time, based on the recent advances in research.
16. The APG classification is increasingly becoming an authoritative point of reference and a significant number of major herbaria, including Kew, Harvard, etc. are arranging their plant specimen collections in accordance with APG.

Demerits of APG

1. Limited to the taxonomic levels of order and family only.
2. It is not very popular in practice in herbaria & flora.
3. Several Families or Genera have not been placed yet.
4. The orders are recognized under informal groups (e.g., Magnoliids, Eudicots, and Core Eudicots etc.). These names do not conform to the ICN.
5. Division rank given to Angiosperms. No formal order-division taxa.

“Anyone who stops learning is old, whether at twenty or eighty. Anyone who keeps learning stays young. The greatest thing in life is to keep your mind young.” — Henry Ford

CHAPTER 4

Tools and Techniques in Taxonomy

Chapter Contents:

- Plant identification keys: Construction and usage of Taxonomic Keys
- Single Access key, Punched Card Keys, Dichotomous key
- Two main Types: Nested/Indented/Yoked Key & Bracketed/Linked/Parallel/Open Key
- Differences between Indented/Yoked Key Vs Bracketed/ Parallel Key
- Other Variations of the Dichotomous Key
- Construction of a Dichotomous Key
- How to Use a Dichotomous Key
- Tips for Effective Use of a Dichotomous Key
- Multi-access key in plant identification
- How does a polyclave key operate?
- Example of polyclave key and How to Use It?
- Principal benefits of polyclave key
- Examples of some renowned online multi-access keys
- Taxonomic Literatures: Types of Taxonomic Literature: Taxonomic Indexes, Flora and e-Flora, Manual, Monographs, Revisions, Conspectus, Icones, Taxonomic Journals, Dictionaries and Glossaries
- Differences: Floras Vs. Manuals, Floras Vs. Catalogues, Manual Vs. Monograph, Manual Vs. Catalogue, Revision Vs. Monograph
- Modern Digital Resources
- Botanical Gardens: Important features, Essential tasks, Difference from parks or normal gardens, Important roles, Specific functions, Examples of some world Botanical Gardens, Examples of some Indian Botanical Gardens
- Brief notes on CAL, Loyd's Botanical Garden (Darjeeling) & National Botanical Research Institute (NBRI)
- Herbarium: Definitions, Methodology, functions, Ethics and Rules, Examples
- Short Notes: Wallichian catalogue, Index Kewensis, IPNI, Virtual herbarium, Role of Botanical Survey of India, Index Herbarium

Plant identification keys: Construction and usage of Taxonomic Keys

In plant identification, taxonomic keys are ordered and contrasted couplets that direct users to a plant's name. They are built based on logical, persistent criteria, such as flower parts or leaf form, rather than ambiguous phrases or seasonal characteristics. Applying dichotomous (two-choice) systems, such as indented or bracketed keys, usage means following the pair of alternatives (leads), choosing the relevant statement, and moving through the key until the organism's identification is made clear. *Statements in the keys are based on the characters of the plants.* Jean Baptiste Lamarck first published taxonomic keys in 1778. These keys aid in the prompt identification of unrecognizable organisms/plants. They come in two different kinds - Single Access key and Multi Access key.

Single Access key

A single access key is an identification key in which the key's developer fixes the order and structure of the identification processes. They have a tight relationship with self-balancing binary search trees or decision trees. Always an option between two contradicting claims is presented. One is rejected and the other receives approval. Each sentence is called LEAD and single pair of lead is called couplet. In indented key/yoked key indents the couplet's leads equally from the left margin. 1 and 1' or 1a and 1b are the indications for the two options, on the other hand, in bracket key both selections are shown side by side. Choices may be numbered/lettered.

Punched Card Keys:

Students utilize punched card keys in schools, universities, and other institutions. Punched card keys consist of cards of sufficient size with names of all the taxa (all families, genera, species for which the key is designed) printed on each one of them. Each card contains a number and any one character written at one of the corners. All the taxa exhibiting this feature are indicated by a hole in front of their names, whereas those missing this character are without any perforation.

Dichotomous key:

A dichotomous key is a scientific method to identify organisms/plants by following a series of paired, contrasting statements (couplets) that split options in half. It guides you step-by-step to a specific identification through a process of elimination, similar to a flowchart, using observable traits like "woody" vs. "herbaceous" to narrow down choices until the specimen's name is revealed. To utilize one, begin with the first pair, select the appropriate description, and proceed as directed (usually to the final name or another couplet). Repeat this process until identification is complete.

Two main Types of dichotomous keys:

The two main formats for dichotomous keys are:

1. Nested/Indented Key: Indented lists place the next step below the previous one.

- ❖ Configuration: A list where the next choice is physically positioned directly just below the previous choice, frequently by means of indentation to explain the hierarchy.
- ❖ Application: Compact and competent for printing, even if can be harder to follow visually for some users.

❖ Example:

- 1. Plant has flowers
 - 2a. Flowers are red.....Species A
 - 2b. Flowers are pink.....Species B
- 1. Plant lacks flowers
 - 3a. Plant has leaves.....Species C
 - 3b. Plant has scales.....Species D

2. Bracketed/Linked/Parallel/Open Key: It prints each couplet together and directs to a different question elsewhere in the text. These styles are frequently used in conjunction with visual Branching Tree/Flowchart styles, which provide a diagrammatic, tree-like structure for simpler visual tracking. The flowchart presents a clear visual path, linked keys combine relevant choices, and compact keys typically use an indented list.

- ❖ Configuration: in this case, all the couplets are written separately; choosing one lead directs user to a different, specific line or number somewhere else in the key.
- ❖ Application: It keeps related choices together, and is excellent for longer keys.
- ❖ Illustration: A bracketed key displays contrasting features side-by-side for easy comparison.

❖ Example:

- 1a. Plant has flowers.....Go to 2
- 1b. Plant lacks flowers.....Go to 3
- 2a. Flowers are red.....Species A
- 2b. Flowers are pink.....Species B
- 3a. Plant has leaves.....Species C
- 3b. Plant has scales.....Species D

This approach, widely used for practical reasons, displays choices together, making identification quick by tying traits like flower color (red/pink) to specific leaf features (e.g., leathery vs. glossy) for various species.

Differences between Indented Key Vs Bracketed key

<i>Points/Features</i>	<i>Indented</i>	<i>Bracketed</i>
<i>Alternative Term</i>	<i>Yoked Key/Nested key</i>	<i>Parallel Key/open/linked key</i>
<i>Structure & Layout</i>	<i>Choices are indented (set to the right) progressively.</i>	<i>Choices are kept together, side-by-side (parallel).</i>
<i>Space Efficiency</i>	<i>High (uses more space, inefficient).</i>	<i>Low (compact, space-efficient).</i>
<i>Visual link</i>	<i>Indented keys offer a better visual depiction of the link between various taxa.</i>	<i>These connections are not visibly represented by bracketed keys.</i>
<i>Comparison</i>	<i>Difficult to compare alternatives.</i>	<i>Easy to compare alternatives directly.</i>
<i>Usage Context</i>	<i>Used to show taxonomic relationships/subgroups.</i>	<i>Usually used in modern manuals for speed.</i>
<i>Numbering</i>	<i>Usually uses 1a, 1b or 1, 1'.</i>	<i>Requires firm numerical/lettering system.</i>

Other Variations of Dichotomous key

- a) **Branching Tree/Flowchart Key:** It is a visual, tree-like illustration where paths branch off at each decision point, directing to identifications. It is very visual and intuitive, clearly presenting the decision path, but it can take up more valuable space.
- b) **Pictorial/Diagrammatic Keys:** For clarity, it includes diagrams with the text.
- c) **Hyperlinked Keys:** Digital keys that use hyperlinks for navigating, as in e-books.

Construction of a Dichotomous Key:

- a) **Choose Your Group:** Decide which organisms/plants you want to identify.
- b) **Identify Key Characters:** List reliable, distinguishing features (e.g., leaf arrangement, floral parts, flower color, presence of thorns) that separate the plants you want to identify.
- c) **Identify Major Differences & Form Couplets:** Start with the most general characteristic that splits your items into two roughly equal groups.
- d) **Form Binary Choices:** Write two contrasting statements for each step. Use "1a" and "1b," "2a" and "2b," etc. (e.g., "Leaves simple" vs. "Leaves compound").
- e) **Sequence & Structure:** Arrange the couplets sequentially, with the lead at each step directing to the next relevant couplet, reducing possibilities until a single plant remains.
- f) **Identify Unique Items:** Continue splitting until only one item matches a description, then name it.

- g) **Test Your Key:** Use the key to identify every item in your original collection to ensure it works correctly and leads to accurate results. If it fails, revise your characteristics or the order of your questions.

Choose a Format:

- a) **Indented (Yoked) Key:** Displays the choices with increasing indentation, making it visually clear which options belong together.
- b) **Bracketed (Parallel) Key:** Uses numbers/letters to link the 2 options, often accessible side-by-side.

How to Use a Dichotomous Key

- a) **Critically observe the plant Specimen:** Carefully examine the unknown plant, noting its overall form, leaves, flowers, fruits, bark, and habitat (wet/dry, sun/shade, shape, color, texture, presence of parts).
- b) **Start at the Beginning:** Always commence at Couplet 1.
- c) **Choose a Statement:** Select the statement from the pair that best describes your plant.
- d) **Follow the Direction:** The chosen statement will lead you to the next couplet number or directly to the name of the plant (e.g., "go to step 3").
- e) **Repeat:** Continue this process, working through sequential couplets, making choices narrowing down options with each decision and following directions until you reach the final identification. When a statement leads directly to a plant's name, you've identified it;
- f) **Verify:** Make sure the final identification makes sense by checking that all "yes" or "no" answers precisely describe your plant specimen.

Tips for Effective Use of a Dichotomous Key

Before You Begin:

Observe the plant Specimen Thoroughly: Take note of all physical characteristics before looking at the key. For living things, observe features like color, shape, size, and structure. For plants, observe leaf arrangement (alternate or opposite) and margins.

Understand Key Terms: Familiarize yourself with the terminology used in the key. Refer to a glossary if necessary to understand structural terms like "lobed," "compound," or "serrated".

Gather Tools: Use magnifying glasses (14X – 20X is perfect) or microscopes for examining small structures, and a ruler for measuring specific features if measurements are provided.

While Using the Key:

Start at the Beginning: Always begin at step 1 and follow the sequence. Do not skip steps.

Evaluate both the Choices: Consider both options in each couplet carefully, even if the first one seems to fit.

Use Observable, Objective character: Focus on concrete, visible trait rather than subjective ones. Use descriptions like "2 pairs of stamens" rather than "small no. of stamens".

Don't Guess: If a choice is unclear, re-examine the plant specimen. Guessing will likely direct to wrong identification.

Consider Multiple Samples: While identifying plants, look at more than one plant specimens to account for natural variation, as some individuals might not fit the description flawlessly.

Finalizing Identification:

Verify the Result: Once you reach an identification, read the description of that organism/object to ensure it matches your specimen.

Re-Key if Unsure: If the final description does not match, go back through the key to identify where a wrong turn might have been taken.

Understand Limitations: If a specimen does not seem to fit any category, it may be because the key is incomplete or does not cover that specific species.

Best Practices:

Use Specific Tools for the Job: Use specialized, regional keys (e.g., "Trees of the Pacific Northwest") for more accurate results than generic, all-encompassing keys.

Try the "Reverse" Test: If you know what the object is, use the key to see if it leads to the correct identification. This tests the accuracy of the key itself.

Multi-access key in plant identification:

(Synonyms: Polyclave or Multiple-access or Random-access or Matrix or Tabular key)

A *Multi-access* key is a versatile tool that allows users to quickly eliminate options by selecting plant features (leaf shape/flower color) in any order. This is in contrast to traditional dichotomous keys, which impose a predetermined order of choices. This makes polyclave keys easy to use, quick, and perfect for computerization to identify plants when only one or a small number of options are left.

Note: Unlike traditional dichotomous keys, which require a sequential choice, a polyclave key for plants allows you to select any feature (such as leaf shape, flower color, or habitat) to begin

identifying a plant through elimination. This makes polyclave keys ideal for computers and users who are unsure of what to look at first. For instance, you may choose "Yellow Flowers" (listing species A, C, and F) and then "Opposite Leaves" (listing species C, G, and H), removing A and F, then C and H, until only one plant is left, as in the Australian Acacia key in Lucid software.)

How does a polyclave key operate?

- a) Multiple Choices: You see a list of traits (e.g., "Leaves opposite," "Petals 5," "Fruit a berry") rather than paired opposed assertions (couplets).
- b) Selection: You choose every trait your plant specimen possesses. Elimination: The list is immediately made smaller by the key, which eliminates any species that lack those selected traits.
- c) Iteration: Until you obtain a single identification, you keep choosing additional characteristics, which narrow the pool of possible plants.

Example of polyclave key: Determining the Pollination System of a Flower (Simplified): In this example, the pollination type of a plant is determined by a list of characters and their potential "states" (properties).

States & Characters:

Flower Color:

- a. White/Pale (WI, FM, MO)
- b. Yellow (BE, BU, BI)
- c. Red/Orange (BI, BU, BA)
- d. Purple/Blue (BE, BU)

Nectar:

- a. Present (WI, FM, BE, BA)
- b. Absent (MO, BU, BI, FS)

Scent:

- a. Strong, sweet (BE, BU)
- b. Foul/Rancid (FS)
- c. Faint/None (WI, FM, MO, BI, BA)

How to Use It (Elimination Process):

- a) **Choose a Character:** You see your unknown flower is Yellow.

- b) **Your list now:** BE, BU, BI (Bee, Butterfly, Bird pollination).
- c) **Select an Alternative:** Nectar is present, as you can see.
- d) **Remove from your list:** 'BU' (Butterflies often need nectar, but some key states eliminate it, let's say BU isn't strongly linked to nectar in this key, or better, use the list from the example: 'b. present...WL,FM,BE,BA', so we keep BE).
- e) **The next item** on your list is BE (Bee pollination).
Select another Alternative (Optional Check): The scent of the flowers is sweet and strong.
- f) **Remove from your list:** 'BE' is a match, thus there is nothing to rule out.
- g) **Result:** This result indicates that your flower is probably bee-pollinated (BE).

Principal benefits of polyclave key:

- a) **Multi-Entry Identification (Start Anywhere):** Users can begin with any character on the specimen that is easiest to see or most noticeable. Because it permits "multi-entry" it is easier for novices to use. They are especially helpful for incomplete specimens because they do not have to adhere to a strict, predetermined character order.
- b) **Flexibility and Usability:** Because polyclav keys can be used in either direction, they are typically quicker and easier to use than dichotomous keys, especially for novices.
- c) **Quick Elimination:** They operate using the elimination concept. A rapid, effective identification method is made possible by selecting a trait, which instantly rules out a significant number of wrong species.
- d) **Computer-friendly:** These keys are easily computerized and perfect for online, digital, and interactive applications that can process a large number of characters and taxa.
- e) **Perfect for Missing Data:** A user can bypass characters that are seasonal, poorly developed, or might not exist because they don't need to follow a precise order.
- f) **Easy to Update:** Synoptic keys enable the addition or removal of species and traits without requiring a complete rewrite, as contrast to dichotomous keys, which necessitate a significant rewrite to add new taxa or characters.
- g) **Increased Accuracy:** They can result in more accurate identifications because they are based on more than two characters.

Examples of some renowned online multi-access keys

- WATTLE Acacias of Australia Lucid Web Player (multi-access key for identifying Australian Acacias)
- Lucid multi-access key: Weeds of Australia Identification Tool. Queensland Government. (1021 species, 55 characters)

- Lucid Online Player - EUCLID Eucalypts of Australia (917 species/subspecies Taxonomy as of December 2009).
- Museum Victoria Delta keys to Squat Lobster Identification (require the Delta program to be downloaded)

TAXONOMIC LITERATURES

Taxonomy is a science that is mostly about describing and documenting things. It has a lot of literature, and that literature is such an important part of its structure that anyone who wants to identify an unknown plant, solve a nomenclatural puzzle, or do a monographic or floristic study needs to know about the most important publications on the subject. Taxonomic literature has always been one of the most important parts of botanical literature, which is hard to classify. This section will try to give examples that show what the subject is all about. Taxonomic literatures cover all written and graphic representations related to classification, identification, naming, description, and relationships of organisms and taxa, whether published or unpublished. Taxonomic literature refers to the vast collection of published written documents (books, journals, manuscripts, etc.) and visual records used as sources of valuable information for the identification, classification, and naming of plants. *A selective guide to botanical publications and collections with dates, commentaries and types* (Stafleu et al. 1921). According to Porter (1967) “***Taxonomic literature runs the gamut from ponderous volumes to obscure notes in periodicals and even letters of correspondence between workers***”. Various forms of literature in Taxonomy are described below:

Types of Taxonomic Literature

1. TAXONOMIC INDEXES

The catalogues prepared to depict a synoptical background of the work done in the subject are called TAXONOMIC INDEXES. Some are related to plant names while some serve as guide to taxonomic literature. Taxonomic indexes, (like the Index Kewensis), help scientists identify, confirm, and classify the world's plant diversity and understand evolutionary relationships by providing quick access to scientific plant names, their original publication details, and their classification (family, genus, etc.). Modern biodiversity informatics relies on these indexes to manage biological information, link alternative names, and disambiguate name uses.

Important Roles of Taxonomic Indexes:

- a) **Name verification:** Confirming whether a scientific name has been accurately given and published or not.

- b) **Locating Original Publication:** Identifying original source of a plant's name.
- c) **Classification Aid:** Using a plant's name to determine its taxonomic rank (family, genus, or species).
- d) **Information Management:** The underlying element of digital systems that handle enormous volumes of biological data.

Some Notable Examples of Taxonomic Indexes:

- a) **Index Kewensis (IK):** Maintained by the Royal Botanic Gardens, Kew, the Index Kewensis (IK) is a foundational botanical publication and database that painstakingly indexes all published names for seed plants (gymnosperms and angiosperms) from 1753 onward, providing authors, publication details, and locations. It is currently accessible digitally and incorporated into the International Plant Names Index (IPNI). It serves as a crucial reference for botanists by listing names that are not necessarily accepted.



Title page of the first volume of Index Kewensis



A plate of Geranium robertianum L. from Flora Londinensis

- a) **Index Londinensis:** A vascular plant illustration index that offers citations to published photos. It was prepared by W.C. Worsdell under the guidance of Arthur W. Hill.
- b) **Gray Herbarium Index:** The names of native New World phanerogams and vascular cryptogams are listed in the Gray Herbarium Card Index.
- c) **Current Advancements:**

- d) **Taxonomic indexing:** involves the process of managing digital biological data by connecting synonyms and homonyms within hierarchical schemes using network services and expert knowledge.
- e) **NameBank:** A particular system designed to establish a registry of names for every organism as part of taxonomic indexing.

2. FLORA & e-Flora

A flora is a kind of taxonomic literature that presents a thorough, methodical inventory and description of plants in a specific geographical area (such as a nation, state, or valley) or for a significant plant category. By describing species, habitats, geographical distribution, and frequently presenting identification keys and illustrations, it serves as an essential tool for plant identification, biodiversity research, and conservation. Unlike manuals that concentrate just on identification or monographs that thoroughly cover a single genus or family, it serves as an overview of plant life for a particular region, detailing species, their names, descriptions, habitats, and distributions.

Important Features of a Flora:

- a) **Area-Specific:** covers a certain region (e.g., North American or British Indian flora).
- b) **Systematic Arrangement:** A recognized classification system (such as Bentham & Hooker or Engler) is used to list plants.
- c) **Content:** Commonly used diagnostic keys for identification, together with scientific names, author citations, synonyms, descriptions, habitat information, and distribution.
- d) **Goals:** to facilitate biodiversity research, assist botanists and plant lovers in identifying plants, and support conservation initiatives.

Types of Flora (by Scope):

- a) **Local/Regional:** Smaller regions, like a city, valley, or mountain range (Nilambur Flora).
- b) **National:** includes the entire nation (Indian Flora).
- c) **Continental:** includes the entire continent (Flora Europaea).

Examples of Flora:

Regional Flora:

- Bengal Plants. 2 vol., D. Prain (1903)
- Flora of British India by J.D. Hooker (1872-1897)
- The Flora of Eastern Himalaya – H. Hara (1963)

- The Flora of Assam – 5 vols., kanjilal et al., 1934-40
- The Flora of the presidency of Bombay – T. Cook (1901-1908)

District Flora:

- Herbaceous Flora of Dehradun, CSIR, New Delhi – Babu, C.R.
- Flora of Delhi- Maheshwari, J.K. (1963, 1966)
- Flora of Bhopal –Oomachan, M (1977)

Continental Flora (cover entire continent):

- Flora Europaea by T.G.Tutin et al., (1964-80)
- Flora Australiensis by G.Bentham (1863-1878)

Forest Flora:

- The forest trees of Travancore. London. –Bourdillon, T.F. (1908)
- A forest Flora of the Andaman Islands – Parkinson, C.E.

Main difference between Floras Vs. Manuals:

Features	Manual	Flora
<i>Definition</i>	Manuals are handbooks giving information for the identification of species names within a certain location, functioning as a guide for local flora or animals.	A flora is a kind of taxonomic literature that presents a thorough, methodical inventory and description of plants in a specific geographical area (such as a nation, state, or valley) or for a significant plant category.
<i>Scope & Focus</i>	Identification tools are the main emphasis of manuals; concise & user –focused;	Flora acts as an exhaustive record of plant life (habitat/distribution); detailed & often extensive;
<i>Primary Aim</i>	Identification of plant species	Documentation of plant species
<i>Content</i>	Identification keys and descriptions are the main topics of manuals.	Flora offers comprehensive ecological data and botanical traits.
<i>Complexity</i>	These are typically handbooks with identification keys.	Floras are often comprehensive, multi-volume books
<i>Example</i>	Manual of Cultivated Plants	Flora of British India

Main difference between Floras Vs. Monographs:

Features	Flora	Monograph
<i>Definition</i>	A flora is a kind of taxonomic literature that presents a thorough, methodical inventory and description of plants in a specific geographical area (such as a nation, state, or valley) or for a significant plant category	Monographs are thorough, detailed scientific studies that give entire, in-depth information on a particular, unique taxonomic group (e.g., a genus or family)
<i>Scope & Content</i>	Geographical (area-centric); offers comprehensive data on habitat, distribution and botanical identification of plant specimens	Taxon-based (taxon-centric)
<i>Usage</i>	For identification of plants found in a specific, or local area	For deep specialized research on single genus or family (in-depth treatment)
<i>Example</i>	Flora of Delhi, Flora of British India	A monograph on the family Poaceae

Main difference between Floras Vs. Catalogues:

Features	Flora	Catalogue
<i>Definition</i>	Flora is a detailed book used to identify and learn about plants	Catalogue is a checklist used to verify the presence or inventory of species in an area
<i>Primary Aim</i>	Description & identification of plant specimens	Inventory & listing of plants
<i>Scope</i>	Geographical (area-centric)/ Regional	Local/collection checklist
<i>Content</i>	Provides comprehensive technical data, illustrations, and botanical identification of plant specimens	It is less descriptive
<i>Identification</i>	Almost always includes dichotomous keys to allow identification of plant species	Does not contain keys to identify plants.
<i>Structure</i>	Arranged in a scientific/ taxonomic order	Usually arranged alphabetically rather than taxonomic order
<i>Details</i>	Includes information on habitat, ecology, and exact distribution within the area	Contains minimal to no descriptions; focuses on listing names
<i>Keys for identification</i>	YES, included	NO, not included
<i>Example</i>	Flora of Delhi, Flora of British India	Seed catalogs from Baker Creek Heirloom Seeds, Botanical records like <i>Hortus Bengalensis</i>

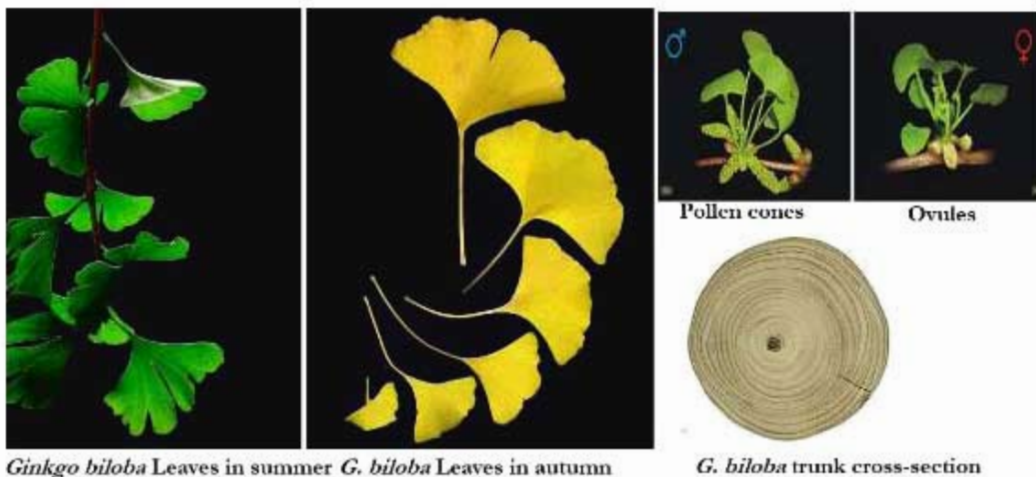
Definition of e-Flora:

The digitized form of traditional floras which are available online containing scientific names, descriptions, images, identification keys, distribution maps, and conservation status are called e-Flora (electronic flora). They serve as modern taxonomic literatures. This evolution of Taxonomy into "e-Taxonomy" makes dynamic exploration of plant diversity efficient for both scientists and the general public.

Examples of e-Flora:

- a) ***eFloras.org***: A large collection of digital floras, such as the Flora of China, the Flora of North America, and the Flora of Pakistan, may be found at eFloras.org.
- b) ***eFlora of India (efloraofindia.com)***: An extensive, user-generated database for plant identification throughout the Indian subcontinent that includes members of the Acanthaceae, Malvaceae, and Gentianaceae families.
- c) ***eflora.co.in***: Provides information about Indian forest and garden plants, including orchids and *Butea monosperma* (Flame of the Forest).
- d) ***E-Flora of Sri Venkateswara College Campus***: A focused, regional research that catalogs 70 species of herbs and shrubs, including economic and medicinal ones, together with taxonomic descriptions and photographs.
- e) ***E-Flora of R.L.T. College Campus***: A customized database that identifies the plants on the campus of R.L.T. College
- f) e-Flora by Missouri Botanical Gardens – www.efloras.org/
- g) ***Flora of China***: The series, which was finished in 2013, has 24 volumes of drawings and 25 volumes of text. The Catalogue of Life China came after the 80-volume *Flora Reipublicae Popularis Sinicae*. More than 39,000 vascular plants, 27,000 fungal species, and 3,000 bryophytes make up China's flora. Southern China (particularly Yunnan) has tropical rainforests, unlike Europe or the US. Conversely, high-altitude vegetation is found on the Tibetan Plateau. Among the iconic species are *Metasequoia* (which was thought to be extinct until a few thousand individuals were found to still exist in China), the plum blossom (which blooms in late winter, is a symbol of tenacity) and old uncommon conifer genus *Cathaya* (endemic to China). With a long history of use as medicine, traditional Chinese medicine makes use of more than 5,000 species. The complete database, which includes distribution maps, descriptions, and identification keys, is accessible online at eFloras.org. Several "living fossils" and plants with cultural significance can be found in it viz.,
 - i. **Dawn Redwood (*Metasequoia glyptostroboides*)**: A deciduous conifer once was believed to be extinct until rediscovered in 1948.

- ii. **Ginkgo (*Ginkgo biloba*):** Another living fossil with a 270 million-year-old ancestry.
- iii. **Dove-tree (*Davidia involucrata*):** well-known for its distinctive, dove-like white bracts.



Important roles of e-Flora in modern taxonomic literature:

- a) **Digital Archive:** It is an online resource that documents plants from a particular region, such as e-Flora of China or e-Flora of India.
- b) **Identification Tool:** Offers dynamic identification keys (such as list or tree keys) for species differentiation, frequently accompanied by thorough descriptions and photographs.

- c) **Data Richness:** Scientific names, synonyms, etymology, colloquial names, phenology (flowering/fruiting times), and voucher specimen citations are all examples of data richness.
- d) **Distribution mapping:** essential for comprehending plant ecology and conservation since it displays geographic ranges and habitat data.
- e) **Conservation Focus:** Supports conservation efforts by highlighting endangered, uncommon, and endemic species.
- f) **Dynamic & Searchable:** Enables users to browse families, do character searches, and access related resources such as herbarium databases (e.g., TROPICOS). Notably, Tropicos, created by Garden botanist Dr. Robert Magill in the early 1980s, now contains 4.2 million herbarium records & data on over 49,000 scientific publications (Website: www.tropicos.org). It is maintained by the Missouri Botanical Garden.

Evolution of Taxonomy:

- The e-Floras revolutionize traditional botany by integrating data from physical specimens and field observations into accessible, interactive online platforms.
- The e-Floras promote "e-Taxonomy," offering crucial, current data for study, specimen identification, and a more comprehensive understanding of science.

3. MANUAL

In contrast to a flora (habitat/distribution) or monograph (single group depth), a taxonomic manual is an essential taxonomic tool that serves as an in-depth resource for identifying and classifying species within a particular area or group. It provides keys, descriptions, and possibly illustrations to assist researchers and plant lovers distinguish between species. By highlighting useful identification tools for an area's biota, a taxonomic manual is vital for biodiversity research and conservation.

Essential Purposes of a Taxonomic Manual:

- a) **Identification:** Offers diagnostic tools and keys (such as dichotomous keys) to identify an unidentified plant or animal.
- b) **Description:** Provides thorough explanations for simple visual comparison, frequently accompanied by pictures or illustrations.
- c) **Scope:** All species (or a sizable part) found in a specific geographic area are covered (e.g., "Manual of Grasses of India").
- d) **Practicality:** Intended not only for detailed taxonomic treatments but also for field biologists, students, and conservationists to use.

e) **Examples:** Manual of Herbarium Taxonomy (De Vogel)

Main difference between Manual Vs. Monograph:

	<i>Manual</i>	<i>Monograph</i>
<i>Definition</i>	Manuals are handbooks giving information for the identification of species names within a certain location, functioning as a guide for local flora or animals	Monographs are thorough, detailed scientific studies that give entire, in-depth information on a particular, unique taxonomic group (e.g., a genus or family)
<i>Scope</i>	It covers all species in a certain region (wide, area-focused)	It covers all known species of one single taxon (narrow, taxon-focused)
<i>Aim</i>	Manuals are designed for simple identification and reference	Monographs are academic, thorough, and exhaustive records of study
<i>Content</i>	Identification keys and names are the main topics of manuals	Monographs give in-depth, updated, and complete information on morphology, ecology, and classification of a particular taxon.
<i>Example</i>	Manual of Herbarium Taxonomy (De Vogel)	Monograph on the family Pinaceae

Main difference between Manual Vs. Catalogue:

<i>Features</i>	<i>Catalogue</i>	<i>Manual</i>
<i>Definition</i>	Catalogue is a checklist used to verify the presence or inventory of species in an area	It is a vital taxonomic handbooks that acts as an in-depth resource for identification and classifying species within a certain area, functioning as a guide for local flora or animals
<i>Purpose</i>	Manuals provide detailed information/instructions (how-to)	catalogues provide a structured list or inventory
<i>Content</i>	It is less descriptive, merely alphabetical or organized listings	It is comparatively more descriptive & instructional
<i>Identification</i>	Catalogues typically lack such detailed identification tools, focusing on naming and listing	Manuals include keys for identifying species.
<i>Usage</i>	It helps find what is available in a collection or store.	A manual helps identify species in a particular area or use a device
<i>Organization</i>	These are almost always arranged alphabetically	These are usually ordered based on, but not limited to, taxonomy
<i>Example</i>	Seed catalogs from Baker Creek Heirloom Seeds, botanical records such as Hortus Bengalensis	Manual of Herbarium Taxonomy (De Vogel)

4. MONOGRAPHS

A monograph is a thorough, reliable study of a particular, often restricted group of organisms (a taxon such as a genus or family) in taxonomic literature. It synthesizes all available data, provides detailed descriptions, identification keys, updated nomenclature, geographical distribution, ecology, and evolutionary context, and acts as a definitive resource for researchers. These lengthy publications are distinct from shorter revisions or floras because they provide comprehensive information as well as illustrations that are essential for biodiversity research and in-depth biological understanding. They go beyond mere listings.

Important Features of a monograph:

- a) **Scope:** Gives a single taxonomic group (such as a genus or family) a lot of attention. Comprehensiveness: Consolidates current information and adds new discoveries in an effort to cover every known facet of the group.
- b) **Content:** Includes in-depth explanations, keys, nomenclature (names, synonyms, types), distribution, habitat, ecology, conservation status, images, maps, and occasionally phylogenetic information.
- c) **Goal:** Supports future research by serving as a fundamental resource for group identification, classification, and understanding.

Examples:

- a) **Robert Morison's 'Plantarum Umbelliferarum Distributio Nova' (1672):** The first monograph on a plant family (Apiaceae).
- b) **A Monograph of the Genus *Avena* by Baum, B.R. (1977):** A classic example of a genus-level monograph.
- c) **A Monograph of the Genus *Crepis* by Babcock, E.B. (1947)**
- d) **A Monograph of the Genus *Datura* by Blakeslee, A.F. et al., 1959.**
- e) **Modern Online Resources:** Increasingly published as searchable online databases (e.g., Solanaceae Source).

Importance of a Monograph:

- **Definitive Reference:** The most recent knowledge of a particular group at the time of publication is captured by the Definitive Reference.
- **Research Support:** Essential for precise identification and in-depth study for the researchers.
- **Biodiversity:** Assists conservation efforts by recording species, their status, and dangers.

5. REVISIONS

Although taxonomic revisions are less comprehensive than monographs, they are crucial for precise biodiversity understanding and uniform identification. They are scientific updates that reevaluate and clarify organism classifications, incorporating new data (morphological, genetic) to refine species descriptions, relationships, and keys, frequently focusing on specific groups or regions. In addition to correcting nomenclature and offering up-to-date synopses, maps, and diagnostic traits for a genus or family, these studies address historical discrepancies or new findings.

Crucial Elements of Taxonomic Revisions

- **Objective:** to enhance identification methods, incorporate new research (such as genetics), update current categories, and clarify ambiguities.
- **Scope:** Though nonetheless thorough for that scope, it is frequently more limited than a monograph, concentrating on a genus, family, or geographic area.
- **Content:** Complete synonymy, thorough diagnostic descriptions (sometimes condensed from monographs), identification keys, distribution maps, and classification changes are all included.
- **Methodology:** Based on a thorough examination of specimens, frequently using databases and herbaria, and sometimes utilizing population-level analysis to comprehend variance.

Examples of Revisions:

- Revisions of genera like *Strobilanthes* (Acanthaceae) or *Flemingia* (Leguminosae) in specific regions.
- Studies detailing species complexes, identifying specific trichome types or leaf characteristics.

Importance of Revisions:

- **Accuracy:** Ensures classifications reflect current biological understanding.
- **Stability & Communication:** Provides stable names and criteria for identification, facilitating scientific communication.
- **Biodiversity:** Essential for understanding evolutionary patterns, biogeography, and conservation.

Main difference between REVISION Vs. MONOGRAPH:

A revision typically covers a smaller group or area and is a detailed treatment, but it is not as comprehensive as a monograph, which includes all elements such as cytology, genetics, and ecology.

6. CONSPECTUS

In taxonomic literature, a Conspectus is a short overview or summary of a specific group of organisms in taxonomic literature that lists taxa (species, genera, etc.), their major synonyms, brief diagnostic descriptions, and geographical range. It serves as a checklist or updated synopsis, frequently compiled from revisions or monographs, to provide an approachable, up-to-date view of classification and nomenclature. It summarizes taxonomic changes and ensures stable nomenclature; it is more thorough than a simple checklist but less detailed than a monograph.

Examples of Conspectus:

- a) **Annotated taxonomic conspectus of the genus *Coffea* (Rubiaceae):** The genus was compiled in an annotated conspectus that listed species, synonyms, range, and vulnerable status.
- b) **Annonaceae (Custard Apple Family):** New genera were added and existing ones were combined to improve classifications for the Indo-Burmese region.
- c) ***Species Plantarum* (Linnaeus, 1753):** Considered a foundational example of an early conspectus, according to this document.
- d) Conspectus of the family Convolvulaceae in Uttar Pradesh, India.
- e) Conspectus of the genus *Pigea* (Violaceae) in India.

Major elements of a Taxonomic Conspectus

- a) **Comprehensive Listing of Accepted Names & Synonyms:** An organized list of scientifically accepted names, including basionyms (original names) and synonyms (homotypic/heterotypic) are included.
- b) **Nomenclatural Details:** Brief citations of authorship and publication, with types (e.g., holotypes) indicated where possible.
- c) **Geographical Distribution & Ecology:** Describes each taxon's known range or habitat, often including regional or national records.
- d) **Identification Aids:** Often includes keys to genera or species serving in identification.
- e) **Taxonomic Notes:** Brief discussions on taxonomic history, affinities, and problematic taxa.

- f) **Literature Citations:** Frequently includes significant supplementary readings, examples, or taxonomic analyses.
- g) **Updates Taxonomy:** Incorporates new classification insights and current taxonomic shifts, such as the splitting or merging of genera.

Use and Objectives of Conspectus:

- a) **Summary Tool:** Provides scholars with a concise, reliable synopsis of a taxonomic group.
- b) **Revision Preparation:** serves as a precursor to a finished flora or monograph.
- c) **Regional studies:** are used to list every species that is known to exist in a given family or genus within a given geographic area.
- d) **Conservation Assessment:** Offers the most recent list of species required to assess the state of conservation.

7. ICONES (ILLUSTARTIONS)

ICONES are the perfect, natural diagrams or pictures of plants; e.g., Hooker's ICONES, Wight's ICONES, ILLUSTARTIONS of plants from Europe (Hegi, 1906-1931), North America (Gleason, 1963), Germany (Garcke, 1972).

Important Features of Taxonomy Icons:

- a) **Aim:** For browsing biological categorization trees and producing documents and webpages.
- b) **Types:** Frequently have intricate drawings or stylized, simplified versions.
- c) **Data Linking:** To offer scientific names and genome sequence information, numerous icons are connected to the NCBI database.
- d) **Usage:** They are frequently freely distributable under Creative Commons licenses (e.g., CC BY 2.1 JP).
- e) These icons act as a visual link between easily navigable digital resources and scientific classification of taxa.

Important Roles of Taxonomic Icons:

- **Reduce Misidentification) by Clarifying Ambiguity:** Illustrations frequently draw attention to diagnostic characteristics that are difficult to express in words alone.
- **Document Biodiversity:** By collecting morphological characteristics crucial to scientific comprehension, they act as permanent recorders of species.

- **Support Taxonomic Keys:** For simpler field identification, they are frequently utilized in pictorial keys, a kind of taxonomic key with illustrated features.

Well-known Instances of Taxonomic Icons:

- **Roxburgh's Icones:** A seminal work with many plates of Indian plants. It came with 2533 plates and was released in 35 volumes.
- **Wight's Icones Plantarum Indiae Orientalis:** Another extensive and significant collection of Indian flora illustrations. It has 2101 plates and was released in 6 volumes. Reprinted from Madras in 1963.
- **J. D. Hooker's ICONES (Illustrations) of Himalayan Plants:** Focused on the flora of the Himalayas, as mentioned.
- **ILLUSTRATIONS of plants from Europe (Hegi, 1906-1931), North America (Gleason, 1963), Germany (Garcke, 1972)**

Modern Context: Today, although traditional illustrated works still remain fundamental, digital databases also provide "taxonomic icons" (image collections) for use in scientific communication.

8. Periodicals, Journals, Bulletin, or Proceeding

A **periodical** is a publication that typically appears on a regular basis. Every issue is referred to as a fascicle, or number. These numbers, or fascicles, add up to a volume. The issues of a calendar year are typically included in a volume for publications that publish at regular intervals, such as biweekly, monthly, or quarterly. In addition to records of its own proceedings, a society may publish a monthly serial that serves as a platform for a range of relatively brief papers supplied by its members. The typical titles for such a publication are ***Journal, Anal, Bulletin, or Proceeding***. In order to accommodate longer and more monumental works, frequently written by a single author, like monographs on floras, the same society may also print another serial at far less frequent intervals. These are frequently referred to as Transactions or Memoirs.

TAXONOMIC JOURNALS

A Taxonomy journal is a publication that typically appears on a regular basis and serves as vital, long-lasting records by offering formal, peer-reviewed publications for describing new species, updating groups, and exchanging research on organism classification, nomenclature, and relationships. Each issue is referred to as a number, or occasionally a fascicle, and taken as together they form a volume.

Important Functions of Taxonomic Journals:

- a) **Official Publication:** Under regulations such as the International Code of Nomenclature for Algae, Fungi, and Plants (ICN) and the International Code of Zoological Nomenclature (ICZN), they serve as the publication site for new species names and formal taxonomic revisions.
- b) **Data Repository:** Compile a wealth of information about species, distributions, and interactions, frequently in difficult-to-access formats (PDFs) with integrated text.
- c) **Legal Documents:** These journals' descriptions act as "vouchers" for the creation of new taxa, guaranteeing their permanence.
- d) **Research Dissemination:** To promote peer review and scientific discussion, publish original research, reviews, and brief messages.

Examples of Taxonomic journals: Bulletin of Asiatic Society of Bengal, Calcutta., Bulletin of Botanical Survey of India, Indian Forest Records, Journal of Bombay Natural History Society, Bombay, Records of Botanical Survey of India, BSI, Calcutta, Taxon, Botanical journal of Linnaean Society, Adansonian, Plant systematics & Evolution, Indian Forest Records, Journal of Bombay Natural History Society, Bombay.

Difficulties & Development:

- **Fragmentation:** Accessing data from older print material is challenging.
- **Digitization:** Legacy works are intended to be digitized through initiatives such as the Biodiversity Heritage Library (BHL).
- **Online Platforms:** Accessibility is enhanced via open-access journals and online catalogs (like the World Spider Catalog).
- Alongside books, floras, and monographs, taxonomic journals serve as vital, long-lasting records by offering formal, peer-reviewed publications for describing new species, updating groups, and exchanging research on organism classification, nomenclature, and relationships.

9. DICTIONARIES & GLOSSARIES

Botanical dictionaries are invaluable & central to taxonomic literature. They contain list & describes all known genera of certain plant groups. On the other hand, a **GLOSSARY** contains alphabetical list of difficult terms with explanations.

Examples and types of Dictionaries & GLOSSARIES:

- a) J.C. Willis (1960) Dictionary of flowering plants and ferns;
- b) Uphof's (1968) Dictionary of Economic Plants
- c) Watt's (1889-1896) Dictionary of Economic Products of India
- d) General Taxonomic Dictionaries: includes comprehensive lists of taxa from several kingdoms.
- e) Botanical Dictionaries: Focus on plant names, anatomy, and related fields.
- f) Digital Resources: Up-to-date modifications, such as the "Taxonomy Dictionary" that is conveniently integrated into spellcheckers.
- g) Jackson's (1928) "A Glossary of Botanic Terms"

Some images of plates from *Plantae Asiae Rariores*



Modern Digital Resources

In 2026, many taxonomic resources are available online to facilitate global biodiversity research:

- a) **International Plant Names Index (IPNI):** A database of the names and associated basic bibliographical details of seed plants, ferns, and lycophytes.
- b) **Integrated Taxonomic Information System (ITIS):** Authoritative taxonomic information on plants, animals, fungi, and microbes.
- c) **Biodiversity Heritage Library (BHL):** A massive digital archive of open-access legacy taxonomic literature.
- d) **MycoBank:** An online repository for documenting new mycological names and descriptions.

BOTANICAL GARDENS

In contrast to ordinary gardens that are only intended for aesthetic purposes, botanical gardens are scientific and public establishments that cultivate documented, labeled living plant collections for research, conservation, education, and display. They provide glasshouses, specialized plant sections (such as cacti and herbs), and educational resources like libraries or herbariums to advance plant science and awareness.

Important features Botanical Gardens:

- a) **Collections with Documentation:** Plants are well documented, frequently identified with their scientific names (genus, species), family, and place of origin.
- b) **Scientific Research:** Uses labs, libraries, and herbaria (collections of dried plants) to support studies in botany, Taxonomy, genetics, and ecology.
- c) **Conservation:** Uses in-situ/ex-situ techniques and propagation to protect rare, endangered, or therapeutic species.
- d) **Education:** Promotes interest in plant life by providing exhibitions, talks, guided tours, and displays for the general public and students.
- e) **Specialized Sections:** Consists of themed spaces such as water gardens, herb gardens, arboretums (trees), alpine cottages, and tropical conservatories.
- f) **Public Access:** The majority are accessible to the general public, providing botanical displays together with cultural and recreational activities (music, art).

Essential Tasks of Botanical Gardens:

- a) **Collecting and Cultivating:** Raising a variety of healthy plants.
- b) **Preservation:** Preserving the biodiversity of plants for coming generations.
- c) **Research:** Expanding our understanding of plants.
- d) **Education:** Teaching guests about the value of plants.
- e) **Display:** Highlighting the diversity and beauty of plants.

Difference between Botanical Garden, Parks (City/National Park) or Normal Gardens (Private/Public)

<i>Botanical Garden</i>	<i>Normal Garden (Private/Public)</i>	<i>Park (City/National Park)</i>
<i>Purpose:</i> Scientific study, education, conservation, research, and display of plants.	Primarily aesthetic enjoyment, relaxation, and beauty.	Public recreation, open space, community gathering, preserving large natural landscapes (National Parks).
<i>Content:</i> Labeled plant collections, taxonomic groupings, geographical origins, rare/endangered species, often includes greenhouses for exotic plants (cacti, tropicals).	Focuses on ornamental plants, flowers, and landscaping for visual appeal.	Open lawns, trees, playgrounds, picnic areas, recreational facilities; less focus on detailed plant labeling or scientific collections.
<i>Layout:</i> Organized scientifically, not just for scenery; focused on botanical classification and research needs.	Designed for scenic beauty and recreational use (paths, benches, water features).	Designed for broad public access and activity.
<i>Staff:</i> Employs professional botanists and horticulturists for research, curation, and education.	Managed by gardeners; less emphasis on scientific staff.	Park rangers, maintenance crews.
<i>Function:</i> Plant propagation, seed banking, research (Taxonomy, breeding), public education (workshops, tours).	Personal enjoyment or public leisure.	Protect ecosystems, wildlife, and landscapes for conservation, recreation, and education to preserve biodiversity, maintain clean air/water, and provide cultural/economic benefits through Eco-tourism, while prohibiting hunting, mining, lodging and deforestation.

Thus, Botanical gardens are *living museums of plants* with a fundamental aim based on scientific study, documentation, and conservation, whereas a normal garden is for pleasure, and a park is a public space for recreation and nature appreciation.

Important roles of botanical gardens:

- a) **Conservation:** Preservation of rare, endangered, and endemic plant species by means of seed banks, living collections, and propagation in preparation for possible reintroduction into the wild.

- b) **Research:** Serving as outdoor labs for scientific investigations in genetics, hybridization, Taxonomy, plant development, and sustainable resource use, frequently in conjunction with related herbaria.
- c) **Education:** Using labeled plants, workshops, and exhibitions to educate the public and students about biology, conservation, local flora, gardening, and plant diversity.
- d) **Display & Recreation:** With elements like themed gardens, greenhouses, and art installations, this area showcases a variety of plant collections for the enjoyment, health, and aesthetic appeal of the general public.
- e) **Public service:** It includes giving horticulture guidance, encouraging sustainable gardening, and providing initiatives that relate plants to local knowledge and human health.
- f) **Economic Contribution:** Creating jobs, drawing tourists, and helping regional economies.

Specific functions of botanical gardens

- a) **Living Libraries:** As essential resources for botanists and the general public, living libraries preserve documented collections of living plants that are frequently identified by their scientific names.
- b) **Gene Pools:** They serve as germplasm banks and protect genetic variety, particularly for wild relatives of economically significant plants.
- c) **Environmental Awareness:** To draw attention to environmental deterioration and the significance of ecosystems, they establish nature centers and activities.
- d) **Horticultural Training:** They offer training in the cultivation and multiplication of plants, which is essential for conservation initiatives.

Examples of some world botanical gardens

- 1) **Royal Botanic Gardens, Kew (UK):** A global leader in plant science and conservation.
- 2) **Singapore Botanic Gardens (Singapore):** A UNESCO World Heritage Site, famous for its Orchid Garden.
- 3) **Brooklyn Botanic Garden (USA):** Known for its diverse collections, including Japanese Hill-and-Pond Garden.
- 4) **Jardín Botánico (Brazil):** Rio de Janeiro's historic botanical garden, showcasing rich Brazilian flora.
- 5) **Kirstenbosch National Botanical Garden (South Africa):** Celebrated for its spectacular Cape Floral Kingdom.

Examples of some indian botanical gardens

- 1) ***Acharya Jagadish Chandra Bose Indian Botanic Garden (Kolkata, West Bengal)***: One of Asia's oldest and largest, famous for its Great Banyan Tree.
- 2) ***Labagh Botanical Garden (Bengaluru, Karnataka)***: Known for its stunning flower shows and diverse plant collections.
- 3) ***Government Botanical Garden (Ooty, Tamil Nadu)***: Famous for its terraced gardens and seasonal flower displays.
- 4) ***Lloyd Botanic Garden (Darjeeling, West Bengal)***: Specializes in alpine and temperate plants.
- 5) ***National Botanical Research Institute (NBRI) Gardens (Lucknow, Uttar Pradesh)***: A leading center for botanical research and conservation.
- 6) ***Jawaharlal Nehru Tropical Botanic Garden (Thiruvananthapuram, Kerala)***: Focuses on tropical plants, especially medicinal ones

Key Founders & Figures of Royal Botanic Garden, Kew:

- a) ***Princess Augusta (1719–1772)***: Established the original nine-acre exotic botanic garden in 1759 on lands leased by her husband, Frederick, Prince of Wales.
- b) ***Lord Bute (1713–1792)***: Also involved in the initial establishment of the garden alongside Princess Augusta.
- c) ***Sir Joseph Banks (1743–1820)***: Became Kew's first unofficial director in 1768, significantly expanding its plant collections with specimens from around the world.
- d) ***Sir William Hooker (1785–1865)***: Appointed as Kew's first official director in 1841, overseeing its transition to a public institution and major scientific center.

Brief Evolution of Royal Botanic Garden, Kew:

- a) ***Origins (1730s-1759)***: The grounds were formerly part of the Kew Estate, leased by the Prince and Princess of Wales.
- b) ***Scientific Growth (late 18th Century)***: Under Banks, Kew became a leading research and collection center in the late 18th century.
- c) ***Public Institution (mid-19th Century)***: Transferred to the Govt., opened for the public, and became a global plant research hub.

ACHARYA JAGADISH CHANDRA BOSE INDIAN BOTANIC GARDEN

Founder: Dr. William Roxburgh (1751–1815), known as the "Father of Indian Botany".

Origin: Roxburgh started the collection in 1793 at the botanic garden (now the *Acharya Jagadish Chandra Bose Indian Botanic Garden*).

Key Contributions: Roxburgh established systematic collection methods, commissioned artists for detailed botanical drawings (the famous Roxburgh Icones), and documented Indian flora extensively.

Expansion: By adding specimens from all throughout British India and through international exchanges, botanists like N. Wallich, J.D. Hooker, and George King helped the collection grow considerably.

BSI Integration: The herbarium was transferred to the Botanical Survey of India (BSI) in 1957 so that it might grow into a national organization.

Modernization: With over 2.5 million specimens, including important archival materials and historical artworks, it developed into a modern national herbarium. It is the oldest and largest national herbarium in India, with various regional sections, crucial archival materials and historical artworks.

Acronym: The acronym for the *Acharya Jagadish Chandra Bose Indian Botanic Garden* is AJCBIBG. However, the Central National Herbarium (CAL), popularly known as CNH.

LLOYD'S BOTANICAL GARDEN (DARJEELING)

It began as an annex to the Calcutta Botanical Garden in 1878 on 40 acres of land donated by William Lloyd. Over time, it expanded to display Himalayan flora and international exotics, becoming a major botanical attraction with specialized sections like the Orchidarium and Cactus House, which are renowned for their weeping willow and rare plants.

Donor (Establishment): William Lloyd, a British resident and owner of Lloyd's Bank, donated 40 acres of land to the government.

Purpose: To create a botanical garden to study Himalayan flora, established under the guidance of Dr. T. Anderson as an annexe to the Calcutta Botanical Garden.

Founding: The garden was officially established in 1878.

Zonal Development: The garden is divided into three sections: the upper part for Himalayan plants (including Sikkim species), the middle for ferns and conifers, and the lower for exotic species from around the world.

Specialized Collections: It developed significant collections, including an Orchidarium (housing ~3000 plants) and a conservatory for cacti and succulents (around 150 species).

Living Fossils: The garden houses rare "living fossil" trees, like the *Ginkgo biloba*, brought from China, adding unique historical value.

Exotic Introductions: Plants from Europe (Hawthorn, Birch), China (Cherries, Weeping Willows), and Australia (Wattle, Silver Oak) were introduced, enriching its diversity.

Medicinal Garden: A dedicated section for indigenous medicinal plants of the Eastern Himalayas was created.

Key Features of Lloyd's Botanical Garden

Iconic Trees & Plants:

- a) **Weeping Willow:** *Salix babylonica* (Salicaceae) famous for its drooping branches, a major attraction. A rapidly growing deciduous tree characterized by elongated, pendulous branches and narrow, pale green foliage that changes to yellow in the autumn season.
- b) **Living Fossils:** Two living fossils viz., *Metasequoia glyptostroboides* (dawn redwood) and *Ginkgo biloba* trees, brought from China, are unique highlights.
- c) **Himalayan Natives:** Oak, *Magnolia*, *Rhododendron*, Bamboo, and wild *Geraniums*.
- d) **Exotic Introductions:** *Cryptomeria*, Ash, Birch, Lilac, Chestnut, Plums, Cherries, and Maples from Asia and Europe.
- e) **Conifers & Ferns:** European conifers and tree ferns add to the alpine feel.
- f) **Cacti & Succulents:** A special conservatory houses 150 species.
- g) **Orchids:** A vast collection, including rare ones from Singalila Ridge, is displayed in the Orchidarium.
- h) **Himalayan Focus:** A repository for rare Himalayan species, including orchids and rhododendrons.
- i) **Annual Flower Show:** Hosts a popular flower show during the summer months.
- j) **Acronym:** The Indian Botanical Garden Network designates this garden with the code WB-DBG.
- k) Today, Lloyd's Botanical Garden is a prominent tourist destination, recognized for its varied plant life, distinctive collections, and calm atmosphere, drawing both visitors and botanists.

THE NBRI HERBARIUM (LWG)

The *National Botanical Research Institute (NBRI) Herbarium (LWG)* evolved from a historic royal garden into a premier national repository for plant specimens, emphasizing systematic research, conservation, and applied plant sciences.

Establishment and Early History

Royal Garden Era: The site was originally established as a royal garden in 1800 AD by Nawab Saadat Ali Khan of Oudh.

British Era: After British control was established in 1858, it was renamed the "Government Horticultural Garden" and managed by British horticulturists. Horticultural activities and public access were the main focus during this time.

National Botanic Gardens (NBG): In 1948, the garden was proposed for reorganization into a center for botanical and horticultural research and renamed the National Botanic Gardens (NBG) by the government of Uttar Pradesh, under the honorary directorship of Professor Kailas Nath Kaul.

Evolution and Growth: The major turning point in the institute's and the herbarium's growth came with its integration into national scientific research infrastructure.

CSIR Takeover: On April 13, 1953, the Council of Scientific and Industrial Research (CSIR) took over the NBG, providing the necessary funding and framework for substantial research and development.

Shift in Focus: Initially engaged in classical botanical disciplines, the institute, under directors like Dr. Triloki Nath Khoshoo (who joined in 1964), began to increasingly emphasize applied and developmental research to meet national priorities in plant sciences.

Renaming to NBRI: In October 1978, the NBG was renamed the National Botanical Research Institute (NBRI) to reflect the expanded scope and applied nature of its R&D activities.

Herbarium (LWG) Development: The herbarium, assigned the international acronym LWG (Lucknow Herbarium), grew as a critical component of the institute's mandate for plant diversity, systematics, and documentation. It functions as a foundational resource for taxonomic research and the study of Indian flora.

Modernization and Curation: The LWG herbarium has grown to include over 253,000 reference collections of flowering and non-flowering plants (angiosperms, gymnosperms, pteridophytes, bryophytes, algae, and lichens) from across India. It serves as a national repository for Indian flora under the Biological Diversity Act, 2002.

The LWG is currently a modern, well-documented herbarium supporting the institute's mandate of plant prospection, conservation, genetic improvement, and the development of new plant resources for human welfare.

HERBARIUM

“A herbarium is better than any illustration; every botanist should make one.” - Carl Linnaeus

- ❖ **Father of herbarium:** Luca Ghini (1490–1556), inventor of the art of making herbarium
- ❖ **Purpose:** The first herbaria, termed *Hortus hiemalis*, were constructed by doctors and botanists to study medicinal plants in winter.
- ❖ **Oldest extant herbarium:** Luca Ghini's herbarium has been lost; now, the oldest extant herbarium is Gherardo Cibo's collection started around 1532; still preserved in Rome.
- ❖ **At the beginning all the** herbarium sheets were bound to a book form. For instance, Flemish Bernardus Wynhouts made Herbarium book around 1633 & is essential historical evidence.
- ❖ Linnaeus, *Father of Taxonomy*, for the first time started to preserve herbarium sheets as separate copies. He introduced the following instructions while making herbarium:
 - a) *Mount just 1 specimen per sheet*
 - b) *Don't bind the sheets together*
 - c) *A specially built cabinet to store (where individual sheet can easily be inserted, removed anytime & reinserted anywhere in the collection)*

Standard Size: Herbarium sheets tend to be standard 42 x 29 cm (± 1 cm) or 11.5 x 16.5 inches, enabling systematic storage often with a label of the size of 12 x 8 cm.



Herbarium book which dates from 1633.
Made by the Flemish Bernardus Wynhouts



Herbarium book with Japanese plants, Siebold collection
Leiden, 1825

DEFINITIONS:

- A **herbarium** is basically a Store house or Library or Museum of dried plant specimens.
- A **herbarium** is a collection of plant specimens that usually have been dried & pressed & are arranged in the sequence of an accepted classification & are available for reference or other scientific study (H.M. Lawrence, 1967)
- Fosberg (1946) - A **modern herbarium** is “a great filing system for information about plants, both primary in the form of actual specimens of the plants & secondary in the form of published information, pictures & recorded notes”.
- Radford (1986) - A **modern herbarium** is “A research, training & service institution that serves as a reference centre, documentation facility & data storehouse”.
- **Modern herbaria** are used as reference centres, documentation centres & data storehouse (store data on ecology, habitat, distribution of plants etc)”.

HERBARIUM METHODOLOGY:

The process of herbarium methodology includes collecting original plant specimens, recording them in detail in the field, pressing them flat with blotting paper in plant presses to dry them, gluing them to sturdy sheets, labeling them with important information (name, location, date, and collector), and methodically storing them to preserve them for botanical study and research

in the future. To preserve scientific value, meticulous collection, pressing/drying, mounting, proper labeling, and pest-controlled custody are essential procedures.

1. Collecting Specimens:

- a) **Choose whole specimens:** If you can, collect plants with roots, stems, leaves, flowers, and fruits; record the stage of development.
- b) **Careful documentation:** In a field notebook, include the collector's name, collection number, date, location, habitat (sun/shade, moisture), and plant characteristics (color, height, sap, and fragrance/odour).
- c) **Careful transport:** For keeping plants fresh for a few hours, use plastic bags filled with damp newspaper or containers filled with water.
- d) **As a plant collector you will need the following equipment:**
 - ❖ a gardener's knife
 - ❖ a plant press or vasculum
 - ❖ blotting papers to dry plants
 - ❖ collecting and mounting sheets
 - ❖ trowel to dig and uproot the plants
 - ❖ gum tape, labels, waterproof ink and pen

Other equipments used in collection are: collecting pick, secateur, vasculum, hatchet, spade, etc.

- a) **Vasculum:** It is made up of a metal cylinder with a sliding door usually worn on a strap over the collector's shoulder into which plant specimen are placed. Polythene bags and paper bags are also used for putting fruits, seeds and small specimens after collection.
- b) **Plant Press:** Plant press is an indispensable tool for pressing fresh plant specimens to subsequently dry them and mount permanently.

Essential points to Remember while collecting plants for a herbarium:

- ❖ **Collecting without permission:** Never collect plants from private property, national parks, or other protected areas without obtaining the necessary permits or landowner consent.
- ❖ **Over-collecting:** Take only a reasonable number of specimens from a single plant population following the "one in twenty" rule where possible (only collect one specimen if you see at least 20 others).
- ❖ **Poor specimen selection:** Avoid collecting damaged, diseased, or overly mature plants; choose healthy specimens with representative features like flowers, leaves, and fruits when applicable.

- ❖ **Insufficient data recording:** Always record the collection site's location, date, habitat, elevation, and any additional plant observations.
- ❖ **Rough handling:** Carefully collect plants, avoiding unnecessary tearing or crushing of leaves and stems.
- ❖ **Collecting rare or endangered species:**
 - ❖ Unless specifically permitted, *do not collect rare or endangered plants*.
 - ❖ Collecting in bad weather:
 - ❖ Avoid collecting plants when wet, as this can lead to poor drying and mold growth.
- ❖ **Not properly labeling:** Ensure each specimen is labeled with accurate collection data including collector's name, date, location, and unique collection number.
- ❖ **The field data:-** the 2 methods for recording field data are as follows:
 - a) Plant collectors retain a *field note book* with specimen numbers, ecological data, and other information.
 - b) *Printed forms* with headings for essential information are placed in handy pads. Each completed printed form is affixed to a specimen and pressed in a field press during collection.

HERBARIUM FIELD NOTE BOOK

SILIGURI COLLEGE

BOTANY DEPARTMENT

Collection No: **001**..... Date.....Altitude.....
 Location.....
 Sub-Division.....District.....
 Forest/Vegetation type.....
 Microhabitat (Marshy, dry, rocky, sandy etc).....
 Botanical name..... Synonym.....
 Family..... Local Name.....
 Biotic association.....
 Frequency of occurrence: Frequent /Abundant/ Occasional.....
 Population & regeneration status.....
 Habit.....Root.....
 Stem.....Bark.....
 Leaves.....Inflorescence.....
 Floral characters.....Flowering/Fruiting/Seeds.....
 Fruits.....Seeds.....
 Special Remarks (Plant – animal relationship, if any)

 Local use.....
 Collected by.....
 Identified by.....

2. Processing (Drying and pressing):

- a) **Pressing:** placing the specimen between layers of blotting or folded cardboard for ventilation and newspaper for absorption.
- b) **Arranging:** Fold flowers to disclose structures, spread leaves to display all sides, and organize the plant in an informative manner.
- c) **Drying:** Until the specimen is totally dry, use plant presses (wooden frames) and replaces the absorbent papers on a regular basis. This process can be accelerated by heated dryers.

☐ The succulents are usually preserved as such in some suitable preervative, e.g., 4% or 5% Formaline solutions or F.A.A. (Formyl Acetic Acid); *F.A.A. is used for long term preservation.*

☐ Many types' fruits, cones of Gymnosperms & inflorescences of palms etc are dried & kept in large containers.

☐ **Formaldehyde solution (5%):** Commercial Formaldehyde (40% pure) -12.5ml; Water – 87.5ml;

☐ **Calculation:** For 100ml of 5% soln. from 40% conc.

$$V_1S_1=V_2S_2$$

$$100\text{ml} \times 5\% = V_2 \times 40\%$$

$$\text{So, } V_2 = 500/40 = 12.5 \text{ ml}$$

☐ **FAA (Formalin-Aceto-Alcohol):** often used to preserve plants while making "wet" herbarium specimens.

☐ **Composition:** To make 100ml solution, add Pure commercial formaldehyde: 5ml, Glacial Acetic Acid: 5 ml and 70% Ethanol: 90ml.

Formaldehyde used in FAA is a non-coagulating fixative that swiftly enters tissues and chemically cross-links cells to prevent degradation and autolysis. *Glacial Acetic Acid* swells tissues to offset alcohol's shrinking action, preserving the specimen's form. The solution is appropriate for long-term preservation in "spirit collections" since *ethanol (70%)* preserves and dehydrates.

FAA usage guidelines:

1. Most plant tissues need 24 hours in FAA for complete fixation before long-term storage in 70% ethanol.
2. As Formaldehyde is poisonous, and acetic acid is highly corrosive, they should be carefully handled in a well-ventilated room or fume hood.

3. Storing in firmly sealed glass jars or vials is recommended to avoid alcohol and formaldehyde evaporation.

Saturated Copper Acetate Method (Preserving the green color of plants in a herbarium)

To preserve green color for a herbarium specimen, the chlorophyll should be fixed before it degrades, as typical drying breaks it down into brown phaeophytin. The best long-term color retention method is Saturated Copper Acetate Method which chemically replaces magnesium in chlorophyll with copper and thus creates a permanent, bright green copper-phylocyanate compound.

Composition: Glacial acetic acid (50%) saturated with copper acetate crystals, Water and 5% formaldehyde solution.

Procedure:

- a) Dissolve copper acetate in 50% acetic acid until no more crystals dissolve (Stock Solution).
- b) Mix (Stock: water = 1:4) one part of the stock solution with four parts of water and boil the sample.
- c) Immerse the green plant specimen in the boiling solution for 10-15 minutes. Initially the plant may lose its color but will regain a bluish-green color later as the copper fixes in the tissue.
- d) Then, thoroughly wash the specimen in cold running water.
- e) Finally, preserve in 5% formaldehyde or continue to press and dry.

Points to remember:

- a) **Fixation:** Kill tissues promptly with 3-5% buffered formalin to prevent leaf separation and color loss.
- b) **Safety:** while handling formaldehydes and copper compounds wear gloves and eyewear and work in a well-ventilated area.
- c) **Fungicide:** Keep specimens dark, cold, and low-humidity to avoid fading and mold.
- d) **Storage:** Keep dried specimens cold, dry, and out of direct light to avoid fading.
- e) **Succulents:** Dip fleshy plants in hot water before crushing to destroy tissues and avoid breakdown.

3. Mounting & Labeling

- a) **Mounting:** Use glue or tape to attach the dried specimen to a standard-sized (such as 29 x 42 cm) acid-free herbarium sheet.

b) **Labeling:** paste a comprehensive label to the sheet's lower right corner, indicating the field notebook number and including all field data.

- **Common Dimensions:** 12 x 8 cm or 7 x 12 cm. (or approximately 3 x 5 inches)
- **Placement:** Bottom right corner of the standard Herbarium mounting sheet.

Essential Information of the Label:

- Scientific Name: Genus, species, authority, and family.
- Locality & Habitat: Exact location, altitude, and environmental description.
- Collection Details: Date, Collector name, and Collection number.
- Material: Acid-free paper is used for long-term preservation.

4. Storage & Preservation

- a) **Pest Control:** To eliminate pests and their eggs, sterilize dried specimens by fumigation or freezing at -80°C.
- b) **Storage:** For long-term preservation, keep mounted sheets in pigeonholes made of steel in a regulated environment with minimal moisture and a constant temperature.
- c) **Complementary Information:** To improve the collection's quality, add pictures, drawings, or wet-preserved specimens (for fleshy sections).

73 FUNCTIONS OF HERBARIUM

(A) Basic Functions & Research:

1. To identify a plant, verify its identity, or conclude that it is novel to science (Taxonomy);
2. To record the theories of the experts who have previously examined the material (taxonomy);
3. To supply resources for morphological measures (systematics, Taxonomy);
4. To supply locale data (Taxonomy, systematics, teaching) for field trip planning.
5. To supply information for floristic research (Taxonomy);
6. To act as a storehouse for fresh collections (systematics and Taxonomy);
7. To supply information for monographs and revisions (systematics);
8. To confirm Latin names for plants (nomenclature);

9. To act as a safe storage facility for "type" specimens those are essential in Plant Taxonomy.
10. To establish the necessary framework for acquiring loans and other research materials (Taxonomy and systematics);
11. To encourage and facilitate the sharing of new information across organizations (Taxonomy);
12. To enable the recording of plant juvenile forms and flowering and fruiting seasons (Taxonomy, systematics, ecology, phenology);
13. To serve as the foundation for a plant illustration (Taxonomy and general publishing);
14. To supply resources for DNA analysis (genetics, evolution, and systematics);
15. To supply data (Taxonomy, ecology, etc.) for GIS studies of previous and upcoming collecting missions;
16. To store vouchers for images that can be utilized in publications, websites, and seminars (Taxonomy);
17. To furnish information on rare, extirpated, or extinct species that are no longer extant in nature (Taxonomy, conservation biology);
18. To supply contemporary specimens for comparative analysis with fossils (e.g., classification of foliar patterns; paleobotany);
17. To present details on rare, extinct, or extirpated species that are no longer found in nature (Taxonomy, conservation biology);
18. To offer contemporary specimens for fossil comparisons (e.g., leaf pattern classification; paleobotany);
19. To trace the history of binomial usage for a particular taxon in a particular area (local flora).
20. To safeguard invaluable historical Records of plant species

(B) Related Research: In biology, collections are indispensable

1. To supply pollen for studies on Taxonomy, systematics, pollination ecology, insect ecology, and medicine, as well as investigations on allergies;
2. To offer reference samples for the identification of plants consumed by animals (animal ecology).
3. Determining natural ranges and recording the plants that flourished where over the years (invasive species, loss of habitat, climate change, etc.)
4. To record which plants grow beside which other plants (ecology, phytogeography);

5. To supply materials for microscopic examinations (morphology and anatomy);
6. To record the anatomy and morphology of individuals of a specific species in various environments (environmental variation);
7. To operate as a storehouse for voucher specimens related to environmental impact research, ethnobotany, ecology, etc.
8. To supply materials for chemical analysis (documentation of pollution, lead uptake, and bio-prospecting for coralline algae, which determines historical ocean temperatures and chemical concentrations).
9. To supply data for research on missions and explorers (scientific history).
10. To supply the field notebooks and label data required for precise specimen databasing (biogeography, biodiversity and conservation biology).
11. To act as a reference library for paleoethnobotany, the identification of plant parts (such as seeds) discovered in archaeological investigations.
12. To set the context for related library and other bibliographic materials (Taxonomy, general research, library sciences, etc.).
13. To act as a repository for relevant documents (letters, reprints, field notes, etc.);
14. To offer details on common plant names and regional applications (anthropology, languages, ethnobotany, economic botany).
15. To offer collections of insects those were unintentionally gathered with the plants (ecology, entomology).
16. To recollect regions mentioned on label data (conservation biology, environmental impact statements, endangered species, etc.) in order to locate rare or potentially extinct species;
17. To provide information on plant predators (e.g., leaf miners, leaf-cutter ants; entomology, ecology).
18. To assess the existence and range of plant diseases, such as anther-smut.
19. To track the introduction and spread of invasive species (ecology);
20. To record carbon dioxide (CO₂) change over the last 10,000–10,000,000 years, which is a more accurate indicator of change in the climate than ice core data?
21. To supply data for foliar physiognomy research on leaf morphology in relation to climate change (paleoecology);
22. To record naturally occurring polyploid populations according to the size of the leaf and epidermal stomatal complex (phylogeography, paleoecology);
23. To record vascular plant and fungal symbionts;

24. To document biogeography of past plant distributions including regional extinctions (paleobiogeography);
25. To record the development of the main vascular plant families (paleobotany);
26. To record small climate cycles (paleoecology);
27. To address carbon isotope ratios caused by climate change, such as Lewis and Clark specimens from 200 years ago having higher C12.

(C) Training and Education

1. To supply educational resources (plant communities, Taxonomy, field botany, ethnobotany, agriculture, dendrology, and forestry);
2. To encourage students, researchers, and the general public to view specimens in order to foster an appreciation of plant diversity.
3. To give graduate and undergraduate students employment and internship possibilities
4. To enable new scientists and students the chance to interact with more seasoned professionals;
5. To introduce students to methodical research;
6. To instruct local volunteers in databasing, scanning, and specimen handling, among other things;
7. To organize public education programs.

(D) Outreach:

1. To act as a hub for the identification of various plant parts for a wide range of people, for example samples for the identification of plants that could be important for forensics or criminal investigations;
2. To act as a public education instrument (school groups, garden clubs, etc.);
3. To serve as the center for all kinds of botanical interactions (club meetings, talks, etc.);
4. To supply examples for educational and museum displays;
5. To give a place to work on specimens for government and state agencies, such as USDA, USGS, and NPS.
6. To give long-term projects (like Smokey Mt. NP ATBI) a place to live;
7. To offer a location for local, regional, or worldwide research;
8. To assist in the creation of new museums;
9. To promote positive international contacts (e.g., collaborative field trips, sister institutions);

10. To present content to the general public, such as precise illustrations;
11. To serve as painters' inspiration;
12. To engage locals in order to establish volunteer organizations for conservation initiatives;
13. To maintain websites that distributes databases, photographs, specimen material, and information about public services;
14. To return data and images from collections to their original countries (international relations);
15. To assist illustrators in creating precise illustrations for children's books;
16. To give details about the wild ancestors of domesticated plants;
17. To enable international exchanges of field excursions.

(E) Money-Making Projects?

1. To arrange plant photos connected to voucher collections;
2. To assist in creating natural history items for gift shops, such as antique illustrations for note cards.

Herbarium Ethics & Rules

1. Proper Handling – scientific value; irreplaceable; Specimens are fragile; the sheets should be kept flat.
2. Folders and sheets should be lifted one at a time.
3. While carrying the specimens from the cabinet to the working table, a *supporting sheet* should be kept below.
4. Heavy books or elbows should not be placed on the sheets.
5. Any broken part should be kept in a small packet in the same folder.
6. Materials for dissection should be taken only sparingly and with permission.
7. Damaged specimens should be kept aside for repair.
8. Do not write anything on sheets without permission
9. Do not re-shelve
10. Specimens if burrowed- should be properly housed in fire proof, dust free & pest free cases; returned within the loan period;
11. Support specimens with ventilator while carrying even to short distance

EXAMPLES OF SOME MAJOR WORLDWIDE AND INDIAN HERBARIA

Herbaria are maintained by numerous universities, museums, and botanical gardens. Additionally, herbaria have been shown to be excellent sources of plant DNA for molecular systematics and Taxonomy. In roughly decreasing order of size, the world's major herbaria are:

- Muséum National d'Histoire Naturelle (P) (Paris, France)
- New York Botanical Garden (NY) (Bronx, New York, USA)
- Komarov Botanical Institute (LE) (St. Petersburg, Russia)
- Conservatoire et Jardin botaniques de la Ville de Genève (G) (Geneva, Switzerland)
- Missouri Botanical Garden (MO) (St. Louis, Missouri, USA)
- British Museum of Natural History (BM) (London, England, UK)
- Harvard University (HUH) (Cambridge, Massachusetts, USA)
- Swedish Museum of Natural History (S) (Stockholm, Sweden)
- United States National Herbarium (Smithsonian Institution) (US) (Washington, DC, USA)
- Nationaal Herbarium Nederland (L) (Leiden, the Netherlands)
- Université Montpellier (MPU) (Montpellier, France)
- Université Claude Bernard (LY) (Villeurbanne Cedex, France)
- National Botanic Garden of Belgium (BR) (Meise, Belgium)
- University of Helsinki (H) (Helsinki, Finland)
- The Berlin Botanic Garden and Botanical Museum (B) (Berlin, Germany)
- The Field Museum (F) (Chicago, Illinois, USA)
- University of Copenhagen (C) (Copenhagen, Denmark)
- Chinese National Herbarium, (Chinese Academy of Sciences) (PE) (Beijing)
- University and Jepson Herbaria (UC/JEPS) (Berkeley, California, USA)
- Herbarium Bogoriense (BO) (Bogor, West Java, Indonesia)
- Royal Botanic Garden, Edinburgh (E) (Edinburgh, Scotland, UK)

Muséum National d'Histoire Naturelle (P) (Paris, France): It was founded by Guy de la Brosse in 1635 as the Royal Garden of Medicinal Plants under King Louis XIII, and the French Convention in 1793 during the Revolution transformed the royal garden into a public institution with renowned professorships.

- **New York Botanical Garden (NY) (Bronx, New York, USA):** was founded in 1891 by botanists Nathaniel Lord Britton and his wife, Elizabeth Gertrude Knight Britton, who

combined scientific and public botany interests. They built a world-class botanical garden and research center in Bronx Park, opening in 1900.

- **Komarov Botanical Institute (LE) (St. Petersburg, Russia):** it was founded in 1931 by merging the historic Botanical Garden (est. 1714 by Peter the Great) and the Botanical Museum. It was named after Vladimir Leontyevich Komarov (1869–1945), a prominent Russian botanist and President of the USSR Academy of Sciences, who influenced its development.
- **Royal Botanic Garden (K) (Kew, England, UK):**

INDIA'S MOST IMPORTANT HERBARIA:

The most significant herbaria in India are listed below, arranged according to the approximate number of specimens they contain:

- **Central National Herbarium (CAL):** Located in Howrah, West Bengal, it is the oldest and largest herbarium in India and among the biggest in Asia containing over 2.5 million (20,00,000 to 25,00,000+) specimens. CAL is affiliated with the Botanical Survey of India (BSI).
- **Forest Research Institute Herbarium (DD):** Located in Dehradun, Uttarakhand; It specializes in forestry research and contains approximately 300,000 to 350,000 specimens.
- **National Botanical Research Institute Herbarium (LWG):** Located in Lucknow, Uttar Pradesh, it contains around 200,000 to 260,000 specimens. It is affiliated with the Council of Scientific and Industrial Research (CSIR).
- **Blatter Herbarium (BLAT):** Associated with St. Xavier's College in Mumbai, Maharashtra, this herbarium contains approximately 200,000 specimens including algae, fungi, bryophytes, pteridophytes, gymnosperms, and flowering plants.
- **Botanical Survey of India, Southern Regional Centre (MH):** Located in Coimbatore, Tamil Nadu; it holds about 70,000 to over 200,000 specimens.
- **Botanical Survey of India, Eastern Regional Centre (ASSAM):** Located in Shillong, Meghalaya, it focuses on the flora of the northeastern region with >100,000 specimens.
- **Lloyd's Botanical Garden, Darjeeling (WB-DBG)**

Q. Write Short note on: Wallichian Catalogue

It is formally known as "A Numerical List of Dried Specimens of Plants in the East India Company's Museum," and is a landmark botanical record produced between 1828 and 1849. It contains a list of 9148 plants collected during Nathaniel Wallich's superintendence

of Royal Botanic Gardens, Calcutta. It lists not only Wallich's own collections, but also plants collected by B. ' Heyne, P. Russell, W. Roxburgh, R. Wight, etc.

Nomenclatural Importance of Wallichian Catalogue:

Since it serves as the foundation for the naming and classification of thousands of Asian plant species, it is essential to contemporary Taxonomy. Many of the names on this list were initially included, but some weren't "validly published" by today's standards until they were validated by other scientists.

Contemporary Access of Wallichian Catalogue:

The catalogue is now the main tool used by researchers to type plant names. It is accessible via the following platforms after being digitized:

- a) **Wallich Catalogue Online:** An interactive tool by the Royal Botanic Garden Edinburgh to help to explain the original hand-written entries and collection data.
- b) **Biodiversity Heritage Library:** original lithographic sheets can be scanned
- c) **Internet Archive:** can be downloaded from internet archive.

(2) Index Kewensis (IK):

IK is the most complete list of scientific names for all flowering plants and is a fundamental taxonomic reference produced by the Royal Botanic Gardens, Kew.

Key aspects & Taxonomic Significance of Index Kewensis are:

- a) **Scope and Origin:** The original 1893 index, created by B.D. Jackson under J.D. Hooker at Charles Darwin's request, sought to enumerate all seed plant names from Linnaeus's time onward.
- b) **Function:** It is primarily a bibliographic index that helps find a scientific name's publication location.
- c) **Limitations:** It excludes ferns, algae, and fungus and does not assess a name's taxonomic validity or acceptability (synonymy).
- d) **Evolution to IPNI:** Currently, the information is combined with the Australian Plant Name Index (APNI) and the Gray Herbarium Index in the IPNI.
- e) **Supplements:** The index has been updated by a number of supplements, and new names are still continuing to register.

(3) A brief note on: IPNI

The International Plant Names Index (IPNI) is a large, free library that has information on how to name vascular plants scientifically. In order to complete this project, the Royal Botanic Gardens, Kew, Harvard University Herbaria, and the Australian National Herbarium have all worked together.

The Goal: is to create a central database of published plant names that includes basic bibliographic information like author, date, and publication source so that researchers don't have to look through original sources over and over again.

Coverage: It mainly looks at vascular plants like seed plants, ferns, and lycophytes, from the family level all the way down to the infraspecific level.

Nature of Data: IPNI is not a taxonomic index; it is a nomenclatural index. Names are listed in the order they were written, but they are not listed as "accepted" or with similar names. Users are advised to visit Plants of the World Online (POWO) to find out about taxonomic status (if a name is currently accepted).

Standards: Based on Brummitt and Powell's Authors of Plant Names, it keeps the digital list of standard author names up to date.

Important Parts of IPNI

- a) ***Index Kewensis (IK):*** Charles Darwin started this to keep track of all the seed plants.
- b) ***The Gray Herbarium Index:*** is mostly about woody plants from the New World.
- c) ***The Australian Plant Name Index (APNI):*** lists the names of plants that grow in Australia.

(4) VIRTUAL HERBARIUM

A virtual herbarium is a digital collection of conserved plant specimens that provides high-resolution photos and comprehensive information (such as location, collector, and scientific name) for biodiversity research, education, and public involvement. This effectively makes physical plant collections accessible to a worldwide audience without requiring the transportation of fragile specimens. Important examples include the Australasian Virtual Herbarium (AVH) and the Indian Virtual Herbarium (IVH), which offer extensive digital resources for researching plant history and recognizing local species.

Main Attributes & Advantages of virtual herbarium:

- a) **Digital Access:** Displays data and pictures of herbarium sheets.

- b) **Rich Information:** Every entry has habitat information, collector details, dates, locations, and scientific names.
- c) **Research Tool:** Helps identify plants and create checklists for taxonomic, ecological, and historical investigations.
- d) **Public Engagement:** Raises awareness and enables users to learn about local plants.
- e) **Preservation:** Avoids damage by reducing sensitive specimen handling.

Examples:

- a) **Indian Virtual Herbarium (IVH):** A large database maintained by BSI, enables digital access to India's flora, including historical collections.
- b) **Australasian Virtual Herbarium (AVH):** It is a cooperative platform for herbaria in Australia and New Zealand.
- c) **Charles Sturt University Virtual Herbarium:** It mainly focuses on plants from specific Australian regions.

What does Virtual Herbarium include?

- a) High-resolution scans or photographs of pressed plant specimens.
- b) Metadata (label data) with collection and identification details.
- c) Barcodes, families, genera, collectors, and locations are frequently used to search data.

NOTEWORTHY WEBSITES FOR VIRTUAL HERBARIA

- a) **Global Biodiversity Information Facility (GBIF):** It is a vast global data database that collects plant specimen photos and data from hundreds of herbaria worldwide, enabling global searches.
- b) **JSTOR Worldwide Facilities:** A vital resource with millions of high-resolution pictures for getting type specimens from numerous herbaria worldwide.
- c) **Integrated Digitized Biocollections (iDigBio):** The US-based portal centralizes digital natural history collections with millions of herbarium specimens.
- d) **The Australasian Virtual Herbarium:** It contains more than six million specimen data from significant herbaria in Australia and New Zealand.
- e) **Indian Virtual Herbarium (IVH):** It is India's largest digital herbarium, built by BSI, contains historical and current plant specimens and metadata.

- f) **JACQ Virtual Herbaria:** A jointly managed herbarium management system and database used by more than 60 herbaria, primarily in Europe.
- g) **The William & Lynda Steere Herbarium** (New York Botanical Garden): Over four million digitized specimens are accessible online.
- h) **Royal Botanic Gardens, Kew:** Millions of specimens, some of which are centuries old, are freely accessible through their web portal.
- i) **Missouri Botanical Garden** (Tropicos): It is a vital source of taxonomic knowledge and provides a wealth of herbarium data.
- j) **Harvard University Herbaria:** Provides online vast databases.

ROLE OF BOTANICAL SURVEY OF INDIA (BSI)

Founded in 1890 under the auspices of the Ministry of Environment, Forests, and Climate Change (MoEFCC), the Botanical Survey of India (BSI) is the leading scientific organization for identifying, cataloging, and preserving India's plant diversity. Its primary functions are:

- a) **Floristic Survey and Exploration:** Identifying and documenting plant species, including non-flowering plants, throughout India's varied habitats through the implementation of comprehensive botanical surveys.
- b) **Documentation and Publication:** The yearly "Plant Discoveries" report, as well as the Flora of India, regional flora, and state flora, are published.
- c) **Conservation of Threatened Plants:** Identifying endangered species (Red List species), overseeing ex-situ conservation in botanical gardens, and preserving rare plants in protected regions.
- d) **Taxonomic research:** It includes the maintenance of national herbaria, such as the Central National Herbarium in Kolkata, and the study of plant Taxonomy, including identification, naming, and categorization.
- e) **Ethnobotanical Study:** Recording indigenous tribes' traditional knowledge of plants. Creating databases of Indian plants, including digital records of biodiversity, botanical artwork, and specimens from herbariums, is known as database management.

The provision of a scientific foundation for the sustainable management of India's natural resources depends on the BSI.

INDEX HERBARIUM (IH)

IH is an international directory of herbaria (over 3,000 operational worldwide herbaria), & searchable database of related personnel & botanical institutes that house plant and fungal

specimens on a permanent basis. It helps study on millions of plant and fungal species by providing essential information including location, names, collection size, and personnel research specializations. Important elements in the Index Herbarium are-

- a) **Purpose:** It serves as a thorough register for botanical collections, providing extensive metadata on the locations of specimens and the people to get in touch with. Origin: Currently run by the New York Botanical Garden (NYBG), it was founded in 1935 by the International Association for Plant Taxonomy (IAPT).
- b) **Contents:** The IH has about 400 million specimens from more than 3,500 active herbaria spread across around 176 countries.
- c) **Function:** It serves the dual purposes of giving each registered herbarium a distinct, official acronym (e.g., NY for the New York Botanical Garden or K for Royal Botanic Gardens, Kew) and finding "type specimens"—the initial samples used to designate a species.

Users can search the database online by institution name, code, location, or individual name.

The species and the genus are always the work of nature (i.e. specially created); the variety mostly that of circumstance; the class and the order are the work of nature and art. - Carl Linnaeus

CHAPTER 5

Study of Selected Dicotyledonous Families

Chapter Contents:

- Names of the families included in Syllabus of different Universities & WBCS Main Examination syllabus for BOTANY (Optional Paper)
- The list of alternate, acceptable names for many plant families is shown below, according to ICN
- The type genera for the chosen Dicot families
- General Botanical Characteristics of different Dicotyledonous families, their Main Diagnostic features, and Systematic Position
- Exceptions (Deviations) from the General Family characters in Dicotyledon
- Advanced characteristics of Asteraceae
- Significant diversity in stamens in Cucurbitaceae
- A brief note on Systematic treatment of Fabaceae sensu lato & Revised Subfamily Classification (LPWG 2017)
- Primitive features of Ranunculaceae and Magnoliaceae
- Exceptional Characteristics with examples of different Dicotyledonous Families

❖ LIST OF ALTERNATE NAMES OF FAMILIES:

According to ICN the alternate, acceptable names for many plant families are shown below:

Eight major approved Alternative Names:

1. Asteraceae (Daisy/Sunflower family) — Compositae
2. Brassicaceae (Mustard/Cabbage family) — Cruciferae
3. Poaceae (Grass family) — Gramineae
4. Clusiaceae (Mangosteen family) — Guttiferae
5. Lamiaceae (Mint family) — Labiatae
6. Fabaceae (Legume/Bean family) — Leguminosae
7. Arecaceae (Palm family) — Palmae
8. Apiaceae (Carrot/Parsley family) — Umbelliferae

Other Validated Alternatives:

1. Caryophyllaceae — Formerly: Alsinaeae

2. Liliaceae — Previously included: Calochortaceae, Convallariaceae, & Uvulariaceae
3. Orchidaceae — Occasionally, referred to historically as: Cyripediaceae
4. Ranunculaceae — Occasionally split into: Helleboraceae and Thalictraceae
5. Apocynaceae — At present includes the former: Asclepiadaceae
6. Araceae — Now includes the former: Lemnaceae
7. Hypericaceae — often treated as a subfamily within Clusiaceae or Guttiferae

Point to remember:

The "-aceae" names are based on a type genus (e.g., *Aster* → Asteraceae), whereas the earlier names (Compositae, Cruciferae, etc.) are descriptive of the plant's traits, such as the composite flowers of the Compositae or the cruciform petals of the Cruciferae.

❖ THE TYPE GENERA OF DICOTYLEDONOUS FAMILIES:

1. Acanthaceae: *Acanthus*
2. Annonaceae: *Annona*
3. Apiaceae (Parsley Family): Type Genus: *Apium* (Celery)
4. Apocynaceae: *Apocynum*
5. Asclepiadaceae: *Asclepias* (Often now treated within Apocynaceae)
6. Asteraceae: *Aster* (Alternative, valid name: Compositae, type genus *Bellis*)
7. Brassicaceae: *Brassica* (Alternative name: Cruciferae, type genus *Crucifera* - rarely used)
8. Cucurbitaceae: *Cucurbita*
9. Dipterocarpaceae: *Dipterocarpus*
10. Ericaceae: *Erica*
11. Euphorbiaceae (Spurge Family): Type Genus: *Euphorbia*
12. Fabaceae (Leguminosae): *Faba* (Defunct, now accepted as *Vicia*)
13. Mimosaceae: *Mimosa*
14. Caesalpiniaceae: *Caesalpinia*
15. Papilionaceae: *Papilio* (Old term) or *Faba* (now *Vicia*),
16. Lamiaceae: *Lamium* (Alternative: *Labiatae*)
17. Magnoliaceae: *Magnolia*
18. Malvaceae: *Malva*
19. Myrtaceae (Myrtle Family): Type Genus: *Myrtus* (Myrtle)
20. Ranunculaceae (Buttercup family): Type genus is *Ranunculus*
21. Rosaceae (Rose family): Type genus - *Rosa*
22. Rubiaceae: *Rubia*
23. Rutaceae (Citrus/Rue family): Type genus – *Ruta*

24. Scrophulariaceae (Figwort family): Type genus - *Scrophularia*
25. Solanaceae (Nightshade/Potato family): Type genus - *Solanum*
26. Sterculiaceae (Cacao family): Type genus - *Sterculia* (Now, under Malvaceae)
27. Tiliaceae (Linden family): Type genus - *Tilia* (Now often included in Malvaceae)
28. Verbenaceae: Type genus - *Verbena*

❖ GENERAL BOTANICAL CHARACTERISTICS OF ACANTHACEAE

Vegetative Features:

Habit: Mostly herbs or shrubs, rarely climber (*Thunbergia*)/small tree (*Avicennia germinans*).

Root: branched, tap root

Stem: Erect, aerial, herbaceous or woody, branched cylindrical, occasionally spinous (e.g., *Barleria*), underground (*Ruellia tuberosa*), node swollen.

Leaves: Simple, opposite-decussate, petiolate, entire, exstipulate, often with cystoliths

Floral characters:

Inflorescence: usually cymose (Solitary axillary as in *Thunbergia*), raceme, or spike (*Blepharis*), frequently with large, persistent bracts and bracteoles.

Flower: Bracteate, bracteolate, bracts and bracteolates prominent, bisexual, complete, strongly zygomorphic, 5-merous, or 4-merous, hypogynous, nectariferous disc present; often showy, large, leafy, or vividly colored bracts frequently enhance the flower's showiness.

Calyx: sepals 4-5, unequal, sometimes reduced, hairy/glandular, imbricate/valvate

Corolla: petals fused, bilabiate/personate, typically, the upper lip has 2 lobes, whereas the lower lip has 3 (or occasionally, the upper lip is repressed), rarely 5-lobed, imbricate/twisted, variously colored and often showy.

Androecium: Stamens 4 (2+2), didynamous or 2 fertile stamens, often with 2-3 staminodes, epipetalous, alternipetalous; anthers 2-celled, dorsifixed, may be spurred, occasionally one lobe is smaller or diminished.

Gynoecium: carpels (2), syncarpous, superior ovary, 2 loculed, 1 or 2 ovules per chamber, style simple, bilobed stigma, in which one lobe is smaller; axile placentation.

Floral Formula: Br. Brl. % ♀ $K_{(4-5)} C_{(5)} \overset{\curvearrowright}{A}_{4 \text{ or } 2+2 \text{ or } 2} \underline{G}_{(2)}$

Fruit and Seeds: *Fruit:* Loculicidal capsule which dehisces explosively

Seeds: many, non-endospermic, ejected by unique retinacula, which are hook-like funiculi.

Main Diagnostic features:

- Mostly herbs, shrubs;
- Leaves opposite decussate, exstipulate,
- Inflorescence cymose,
- Flowers often showy, bracteate, bracteolate, strongly zygomorphic, bisexual,
- Calyx 5 or 4 united,
- Corolla pentapartite, gamopetalous, often 2-lipped;
- Stamens 4 (2+2) didynamous, or 2, free, epipetalous;
- Carpels 2, syncarpous, ovary superior, axile placentation, style simple, stigma bilobed;
- Fruit loculicidal capsule,
- Seeds non-endospermic with jaculators.
- Endosperm in seeds.

General Botanical Characteristics of Annonaceae

Vegetative Features:

Habit: Mostly evergreen trees or shrubs, with some lianas (e.g., *Artabotrys*), featuring aromatic tissues with essential oils.

Leaves: Simple, alternate, often distichous (arranged in two vertical rows), entire margin, gland-dotted, and exstipulate.

Stem: Woody, with fibrous bark.

Floral characters:

Inflorescence: Usually solitary or in small axillary cymes.

Flowers: Bisexual (rarely unisexual as in *Alphonsea*, *Guatteria*, *Orophea*, *Phaeanthus*), actinomorphic, and trimerous. Some members exhibit cauliflory (flowers directly on the trunk) e.g., *Stelechocarpus burahol*, *Annonidium mannii*, *Uvariopsis* spp (*Uvariopsis submontana*, *U. congolana*, *U. guineensis*, and *U. vanderystii*).

Perianth: Generally arranged in 3 whorls of 3 (3 sepals, 6 petals in two whorls) or sometimes 3+3+3, often fleshy, greenish, or brown.

Androecium: Many stamens arranged spirally, with short filaments and a distinct, expanded, often flattened, or hood-like connective above the anther.

Gynoecium: Carpels many, free, arranged spirally, each with 1–many ovules.

Floral Formula: Br. $\oplus \overset{\gamma}{\text{P}}_{2+3+3} \text{A}_{\infty} \underline{\text{G}_{\infty}}$

Fruit and Seeds: **Fruit:** Etaerio of berries or sometimes fused into a fleshy syncarp.

Seeds: Large, with ruminated endosperm, often with a fleshy aril.

Main Diagnostic features:

- Simple, aromatic leaves.
- Trimerous, fleshy, aromatic flowers.
- Numerous, spirally arranged stamens with enlarged connectives.
- Apocarpous (separate) pistils.
- Ruminated endosperm in seeds.

❖ GENERAL CHARACTERISTICS OF APIACEAE

Vegetative Features:

Habit: Plants are mostly herbs (annual, biennial or perennial), rarely shrubs, aromatic (odour because of oil ducts); *Pseudocaryum* climbs by means of its petioles.

Root: Tap, branched sometimes swollen for the storage of food material e.g., Carrot (*Daucus carota*).

Stem: Erect/prostrate (climbing in *Pseudocaryum*); swollen nodes, sometimes ridged, usually fistular, glaucous or glabrous.

Leaf: Cauline and ramal; radical in young plants of *Daucus*, usually exstipulate, stipulate in *Centella*; alternate, opposite in some species (*Apiastrum*); simple or much dissected, often decompound; petiolate, petiole usually *sheathing at the base*, venation reticulate unicostate (*Centella*), multicostate (*Astrantia*), Palmately lobed leaves in *Sanicula*.

Note: *Eryngium* and *Aciphylla* are significant deviations within the Apiaceae family, as they display leaves with parallel venation, comparable to monocotyledonous plants. Despite this, they are dicots.

Floral characters: **Inflorescence:** Simple or compound umbel delimited by thin leafy bracts called involucre; bracteate (*Centella*) or ebracteate (*Foeniculum*), sometimes reduced to single flower (e.g., *Azorella*) or to a compact head (*Eryngium*).

Flower: Small, Pedicellate, perfect, complete, regular, sometimes zygomorphic (*Coriandrum*); bisexual, pentamerous, epigynous, disc present. Every umbel of *Echinophora* contains 1-

central female flower surrounded by male flowers. In *Arctopus* and *Aciphylla* the flowers are entirely dioecious. However, in *Astrantia* a transitional condition is present.

Calyx: Sepals 5, minute, connate in a 5-small toothed calyx or absent (*Foeniculum*), adnate to the ovary, often persistent, valvate, green.

Corolla: Petals 5, polypetalous, often unequal and margins incurved, valvate (*Foeniculum*) or imbricate, coloured.

Androecium: Stamens 5, free, inserted under the disc, alternating with petals, anthers bithecal, basifixed/dorsifixed, introrse, filament long, equal in length, inflexed in bud but eventually spreading out.

Gynoecium: Carpels 2, syncarpous, median, inferior, 2-locular with a single pendulous ovule in each chamber, raphe ventral, axile placentation, style 2, free but swollen at base; stigmas 2, capitate; crowned by an epigynous glandular-stylopodium.

Floral Formula: Central Flower: Br. $\oplus \varnothing K_{(5)} C_5 A_5 \overline{G}_{(2)}$

Peripheral Flower: Br. $\% \varnothing K_{(5)} C_5 A_5 \overline{G}_{(2)}$

Fruit and Seeds: **Fruit:** Schizocarpic cremocarp which splits into two one seeded mericarps, which remain attached to a slender often forked axis – the carpophore; mericarps are longitudinally ridged and furrowed, in between the ridges are the furrows with schizogenous oil ducts (vittae). **Seed:** Endospermic, **Embryo:** - small

Main Diagnostic features:

- Mostly herbs - annuals or biennials, internodes hollow
- Leaves finely dissected or decomposed, alternate, exstipulate, sheathing leaf base
- Inflorescence umbel (simple or compound) surrounded by involucre
- Flowers small, epigynous
- Sepals 5, united
- Petals 5, polypetalous
- Stamens 5, inserted under the disc, anthers bithecal, versatile, introrse
- Carpels 2, syncarpous, inferior ovary, 2-locular, single pendulous ovule in each loculus
- Presence of glandular-stylopodium
- Fruit Schizocarpic cremocarp with carpophore

General Characteristics of Apocynaceae (Dogbane/Milkweed family)

Vegetative Features:

Habit & Sap: Typically woody climbers (lianas), shrubs, or trees, less frequently perennial; plants, almost all carrying deadly milky latex (laticifers). Examples:

Lianas (Woody Vines) - *Allamanda cathartica*, *Cryptostegia grandiflora*, *Macropharynx peltata*

Trees - *Alstonia scholaris*, *Plumeria alba*, *Cascabela*

Shrubs - *Acokanthera*, *Adenium obesum*, *Carissa edulis*, *Nerium*

Leaves: Simple, whole, mainly opposite or whorled, and exstipulate.

Floral characters: Inflorescence: Typically axillary or terminal cymes.

Flowers: Bisexual, actinomorphic, and 5-merous (occasionally 4-merous).

Calyx: 5-lobed, often with basal glandular structures.

Corolla: Usually twisted in bud, gamopetalous (fused), salver- or funnel-shaped or rotate.

Androecium: Stamens 5, (sometimes 4), epipetalous, alternipetalous, filaments Short, free, occasionally connected to the style head, with anthers frequently sagittate and connivent (converging) around the style head; Anthers 2-celled, introrse, sagittate at the base, anthers form a cone-shaped structure on top of the style that connects to the stigma head (called Gynostegium); In *Nerium*, anthers have hairy, twisting, or pointed appendages; Pollen is shed as monads (single grains) in Rauvolfioids and pollinia in Asclepiadoideae; dehiscence longitudinal. Pollen is normally shed as monads (as in subfamily Rauvolfioids), or as pollinia (as in subfamily Asclepiadoideae).

Gynoecium: Carpels 2, at the base, the two superior ovaries are free (apocarpous) yet linked by a single, shared style and stigma. Sometimes carpels are totally merged (syncarpous), as in *Carissa*; ovary 1-locular with numerous ovules, anatropous to campylotropous, marginal placentation; when united, ovaries are often 2-locular with axile placentation; style short, filiform; stigmas thickened, Dumbbell-shaped. Some members have nectary discs at the ovary base, e.g., *Thevetia*, *Catharanthus*, *Allamanda*, and *Rauvolfia*.

Floral Formula: $\text{Br} \oplus \overset{3}{\curvearrowright} K_{(5)} C_{(5)} A_5 \underline{G}_{(2)}$

Fruit and Seeds: Fruit: Typically paired follicles (*Nerium*, *Plumeria*), or berries, (*Carissa*), or drupes (*Thevetia*). **Seeds:** Frequently flat, winged or comose (capped with a spike of hairs).

Main Diagnostic features:

- Plants carrying deadly milky latex (laticifers)
- Leaves: Simple, exstipulate
- Corolla salver- or funnel-shaped or rotate, throat with corona
- anthers sagittate, disc present
- Carpels 2, connate above (by styles) and free below
- Dumbbell-shaped stigmas
- Fruit: Typically paired follicles
- Seeds: Frequently flat, winged or comose

General Characteristics of Asclepiadaceae**Vegetative Features:**

Habit: Perennial herbs, shrubs, or rarely small trees; sometimes woody climbers/vines with milky, white latex

Leaves: usually simple, petiolate, entire, opposite-decussate, rarely whorled, exstipulate, waxy. In *Dischidia rafflesiana* leaves are adapted into pitchers, absent in *Periploca*, succulent in *Hoya*.

Floral characters: Inflorescence: Mostly umbellate cymes (*Calotropis*) or dichasial/monochasial cyme, Bracteate or ebracteate.

Flowers: - pedicellate, highly specialized, complete, bisexual, actinomorphic (regular), seldom zygomorphic (*Ceropegia*), 5-merous, hypogynous.

Calyx: Sepals 5, polysepalous or united in deeply partite calyx (fused near the base), quincuncial, occasionally valvate.

Corolla: Petals 5, united in a rotate, campanulate or salver-shaped corolla, 5 lobed, either twisted or valvate, corona may be scaly or hairy – (corolline corona in *Cryptostegia*, *Cryptolepis* or form staminal corona in *Calotropis* and *Asclepias*).

Androecium: Stamens 5, synandrous, rarely free, anthers bithecal, epipetalous, coherent;

Corona: is a specialized, typically fleshy, nectar-storing outgrowth forming a "crown" between the corolla and stamens. These complicated, often 5-lobed structures, which are mostly derived from staminal column, are crucial for pollination by serving as supplementary nectar holders. They are essential to the GYNOSTEGIUM and used for species identification.

Gynostegium: usually 5 stamens are fused with the stigma of the bicarpellary gynoecium, forming a single complex, disc-like structure called Gynostegium

Pollinia: pollen grains create cohesive, waxy aggregates called pollinia (singular: pollinium). Small stalks, called caudicles, join two pollinia from neighboring anthers to the corpusculum, a sticky gland. The translator device attaches to insects for cross-pollination. Thus each stamen has two pollinia. *Mechanism of pollination:* When an insect visits the bloom, the sticky corpusculum attaches to its legs or mouthparts, drawing out the whole mechanism.

Function of pollinia: The insect transfers the pollinia to another flower, where they are put into the stigmatic chamber, allowing pollination.

Gynoecium: Carpels 2, syncarpous, ovaries free, superior, covered in staminal tube, ovules numerous, anatropous, marginal placentation, 1-locular; style 2, free, connate above; stigma discoid, 5-angled;

Floral Formula: $\text{Br} \oplus \overline{\text{K}}_{(5)} \text{C}_{(5)} \text{A}_5 \text{G}_{(2)}$

Fruit and Seeds: Fruit: etaerio of follicles (usually two, sometimes one aborts).

Seeds: Many, compressed, small, brown, with a terminal tuft of silky hairs (coma), adapted for wind dispersal.

Main Diagnostic features:

- Herbs, shrubs, or vines with milky/white latex
- Leaves opposite-decussate, simple, entire, exstipulate
- Flowers gynandrous
- calyx of 5 sepals, imbricate
- corona arising as outgrowth of petals or stamens
- All the 5 stamens fused with stigmatic disc to form gynostegium
- pollens forming pollinia
- Carpels 2, syncarpous, ovaries and style free, only stigma fused to form disc
- Marginal placentation
- Fruit etaerio of follicles
- Seeds many, compressed, comose

General Characteristics of Asteraceae

Vegetative Features:

Habit: Mostly herbs (*Helianthus annuus*, *Tagetes*, *Ageratum conyzoides*, *Lactuca sativa*, *Taraxacum officinale*, *Matricaria chamomilla*), or shrubs (*Santolina*, *Inula*, *Eupatorium*) rarely trees (*Senecio johnstoni*, *Vernonia arborea*, *Espeletia hertwegiana*, *Leucomeris*, *Scalesia*). Many of the plants are xerophytes (*Carthamus tinctorius*, *Encelia farinosa*,

Artemisia tridentate, *Proustia*, *Chrysothamnus*), hydrophytes (*Caesulia axillaris*, *Cotula*, *Petasites*).

Root: Tap root, occasionally modified into tubers (*Dahlia*).

Stem: Erect, or prostrate, herbaceous or woody (*Artemisia*), hairy, sometimes with latex. Stem tubers are also present (*Helianthus*); tubers are edible (*H. tuberosus*); cylindrical; glabrous, solid or fistular, stem may be leaf-like (*Baccharis*).

Leaf: Alternate, sometimes opposite (*Zinnia*, *Dahlia*) or rarely whorled (*Eupatorium*); petiolate or sessile, exstipulate, simple or pinnately or palmately lobed, sometimes scale-like (*Senecio*), unicostate or multicostate reticulate venation.

Floral characters: **Inflorescence:** head/capitulum consists of closely arranged florets surrounded by involucre bracts (carry out the function of protection). The entire capitulum is apparently looks like a single flower.

On the basis of type of florets the capitula are of 3 types:

1. Heterogamous or radiate heads. The outer ray-florets are ligulate, zygomorphic, pistillate /neutral (*Eclipta alba*) and central disc-florets are bisexual, tubular and actinomorphic (e.g., *Helianthus*).
2. Homogamous-rayed or ligulate heads. All the florets are ligulate, zygomorphic and alike (e.g., *Lactuca sativa*, *Taraxacum officinale*, *Sonchus*, *Cichorium*)
3. Homogamous-non-rayed or discoid heads. All the florets are tubular, actinomorphic and alike, e.g., *Eupatorium*, *Ageratum*, *Vernonia*.

Distribution of sex: The flowers of a capitulum may be all Bisexual (*Ageratum*), or ray-florets are female or neuter and inner ones Bisexual, or male; rarely the entire capitulum bears unisexual flowers.

Flower: Bracteate, sessile, (*Sonchus*, *Ageratum*), Bisexual (*Ageratum*), or unisexual, 5-merous, tubular (actinomorphic) or ligulate (zygomorphic), epigynous.

Ray-florets: Zygomorphic, ligulate, pistillate/neutral (*Eclipta alba*) or bisexual, epigynous.

Calyx: absent or modified into tuft of hairs (pappus) or scales.

Corolla: Petals 5, gamopetalous, coloured, ligulate, strap-shaped, valvate.

Androecium: Absent, when present, 5, epipetalous, syngenesious, protandrous, introrse.

Gynoecium: Absent; when present, Carpels 2, syncarpous, inferior, 1-locular, basal placentation, one ascending anatropous ovule; style 1, long; stigma bifid/bilobed.

Floral Formula: Ray Floret: Br. % ♂ $K_{\text{pappus}} C_{(2/3) \text{ or } 0/5} A_0 \overline{G}_{(2)}$

Disc Floret: Br. ⊕ ♂ $K_{\text{pappus}} C_{(5)} A_{(5)} \overline{G}_{(2)}$

Fruit and Seeds: Fruit: cypsela. Seed: Non-endospermic. Embryo: Straight

Main Diagnostic features:

- Mostly herbs or shrubs or rarely trees;
- Leaves alternate, rarely opposite, exstipulate
- Inflorescence capitulum bounded by involucre of bracts consisting of ray and disc florets
- Flower tubular (actinomorphic) or ligulate (zygomorphic), bi- or unisexual, 5-merous
- Calyx: absent or modified into pappus
- Androecium: Absent or when present, Stamens 5, epipetalous, syngenesious, protandrous
- Ovary unilocular, inferior, stigma bifid;
- Basal placentation,
- Fruit cypsela.

❖ ADVANCED CHARACTERISTICS OF ASTERACEAE

- a) **Herbaceous habit:** Mostly herbs - annuals or perennials, which allow them to finish their lifecycles fast in diverse conditions; the herbaceous nature also enables for quick colonization of different environments, including deserts and cold areas.
- b) **Cosmopolitan distribution**
 - **Worldwide Distribution:** The family is present on every continent except Antarctica, ranging from tropical to subpolar climates.
 - **Arid/Semi-Arid Dominance:** Although worldwide, the largest concentration of species occurs in arid and semi-arid regions of subtropical and temperate latitudes.
 - **Habitat Adaptability:** They are found in different environments, including woods, grasslands, and notably in open and disturbed regions, frequently serving as effective invasive or weed species.
- c) **Diversity of Massive Species (one of the Largest Family):**
 - **Species Count:** With approximately 32,000 recognized species in more than 1,600 to 1,900 genera, Asteraceae is one of the biggest families of flowering plants.
 - **Representativeness:** It represents around 10% of all angiosperm species.
 - **Evolutionary Success:** The abundance of species indicates rapid evolution and adaptability, allowing them to fill nearly all ecological niches.

- d) **Specialized Inflorescence (Capitulum/Pseudanthium):** Capitula replace solitary flowers, assembling tiny florets into a large bloom. This saves energy and attracts insects to a focused, effective, and appealing unit, improving pollination.
- e) **Capitulum structure:** The tight packing of florets in a head (capitulum) functions as a cohesive structure that inhibits the flow of rainfall into the individual, upright tubes of the florets.
- f) **Involucral Bracts (Phyllaries):** The entire floral head is encircled by a whorl of bracts called phyllaries, which give extra protection to the growing flowers and their nectar.
- g) **Distinctive Floret Types:** The head typically features central tubular disc florets and peripheral ray florets, optimizing both reproduction and attraction.
- h) **Reduced Calyx (Pappus):** The calyx is modified into hairs, bristles, or scales (pappus) at the top of the fruit (cypsela), facilitating wind dispersal.
- i) **Syngenesious Anthers & Plunger Mechanism:** The anthers are syngenesious around the style, which acts as a plunger, brushing pollen upward as it elongates.
- j) **Reduction in the no. of carpels to 2:** The gynoecium has only two fused (syncarpous) carpels, generating a single compound pistil.
- k) **Unilocular Ovary:** Despite having two carpels, the ovary is unilocular and has one basal ovule. This simplicity maximizes resource allocation to one, high-quality seed instead of many, smaller seeds, improving survival and dissemination.
- l) **Inferior Ovary:** The ovary is situated below the other floral parts (epigynous), offering maximum protection.
- m) **Specialized Style & Stigma:** The solitary style usually terminates in 2 stigmatic branches (bifid), which function in a specific way to gather and display pollen prior to receiving it.
- n) **Evolutionary Significance:** Asteraceae's reduction to a single-seeded, bicarpellary gynoecium represents a highly evolved, advanced condition intended for effective pollination and seed dispersal (often aided by the modification of the calyx into a pappus), in contrast to primitive families that have many free carpels (apocarpy).
- o) **Advanced Pollination & Breeding Systems:** The flowers are often protandrous to promote cross-pollination, yet possess mechanisms for self-pollination if required.
- p) **Growth:** The florets are arranged in precise, complex spiral patterns (parastichies) based on the Fibonacci sequence.
- q) **Easily accessible nectar for Insects (protected against rain):** Despite being shielded, the nectar is readily available to a broad range of insects due to the shallow, open form of the capitulum, allowing for effective pollination by different insects.

- r) **Fruit dispersal by pappus (formed by modification of calyx):** Pappus assists in the dissemination of the one-seeded fruit (cypsela) by 2 basic mechanisms:
- **Anemochory (Wind Dispersal):** The fruit may travel great distances by wind thanks to the pappus's parachute-like structure, which increases surface area and air resistance and frequently aids in the colonization of new, far-off environments.
 - **Epizoochory (Animal Dispersal):** In certain species, the pappus is transformed into hooks, barbs, or awns (e.g., *Bidens*), which cling to the fur of animals or feathers of birds for dispersal.

Advantages of this Adaptation are:

- **High-Efficiency Dispersal:** The pappus functions as a light, effective parachute mechanism, typically enabling plants to adapt disturbed or new settings fast.
 - **Aerodynamic Stability:** Scientific investigations indicate that the pappus forms a separated vortex ring in its wake, stabilizing the flight and providing additional lift/drag.
 - **Moisture-Dependent Behavior:** Some pappi are hygroscopic, altering their structure to open in dry circumstances for flight and close in wet conditions, which can assist regulate the timing of dispersion and germination.
 - **Germination & Seed Protection:** under addition to dispersing the fruit, the persistent pappus can shield it from herbivores and, under some situations, help it absorb water to promote germination.
- s) **Specialized Metabolism & Chemical Defenses:** They possess laticiferous vessels (milky sap) and produce various secondary metabolites (such as sesquiterpene lactones and inulin), which provide protection against herbivores and pests, contributing to their, nearly, global success.

These features contribute to Asteraceae being one of the largest and most widely distributed angiosperm families.

General Characteristics of Brassicaceae (Cruciferae)

Vegetative Features:

Habit: commonly annual (*Brassica*, *Capsella*), biennial (*Brassica oleracea*, *Alliaria petiolata*, *Isatis tinctoria*, *Brassica rapa* subsp. *rapa*), or perennial (*Armoracia rusticana*, *Crambe maritima*, *Nasturtium officinale*) herbs, sometimes shrubs (*Crambe cordifolia*, *Arabis kennedyae*, *Iberis*, *Erysimum*, *Aethionema*). Vegetative reproduction is by bulbils (*Cardamine bulbifera*) or by coral roots (*Cardamine pentaphyllos*).

Roots: Tap root, swollen due to stored foods, may be Napiform/Top-shaped (*Turnip-Brassica rapa*), Fusiform/Spindle-shaped (*Radish-Raphanus sativus*) or Conical in Carrot.

Stem: Herbaceous, erect, round (*Iberis, Brassica*), seldom woody (*Farsetia jacquemontii*), sometimes reduced (*Raphanus, Brassica*), glabrous or hairy, solid and branched.

Leaves: Alternate or sub-opposite (*Cardamine concatenata*), simple, entire, exstipulate (*Raphanus sativus, Capsella bursa-pastoris*). May be cauline or radical (*Raphanus*), generally sessile, hairy, unicostate reticulated.

Floral characters:

Inflorescence: Ebracteate, Raceme (*Raphanus sativus*), corymbose raceme (*Iberis amara*) or corymb (*Brassica oleracea*).

Flower: Pedicellate, bisexual, actinomorphic rarely zygomorphic (candytuft – *Iberis amara*), hypogynous, complete or incomplete (*Iberis, Lepidium*), 4-merous.

Calyx: Sepals 4, free, 2 antero-posteriors & 2 lateral which may be saccate, imbricate.

Corolla: Petals 4, alternate with sepals, free, equal, rarely unequal (*Iberis, Teesdalia*) or sometimes may be replaced by stamens (*Capsella bursa pastoris*), arranged in the form of across (cruciform), usually clawed.

Androecium: Stamens 6 (2+4), arranged in two whorls, tetradynamous (outer two short and inner 4 long), free, anthers bithecous, basifixed, introrse; staminal base contains disc like nectarines; sometimes, number of stamens may be 16 (or up to 24) as in *Megacarpaea*, 4 as in *Cardamine hirsuta* (Hairy Bittercress), 2 (or 4) – as in *Coronopus* (Swine Cress) etc.

Gynoecium: Bicarpellary (Exception: tricarpeal in *Lepidium sativum*, tetracarpeal in *Nasturtium* or watercress), syncarpous, ovary superior, 1-locular, but becomes 2-locular due to the expansion of replum (false septum); placentation parietal, ovules many, style short, stigma simple/bifid. Notably, morphologists have long been intrigued by the crucifer carpel – this attracted their attention to this puzzling subject for quite a long time.

Floral Formula: (Brassica): $\text{Ebr} \oplus \overset{\curvearrowright}{K}_{2+2} C_4 A_{2+4} \underline{G}_{(2)}$

(*Iberis*): $\text{Ebr} \% \overset{\curvearrowright}{K}_{2+2} C_{2+2} A_{2+4} \underline{G}_{(2)}$

Fruit and Seeds: **Fruit:** Siliqua (*Eruca sativa, Brassica oleracea*) or silicula (*Iberis amara, Coronopus didymus, Capsella bursa-pastoris*), when the valves separate in a siliqua the seeds remain attached to persistent replum; sometimes lomentum (*Raphanus sativus* - unlike a siliqua that splits apart, the lomentum is constricted between the seeds and breaks into one-seeded, indehiscent segments/mericarps at maturity); **Seed:** non-endospermic

Main Diagnostic features:

- Flowers actinomorphic, Bisexual
- Sepals 4, in two whorls of two each,
- Petals 4, cruciform;
- Stamens 6, tetradynamous;
- Gynoecium bicarpellary, syncarpous, parietal placentation, 2-locular due to the formation of replum;
- Fruit siliqua or silicula

General Characteristics of Cucurbitaceae

Vegetative Features: Habit: Mostly annual (*Cucumis sativus*, *Lagenaria siceraria*) or perennial (*Coccinia grandis/indica*, *Trichosanthes dioica*, *Sechium edule*) herbs, rarely shrubs (*Acanthosicyos*, *Cucurbita pepo*) or small trees (*Dendrosicyos socotrana*, *Gerrardanthus macrorrhizus*), usually trailing, climbing with simple/branched tendrils, *Xerosicyos danguyi* is a succulent, woody climber.

Root: Tap root, branched.

Stem: Herbaceous, branched, 5-angled, climbing, angular, fistular.

Leaves: Alternate, petiolate-petiole long and hollow; simple, lobed, exstipulate, palmately veined; tendrils present in the axil of leaf or opposite to the leaf. In *Acanthosicyos* the leaves are absent but thorns are present.

Tendrils: In Cucurbitaceae, tendrils are specialized, thin, coiling, lateral organs that emerge in leaf axils for climbing support, often viewed as modified stem structures (branches). They are morphologically complicated, resembling modified axillary shoots or modified stipules and leaf/stem components, and coiling around objects.

Floral characters: Inflorescence: There is great variation in the inflorescence. Flowers are solitary, or racemose or cymose panicles (*Actinostemma*).

Flower: Regular, mostly unisexual rarely bisexual (*Schizopepon*), incomplete, epigynous, small or large, mostly white or yellow, pentamerous.

Male flower: Produced in large numbers.

Calyx: Sepals 5, united, pointed, rarely petaloid, campanulate, aestivation imbricate.

Corolla: Petals 5, gamopetalous united at the base (*Momordica*) or through out (*Cucurbita*, *Coccinea*), polypetalous (*Luffa*, *Lagenaria*), campanulate, rotate, imbricate/valvate aestivation.

Androecium: Highly variable (3–5 stamens), sometimes free or combined to form a central column, anthers dithecal extrorse, dehiscence longitudinal

Significant Diversity (Variation) in Stamens in Cucurbitaceae:

- a) **Number:** Although 5 is the original condition, most current Cucurbitaceae have 3 stamens, or in certain cases, all are fused into a single column.
- b) **Fusion (Filaments and Anthers):**
- c) **Syngenesious:** Filaments are free, but stamens are joined by their anthers (e.g., *Momordica*, *Cucumis*).
- d) **Synandrous:** Both filaments and anthers are joined (e.g., *Cyclanthera*).
- e) **Distinct:** In certain genera like *Thladiantha* and *Fevillea*, the 5 stamens are free.
- f) **Anther Morphology:** To increase pollination effectiveness, anther thecae are frequently curved, sinuous, coiled, or twisted (e.g., *Cucurbita*).
- g) **Staminodes:** The androecium in female (pistillate) flowers is reduced to sterile, non-functioning structures called staminodes.

❖ VARIATION OF ANDROECIUM IN CUCURBITACEAE

- a) ***Cucurbita* (squash, pumpkin):** Three stamens with anthers those are severely coiled or twisted.
- b) ***Sicyos & Sechium* (Chayote):** A central column is formed by the union of filaments.
- c) ***Cyclanthera*:** A single, ring-like structure is formed by the union of all stamens.
- d) ***Sincydium*:** The pairs of stamens are united below
- e) ***Momordica* (Bitter Gourd), *Citrullus*:** union of pairs of stamens is complete showing (apparently) 3 distinct stamens with joined anthers and free filaments.
- f) ***Thladiantha*:** Usually in pairs, there are 5 stamens, (Two pairs of stamens are closely approximated in the lower part of their filaments and the fifth stands apart), sometimes 4.
- g) ***Fevillea*:** a polyandrous condition is observed with all the 5 stamens free and alternating to the petals. It is a primitive genus.

This diversity indicates evolutionary trends within Cucurbitaceae family toward increasing specialization and fusion, frequently connected with unique pollination techniques.

Genoecium: Reduced or rudimentary or absent.

Female flower: They are fewer in number than the male flowers.

Calyx: Sepals 5, gamosepalous, calyx tube adnate to the ovary wall; imbricate aestivation, superior.

Corolla: Petals 5, gamopetalous, inserted on calyx tube; imbricate aestivation, superior.

Androecium: Staminodes 0, 3, 5.

Gynoecium: Tricarpellary, syncarpous, ovary inferior, unilocular with parietal placentation, the intruding placentae make the ovary to appear trilocular.

In *Luffa* the ovary is narrow and ultimately 3-4 celled and apparently of the axile type. In *Sechium* the ovary is unilocular with only a single ovule; ovule bitegmic. Style stout and columnar and bears a forked stigma for each carpel.

The stigmas are commissural i.e. stand above the dividing lines between the carpels. This is explained by assuming that each is a joint structure and composed of a branch of the stigmas of two adjacent carpels.

Floral Formula: Male Flower: $\text{Br} \oplus \text{♂ } K_{(5)} C_{(5)} A_{5 \text{ or } (2) + (2) + 1} \bar{G}_0$;

Female Flower: $\text{Br} \oplus \text{♂ } K_{(5)} C_{(5)} A_{5 \text{ or } (2) + (2) + 1} \bar{G}_{(3)}$

Fruit and Seeds: **Fruit:** Soft, fleshy, indehiscent, and berry-like or pepo.

Seed: Exalbuminous, flattened, numerous, embryo straight, cotyledons large and oily.

Main Diagnostic features:

- Prostrate herb with five-angled stem & simple/branched tendrils
- Leaves palmately lobed, surface hispid
- Flowers 5-merous, unisexual, monoecious or dioecious, epigynous
- Stamens Highly variable (3–5 stamens)
- Ovary inferior, 3-locular, ovules many, bitegmic
- Placentation parietal
- Fruit fleshy, pepo

General Botanical Characteristics of Dipterocarpaceae

Vegetative characters:

Habit: Gigantic trees, rarely shrubs (*Vatica lanceifolia*, *Stemonoporus*, *Hopea glabra*).

Root: Branched Taproot, deep, typically linked with ectomycorrhizal fungi.

Stem: Erect, tall, woody, branched, with resin ducts.

Leaf: Simple, entire, coriaceous, stipulate.

Floral characters:

Inflorescence: Paniculate terminal or axillary spikes or racemes.

Flowers: Actinomorphic, bisexual, small, often fragrant, hypogynous, 5-merous; flower axis broad. Saucer shaped or concave sometimes; complete.

Calyx: Sepals 5, unequal, free, persistent, enlarged wing-like in fruit (*Dipterocarpus*, *Shorea*), imbricate or valvate.

Corolla: Petals 5, free, imbricate/contorted.

Androecium: Stamens 5 to 15 or many; filaments short, rarely long, anther lobes unequal, connective produced at the apex.

Gynoecium: Carpels 3, syncarpous, superior, 3-locular, axile placentation, ovules 2 in each locule; stigma always exceeds the stamens.

Floral Formula: $\text{Br. } \oplus \text{ } \overline{\text{K}}_{(5) \text{ or } 5} \text{ C}_{(5) \text{ or } 5} \text{ A}_{\infty \text{ or } 5-15} \underline{\text{G}}_{(3-5)}$

Fruit and Seeds: **Fruit:** Woody, indehiscent, 1-seeded (sometimes 2) nut enclosed by persistent winged calyx, forming a samara. **Seed:** Exalbuminous with fleshy cotyledons.

Main Diagnostic features:

- Gigantic timber trees with an abundant aromatic resins;
- Leaves coriaceous, stipulate;
- Flower regular, bisexual, hypogynous;
- Sepals 5, polysepalous, persistent;
- Petals 5, polypetalous; stamens many in one to several whorls, slightly polyandrous,
- Carpels 3, syncarpous, superior;
- Fruit samara enclosed in persistent sepals.

General Botanical Characteristics of Ericaceae (heath family)

Vegetative Features:

Habit: chiefly shrubs, or small trees, with some herbs and, rarely, mycoheterotrophic (chlorophyll less) parasitic plants (e.g., *Monotropas*).

Leaves: typically evergreen, simple, alternate or whorled, leathery (coriaceous), frequently with a shiny surface.

Roots: typically with specialized hair roots forming symbiotic relationships with mycorrhizal fungi to help in nutrient absorption in acidic soil.

Stems: chiefly woody, occasionally with exfoliating bark.

Floral characters: Inflorescence: terminal or axillary racemes, or spikes, also can be solitary.

Flowers: Typically regular, 4-5 merous.

Calyx: Sepals typically 4 or 5, (ranging from 2 to 7), connate at the base, cup-like, valvate or imbricate, can become fleshy, Persistent, surrounding the fruit (e.g., *Erica*, *Gaultheria*)

Corolla: Petals 4-5, gamopetalous, urn-shaped (urceolate), bell-shaped (campanulate), or tubular, corolla lobes short.

Androecium: typically 8-10 stamens (twice the number of petals), arranged in two whorls, epipetalous, polyandrous; filaments distinct (free), often flattened, sometimes, S-shaped; anthers open by apical pores, anthers frequently form with the base at the apex, a condition called developmental inversion, bears 2 noticeable appendages that resemble spurs or awns (crucial character); Pollen typically bound together by viscin threads & distributed in tetrads.

Gynoecium: Carpels 4-5 (sometimes 2-10), syncarpous; ovary typically superior (hypogynous), but in the Vaccinioideae subfamily (blueberries, cranberries), it is inferior (epigynous), 3 to 5 loculed; axile placentation; from the apex of the ovary, a single, thin, frequently hollow style emerges. Typically, the stigma is lobed, capitate, or head-like; Presence of a distinctive nectar-producing disk at the base of ovary.

Floral Formula: Br. $\oplus$ or $\% \text{ } \overline{\text{K}}_{(4-5)} \text{ C}_{(4-5)} \text{ A}_{8-10} \underline{\text{G}}_{(2-10)}$

Fruit and Seeds: Fruit: Highly variable, may be dry loculicidal/septicidal capsules encircled by colorful, fleshy calyx lobes (e.g., *Rhododendron*, *Kalmia*), fleshy berries (e.g., *Vaccinium*) or drupes (e.g., *Arctostaphylos*, *Gaultheria*).

Seeds: typically tiny and many, have a hard, woody, or bony testa, surface can be smooth, granular, or ribbed, frequently winged or tailed in capsular kinds for wind dispersal

Embryo: tiny, straight, sometimes embryos are green (such as *Vaccinium*).

Main Diagnostic features:

- Mostly evergreen, woody shrubs or small trees, frequently thriving in acidic, nutrient-poor soils
- Leaves simple, leathery, alternate or whorled,
- Flowers showy, gamopetalous, usually bell- or urn-shaped.
- Poricidal anthers, awned
- 5-lobed (syncarpous) ovary with nectary disc
- Fruits dry loculicidal/septicidal capsules
- Seeds: tiny and many

Important Taxonomic Notes:

- The family is classified within the asterids clade.
- It is regarded as a significant family in the Ericales order.
- It comprises numerous previous families like as Pyrolaceae, Monotropaceae, and Vacciniaceae, which have been included in Ericaceae.

General Botanical Characteristics of Euphorbiaceae

Vegetative Features:

Habit: Highly diverse, starting from annual or perennial herbs (e.g., *Euphorbia hirta*) to shrubs (*Jatropha*) and large trees (*Hevea brasiliensis*), sometimes, succulents with fleshy stems.

Roots: usually a branched taproot system; sometimes starch-rich tuberous roots (*Manihot esculenta*).

Latex: mostly characteristic milky or watery latex, which is often toxic or irritating to skin and eyes.

Leaves: Usually simple, alternate, sometimes opposite or whorled, stipulate, In some succulent species, leaves are reduced or fall off early.

Floral characters: Inflorescence: complex and variable, Cyathium is most distinctive type (as in *Euphorbia pulcherrima*, *Euphorbia hirta*, *Euphorbia milii*, *Pedilanthus*) where a false flower made of a cup-like involucre containing a single central female flower remains surrounded by multiple reduced male flowers; other types are - Compound Raceme / Panicle (*Ricinus communis*), Simple Raceme / Spike (*Croton sparsiflorus*, *Croton tiglium*), Catkin (*Acalypha indica*), Terminal Cyme (*Jatropha curcas*, *Jatropha gossypifolia*), Solitary Axillary (*Phyllanthus amarus*), Complex/Specialized Pseudanthia (*Dalechampia*, *Pera*)

Flowers: Always unisexual, actinomorphic, monoecious (*Manihot esculenta*, *Ricinus communis*) or dioecious (*Excoecaria agallocha*, *Putranjiva roxburghii*, *Bridelia*).

Perianth: Often reduced or absent. When present, it consists of sepals only; petals are rarely found.

Androecium: Stamens 1 (*Euphorbia*) to many (*Croton*), up to 1,000 stamens in *Ricinus* which may be often branched, may be free or united (monadelphous); nectariferous disc present around androecium; bithecal anthers have longitudinal or apical dehiscence.

Gynoecium: Carpels 3, syncarpous, superior ovary 3 chambered, 1 or 2 pendulous, anatropous ovules per locule; ovary base often has nectariferous discs or glands; styles 3, free or basally connate, bipartite (forked) or bifid; Placentation Axile.

Floral Formula: *Croton*: Male Flower: Br brl $\oplus$ ♂ K₅ C₅ A₍₅₊₅₎ G₀;

Female Flower: Br $\oplus$ ♀ K₅ C₅ A₀ G₍₃₎

Fruit and Seeds: **Fruit:** schizocarpic capsule (Regma) as in (*Ricinus communis*, *Jatropha curcas*, *Manihot esculenta*, *Hevea brasiliensis*, *Croton tiglium*), at maturity, Regma frequently dehisces into 3 (or occasionally more) cocci, (mericarps), which are single-seeded parts; rarely a fleshy, indehiscent drupe with a hard, stony inner layer (endocarp) as in *Phyllanthus emblica*, *Bridelia*, *Trewia*, *Drypetes*; very rarely a berry (fleshy fruit without a stony endocarp) as found in *Securinega*.

Seeds: Endospermic, an abundant caruncle (a fleshy, white protrusion) near the hilum aids ant-mediated dissemination; *Euphorbia exigua* shows bilobate caruncle, orbiculate-quadrangulate; *Euphorbia falcate* shows conical caruncle, compressed-ovoid-quadrangular; *Euphorbia hirta* and *E. thymifolia* show oblong, obtusely tetragonal, two-layered, collapsing testa.

Main Diagnostic features:

- Plants contain white, yellow, or red latex
- Cyathium Inflorescence
- Unisexual Flowers, apetalous
- Perianth often reduced or absent
- Stamens 1 to many
- Tricarpellary, syncarpous, ovary superior, 3 chambered
- Fruit: schizocarp or capsule, dehiscent
- Albuminous seeds carunculate

General Botanical Characteristics of Fabaceae sensu lato

Classification of Subfamilies under APG IV

APG IV classifies Fabaceae as a single family. Although historically it was separated into three (Mimosoideae, Caesalpinioideae, Papilionoideae), the Legume Phylogeny Working Group (LPWG) has further broken this into six subfamilies in order to reflect that the old Caesalpinioideae was paraphyletic.

Cercidoideae (formerly a member of Caesalpinioideae)

Detarioideae (formerly belonging to Caesalpinioideae)

Dialioideae (previously in Caesalpinioideae)

Caesalpinioideae (which comprises most of the previous Caesalpinioideae along with

Mimosoideae)

Faboideae (or Papilionoideae)

Duparquetioidae

Important Features under APG IV

- a) Monophyly: The family is solidly proven as monophyletic.
- b) Phylogenetic Context: It is closely linked to the families Polygalaceae, Surianaceae, and Quillajaceae under the order Fabales.
- c) Subfamily Merge: In several evolutionary studies, the Mimosoideae are nested within the larger Caesalpinioideae, which leads to their rearrangement.

General Botanical Characteristics of Mimosaceae (or Mimosoideae)

Vegetative Features:

Habit: chiefly woody trees & shrubs, sometimes lianas, rarely herbs (e.g., *Neptunia*), often with armed with spines or prickles.

Leaves: Mostly alternate, stipulate, typically bipinnately compound, sometimes reduced to 1-pinnate, petiole-bases swollen (pulvini), which aid sensitive leaf movement (*Mimosa pudica*).

Floral characters: Inflorescence: arranged in compact, dense heads, spikes, or racemes.

Flowers: Small, regular, bisexual, hypogynous, tetramerous to pentamerous.

Perianth: sepals united), petals valvate.

Androecium: Stamens many, free or slightly connate at the base, filaments long, filiform, exserted, often brightly colored, and showy; anthers bithecal, versatile/dorsifixed, introrse.

Gynoecium: Monocarpellary (*which is a crucial trait*), ovary superior, 1-locular, marginal placentation; Style long & filiform, stigma small & terminal

Floral Formula: $\text{Br. } \oplus \overset{\circ}{\text{K}}_{(4) \text{ or } (5)} \text{C}_4 \text{ or } 5 \text{A}_\infty \underline{\text{G}}_1$

Fruit and Seeds: **Fruit:** typically a dry, dehiscent or indehiscent legume or pod; they might be flat, thin, and straight, or can be woody, coiled, or spiraling (like *Pithecellobium dulce*); pods of several genera, like *Entada* and *Mimosa*, are lomentaceous, which at maturity split into one-seeded segments called "loment."

Main Diagnostic features:

- Mostly tropical/subtropical trees and shrubs, often characterized by thorny stems

- Bipinnately compound leaves with pulvini
- Inflorescence showy, dense heads or spikes
- Flowers are bisexual
- conspicuous numerous stamens, often brightly colored, exserted
- Single superior ovary
- Fruit is a legume or lomentum or pod.

General Botanical Characteristics of Caesalpiniaceae (or Caesalpinioideae)

Vegetative Features:

Habit: Mostly trees or shrubs, sometimes woody climbers (e.g., *Caesalpinia*) or rarely herbs

Stem: woody, round, branched

Leaves: Alternate, stipulate, compound (typically pinnate or bipinnate), leaf bases swollen (pulvinus), leaflets opposite, sometimes with stipels.

Floral characters: Inflorescence: Racemes or panicles, axillary or terminal.

Flowers: Bisexual, rarely unisexual, pedicellate, pentamerous, strongly zygomorphic.

Calyx: Sepals 5, usually free or connate at the base, often unequal with the lowest one largest.

Corolla: Petals 5, typically polypetalous, often clawed, with ascending imbricate aestivation (posterior/standard petal is innermost).

Androecium: Stamens 1-10 (often 10), Polyandrous (free) or rarely connate (e.g., *Tamarindus*), sometimes modified to staminodes; often unequal in length, exserted, anthers bithecal.

Gynoecium: Carpel 1, superior stalked ovary, unilocular, 2 to many ovuled, placentation marginal; style long, often simple; stigma terminal or simple.

Floral Formula: Br. % ♂ $K_{(5)} C_5 A_{5+5} \underline{G}_1$

Fruit and Seeds: Fruit: dry, dehiscent pod (legume) or a lomentum; indehiscent in *Tamarindus*.

Seeds: Often with aril or endosperm, frequently dispersed by wind (anemochory - *Tipuana tipu* has winged, samara that turns like a helicopter while falling) or water (hydrochory - *Caesalpinia crista*).

Main Diagnostic features:

- Chiefly tropical trees, shrubs, or woody climbers

- Pinnately or bipinnately compound leaves
- Flowers showy, zygomorphic with ascending imbricate aestivation
- Sepals 5 and petals 5,
- Ovary superior
- Stamens 10 or fewer
- Fruit typically a pod (legume or lomentum)

General Botanical Characteristics of Papilionaceae (or Faboideae)

Vegetative Features:

Habit: Mostly herbs, shrubs, or climbers often with tendrils.

Root: Taproot system with distinct nodules containing N₂-fixing bacteria (*Rhizobium*).

Leaves: Alternate, stipulate, usually compound (pinnate or simple), swollen leaf base (pulvinus).

Floral characters: Inflorescence: Commonly racemose, often axillary or terminal racemes.

Flower: Bisexual, zygomorphic, pentamerous.

Calyx: Sepals 5, gamosepalous, the odd sepal is anterior, campanulate (bell-shaped) or tubular, imbricate, often persistent.

Corolla: petals 5, polypetalous, papilionaceous (butterfly-shaped); five petal components are arranged as follows in descendingly imbricate (vexillary) aestivation:

- The largest, posterior, outermost petal is called Vexillum (Standard/ banner);
- Alae (Wings) are the 2 lateral, wing-like petals.
- Carina (Keel) is the 2 anterior, innermost, fused or coherent petals that form a boat-shaped structure protecting the stamens and pistil.

Androecium: Stamens 10, all fertile, usually diadelphous (9 fused + 1 free), rarely monadelphous (*Crotalaria*) or very rarely 9 (*Abrus*); anthers bithecal, versatile/basifixed, longitudinal dehiscence

Gynoecium: Monocarpellary, ovary superior, 1-locular, many ovuled, campylotropous/anatropous; placentation marginal (ovules are attached to the ventral suture); style bent or curved; stigma simple/capitate.

Floral Formula: *Crotalaria*: Br. % ♂ K₍₅₎ C₁₊₂₊₍₂₎ A₍₁₀₎ G₁

Clitoria: Br. % ♂ Epik. K₍₅₎ C₁₊₂₊₍₂₎ A₍₉₎₊₁ G₁

Fruit and Seeds: Fruit: A legume or pod, dehisces into 2 valves at the ventral/dorsal sutures, occasionally a lomentum (*Mimosa pudica*, *Desmodium*, *Hedysarum*, *Zornia*).

Seeds: Non-endospermic, smooth, rarely pitted (genus *Tephrosia*, Tribe Desmodieae), sometimes arillate (*Cytisus scoparius*, *Stylosanthes scabra*)

Embryo: curved.

Main Diagnostic features:

- Herbaceous, root nodules present for nitrogen fixation
- Alternate, pinnately compound leaves with pulvinate bases
- Flowers strongly zygomorphic,,
- Sepals 5, gamosepalous, the odd sepal is anterior, campanulate (bell-shaped) or tubular, imbricate
- Five petals ("butterfly-shaped"), arranged in vexillary aestivation
- Stamens usually diadelphous (9 fused + 1 free)
- Fruit legume/pod

General Botanical Characteristics of Lamiaceae

Vegetative Features:

Habit: Plants are usually annual or perennial herbs or shrubs, rarely trees (*Leucoseptrum*) with square stem & aroma.

Stem: Distinctly square in cross-section, often hairy.

Leaves: Simple, opposite decussate, exstipulate, hairy, when crushed, often release a strong, aromatic fragrance due to essential oils.

Floral characters: Inflorescence: Typically a verticilaster consisting of condensed cymes arranged in whorls at leaf axils, often forming spike-like structures; (spike- *Teucrium*, axillary cyme-*Leucas prostrate*, racemose- *Scutellaria*);

Flowers: bisexual, zygomorphic (regular in *Mentha*), hypogynous, bracteate.

Calyx: Sepals- 5, united, persistent, campanulate or tubular, sometimes bilabiate; valvate or imbricate.

Corolla: Gamopetalous, corolla bilabiate/two-lipped with 2/3 arrangement (upper lip with 2 & lower lip with 3 petals); (exception: - bilabiate 4/1 arrangement in *Ocimum*, *Hyptis*; & 0/5 arrangement in *Teucrium*), Imbricate.

Androecium: Stamens 4, (2 in *Salvia*, *Meriandra*; monadelphous- *Coleus*); didynamous (2 long and 2 short), epipetalous.

Gynoecium: Carpels-2 (bicarpellary), syncarpous, ovary 2-chambered which ultimately become deeply 4-lobed; placentation axile; style gynobasic.

Floral Formula: *Leucas*: Br. % ♂ $K_{(5)} C_{(2+3)} \wedge A_{2+2} \underline{G}_{(2)}$

Fruit and Seeds: Fruit: 4 one-seeded nutlets (schizocarpic carcerulus)

Seeds: Exalbuminous; testa thin; Embryo: with flat cotyledon (parallel to fruit axis)

Main Diagnostic features:

- Fragrant herbs or shrubs
- Rectangular stems
- Leaves opposite decussate, exstipulate, hairy
- Inflorescence: typically a verticilaster
- Gamopetalous corolla bilabiate/two-lipped
- Stamens 4, didynamous (2 long and 2 short), epipetalous.
- Style gynobasic
- Fruit: - 4 one-seeded nutlets (schizocarpic carcerulus)

General Botanical Characteristics of Magnoliaceae

Vegetative Features:

Habit: Trees or shrubs sometimes climbing. Oil sacks present in stem and leaves.

Root: Tap branched.

Stem: Erect, aerial, woody, branched.

Leaves: Alternate, simple, entire, commonly ever-green, coriaceous, stipules large (Magnolia) covering young leaves.

Floral characters: **Inflorescence:** Solitary, terminal or axillary.

Flower: Large (*Magnolia*, *Fraseri*), complete, regular, unisexual (*Drimys*), typically bisexual, hypogynous, aromatic with long & convex Floral axis (torus).

Perianth: Nine to many, free, all alike and petaloid or the three outer ones green (*Liriodendron*), arranged in whorls of three, imbricate and cyclic (*Magnolia* and *Michelia*) or acyclic (spiral) arranged on an elongated or semi-elongated convex torus, free, inferior.

Androecium: Stamens many, free, often spirally arranged in a beautiful series, filaments short or absent, anther lobes linear, with a prolonged connective, Introrse (*Magnolia*, *Manglietia*) or Extrorse (*Michelia*, *Liriodendron*).

Gynoecium: Carpels many, free, superior, arranged spirally on a cone-shaped elongated thalamus (gynophore), rarely syncarpous (*Zygogynum*), placentation marginal.

Floral Formula: (*Michelia*): Br. $\oplus \overline{\sigma} K_3 C_{3+3} A_\infty \underline{G}_\infty$ or, Br. $\oplus \overline{\sigma} P_{3+3+3} A_\infty \underline{G}_\infty$

Fruit and Seeds: **Fruit:** Aggregate of Follicles (woody or leathery) in *Magnolia grandiflora*, *Magnolia campbellii*; Aggregate of Samaras (papery/dry) in *Liriodendron tulipifera*; Fleshy/Berry-like Aggregate in *Talauma candollei*; **Dehiscence:** Follicles split open all along the abaxial side, frequently leaving seeds hanging by a thread-like funiculus.

Seed: Large, typically, 1–2 per follicle, endospermic, with a red/orange, fleshy sarcotesta that makes them highly decorative & attracts birds assisting in seed dispersal.

Main Diagnostic features:

- Trees and shrubs;
- Leaves 2-ranked, stipulate,;
- Flowers bisexual, regular, large;
- Perianth usually 3-merous, whorled or spiral;
- Stamens and carpels many & free, spirally arranged on elongated axis,
- Fruit an etario of follicles or berries, sometimes samara.

❖ PRIMITIVE FEATURES OF MAGNOLIACEAE:

The Magnoliaceae family is regarded as primitive because of its large flowers, which include numerous separate (apocarpous) carpels and stamens on an elongated receptacle (torus), and many spirally arranged, undifferentiated tepals (petals and sepals). These characteristics reflect ancestral traits like beetle pollination and a distinct, early-diverging lineage in the evolution of angiosperms, though some more recent views also suggest relative specialization. Their apocarpous gynoecium, many parts, and spiral arrangement of floral elements are essential fundamental characteristics that set them out as ancient flowering plants.

Important Primitive Features are:

- a) **Floral Structure:** Large, single, ostentatious blooms with spirally organized pieces instead of separate whorls.
- b) **Perianth:** A large number of closely related tepals, or sepals that resemble petals, those are difficult to distinguish between sepals and petals.
- c) **Androecium (Stamens):** A large number of spirally arranged stamens with short filaments and frequently thicker connective tissue.

- d) **Gynoecium (Carpels):** A large number of unique (apocarpous) carpels, each containing a single ovule, grouped in a spiral pattern on a long container (torus).
- e) **Fruit:** A collection of follicles, frequently containing sarcotesta (suspended seeds).
- f) **Pollination:** An old pollination phenomenon, mostly beetle-pollinated.

What Makes Them Primitive?

These characteristics resemble the early angiosperms' supposed ancestral floral shape, when parts were fewer and grouped in whorls (for example, four or five petals/sepals in different whorls). The Magnoliaceae family is important for exploring the origins of angiosperms because of its spiral layout and many sections, which are thought to be evolutionary remnants from non-flowering predecessors.

General Botanical Characteristics of Malvaceae

Vegetative Features:

Habit: usually erect herbs (*Abutilon*, *Malva*, *Sida*, *Urena*), shrubs (*Hibiscus*, *Gossypium*), rarely woody trees (*Gossypium arboreum*), mucilaginous sap present in all parts; usually young parts are covered with stellate (star-shaped) hairs.

Root: Tap, root, branched.

Stem: Herbaceous (*Malva*) or woody (*Hibiscus*), branched, erect or spreading (*Sida*, *Malva parviflora*) pubescent with stellate hairs.

Leaves: Alternate, petiolate, stipulate, free lateral (as in *Hibiscus rosa-sinensis*, *Sida*), stipules deciduous i.e., short-lived and fall early as in *Malva*, simple (often palmately lobed/parted), margin wavy or serrate, apex acute, multicostate reticulated.

Floral characters: Inflorescence: Solitary axillary (*Hibiscus*, *Urena*), solitary terminal (*Abutilon*), raceme (*Althaea*), panicle (*Kydia*).

Flower: Pedicellate, bracteate, bracteolate in the form of epicalyx, bisexual, rarely unisexual (*Napaea*), complete, regular, 5-merous, hypogynous.

Epicalyx: Epicalyx 3 (*Gossypium*), 7 to 9 (*Althaea*) but totally absent in *Abutilon*, *Sida*.

Calyx: Sepals 5, connate at base, persistent, occasionally forming a tube (*Urena*), valvate.

Corolla: Petals 5, polypetalous, sometimes slightly connate at base with the staminal tube-thus epipetalous, showy, twisted or contorted, petals show clear venations.

Androecium: Stamens many, monadelphous, forming a staminal tube; epipetalous staminal tube united with the corolla, anthers monothealous (one-celled), reniform, basifixed, filament short, introrse.

Gynoecium: Carpels usually five (*Hibiscus*) or 10 (*Althaea*), many (*Abutilon*) or 3 (*Kydia*); syncarpous, ovary superior, penta or multi-chambered, placentation axile, 1 to many ovuled in each chamber; style 1, long, passing through the staminal tube; stigma correspond to the no. of carpels.

Floral Formula: Br. Br1. $\oplus \varnothing K_5 C_5 A_\infty \underline{G}_1$

Fruit and Seeds: **Fruit:** Schizocarpic (*Abutilon*, *Malva*, *Sida*), loculicidal capsule (*Hibiscus*, *Gossypium*), berry (*Malvaviscus*).

Seed: Non-endospermic, reniform (kidney-shaped), occasionally seed coat is densely tomentose (*Gossypium*).

Main Diagnostic features:

- All young parts are covered with Stellate hairs, mucilaginous juice present,
- leaves alternate, stipulate, multicostate reticulated;
- Inflorescence solitary or cyme;
- Flower regular, bisexual, hypogynous, 5-merous, with epicalyx,
- Stamens many, monadelphous, epipetalous, anthers monothealous, reniform,
- Carpels often 5, syncarpous, ovary multilocular, superior, axile placentation;
- Style 1, long, passing through the staminal tube
- Fruit schizocarpic carcerulus/capsule.
- Pollen grains large, spherical, spiny

General Botanical Characteristics of Myrtaceae

Vegetative Features:

Habit: chiefly trees (*Eucalyptus*, *Syzygium*, *Psidium*) or shrub (*Carreya*), rarely herbs.

Root: branched tap root

Stem: Erect woody, branched, bark very shining, smooth and goes off in old trees (*Eucalyptus*);

Leaves: Simple, opposite, alternate (*Eucalyptus*), or whorled, shortly petiolate, exstipulate or with minute stipule, gland dotted, coriaceous, evergreen.

Floral characters: Inflorescence: typically cymes, sometimes panicle cyme or corymbose cyme, drooping spike in *Callistemon*; axillary in *Psidium*; solitary axillary (*Myrtus communis*); trichotomous cyme (*Syzygium*); paniculate cyme (*Eucalyptus*).

Flower: Pedicellate (*Eucalyptus*) or sessile (*Callistemon*), complete, bracteate usually with two bracteoles (*Callistemon*), ebracteate (*Eucalyptus*) regular, bisexual, epigynous sometimes perigynous;

Calyx: Sepals 4-5, free or united, rarely reduced or thrown off like a lid as the flower opens (*Eucalyptus*); quincuncial aestivation.

Corolla: Petals 4-5, free, at times gamopetalous, forming cap (*Eucalyptus*), quincuncial.

Androecium: Stamens many, arranged in several whorls at the edge of the receptacle, free, rarely monadelphous (*Callistemon*); In *Melaleuca leucadendron* the stamens are many but in five bundles, antipetalous, anthers dorsifixed or versatile, dithecal, small, introrse, connectives of anthers are usually gland dotted. Stamens are bent in bud.

Gynoecium: Carpels 2 to many, usually syncarpous; perigynous to epigynous, ovary inferior, 2 to many locular, usually axile placentation, rarely parietal (*Rhodamnia*), 2 to many anatropous/campylotropous ovules per loculus; style usually simple, long, stigma capitate/flat

Floral Formula: Br. Brl. $\oplus \overline{\text{K}}_{(4+5)} \overline{\text{C}}_{4-5} \overline{\text{A}}_{\infty} \overline{\text{G}}_{(2-\infty)}$

Fruit and Seeds: Fruit: Mostly Berry (*Psidium*, *Syzygium cumini*, *Eugenia uniflora*) and capsule (*Callistemon citrinus*, *Eucalyptus*); **Seed:** Non-endospermic

Main Diagnostic features:

- Leaves aromatic, gland dotted, entire, exstipulate
- Flower bisexual, regular, epigynous
- Sepals 4 or 5, united
- Petals 4 or 5
- Stamens numerous
- Carpels 2-5, syncarpous, ovary inferior, placentation axile;
- Fruit berry/drupe

General Botanical Characteristics of Ranunculaceae (buttercup family)

Vegetative Features:

Habit: The plants are annual or perennial herbs or a climbing shrubs (*Clematis*, *Naravelia*), rarely trees. They perennate by means of tuberous roots (*Aconitum*) or rhizomes.

Root: Tap root, adventitious or tuberous (*Ranunculus* spp. and *Aconitum*). The tap root system is in the initial stage but sooner or later replaced by the adventitious roots.

Stem: Herbaceous, in some climbing (*Clematis*) or underground rhizome or erect, branched.

Leaves: commonly simple, alternate, or opposite (*Clematis*), exstipulate, rarely stipulate (*Thalictrum*), sheathing leaf base, petiolate rarely sessile (*Delphinium*). In some aquatic species leaves may show dimorphy (*Ranunculus aquatilis*); venation unicostate or multicostate reticulate.

Floral characters: Inflorescence: Solitary terminal (*Anemone*), axillary (*Clematis*), raceme (*Aconitum*, *Delphinium*) and cymose (*Ranunculus* spp.).

Flower: Pedicellate, ebracteate rarely bracteate, bisexual, (unisexual in *Thalictrum*). Mainly regular (*Ranunculus*), rarely zygomorphic (*Delphinium*, *Aconitum*) hypogynous, complete, pentamerous.

Calyx: There is no distinction of calyx and corolla in most of the flowers. Sepals 5, caducous, polysepalous, petaloid, imbricate or valvate.

Corolla: Petals 5, polypetalous, variously coloured, caducous or wanting; nectaries present at the base of petals. Petals are united to form spur (*Delphinium*).

Androecium: Stamens many, free, spirally arranged on the thalamus, *Aquilegia* contains 50 stamens arranged in radial rows; *Nigella* has 32 stamens in 8 rows; 80 to 150 stamens in *Caltha*; stamens of *Thalictrum* are brightly coloured; anthers bithecous, extrorse, adnate.

Gynoecium: carpels 3 to many (one in *Delphinium*, 3 to 5 in *Aconitum*), apocarpous, rarely syncarpous (*Nigella*), arranged spirally on the torus; ovary superior, unilocular with 1 (*Clematis*) to many (*Caltha*) ovules which are anatropous; marginal placentation (axile in *Nigella*).

Floral Formula: $\text{Br. Brl. } \oplus \overset{\curvearrowright}{\text{K}}_5 \text{C}_5 \text{A}_\infty \underline{\text{G}}_1$

Fruit and Seeds: Fruit: typically Aggregate fruits, Etaerio of Achenes (*Ranunculus*, *Anemone*, *Clematis*), Etaerio of Follicles (*Aconitum*, *Helleborus*, *Aquilegia*), Etaerio of Drupes (*Adonis*), etario of berries (*Hydrastis*), single follicle (not in an aggregate cluster) as in *Delphinium*, berry (*Actaea*), Septicidal Capsule (*Nigella*), or Simple Pod (*Xanthorrhiza*).

Seed: Small, oily, endospermic; Embryo: Minute

Note: Etaerio of Achenes in *Clematis* and *Anemone*, frequently have long, persistent, feathery styles meant for wind dispersal.

Main Diagnostic features:

- Herbs,
- Leaves exstipulate, incised blades, sheathing bases,
- Flowers hypogynous, spiral or spirocyclic;
- Sepals often deciduous, usually petaloid; calyx and corolla free;
- Stamens indefinite, free;
- Carpels polycarpellary, apocarpous;
- Fruit aggregate.

❖ PRIMITIVE FEATURES OF RANUNCULACEAE

One of the earliest and most primitive families of herbaceous eudicots is the Ranunculaceae, which has several spirally arranged, free floral components (stamens and carpels), among other primitive traits. The absence of a hypanthium, superior ovaries, and an apocarpous gynoecium are important basic traits.

Important Primitive Characteristics of Ranunculaceae are as follows:

- a) **Habit:** Mostly annual or perennial herbaceous plants, which is regarded as a primitive dicot habit.
- b) **Vegetative Characteristics:** Sheathing bases, alternating, exstipulate leaves are common.
- c) **Floral Arrangement:** On an extended container, the floral components (sepals, petals, stamens, and carpels) are usually arranged in a spiral or spirocyclic pattern.
- d) **Androecium and Gynoecium:** Stamens are free and many. The gynoecium is apocarpous, polycarpellary.
- e) **Perianth:** Flowers typically feature a simple perianth, with sepals that often take on the appearance of petals.
- f) **Flower Symmetry and Structure:** Most flowers are bisexual and regular, or radially symmetrical.
- g) **Ovary Position:** The flower is hypogynous, ovary superior.
- h) **Fruit Type:** typically, the fruit is a collection of achenes or follicles.
- i) Although many members of the family display these fundamental characteristics, other genera in the family also display more sophisticated qualities, such as zygomorphy (bilateral symmetry) in *Aconitum* and *Delphinium*.

Important Ranunculaceae tribes

- Three tribes: Helleboreae, Anemoneae, and Paeoniaeae.
- Hutchinson: Helleboroideae (carpels with >1 ovule) and Ranunculoideae.

In contrast to APG III, the Ranunculales order did not alter in APG IV, maintaining its crucial role in the molecular-based categorization scheme.

General Botanical Characteristics of Rosaceae

Vegetative Features:

Habit: vast variation; annual (*Neurada*) or perennial prostrate herbs, scandent or climbing or erect (*Rosa*), shrubs; Woody trees are also common (e.g. *Prunus amygdalus*, *Prunus persica*, *Pyrus communis* *Pyrus mains*); *Cydonia* sp are bush-like.

Root: Tap, branched occasionally adventitious.

Stem: Erect, prostrate or climber, branched, hard and woody; Vegetative propagation takes place by means of runner or sucker or cuttings, stems often possess spines or prickles (e.g., roses, blackberries).

Leaves: Alternate, rarely opposite (*Rhodotypos*), simple or compound sometimes pinnately compound, stipulate, stipule may be minute and caducous (*Spiraea*, *Pyrus*), adnate and persistent (*Rosa*, *Rubus*), leaf base conspicuous.

Floral characters: **Inflorescence:** Solitary (*Potentilla*, *Rosa serfica*) or racemose (*Agrimonia*); terminal corymbose (*Rosa moschata*), terminal cyme (*Geum*) or corymbose cyme (*Potentilla sibbaldi*).

Flower: Regular very rarely zygomorphic (*Chrysobalanoideae*), usually bisexual, rarely unisexual (*Spiraea aruncus*), 5-merous or 4-merous, hypogynous or epigynous (*Pyrus*) or perigynous (*Rosa*); showy; often with stipules at the base of petiole.

Calyx: Sepals 5, gamosepalous, adnate to the receptacle; occasionally epicalyx present, in *Potentilla*, 5 genuine sepals alternate with a 5-segmented epicalyx. *Fragaria* also has a structure like that; calyx tube remains free or adnate to the ovary, imbricate/valvate.

Corolla: Petals 5, or multiples of 5, polypetalous, rosaceous, inserted, coloured; petals entirely absent (*Pygeum gardneria*, *Poterium*, *Alchemilla*), or petals may be numerous (*Rosa*); sometimes stamens may be transformed into petal like structures; imbricate.

Androecium: Stamens are typically many (For instance, Apricot (peach/plum), *Rosa* (rose) have numerous stamens), rarely stamens 1 to 4 (*Alchemilla*), polyandrous, frequently 2 to 4 times as many as petals, or grouped in many whorls, usually placed on the perigynous margin of the hypanthium; anthers small, longitudinally divided, 2-celled, introrse.

Gynoecium: Carpel 1 (*Prunus*, *Prinsepia*) or 5 (*Pyrus*) or indefinite (*Fragaria* and *Rosa*), apocarpous (*Rosa*, *Fragaria*), rarely syncarpous (*Pyrus*), ovary superior occasionally inferior

(apple or pear); When the carpel is apocarpous or solitary, placentation is basal; when it is syncarpous, it is axile; nectar secreting disc present between stamens and carpels.

Floral Formula: $\text{Br.} \oplus \overset{\curvearrowright}{K}_{(5)} \text{ or } 5 \text{ C}_5 \text{ A}_\infty \underline{\text{G}}_{1-\infty}$

Fruit and Seeds:

Fruit: this family shows high fruit diversity: Pome (Apples, pears), Drupe (Peaches, plums, cherries), berry (*Eriobotrya japonica*), Aggregate fruits for example, Raspberries & Blackberries (*Rubus* spp.), Cloudberry & Loganberry (*Rubus* spp.) are etaerio of drupelets; Strawberries (*Fragaria* spp.), *Rosa* spp are etaerio of achenes;

Seed: Non-endospermic.

Main Diagnostic features:

- Shrubs with prickles or Woody trees
- Leaves simple or compound, pinnate, alternate, stipulate;
- Flowers actinomorphic very rarely zygomorphic hypo-, peri- or epigynous;
- Calyx gamosepalous, 5, often with epicalyx;
- Petals 5, free;
- Stamens indefinite;
- Carpels 1 to many, apo- or syncarpous, located on swollen receptacle;
- Fruit pome, or Aggregate fruits like etaerio of achenes, etaerio of drupelets

General Botanical Characteristics of Rubiaceae

Vegetative Features:

Habit: Mainly trees (*Cinchona*, *Coffea*, *Neolamarckia*, *Adina*), or Shrubs (*Ixora*, *Gardenia*, *Mussaenda*, *Hamelia*); also Herbs (*Galium*, *Rubia*, *Oldenlandia*), Climbers/woody Vines (or lianas- *Paederia*, *Uncaria*); epiphytes (*Neohymenopogon parasiticus*, *Hydnophytum formicarum*, *Myrmecodia tuberosa*, *Squamellaria*, *Schradera*).

Root: Much branched tap root system.

Stem: Erect, herbaceous or woody or twinning (*Manettia*), climbing by hooks (*Uncaria*), branched, cylindrical or angular, hairy or smooth.

Leaves: Cauline, ramal, Simple, entire, opposite or whorled, stipules unicostate reticulate venation, stipulate, stipules may be of various types: Interpetiolar stipules (Most Common type) Examples: *Coffea*, *Ixora*, and *Gardenia*; Intrapetiolar (e.g., *Gardenia*); Foliaceous (leaf-like) Examples: *Rubia* and *Galium*; Ochreate: Examples: *Richardia*, *Diodia*, *Borreria*;

Fimbriate/Laciniate: (e.g., *Palicourea*, *Damnacanthus*, *Pentas*); Caducous/Withering (e.g., *Didymaea*).

Floral characters: Inflorescence: Solitary (*Gardenia*) usually cymose or globose head (*Adina*), or paniced cyme; may be axillary (*Coffea arabica*) or terminal cyme (*Mussaenda glabra*).

Flower: Actinomorphic, rarely zygomorphic (some what bilabiate in *Henriquezia*), mostly bisexual, rarely unisexual, epigynous, pedicellate or sessile (*Greenia*, *Randia*), bracteate or ebracteate, complete, tetra or pentamerous, cyclic, variously coloured.

Calyx: Sepals 4 or 5, gamosepalous (fused at base), persistent, sometimes one sepal modified into coloured bract like structure (*Mussaenda*), valvate.

Corolla: Petals 4 or 5, often fused tubular (*Ixora*); sometimes salver shaped (*Gardenia*), or funnel-shaped (*Cinchona*, *Coffea*); valvate to twisted or imbricate; In order to draw pollinators, *Mussaenda* species frequently display a "semaphyl," in which one calyx-lobe is altered into a big, vividly colored (petaloid) form. Notably, *Mussaenda frondosa* show extension of a single sepal into a huge, white foliar form.

Androecium: Stamens 4 or 5, rarely many (*Gardenia*), the number of stamens is equal to the number of corolla lobes; epipetalous, alternipetalous, inserted near the mouth of corolla tube; anthers introrse, linear, bitheous, dehiscing longitudinally; filament short, usually free from one another, but can occasionally be connected via their anthers (e.g., *Argostemma*); Heterostylous arrangements to encourage outcrossing are common; Specialized crystal deposits may be seen in the anther septa of *Cephalanthus glabratus*.

Gynoecium: Bicarpellary, rarely polycarpellary, syncarpous, epigynous ovary inferior, rarely half inferior (*Synaptanthera*) or superior (*Paganea*), sometimes 1-locular (*Gardenia*) with 1- to many anatropous ovules in each loculus, axile placentation (parietal placentation in *Gardenia*), style 1, occasionally bifid/multifid, stigma simple/bilobed; ovary often has an epigynous nectariferous disk on its top..

Floral Formula: $\text{Br.} \oplus \overset{\curvearrowright}{K}_{(5)} \text{ or } 5C_{(4-5)} A_4 \text{ or } 2 \overline{G}_{(2)}$

Fruit and Seeds: Fruit: Capsular (*Anotis*), berry (*Ixora*, *Mussaenda*).

Seed: Endospermic, sometimes winged.

Main Diagnostic features:

- Trees or herbs;
- Leaves alternate or opposite; stipules interpetiolar or intrapetiolar,
- Inflorescence cymose;

- Flowers tetra or pentamerous, bisexual, actinomorphic, epigynous,
- Corolla, gamopetalous;
- Stamens 4-5; epipetalous, introrse, ditheous;
- Ovary inferior, bilocular with one or many ovules in each loculus;
- Fruit capsule or berry.

Important Taxonomic Notes:

Order: Placed solidly inside Gentianales together with Apocynaceae, Gelsemiaceae, Loganiaceae, and Gentianaceae.

Circumscription: According to genetic evidence, a wide variety of species that were once identified as distinct families (such as Theligonaceae) are now mainly included under Rubiaceae.

Diversification: With over 611 genera and more than 13,000 species, it is one of the biggest families of flowering plants.

Subfamilies: Rubioideae, Cinchonoideae, and Ixoroideae (previously frequently referred to under a larger Dialypetalanthoideae notion) are the three primary subfamilies that make up the family.

General Botanical Characteristics of Rutaceae

Vegetative Features:

Habit: Normally shrubs (*Murraya*, *Limonia*, *Zanthoxylum*), trees (*Aegle*, *Citrus*, *Feronia*), rarely herbs (*Ruta graveolens*) with strong fragrance; shrubby climbers like *Paramignya* (*P.monophylla*, *P. armata*, *P.scandens*) climbs by means of sharp, curved, axillary thorns.

Root: Tap root, branched often infected with fungus.

Stem: Woody (*Citrus*, *Feronia*), erect, cylindrical, branched, solid often thorny (*Citrus*), gland dotted.

Leaves: Alternate (*Citrus*, *Murraya*) or opposite (*Evodia*), petiolate, petiole may be winged (*Citrus aurantium*), simple or compound-pinnate (*Murraya*), palmate (*Aegle and Citrus*) smooth gland dotted, glands with essential oils, exstipulate, margin entire or serrate, unicostate reticulate venation. In *Citrus* petiole is winged.

Floral characters: Inflorescence: Usually cyme or axillary or terminal corymb (*Murraya paniculata*) some times racemose or solitary.

Flower: Pedicellate, ebracteate, bisexual or unisexual (*Zanthoxylum*, *Evodia*, *Feronia*), actinomorphic rarely zygomorphic (*Dictamnus* and *Correa*), hypogynous, complete, pentamerous or tetramerous (*Acronychia* and lateral flowers of *Ruta*).

Calyx: Sepals 5 or 4, free or fused; in zygomorphic flower it becomes gamosepalous and tubular; imbricate; sometimes deciduous.

Corolla: Petals 5 or 4, polypetalous rarely gamopetalous (*Correa speciosa*) or absent (*Zanthoxylum*), variously coloured, imbricate.

Androecium: In majority of cases the stamens are obdiplostemonous and 10 in number; in *Citrus* numerous stamens with polyadelphous condition; in *Zanthoxylum* 3 stamens and in *Skimmia* 5 stamens; anthers introrse, dithecal, basifixed or versatile.

Gynoecium: Pentacarpellary and only slightly united at the base or the sides forming a deeply lobed ovary with fused styles originating from the centre. In *Citrus* and *Toddalia* the carpels are fully united. In *Feronia* the carpel is only one celled with many parietal placentae. In other genera the placentation is of the axile type. Typically the ovary is superior with a prominent nectariferous disc below it. Ovule anatropous.

Floral Formula: $\text{Br.} \oplus \text{ } \overline{\text{K}}_{4-5} \text{C}_4 \text{ or } 5 \text{ A}_8 \text{ or } 10 \text{ } \underline{\text{G}}_{(4) \text{ or } (5)}$

Fruit and Seeds: **Fruit:** In Flindersioideae there is septicidal or loculicidal capsule; in Toddalioidae a drupaceous fruit; hesperidium in *Citrus* and berry in *Murraya*.

Seed: Endospermic or exalbuminous.

Main Diagnostic features:

- Aromatic
- Leaves gland dotted, simple or compound;
- Flower bisexual, hypogynous, regular with a disc below the ovary;
- Corolla polypetalous;
- Stamens ten, obdiplostemonous;
- Carpels 5 or many, ovary superior, multilocular;
- Fruit capsule or berry

General Botanical Characteristics of Scrophulariaceae

Vegetative Features:

Habit: Mostly herbs (*Antirrhinum*) or shrubs, rarely trees (*Paulownia*), climbers (*Maurandia*) or root parasites (*Pedicularis*).

Root: Branched tap root system.

Stem: erect, aerial, herbaceous, or woody (*Paulownia*).

Leaves: Alternate, or opposite, rarely whorled (*Veronica*), simple; in *Limnophila* leaves are dimorphic, exstipulate, margin entire, unicostate reticulate (net-like), in parasitic species leaves are reduced.

Floral characters: Inflorescence: Cymose or racemose, it may be spike, rarely solitary axillary (*Scoparia*, *Striga densiflora*).

Flower: Bracteate, pedicellate, or sessile (*Lindenbergia*), bisexual, pentamerous, hypogynous, complete, zygomorphic, rarely actinomorphic (*Verbascum*, *Veronica*).

Calyx: Sepals 5, rarely 4 (*Veronica*, *Scoparia*), gamosepalous, imbricate or valvate aestivation, persistent; calyx teeth may be 2/5, campanulate or shortly tubular; inferior.

Corolla: Petals 5, gamopetalous, zygomorphic petals, fused together, Bilabiate (Two-lipped) in *Mimulus* (Monkey flower), *Penstemon* (Beardtongue); Personate (Masked) as in *Antirrhinum majus* (Snapdragon), *Linaria vulgaris* (Toadflax), *Lindenbergia*; Campanulate (Bell-shaped) as in *Digitalis purpurea* (Common foxglove); Rotate (Wheel-shaped) as in *Verbascum* (Mullein), *Veronica* (Speedwell); Spurred as in *Linaria* (Toadflax); Saccate/Gibbous as in *Angelonia*; imbricate aestivation, variously coloured.

Androecium: Stamens 4 in *Digitals*, 5 in *Verbascum* or 2 in *Veronica*; when didynamous, there are 4 fertile stamens & 1 staminode as seen in *Digitals purpurea*, *D. lanata*, *Penstemon*; epipetalous, polyandrous; anthers basifixed/ dorsifixed, bithecal, filament short, introrse.

Gynoecium: Bicarpellary, syncarpous, superior, 2-chambered, placentation axile, ovules many in each chamber; style short, simple; stigma bifid; typically nectariferous disc present beneath the ovary.

Floral Formula: Br. $\oplus$ or $\% \text{ } \overline{\text{K}}_{4-(5)} \text{C}_4 \text{ or } 5 \text{ } \underline{\text{G}}_{(2)}$

Fruit and Seeds: Fruit: may be Septicidal Capsule as seen in *Digitalis* (Foxglove), *Verbascum* (Mullein); Loculicidal Capsule as seen in *Antirrhinum* (Snapdragon); Poricidal Capsule as seen in *Linaria* (Toadflax); or Berry as seen in Brahmi (*Bacopa monnieri*).

Seed: Small, many, endospermic.

Main Diagnostic features:

Plants mostly herbs; leaves alternate or opposite, exstipulate; flowers zygomorphic and hypogynous, bisexual; calyx gamosepalous; corolla gamopetalous; stamens four or two, if four

didynamous; epipetalous; gynoecium bicarpellary, syncarpous, bilocular, axile placentation with many ovules; fruit capsule or berry; seeds endospermic.

General Botanical Characteristics of Solanaceae

Vegetative Features:

Habit: Mostly herbs (*Petunia*, *Withania*), shrubs (*Cestrum nocturnum*, *Lycium barbarum*, *Solanum rantonnetii*) and small trees (*Solanum mauritianum*, *Nicotiana glauca*, *Cyphomandra betacea*).

Root: A branched tap root system.

Stem: Aerial, erect, climbing (*Solanum jasminoides*), herbaceous, or woody, cylindrical, branched, solid or hollow, hairy, or glabrous, underground stem in *Solanum tuberosum*.

Leaves: Cauline, ramal, exstipulate, petiolate or sessile (*Nicotiana tabacum*, *Solanum rantonnetii*), alternate sometimes opposite, simple, entire pinnatisect in *Lycopersicum*, unicostate reticulate (net-like) venation.

Floral characters: Inflorescence: Solitary axillary, umbellate cyme, or helicoid cyme in *Solanum*.

Flower: Bracteate or ebracteate, pedicellate, complete, actinomorphic, pentamerous, hypogynous; Most of them are bisexual, such as the deadly nightshade (*Atropa belladonna*), potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), brinjal (*Solanum melongena*), bell pepper (*Capsicum annuum*), tobacco (*Nicotiana tabacum*), and some are dioecious, like *Solanum appendiculatum*, *Withania aristata*, *Symonanthus*.

Calyx: Sepals 5, gamosepalous, tubular or campanulate, valvate or imbricate, persistent, often enlarged (accrescent) as in *Physalis peruviana*, green or coloured, hairy, inferior.

Corolla: Petals 5, gamopetalous, tubular or infundibuliform, valvate or imbricate aestivation, scale or hair-like outgrowth may arise from the throat of the corolla tube, coloured, inferior; Shapes vary greatly, they might be rotate (wheel-shaped) to Campanulate in *Solanum tuberosum*, funnel-shaped (infundibuliform) in *Datura*, *Petunia*, or tubular/campanulate in *Nicotiana tabacum*, star shaped in *Solanum nigrum*.

Androecium: Stamens 5, sometimes reduced to 4 (didynamous) or 2 in *Salpiglossis*, *Schizanthus*, epipetalous, polyandrous, alternipetalous, filaments inserted deep in the corolla tube, anthers ditheous, usually basifixed or dorsifixed, introrse; Dehiscence by longitudinal slits (*Capsicum annuum*, *Petunia*) or by apical pores (*Solanum nigrum*).

Gynoecium: Bicarpellary, syncarpous, ovary superior, commonly bilocular, sometimes 1-locular (*Capsicum*), or 3-5 locular (rarely) as in *Nicandra*, axile placentation, many ovules in each loculus, ovary obliquely placed; in some cases nectariferous disc is present; style simple; stigma bifid/Bilobed (*Datura*, *Capsicum annuum*, *Solanum nigrum*, *Withania somnifera*) or capitate (Head-shaped) as in Tomato, Brinjal, Petunia, Tobacco, Belladonna;

Floral Formula: $\text{Br.} \oplus \overset{\nearrow}{\text{K}}_{(5)} \text{C}_{(5)} \wedge \text{A}_5 \underline{\text{G}}_{(2)}$

Fruit and Seeds: Fruit: A capsule (*Datura*, *Tobacco*, *Petunia*, *Belladonna*) or berry (*Tomato*).

Seed: flat, compressed, many, endospermic; **Embryo:** curved or semi- straight.

Main Diagnostic features:

- Plants herbs, shrubs rarely trees;
- Leaves alternate,
- Flowers solitary or in cymes; axillary or terminal;
- Flowers pentamerous, actinomorphic, hypogynous, bisexual,
- Calyx persistent, gamosepalous, corolla gamopetalous, campanulate; stamens epipetalous;
- Gynoecium bicarpellary, syncarpous, ovary obliquely placed, axile placentation; ovules many in each chamber;
- Fruit capsule or berry.

General Botanical Characteristics of Sterculiaceae

Vegetative Features:

Habit: mainly trees and shrubs, occasionally herbs or lianas (e.g., *Ayenia*); often found with buttresses.

Stem: with mucilaginous tissues and fibrous wood, stellate hairs present

Leaves: alternate, simple or palmately compound/lobed, often with stellate hairs or scales, stipulate (free lateral, caducous).

Floral characters: Inflorescence: cymose, paniculate, or rarely solitary.

Flowers: actinomorphic (radially symmetrical), bisexual or unisexual (*Cola*, *Sterculia*), hypogynous.

Perianth: Calyx usually 3–5 lobed, basally united, valvate; Corolla of 5 valvate petals, often adnate to base of staminal column, rarely absent.

Androecium: 5-10 stamens, monadelphous, fertile stamens alternate with staminodes, anther 2-lobed.

Gynoecium: 2-5 carpels, syncarpous, ovary superior, usually 5-chambered, style as many as carpels, variously connate, axile placentation.

Floral Formula: $\text{Br.} \oplus \overline{\text{K}}_5 \text{C}_5 \text{A}_{(\infty) \text{ or } \infty} \underline{\text{G}}_{(5)}$

Fruit and Seeds: Fruit: typically a schizocarpic or typical capsule, sometimes follicle/winged (samaroid). Seeds: often oily. Embryo: possesses flat, leafy or folded cotyledons.

Main Diagnostic features:

- Stem with mucilaginous tissues & stellate hairs
- Leaves alternate, simple or palmately compound/lobed, often with stellate hairs, stipulate (free lateral, caducous)
- Flowers actinomorphic (radially symmetrical), bisexual, hypogynous
- 5-10 stamens, monadelphous
- schizocarpic or typical capsule
- Carpels 2-5, syncarpous, ovary superior, usually 5-chambered, style as many as carpels, variously connate, axile placentation.
- Embryo with leafy cotyledons.

General Botanical Characteristics of Tiliaceae

Vegetative Features:

Habit: Shrubs or trees, rarely herbs (*Corchorus*).

Root: Tap and branched.

Stem: Erect, round (or angular), woody, solid, branched, frequently with mucilaginous sap.

Leaves: Simple, alternate, rarely opposite, margin serrate or dentate, stipulate, stipule caducous (*Tilia*), palmately veined or stellate, pubescent.

Floral characters: Inflorescence: typically cymose (often paniculate cymes)

Flowers: Pedicellate, actinomorphic, usually bisexual, rarely unisexual (*Carpodiptera*), hypogynous, tetra or penta-merous, occasionally with epicalyx..

Calyx: 5 (or 4) sepals, usually free or basally connate, valvate.

Corolla: 5 (or 4) petals, absent in *Prockia*, free, frequently with glandular hairs at base, imbricate.

Androecium: Stamens usually many, sometimes 5-10, free or united in groups (*Grewia*), inserted, anther 2-celled, extrorse, dehiscence by apical pores or longitudinal slits.

Gynoecium: Carpels 2 to 10 or many (Apeiba), syncarpous, ovary 2-5 chambered, superior, 1 to many anatropous ovules in each loculus, axile placentation; style simple; stigma capitate/lobed.

Floral Formula: $\text{Br.} \oplus \varnothing K_5 C_5 A_{5-\infty} \underline{G}_{(5-10)}$

Fruit and Seeds: Fruit: Varies from dry, dehiscent capsules (e.g., *Corchorus*) to bristly drupes (e.g., *Grewia*). Seeds: with fleshy endosperm. Embryo: curved with leafy cotyledon

Main Diagnostic features:

- Leaves simple, stipulate
- Typically cymose
- Flower bisexual, hypogynous, actinomorphic
- Petals frequently with glandular hairs
- Stamens indefinite sometimes 5 to 10
- Carpels 2 to indefinite, syncarpous, axile placentation
- Fruit capsule or drupe
- Embryo curved with leafy cotyledon

General Botanical Characteristics of Verbenaceae

Vegetative Features:

Habit: perennial or annual herbs, shrubs, or trees (e.g., teak), some are climbers (*Holmskioldia sanguine* - Now placed within Lamiaceae).

Stem: usually quadrangular, often woody, and occasionally covered with rough hairs.

Leaves: Simple, rarely palmately or pinnately compound (*Vitex*), opposite or whorled, exstipulate; often aromatic with unpleasant odor.

Floral characters: Inflorescence: cymose, racemose (raceme or head like spike), or cymose panicle, often with distinct colored bracts.

Flowers: Bisexual, zygomorphic, (regular in *Callicarpa*), hypogynous, often 4–5-merous.

Calyx: Sepals 5, united, persistent, tubular or bell-shaped, 4-8 toothed, valvate.

Corolla: Petals 5, Gamopetalous, funnel-shaped, often tubular or bilabiate with spreading limb, lobes imbricate, often oblique.

Androecium: Stamens 4, didynamous, epipetalous, introrse, 2-celled anther.

Gynoecium: Carpels 2, rarely 4 (*Duranta*) or 5 (*Geunsia*), syncarpous, superior ovary, 2-4 chambered, 1-2 ovuled; placentation axile.

Floral Formula: Br.Brl. % $\overset{\curvearrowright}{K}_{(5)}C_{(5)}\hat{A}_{2+2}\underline{G}_{(2)}$

Fruit and Seeds: Fruit: usually a drupe or a schizocarp, which breaks into 1-seeded mericarps of 4 nutlets. Seeds: Typically lack endosperm. Embryo: - straight

Main Diagnostic features:

- Stem quadrangular, often woody
- Flowers Bisexual, zygomorphic
- Sepals 5, united, persistent
- Petals 5, gamopetalous, funnel-shaped, often tubular or bilabiate, often oblique
- Stamens 4, didynamous, epipetalous
- Carpels 2, syncarpous, superior ovary, 1-ovuled, placentation axile
- Fruit a drupe or a schizocarp

❖ SYSTEMATIC POSITIONS FOR THE FAMILIES

Diocot Families:

1. Acanthaceae (*Acanthus* Family)

Bentham & Hooker (1862–1883): Dicotyledons→Gamopetalae→Bicarpellatae
→Personales→Acanthaceae

Engler-Prantl (1896, 1931): Archichlamydeae→Tubiflorae→Acanthaceae

Hutchinson (1959, 1973): Herbaceous→Lamiales→Acanthaceae

Cronquist (1981, 1988): Asteridae→Scrophulariales→Acanthaceae

APG IV (2016): Eudicots→Asterids→Lamiales→Acanthaceae

2. Annonaceae (Custard Apple Family)

Bentham & Hooker: Dicotyledons→Polypetalae→Thalamiflorae→Ranales

Engler-Prantl: Archichlamydeae→Ranales→Annonaceae

Hutchinson: Lignosae→Annonales→Annonaceae

Cronquist: Magnoliidae→Magnoliales→Annonaceae

APG IV: Magnoliids→Magnoliales→Annonaceae

3. Apiaceae/Umbelliferae (Carrot Family)

Bentham & Hooker: Dicotyledons→Polypetalae→Calyciflorae→Umbellales

Engler-Prantl: Archichlamydeae→Umbelliflorae→Apiaceae

Hutchinson: Herbaceous→Umbellales→Apiaceae

Cronquist: Rosidae→Apiales→Apiaceae

APG IV: Eudicots→Asterids→Apiales→Apiaceae

4. Apocynaceae (Dogbane Family)

Bentham & Hooker: Dicotyledons→Gamopetalae→Bicarpellatae→Gentianales

Engler-Prantl: Sympetalae → Contortae → Apocynaceae

Hutchinson: Lignosae → Apocynales → Apocynaceae

Cronquist: Asteridae → Gentianales → Apocynaceae

APG IV: Eudicots → Asterids → Gentianales → Apocynaceae

5. Asclepiadaceae (Milkweed Family)

Bentham & Hooker: Dicotyledons→Gamopetalae→Bicarpellatae →Gentianales

Engler-Prantl: Sympetalae →Contortae →Asclepiadaceae

Hutchinson: Herbaceous→Gentianales→Asclepiadaceae

Cronquist: Note: Included within Apocynaceae.

APG IV: Subfamily Asclepiadoideae under Apocynaceae.

6. Asteraceae/Compositae (Sunflower Family)

Bentham & Hooker: Dicotyledons→Gamopetalae→Inferae→Asterales

Engler-Prantl: Sympetalae → Campanulatae →Asteraceae

Hutchinson: Herbaceous → Asterales →Asteraceae

Cronquist: Asteridae → Asterales → Asteraceae

APG IV: Eudicots → Asterids → Asterales → Asteraceae

7. Brassicaceae/Cruciferae (Mustard Family)

Bentham & Hooker: Dicotyledons→Polypetalae →Thalamiflorae→Parietales

Engler-Prantl: Archichlamydeae →Rhoecadales→ Brassicaceae

Hutchinson: Herbaceous→Cruciales→Brassicaceae

Cronquist: Dilleniidae →Capparales→Brassicaceae

APG IV: Eudicots → Rosids → Brassicales → Brassicaceae

8. Cucurbitaceae (Gourd Family)

Bentham & Hooker: Dicotyledons →Polypetalae →Calyciflorae→Passiflorales

Engler-Prantl: Archichlamydeae →Cucurbitales →Cucurbitaceae

Hutchinson: Herbaceous → Cucurbitales →Cucurbitaceae

Cronquist: Rosidae →Violales →Cucurbitaceae

APG IV: Eudicots → Rosids →Cucurbitales→Cucurbitaceae

9. Dipterocarpaceae (Meranti Family)

Bentham & Hooker: Dicotyledons →Polypetalae→Thalamiflorae→Guttiferales

Engler-Prantl: Archichlamydeae→ Parietales → Dipterocarpaceae

Hutchinson: Lignosae → Theales → Dipterocarpaceae

Cronquist: Dilleniidae → Theales → Dipterocarpaceae
APG IV: Eudicots → Rosids → Malvales → Dipterocarpaceae

10. Ericaceae (Heath Family)

Bentham & Hooker: Dicotyledons → Gamopetalae → Heteromerae → Ericales
Engler-Prantl: Sympetalae → Ericales → Ericaceae
Hutchinson: Lignosae → Ericales → Ericaceae
Cronquist: Dilleniidae → Ericales → Ericaceae
APG IV: Eudicots → Asterids → Ericales → Ericaceae

11. Euphorbiaceae (Spurge Family)

Bentham & Hooker: Dicotyledons → Monochlamydeae → Unisemales → Euphorbiaceae
Engler-Prantl: Archichlamydeae → Geraniales → Euphorbiaceae
Hutchinson: Lignosae/Herbaceae (varied) → Euphorbiales → Euphorbiaceae
Cronquist: Rosidae → Euphorbiales → Euphorbiaceae
APG IV: Eudicots → Rosids → Malpighiales → Euphorbiaceae

12. Fabaceae/Leguminosae (Pea Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Calyciflorae
Rosales (subfamilies: Papilionaceae, Caesalpinioideae, Mimosaceae treated separately)
Engler-Prantl: Archichlamydeae → Rosales → Leguminosae
Hutchinson: Lignosae/Herbaceae → Leguminales → Fabaceae
Cronquist: Rosidae → Fabales → Fabaceae
APG IV: Eudicots → Rosids → Fabales → Fabaceae

❖ SYSTEMATIC TREATMENT OF FABACEAE *SENSU LATO*

The systematic treatment of the Fabaceae (Leguminosae) family *sensu lato* (in the broad sense) underwent major revision according to current phylogenomic findings. Conventionally regarded as a single family with three subfamilies, it is now officially classified into six different subfamilies by the Legume Phylogeny Working Group (LPWG).

Revised Subfamily Classification (LPWG 2017)

It was found that the former "three-subfamily" classification (*Mimosoideae*, *Caesalpinioideae*, and *Papilionoideae*) was paraphyletic. The current systematic treatment accepts:

- **Papilionoideae (Faboideae):** The largest subfamily, characterized by zygomorphic "pea-like" blooms with a diadelphous androecium (9+1 arrangement).

- The old Mimosoideae is now included in the nested clade Caesalpinioideae. It often exhibits zygomorphic blooms with imbricate aestivation.
- **Cercidoideae:** Includes genera including *Cercis* (redbuds) and *Bauhinia*, frequently with simple, bilobed leaves.
- **Detarioideae:** A broad group mostly found in tropical Africa and Asia.
- **Dialioideae:** Mostly tropical trees, this small subfamily consists of about 17 taxa.
- **Duparquetioideae:** A monotypic subfamily comprising only Duparquetia orchidacea
- Synapomorphies in Morphology
- Despite its diversity, the family Fabaceae *sensu lato* is distinguished by several fundamental features:
 - a) **Fruit Type:** Usually a legume that dehisces along 2-sutures, some are indehiscent.
 - b) **Gynoeceum:** Monocarpellary with a superior ovary.
 - c) **Root Nodules:** Mostly are involved in N₂-fixing symbiosis with *Rhizobium* bacteria.
 - d) **Leaves:** Generally alternate, compound (pinnate or bipinnate), occasionally contain a pulvinus at the base permitting leaf movement.

Molecular Systematic Tools

In order to resolve complicated genera like *Acacia sensu lato* and *Desmodium sensu lato*, which have been divided into smaller, monophyletic genera (e.g., *Vachellia*, *Senegalia*, *Grona*), modern treatments mainly rely on DNA barcoding and plastid genome sequencing.

Important markers are: *rbcL* and *matK* for genus-level identification.

Higher-level clades are defined by inversions of the plastid genome (plastome).

Systematic Position of Fabaceae (APG IV, 2016):

The three conventionally recognized families—Mimosaceae, Caesalpinaceae, and Papilionaceae (Fabaceae)—are regarded as subfamilies within the Fabaceae (or Leguminosae)

Kingdom: Plantae

Clade: Tracheophytes (vascular plants)

Clade: Angiosperms

Eudicot clade

Clade: Superrosids

Clade: Rosids

Clade: Fabids (nitrogen-fixing clade)

Order: Fabales

Family: Fabaceae (nom. cons. = Leguminosae Juss.)

13. Lamiaceae/Labiatae (Mint Family)

Bentham & Hooker: Dicotyledons → Gamopetalae → Bicarpellatae → Lamiales

Engler-Prantl: Sympetalae → Tubiflorae → Labiatae

Hutchinson: Herbaceae → Lamiales → Labiatae

Cronquist: Asteridae → Lamiales → Lamiaceae

APG IV: Eudicots → Asterids → Lamiales → Lamiaceae

14. Magnoliaceae (*Magnolia* Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Thalamiflorae → Ranales

Engler-Prantl: Archichlamydeae → Magnoliales → Magnoliaceae

Hutchinson: Lignosae → Magnoliales → Magnoliaceae

Cronquist: Magnoliidae → Magnoliales → Magnoliaceae

APG IV: Magnoliids → Magnoliales → Magnoliaceae

15. Myrtaceae (Myrtle Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Calyciflorae → Myrtales

Engler-Prantl: Archichlamydeae → Myrtiflorae → Myrtaceae

Hutchinson: Lignosae → Myrtales → Myrtaceae

Cronquist: Rosidae → Myrtales → Myrtaceae

APG IV: Eudicots → Rosids → Myrtales → Myrtaceae

16. Malvaceae (Mallow Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Thalamiflorae → Malvales

Engler-Prantl: Archichlamydeae → Malvales → Malvaceae

Hutchinson: Lignosae → Malvales → Malvaceae

Cronquist: Dilleniidae → Malvales → Malvaceae

APG IV: Eudicots → Rosids → Malvales → Malvaceae

17. Ranunculaceae (Buttercup Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Thalamiflorae → Ranales

Engler-Prantl: Archichlamydeae → Ranales → Ranunculaceae

Hutchinson: Herbaceae → Ranales → Ranunculaceae

Cronquist: Magnoliidae → Ranunculales → Ranunculaceae

APG IV: Eudicots → Ranunculales → Ranunculaceae

18. Rosaceae (Rose Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Calyciflorae → Rosales

Engler-Prantl: Archichlamydeae → Rosales → Rosaceae

Hutchinson: Lignosae → Rosales → Rosaceae

Cronquist: Rosidae → Rosales → Rosaceae
APG IV: Eudicots → Rosids → Rosales → Rosaceae

19. Rubiaceae (Coffee Family)

Bentham & Hooker: Dicotyledons → Gamopetalae → Inferae → Rubiales
Engler-Prantl: Sympetalae → Rubiales → Rubiaceae
Hutchinson: Lignosae → Rubiales → Rubiaceae
Cronquist: Asteridae → Rubiales → Rubiaceae
APG IV: Eudicots → Asterids → Gentianales → Rubiaceae

20. Rutaceae (*Citrus* Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Disciflorae → Geraniales
Engler-Prantl: Archichlamydeae → Rurales → Rutaceae
Hutchinson: Lignosae → Rurales → Rutaceae
Cronquist: Rosidae → Sapindales → Rutaceae
APG IV: Eudicots → Rosids → Sapindales → Rutaceae

21. Scrophulariaceae (Figwort Family)

Bentham & Hooker: Dicotyledons → Gamopetalae → Bicarpellatae → Personales
Engler-Prantl: Sympetalae → Tubiflorae → Scrophulariaceae
Hutchinson: Herbaceous → Personales → Scrophulariaceae
Cronquist: Asteridae → Scrophulariales → Scrophulariaceae
APG IV: Eudicots → Asterids → Lamiales → Scrophulariaceae
(Note: Many former members moved to Orobanchaceae/Plantaginaceae in APG IV)

22. Solanaceae (Potato/Nightshade Family)

Bentham & Hooker: Dicotyledons → Gamopetalae → Bicarpellatae → Polemoniales
Engler-Prantl: Sympetalae → Tubiflorae → Solanaceae
Hutchinson: Herbaceous → Solanales → Solanaceae
Cronquist: Asteridae → Solanales → Solanaceae
APG IV: Eudicots → Asterids → Solanales → Solanaceae

23. Sterculiaceae (Cacao Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Thalamiflorae → Malvales
Engler-Prantl: Archichlamydeae → Malvales → Sterculiaceae
Hutchinson: Lignosae → Malvales → Sterculiaceae
Cronquist: Dilleniidae → Malvales → Sterculiaceae
APG IV: Subfamily Sterculioideae under Malvaceae.

24. Tiliaceae (Linden Family)

Bentham & Hooker: Dicotyledons → Polypetalae → Thalamiflorae → Malvales

Engler-Prantl: Archichlamydeae → Malvales → Tiliaceae

Hutchinson: Lignosae → Malvales → Tiliaceae

Cronquist: Dilleniidae → Malvales → Tiliaceae

APG IV: Subfamily Tilioideae under Malvaceae.

25. Verbenaceae (Verbena Family)

Bentham & Hooker: Dicotyledons → Gamopetalae → Bicarpellatae → Lamiales

Engler-Prantl: Sympetalae → Tubiflorae → Verbenaceae

Hutchinson: Lignosae → Verbenales → Verbenaceae

Cronquist: Asteridae → Lamiales → Verbenaceae

APG IV: Eudicots → Asterids → Lamiales → Verbenaceae

❖ DEVIATIONS FROM GENERAL FAMILY CHARACTERS:

1. Acanthaceae

- The following are significant instances and exceptions within the Acanthaceae family:
 - **Unusual Habits (Climbers & Xerophytes):** Although the family is mostly herbs/shrubs, some species have adapted to extreme niches. e.g., Climbers: *Thunbergia*, Xerophytes (Desert-adapted): *Barleria* and *Blepharis*., Aquatic: *Hygrophila auriculata*, Halophytes (like *Acanthus ilicifolius*)
 - **Reduced Corolla:** The corolla of *Acanthus mollis* is single-lipped, giving the impression that the upper lip is absent.
 - **Showy Bracts:** The Flowers of many species are modest, but they are encircled by enormous, vibrantly colored bracts that serve as petals. e.g., *Justicia brandegeana*.
 - **Absence of Retinaculate Fruits:** Not all Acanthaceae feature "retinacula" (a hook-like projection of the funiculus/seed stalk). These are absent in Nelsonioideae and Thunbergioideae, hence some earlier classifications eliminate them.
 - **Irregular/Regular Corolla Variance:** this feature is typical of this family. However, *Asystasia gangetica* has a regular corolla, which is rare for the family.
 - **Absence of Cystoliths:** cystoliths are hallmarks of this family present in the epidermal cells but in subfamily Nelsonioideae, and tribe Acantheae is notably devoid of them.
 - **Fruit Structure Deviation:** In contrast to the family's loculicidal capsules, *Avicennia* (previously in its own family, now sometimes placed in Acanthaceae

sensu lato) has different fruit type showing departure from the normal Acanthaceae capsule structure.

- **Stem Structure:** Even though commonly characterized by jointed stems, certain members, (Nelsonioideae subfamily), lack this articulation.
- **Staminal Variation:** The subfamily Thunbergioideae (e.g., *Thunbergia*) has spurred anthers without an endothelial cell layer, unlike other Acanthaceae, which have two or four didynamous stamens. Thus showing departure from the normal staminal structure as found in other members of Acanthaceae.
- Examples of Specific Exception Genus/Groups:
 - a) ***Thunbergia* (Thunbergioideae):** No stem articulation, no retinacula.
 - b) ***Nelsonia* / *Elytraria* (Nelsonioideae):** No retinacula, no cystoliths, and non-articulate stems.
 - c) ***Asystasia*:** Nearly regular flower
 - d) ***Avicennia* (black mangroves):** have special fruit, salt-excreting leaves, pneumatophores, and mangrove habit, but most are terrestrial herbs/shrubs.

Summary Table of Exceptional characteristics in Acanthaceae

Features	General Characteristics	Exceptions/Deviations
<i>Habit</i>	Herbs, shrubs	Occasionally trees, climbers/woody shrubs
<i>Leaves</i>	Opposite-decussate, simple, entire	Spiny leaf blades (in xerophytes)
<i>Stem</i>	Quadrangular, swollen nodes	Cylindrical stems (in some genera)
<i>Anatomy</i>	Cystoliths present	Absent in Tribe Acantheae
<i>Inflorescence</i>	Cymose/Racemose	Solitary flowers
<i>Calyx</i>	5-lobed (synsepalous)	4-partite calyx (in <i>Acanthopsis</i>)
<i>Corolla</i>	Bilabiate (2-lipped)	1-lipped (e.g., <i>Acanthopsis</i>), or 5-lobed
<i>Stamens</i>	4 (didynamous) or 2	Rarely 5
<i>Fruit</i>	2-celled capsule, explosive mechanism	Non-explosive or succulent fruits (e.g., <i>Mendoncia</i>)
Pollen	Variable (often tricolporate)	Diporate (e.g., <i>Phlogacanthus</i>)

Important Remarks on Significant Exceptions in Acanthaceae

- **Fruit Dehiscence:** Explosive capsules with hooked seeds (retinacula) are a common feature of this family. However, this explosive dehiscence is absent from the genus *Avicennia* (often included here), the subfamilies Nelsonioideae, Mendoncioideae, and Thunbergioideae.
- **Flower Type:** Although many are highly bilabiate, certain taxa, such as *Acanthopsis*, have reduced lobes or a 1-lipped flower with the upper lip repressed.
- **Woody Habits:** Some species, especially in tropical environments, have evolved into woody, spreading, or climbing plants, while often being herbs or tiny shrubs.
- **Habitat Adaptations:** Most species are mesophytes, although some are halophytes (like *Acanthus ilicifolius*) or xerophytic (spiny).
- **Interxylary Phloem:** Unusual for the family, found in *Mendoncia* and *Thunbergia*.

2. Annonaceae

- **Critical Annonaceae Exceptions are as follows:**
 - **Syncarpous Ovary (Fused Carpels):** In contrast to the majority of Annonaceae, which have apocarpous pistils, the tribe Monodoreae (*Monodora* sp.) has a syncarpous ovary, which produces a unilocular fruit with parietal placentation.
 - **Habit:** Lianas (Climbing Shrubs): Even though mainly trees or shrubs, certain genera are lianas, e.g., *Artabotrys*, *Uvaria*.
 - **Specialized Inflorescence (Hooked Peduncles):** Some members (*Artabotrys uncinatus*) have developed specialized, woody, hook-shaped peduncles meant for climbing, while many have simple, axillary flowers.
 - **Leaf Characteristics:** Certain species are deciduous, but most are evergreen. Additionally, *Uvaria* frequently has cordate leaf bases, while the majority of leaves are whole and alternate. They can also be leathery or papery.
 - **Floral Structure:** Although the majority of the flowers are trimerous, distinct tribes have diverse perianth arrangements, which can be valvate, imbricate, or restricted.
- **An overview of instances of exceptions:**
 - **Monodora:** A syncarpous exception to apocarpy.
 - **Artabotrys:** An exception to inflorescence (hooked) and habit (liana/climber).
 - **Uvaria:** The ascending exception to the rule.

- Unlike *Artabotrys*, *Xylopi*a has big trees with recognizable, non-hooked axillary inflorescences.
 - **Deviation:** Although usually trimerous with free carpels, *Eupomatia* (sometimes placed here or in its own family) has epigynous flowers and a synchocarpous gynoecium.
 - **Deviation:** *Artabotrys* acts as a hook-climber, not a typical erect tree or shrub.
 - **Deviation:** Some members exhibit cauliflory (flowers directly on the trunk) e.g., *Stelechocarpus burahol*, *Annonidium mannii*, *Uvariopsis* spp (*Uvariopsis submontana*, *U. congolana*, *U. guineensis*, and *U. vanderystii*).
- Unisexual as in *Alphonsea*, *Guatteria*, *Orophea*, *Phaeanthus*; perigynous (*Eupomatia*).

Summary Table of Exceptional characteristics in Annonaceae

Features	General Characteristics	Exceptions/Deviations
<i>Habit</i>	Trees or shrubs	Scrambling lianas (climbing vines) are common in some genera (e.g., <i>Uvaria</i> , <i>Artabotrys</i>).
<i>Sexuality</i>	Bisexual (hermaphrodite)	Unisexual flowers (dioecious) occur in some taxa, such as <i>Pseuduvaria</i> and <i>Guatteria</i> species.
<i>Flower Symmetry</i>	Actinomorphic (regular)	Zygomorphic flowers occur in certain, more derived genera.
<i>Petal Number/Series</i>	6 petals in two whorls (3+3)	6–15 petals; some species have inner petals much narrower or absent (<i>Acutiflobae</i> group).
<i>Gynoecium Fusion</i>	Apocarpous (free carpels)	Syncarpous (fused carpels) in the genus <i>Annona</i> and <i>Monodora</i> .
<i>Pollen Aperture</i>	Monocolpate/Monosulcate	Some lack visible apertures (inaperturate) or are disulcate.
<i>Stomata Type</i>	Paracytic	Pericytic (e.g., <i>Cananga odorata</i>), 1+2 laterocytic (e.g., <i>Isolona zenkeri</i>), or stephanocytic (e.g., <i>Letestudoxa bella</i>).

Important Remarks on Significant Exceptions in Annonaceae

- a) **Fruit Structure:** Fruit of *Annona* is largely syncarpous, or a "multiple fruit" created by fusion of berries, but many are aggregate.
- b) **Petal Texture:** Although they can occasionally be reduced to rudiments, inner petals serve to form a dome over reproductive regions and are frequently smaller, thicker, and fleshier than outer petals.
- c) **Pollination Agents:** Although beetles are the primary pollinators, flies, bees, and even rodents may pollinate some species.
- d) **Chromosome Numbers:** Although many are based on $x=7$ or $x=8$, *Annona* has been found to have diploidy ($2n = 2x = 14$) and hexaploidy ($2n = 2x = 42$), indicating a large variance in ploidy levels. In *Annona*, the fundamental chromosomal number is 7 ($x=7$). The majority of its species are diploids ($2n = 14$ or $2n = 16$), including *Annona squamosa*, *A. muricata*, and *A. cherimola*.
- e) **Polyploidy:** Although diploidy is prevalent, the genus has tetraploid species ($2n = 4x = 28$; *A. glabra*, for example) and even hexaploid species ($2n = 6x = 42$; *A. neosalicifolia*).
- f) **Atemoya Hybrid:** Although the hybrid Atemoya (*A. cherimola* $\times$ *A. squamosa*) frequently exhibits diploid behavior ($2n=14$), research has revealed that its offspring can have substantial ploidy diversity (up to 35% triploids).

3. Apiaceae

An overview of instances of exceptions in Apiaceae family:

a. Deviations in the Inflorescence

Although the compound umbel is the hallmark of the family, some members display highly modified structures:

- **Capitate Heads:** Flowers are firmly packed into thick, head-like clusters rather than an outstretched umbel. e.g., *Sanicula* and *Eryngium*.
- **Simple Umbels:** Instead of using a compound umbel, certain specialized or primitive members continue to use a simple one. e.g., *Hydrocotyle* and *Centella asiatica*.
- **Dark-Centred Umbels:** A rare evolutionary characteristic in which one or a small number of sterile, dark-colored, and larger central flowers resemble insects in an attempt to draw pollinators or ward off pests. e.g., *Daucus carota*.

b. Variations in the Symmetry of Flowers

The majority of Apiaceae flowers are actinomorphic, or radially symmetrical, but many exhibit zygomorphy, or bilateral symmetry, particularly in the umbel's periphery, which makes the entire inflorescence appear to be one large flower in order to draw insects. e.g., *Heracleum* and *Coriandrum sativum*.

c. Diversity in Sexuality (Unisexual Flowers)

Though typically hermaphroditic, some genera are dioecious (separate male and female plants) or andromonoecious (male and bisexual flowers on the same plant).

Arctopus and *Aciphylla* are examples of dioecious organisms. *Echinophora* is an example of andromonoecious plants, in which male flowers encircle a central female flower.

d. Outstanding Leaves and Habits

- **Non-dissected Leaves:** Although some members have simple, undivided leaves, the majority have deeply dissected, fern-like leaves. e.g., *Centella* and *Bupleurum*.
- **Shrubby/Woody Habit:** Although mostly herbaceous, some species can grow into shrubs or even little trees in some settings.
- Examples include several species of *Eryngium* and the tree-like genus *Steganotaenia*.

e. Highly Toxic Specialized Metabolites

Many of them are edible (carrots, celery), but some are among the most dangerous plants in nature because they contain deadly alkaloids like cicutoxin or coniine. e.g., *Conium maculatum* and *Cicuta*.

Summary Table of Exceptional characteristics in Apiaceae

Features	General Characteristics	Exceptions/Deviations
<i>Habit</i>	Annual, biennial, or perennial herbs	Woody shrubs, trees, or lianas (e.g., <i>Bupleurum fruticosum</i> , <i>Eryngium</i>)
<i>Stem</i>	Fistular (hollow)	Solid stems (<i>Daucus carota</i> - Carrot)
<i>Leaves</i>	Alternate, pinnately/palmately dissected	Simple, entire, or perfoliate leaves (<i>Bupleurum</i>), or linear/phyllodineous (<i>Lilaeopsis</i>)
<i>Leaves</i>	Exstipulate (no stipules)	Stipulate (sometimes present in <i>Hydrocotyle</i>)

Features	General Characteristics	Exceptions/Deviations
<i>Inflorescence</i>	Compound Umbel	Simple umbel, heads (capitate), or reduced to a single flower
<i>Bracts</i>	Involucre (at base of umbel)	Absent in some genera
<i>Flower Symmetry</i>	Actinomorphic (regular)	Zygomorphic (irregular) marginal flowers (<i>Coriandrum</i> , <i>Daucus</i>)
<i>Sexuality</i>	Bisexual (hermaphrodite)	Monoecious or dioecious (staminate only)
<i>Calyx</i>	Small, 5 sepals, often 0	Calyx teeth may be prominent in some species
<i>Corolla</i>	5 petals, white or yellow	Petals absent (rare)
<i>Gynoecium</i>	2 carpels, inferior ovary	1 carpel (rare), ovary rarely partially superior
<i>Fruit</i>	Dry schizocarp (cremocarp)	Fleshy, drupaceous fruits (e.g., <i>Myrrhidendron</i>)
<i>Habitat</i>	Terrestrial, temperate	Aquatic or maritime plants (<i>Crithmum</i> , <i>Apium</i>)

Important Remarks on Significant Exceptions in Apiaceae

- **The Bupleurum Exception:** *Bupleurum* species have simple, entire, and frequently perfoliate (stem-clasping) leaves, in contrast to most members with finely dissected, fern-like leaves.
- **Marginal Flower Variation:** Although flowers are typically radially symmetrical, certain plants, like *Daucus* and *Coriandrum*, have marginal flowers that are zygomorphic (have bigger outer petals) in order to draw pollinators.
- **Fruit Structure:** Although the distinguishing characteristic is the schizocarp separating into two mericarps, certain tribes (such as Saniculeae) have fruits with spines or hooks that make splitting difficult.
- **Araliaceae Overlap:** Because of their intermediate features, several taxa, such as, *Hydrocotyle*, are occasionally included under the Araliaceae.

4. Apocynaceae

An overview of instances of exceptions in Apocynaceae family:

- **Lianas (Woody Vines)** - *Allamanda cathartica*, *Cryptostegia grandiflora*, *Macropharynx peltata*
- **Trees** - *Alstonia scholaris*, *Plumeria alba*, *Cascabela*
- **Shrubs** - *Acokanthera*, *Adenium obesum*, *Carissa edulis*, *Nerium*
- In *Nerium*, anthers have hairy, twisting, or pointed appendages;
- **General Character:** Latex present, opposite leaves, superior ovary.

Exceptions:

- **Ovary Position:** Although generally superior, certain members of this family (formerly classified in Asclepiadaceae) may show inferior or semi-inferior ovaries.
- **Deviation:** Although typically characterized by milky sap, many woody members have clear sap.
- **Deviation:** Gynoecium is usually bicarpellary/syncarpous, but some (e.g., *Rauvolfia*) have drupaceous fruits rather than follicles.

5. Asclepiadaceae (Now often within Apocynaceae)

Deviation: Presence of a highly complex gynostegium (anther-stigma fusion) and pollinia (pollen sacs), which are unique modifications compared to other dicots.

Deviation: Seeds usually have a coma (hairs), but some are naked.

Leafless Stem Succulents: Although most members are leafy shrubs or climbers, some species are completely leafless and resemble cacti (cactus-like habit) (e.g., *Stapelia gigantea*, *Caralluma*, *Hoodia*).

Epiphytic Habit: Although mostly terrestrial, some species grow on trees as epiphytes (e.g., *Hoya longifolia*).

Leaf Modification: In arid conditions, some species have leaves modified into spines, despite others having lush foliage.

Floral and Reproductive Exceptions

Pollen Structure (Periplocoideae): The family is renowned for having pollen united into waxy bodies called pollinia. Though, the subfamily Periplocoideae, often grouped within it, has granular pollen in tetrads instead of waxy pollinia (e.g., *Cryptolepis*, *Hemidesmus indicus*).

Number of Pollinia: Although typical taxa have 2 pollinia per anther (e.g., *Calotropis*), others have 4 (the Tribe Secamoneae) (e.g., *Secamone*).

Calyx Structure: usually, calyx is fused, but in some species, it is free.

Unique Adaptations:

Ant Plants (Domatia): several plants are specialized with hollow, inflated leaves that abode ants (e.g., *Dischidia rafflesiana*).

Rotten Flesh Smell: although many are sweet-scented, some are well-known for producing a strong odor of rotting meat to attract fly pollinators (e.g., *Stapelia hirsute*).

Large Caudex: several species produce a massive, thick, brown stem base (caudex) with minimal leafy branches. (e.g., *Fockea*).

6. Asteraceae

An overview of instances of exceptions in Asteraceae family:

1. Unique Inflorescence Structure (1-Flowered Head)

- **Exception:** The majority of Asteraceae have a single head (capitulum) with several tiny blooms. Some, on the other hand, have trimmed the head such that it only has one or a small number of blooms, which are frequently unisexual. e.g.,
 - **Corymbium:** Species in this genus have 1-flowered bisexual head.
 - **Gundelia:** has 1-flowered unisexual head.
 - **Gymnarrhena micrantha:** shows 1-flowered female head and few-flowered male heads.
 - **Echinops (Globe Thistles):** Each unit within the global head is a one-flowered capitulum that forms a big, global, "thistle-like" head.

2. Departure from "Ray and Disc" Structure

- **Exception:** Although many, like the sunflower, have distinct ray (petalled) and disc (tubular) flowers, others are composed entirely of one type.
- **Examples:**
 - **Liguliflorae** (e.g., *Sonchus*, *Lactuca*, *Taraxacum*): flowers ligulate, bisexual.
 - **Discoïd/Disciform** (e.g., *Ageratum*, *Artemisia*): with regular, tubular flowers.
 - **Dioecious Genus (*Baccharis*):** Dioecious & lack ray flowers.

3. Unusual Pollination and Breeding Systems

Exception: Some plants have switched to anemophily despite insect pollination being the norm. e.g., *Ambrosia* & *Artemisia* (Wind Pollinated), *Mutisia* (ornithophilous).

4. Vegetative and Ecological Exceptions

- **Exception:** Although mainly herbs/small shrubs, some are woody trees.
- **Examples:** *Vernonia arborea* and *Dasyphyllum excelsum* can grow as trees.
- **Apomictic species** (e.g., *Taraxacum*): Many dandelions are apomictic

5. Leaf Arrangement

- **Exception:** Leaves are normally alternate, but some are opposite.
- **Examples:** *Zinnia* and *Dahlia* are with opposite leaves.

6. Flower Part Variation (Stamen/Carpel Count)

- **Exception:** Although generally pentamerous with 5 anthers, some, like *Bidens tripartita*, can have disc florets with only 4 lobes.
- Flowers sessile, (*Sonchus*, *Ageratum*);
- Ray floret pistillate/neutral (*Eclipta alba*)

Summary Table of Notable Exceptions in Asteraceae

Feature	Typical characters	Exception (Example)
<i>Inflorescence</i>	Many-flowered capitulum	<i>Echinops</i> (1-flowered heads)
<i>Flower Types</i>	Ray + Disc florets	<i>Sonchus</i> (All ray), <i>Ageratum</i> (All disc)
<i>disc florets</i>	actinomorphic in disc florets	<i>Gerbera</i> (zygomorphic)
<i>Pollination</i>	Insect	<i>Ambrosia</i> (Wind), <i>Mutisia</i> (Bird)
<i>Habit</i>	Herb/Shrub	Woody Tree - <i>Senecio johnstoni</i> , <i>Vernonia arborea</i> , <i>Espeletia hertwegiana</i> , <i>Leucomeris</i> , <i>Scalesia</i> Xerophytes (<i>Carthamus tinctorius</i> , <i>Encelia farinose</i> , <i>Artemisia tridentate</i> , <i>Proustia</i> , <i>Chrysothamnus</i>), Hydrophytes (<i>Caesulia axillaris</i> , <i>Cotula</i> , <i>Petasites</i>)
<i>Reproduction</i>	Sexual	<i>Taraxacum</i> (Apomictic/Asexual)
<i>Leaf Arrangement</i>	Alternate	<i>Zinnia</i> , <i>Dahlia</i> (Opposite), whorled (<i>Eupatorium</i>)

7. Brassicaceae

An overview of instances of exceptions in Apiaceae family:

The following are significant exceptions within Brassicaceae family suitable instances:

1. Exceptions in Stamens (Staminal Number)

- The family's typical trait is tetradynamous (6 stamens: 2 outer short, 4 inner long). Less than 6 stamens are seen in *Lepidium* or *Cardamine*; Species may have 4 stamens, whereas *Coronopus* (now frequently *Lepidium*) may have just two.
- Increased Stamens: *Megacarpa* is a noteworthy exception with 16 stamens.

2. Exceptions in Petals

- The family's typical trait is 4 free, cruciform corollas.
- Petals are absent: in *Lepidium* and *Coronopus*.
- Petals Transformed into stamens: In *Capsella* (Shepherd's purse)

3. Exceptions in Pollination and Breeding

- Nearly every member of the Brassicaceae family is bisexual and entomophilous.
- Wind Pollination: *Pringlea antiscorbutica* is an exception, being adapted for wind pollination.
- Closed Flowers (Cleistogamy): *Cardamine chenopodifolia* are exclusively self-pollinated, with closed, underground flowers.
- Non-Hermaphrodite: Although extremely uncommon, several *Lepidium* species defy the hermaphrodite rule.

4. Exceptions in Carbon Fixation (Metabolism)

- The *Moricandia* Intermediate System:
- Species: The genus *Moricandia* has a number of species (*M. arvensis* and *M. suffruticosa*) that are classified as intermediate. *Brassica gravinae* and *Diplotaxis tenuifolia* are two other instances.
- The Hybrid System ("Glycine Shuttle"): These species follow a "photorespiratory glycine shuttle" instead of a complete, classical pathway.
- Within the family, especially in the Oleracea group, the C₃-C₄ characteristic has undergone many separate evolutionary cycles.
- Anatomical Changes: In contrast to typical C₃ Brassicaceae, the intermediates have "Kranz-like" anatomy, with a greater density of mitochondria and chloroplasts in the bundle sheath cells.

5. Exceptions in Inflorescence & Fruit

- The family's typical trait for inflorescence is a simple raceme, and the fruit is a silique.
- Inflorescence Type: *Iberis amara* has a corymb type of inflorescence, where lower flowers have much longer pedicels than upper ones.

- Compound Inflorescence: Cauliflower has a compound inflorescence.
 - Fruit Shape: *Capsella*, *Iberis*, *Lepidium*, and *Alyssum* have silicula rather than a siliqua.
6. Exceptions in Habit
- Mostly herbaceous.
 - Shrubs: Although rare, certain members are undershrubs, e.g., *Aethionema* species.
 - Deviation: Typically non-woody, *Erysimum* and some *Alyssum* species are sub-shrubs.
 - Leaves sub-opposite (*Cardamine concatenata*), exstipulate (*Raphanus sativus*, *Capsella bursa-pastoris*). Leaves radical (*Raphanus*);

Summary Table of major Exceptions in Brassicaceae

<i>Feature</i>	<i>Typical character</i>	<i>Exception (Examples)</i>
<i>Root</i>	Tap root	Root Napiform (Top-shaped) in Turnip (<i>Brassica rapa</i>), Fusiform (Spindle-shaped) in Radish (<i>Raphanus sativus</i>) or Conical in Carrot
<i>Stem</i>	Herb	woody (<i>Farsetia jacquemontii</i>)
<i>Inflorescence</i>	Simple Raceme	<i>Iberis amara</i> (Corymb), Cauliflower (Compound)
<i>Flower</i>	Complete	Incomplete (<i>Iberis</i> , <i>Lepidium</i>)
<i>Petals</i>	4	<i>Lepidium</i> , <i>Coronopus</i> (Absent)
<i>Stamens</i>	6 (2+4)	<i>Megacarpa</i> (16), <i>Cardamine hirsute</i> (4), <i>Coronopus</i> (2)
<i>Fruit</i>	Siliqua	Silicula: <i>Iberis amara</i> , <i>Coronopus didymus</i> , <i>Capsella bursa-pastoris</i> ; Lomentaceous fruit (breaking into segments): <i>Raphanus sativus</i> , <i>Rapistrum rugosum</i> , <i>Erucaria erucarioides</i> ; nut-like fruits, e.g., <i>Isatis tinctoria</i> , <i>Neslia paniculata</i> , <i>Myagrum perfoliatum</i> ;
<i>Pollination</i>	Insects	<i>Pringlea</i> (Wind)
<i>Fertilization</i>	Cross-pollination	<i>Cardamine chenopodifolia</i> (Closed flowers)
<i>Metabolism</i>	C ₃	<i>Moricandia</i> (intermediate)

8. Cucurbitaceae

The following are significant exceptions within this family suitable instance:

1. Growth Habit Exceptions (Non-Climbing/Perennial)

- **Bushy Growth Habit (No Tendrils):** Unlike the distinctive trailing/climbing vines, Zucchini (*Cucurbita pepo* var. *cylindrica*) often displays a bushy growth habit and may be without functional tendrils.
 - **Perennial Habit:** Mostly are annuals, but *Sechium edule* and *Coccinia grandis* are perennial, growing back from the same rootstock for quite a few years.
 - **Woody Lianas/Trees:** Although majorities are herbaceous, certain tropical species are woody, and the *Dendrosicyos* genus (e.g., *Dendrosicyos socotrana*) contains tree-like species.
2. Sexual Expression Exceptions
- **Dioecious (Male/Female on Separate Plants):** The typical standard is monoecious but Parwal/Pointed Gourd (*Trichosanthes dioica*), *Coccinia* (*Coccinia grandis*), and Kakrol (*Momordica dioica*) are dioecious.
3. Bisexual/Hermaphrodite Flowers: Although majority are unisexual, flowers bisexual in *Satputia* variety of ridged gourd and certain lines of Muskmelon.
4. Fruit and Seed Exceptions
- **One-Seeded Fruit:** Most cucurbits are many seeded, but *Sechium edule*, *Sicyos* (bur cucumber), and *Sechium* genera typically produce a single seed in their fruits.
 - **Winged Seeds:** A few, like *Alsomitra macrocarpa*, have winged seeds for wind dispersal, rather than the typical, unwinged seeds of squash or melon.
 - **Dehiscent/Squirting Fruit:** Although majority of cucurbit fruits are indehiscent, *Ecballium elaterium* forcefully ejects seeds & pulp when ripe.
5. Genetic/Structural Exceptions
- **Unusual Chromosome Count:** *Cucurbita ficifolia* does not hybridize well with other *Cucurbita* species due to considerably dissimilar chromosomes & enzymes.
 - **Free Petals:** Although mostly gamopetalous, *Fevillea* has free petals (a deviation).

Summary Table of Key Exceptions

Features	Common trait	Exception Examples
Habit	Annual climbing vines	<i>Sechium edule</i> , <i>Coccinia grandis/indica</i> , <i>Trichosanthes dioica</i> (Perennial); <i>Acanthosicyos</i> , <i>Cucurbita pepo</i> (Bush/shrub type); small trees (<i>Dendrosicyos socotrana</i> , <i>Gerrardanthus macrorhizus</i>);
Stem	Herbaceous	<i>Dendrosicyos</i> (Tree-like)

Tendril	Present	Acanthosicyos is without tendrils
Gender	Monoecious	<i>Trichosanthes dioica</i> (Dioecious), <i>Satputia</i> (Hermaphrodite)
Flower	Unisexual	Bisexual (Schizopepon, Ecballium);
Fruit	Many-seeded, indehiscent	<i>Sechium edule</i> (One-seeded), <i>Ecballium</i> (Squirting)

9. Dipterocarpaceae

An overview of instances of exceptions in Dipterocarpaceae family are:

1. Growth Habit Exceptions (Not always giants)
 - Although known as "emergent" trees, some species are not massive.
 - Small/Dwarfed Trees: Some dipterocarps are small and gnarled, not giant.
 - Shrubs: Although "rarely shrubs," some species do not attain typical gigantic stature.
2. Ecological Exceptions (Not just wet lowlands)
 - Most dipterocarps require high, year-round rainfall, but some are specialized.
 - Dry/Deciduous Forest Species: *Dipterocarpus intricatus*, *D. tuberculatus*, *D. obtusifolius*, and *Shorea siamensis* grow in seasonal forests with dry seasons lasting 5–7 months.
 - Limestone Inhabitants: Dipterocarps are usually absent from limestone, but *Hopea ferrea* and *Pentacme siamensis* are adapted to grow on limestone rocks.
 - Swamp Residents: Although typically found in well-drained soil, species like *Shorea albida* can form gregarious forests in peat swamps.
3. Floral and Structural Exceptions
 - Non-standard Fruit Dispersal: Although the family is renowned for 2-winged, wind-dispersed fruits, species in the genus *Vateria* have large fruits that do not fit the typical "2-winged" description, frequently breaking into 3-valves (e.g., *Vateria indica*).
 - Secund Flowers: Although most have panicles, the genus *Hopea* (e.g., *Hopea ponga*) has flowers that are secund—directed to one side only.
 - Unique Stipules: In *Shorea macrophylla*, stipules are consistently revolute, (unusual feature in *Shorea*)
4. Genetic Exceptions (Polyploidy)
 - Most dipterocarps are diploid ($2n=20$), but polyploid species are found in the genera *Hopea* and *Shorea*.
 - Aneuploidy: Aneuploidy has been observed in the genera *Anisoptera* and *Dipterocarpus*.

5. Taxonomic Reclassifications (Excluded Genera)

- *Ancistrocladus* & *Lophira*: Formerly included in Dipterocarpaceae, these were shifted to Ancistrocladaceae and Ochnaceae, respectively, as they did not fully match the family's characterization.

Summary Table of Exceptions

Feature	Typical character	Exceptions/Exceptions to the Rule
Distribution	Primarily South-East Asian tropics	Monotoideae in Africa/Madagascar; Pakaraimoideae in South America (Guyana/Venezuela)
Habitat	Well-drained lowland forests, 0-300m alt.	High, often exclusive, diversity in peat swamp forests (e.g., <i>Shorea albida</i>)
Habit	Giant trees	Rarely shrubs (<i>Vatica lanceifolia</i> , <i>V. oblongifolia</i> , <i>Stemonoporus</i> , <i>Hopea glabra</i>)
Taxonomy	Monophyletic; 3 Subfamilies	Phylogenetic placement of <i>Dipterocarpus</i> and <i>Dryobalanops</i> remains uncertain
Phylogeny	<i>Hopea</i> & <i>Shorea</i> distinct	<i>Hopea</i> forms a clade with specific <i>Shorea</i> sections (<i>Anthoshorea</i> & <i>Doona</i>)
Leaf Structure	Entire margin	Bumpy or wavy margins (e.g., <i>Dipterocarpus elongatus</i>)
Leaf Symmetry	Symmetrical	Asymmetrical base in some <i>Hopea</i> species
Resin	Present in all parts	Lacking in Monotoideae
Fruit	5-winged, persistent calyx (<i>Dipterocarpus</i> , <i>Shorea</i>)	Wingless seeds (Note: phylogenetic dependence shown in studies)
Genetic Exceptions	Mostly are diploid (2n=20)	Polyploidy (<i>Hopea</i> and <i>Shorea</i>) Aneuploidy (<i>Anisoptera</i> & <i>Dipterocarpus</i>)
Persistence	Generally not Endangered	74% of 491 assessed species are Threatened in the wild
Extinction	No known extinct species	<i>Hopea shingkeng</i> is listed as extinct (last seen 1911)

10. Ericaceae

An overview of instances of exceptions in Ericaceae family:

- Parasitic plants (e.g., *Monotropa*); Persistent calyx, surrounding the fruit (e.g., *Erica*, *Gaultheria*); Fruit dry loculicidal/septicidal capsules encircled by colorful, fleshy calyx lobes (e.g., *Rhododendron*, *Kalmia*), fleshy berries (e.g., *Vaccinium*) or drupes (e.g., *Arctostaphylos*, *Gaultheria*);
- Deviation: Typically requires acidic soil, but some *Rhododendron* species can tolerate slightly alkaline conditions.
- Deviation: Mostly woody, but some *Monotropa* are parasitic and lack chlorophyll.

Non-photosynthetic/Parasitic Exceptions

- Most Ericaceae are photosynthetic, but some have lost the ability to produce chlorophyll and live as myco-heterotrophs (parasitic on fungi).
- Indian Pipe (*Monotropa uniflora*): Lacks chlorophyll and is white, appearing parasitic.
- Pinesap (*Monotropa hypopitys*): A non-photosynthetic, yellow or red plant.
- Sugarstick (*Allotropa virgata*): A striking, striped non-photosynthetic herb.
- Pine-drops (*Pterospora andromedea*): A tall, parasitic plant often found in coniferous forests.

Herbaceous/Small Habit Exceptions

- Although mainly woody shrubs or trees, some members are small, herbaceous, or creeping plants.
- Wintergreen (*Pyrola* spp. and *Chimaphila* spp.): These were formerly placed in their own family (Pyrolaceae) and are often low-growing herbs with evergreen leaves rather than shrubs.
- Trailing Arbutus (*Epigaea repens*): A creeping, woody subshrub that often sits low to the ground.

Flower Structure Exceptions

- Most Ericaceae feature fused, urn-shaped (urceolate) corollas (e.g., *Vaccinium*), but some have open, trumpet-shaped, or polypetalous flowers.
- *Rhododendron* and *Azaleas*: These have relatively open, bell-shaped, or wide-mouthed flowers rather than the typical tight urn shape.
- Mountain Laurel (*Kalmia latifolia*): Features bowl-shaped flowers with distinct, stamens caught in pockets.
- Elliottia (*Elliottia pyroliflora*): Features more distinct, petals rather than a strongly fused corolla.

Leaf Habit Exceptions

- Many members are evergreens, but there are significant deciduous exceptions.
- Deciduous *Azaleas* (*Rhododendron* spp.): Many species lose their leaves in winter, contrary to the "evergreen" rule for the family.
- Blueberries (*Vaccinium* sect. *Cyanococcus*): Many species are deciduous, dropping their leaves in autumn.

Mycorrhizal Association Exceptions

- Mainly Ericaceae form "ericoid" mycorrhizae, but several basal, woody lineages do not.
- Arbutoid Mycorrhizae: *Arbutus* (Manzanitas) and *Arctostaphylos* (Bearberry) form arbutoid mycorrhizae rather than the typical ericoid form.

Summary of Exceptional Characters

<i>Feature</i>	<i>General Characteristic</i>	<i>Notable Exception(s)</i>
<i>Habit</i>	Woody shrubs or trees	Herbaceous perennials (e.g., <i>Pyrola</i> , <i>Orthilia</i>); achlorophyllous myco-heterotrophs (<i>Monotropa</i> , <i>Pityopus</i>).
<i>Habitat</i>	Acidic soils, heathland	Occasional occurrence in more varied habitats, though generally rare.
<i>Leaves</i>	Simple, evergreen, leathery	Deciduous leaves (e.g., <i>Vaccinium</i> spp.); scale-like or needle-like leaves (e.g., <i>Erica</i> spp.).
<i>Corolla</i>	Sympetalous (fused), urn-shaped	Free or nearly free petals (e.g., <i>Ledum</i> , <i>Bejaria</i>).
<i>Ovary</i>	Superior	Inferior ovary (subfamily Vaccinioideae, including <i>Vaccinium</i> , <i>Gaylussacia</i>).
<i>Anthers</i>	Poricidal dehiscing (pores)	Longitudinal slits (e.g., in some Styphelioideae/Epacridaceae).
<i>Mycorrhizae</i>	Ericoid mycorrhizae	Arbutoid mycorrhizae (<i>Arbutus</i> , <i>Arctostaphylos</i>); Monotropoid mycorrhizae (Monotropoideae).
<i>Fruit</i>	Capsule, berry, or drupe	Dry, indehiscent fruits in some species (e.g., <i>Empetrum</i>).
<i>Placentation</i>	Axile	Parietal (often associated with 1-locular, dry fruits).

11. Euphorbiaceae

An overview of instances of exceptions in Apiaceae family:

- Perennial herbs (e.g., *Euphorbia hirta*), shrubs (*Jatropha*), large trees (*Hevea brasiliensis*); exceptional inflorescence: Compound Raceme / Panicle (*Ricinus communis*), Simple Raceme/Spike (*Croton sparsiflorus*, *Croton tiglium*), Catkin (*Acalypha indica*), Terminal Cyme (*Jatropha curcas*, *Jatropha gossypifolia*), Solitary Axillary (*Phyllanthus amarus*), Complex/Specialized Pseudanthia (*Dalechampia*, *Pera*);
- Monoecious (*Manihot esculenta*, *Ricinus communis*), dioecious (*Excoecaria agallocha*, *Putranjiva roxburghii*, *Bridelia*);
- Stamens 1 in *Euphorbia*, many stamens in *Croton*, up to 1,000 stamens in *Ricinus*;
- Regma in *Ricinus communis*, *Jatropha curcas*, *Manihot esculenta*, *Hevea brasiliensis*, *Croton tiglium*; fleshy, indehiscent drupe in *Phyllanthus emblica*, *Bridelia*, *Trewia*, *Drypetes*; very rarely a berry found in *Securinega*; *Euphorbia exigua* shows bilobate caruncle; *Euphorbia falcate* shows conical caruncle, compressed-ovoid-quadrangular; *Euphorbia hirta* and *E. thymifolia* show oblong, obtusely tetragonal, two-layered, collapsing testa.

1. Absence of Milky Latex

- Although most *Euphorbia* species produce white, toxic latex, many other members of the family, particularly in the subfamily Crotonoideae, have watery or colored sap, or no latex at all.
- Exception Example: *Croton* species often lack the milky, toxic latex found in *Euphorbia*.

2. Deviations in Inflorescence (Non-Cyathium)

- The cyathium (a, "false flower" composed of small male flowers surrounding a female flower, often with petal-like bracts) is characteristic of the tribe Euphorbieae. Many other members have conventional, separate inflorescences.
- Exception Examples: *Ricinus communis* (Castor) and *Manihot esculenta* (Cassava) do not have cyathia; they have distinct, separate male and female flowers.

3. Leaf and Stem Variations

- Although mostly simple, alternate leaves are the norm, some species deviate significantly.
- Compound Leaves: *Manihot esculenta* (Cassava) has palmately compound leaves.

- Reduced/Absent Leaves: Succulent species like *Euphorbia tirucalli* (Pencil tree) have severely reduced leaves, while others are entirely leafless, relying on succulent stems for photosynthesis.

4. Fruit Structure Exceptions

- The typical fruit is a 3-celled capsule (regma) that splits explosively.
- Exception Examples: *Hura crepitans* (Sandbox tree) has a pumpkin-shaped, multi-seeded capsule that can have 11–14 mericarps (sections), rather than the standard three.
- Fleshy Fruits: *Phyllanthus emblica* (Amla/Indian Gooseberry) produces a fleshy, berry-like fruit rather than a dehiscent dry capsule.

5. Growth Habit (Beyond Shrubs/Herbs)

- Although mostly herbs and shrubs, the family contains massive, woody trees, and some specialized forms.
- Tree Example: *Hevea brasiliensis* (Pará rubber tree) is a large tree.
- Climbers/Vines: Some species, such as those in the genus *Tragia*, are climbers.

6. Reproductive Variations

- The family is typically monoecious (male and female flowers on the same plant), but some exceptions exist.
- Dioecious Example: *Mercurialis* (Mercury) plants are often dioecious.

7. Seed Morphology

- Seeds in the family are usually carunculate; Exception Example: Seeds of *P. volubilis* (Subfam. Acalyphoideae) lack this structure and lack the typical bilateral symmetry of the family.

Summary Table of Exceptional characteristics in Euphorbiaceae

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>
<i>Habit</i>	Herbs, shrubs, or trees	Includes numerous succulent, cactus-like plants (e.g., <i>Euphorbia</i>) and climbers.
<i>Latex</i>	Milky, white, and often toxic	Absent in many taxa; some taxa have colored (yellow/red) or watery sap.
<i>Leaves</i>	Alternate, simple, with stipules	Can be opposite or whorled; sometimes compound (palmate).

<i>Stipules</i>	Present	Reduced to hairs, glands, or spines; or totally absent.
<i>Inflorescence</i>	Varied (racemose/cymose)	Highly specialized "false flower" (cyathium) in <i>Euphorbia</i> and its allies.
<i>Perianth</i>	Uniseriate (sepals only) or absent	Sometimes biseriate (both calyx and corolla present, e.g., <i>Jatropha</i>), often very reduced.
<i>Stamens</i>	1 to many	Reduced to a single stamen in the male flowers of <i>Euphorbia</i> .
<i>Ovary</i>	Tricarpellary, superior, 3-loculed	2-many carpellate (can be 1–20+), locules may be reduced or increased.
<i>Fruit</i>	Schizocarpic capsule (3-cocci)	Berry or drupe (e.g., <i>Phyllanthus</i>).
<i>Seeds</i>	Often with a caruncle (aril)	Caruncle can be absent.

Important Remarks on Significant Exceptions in Euphorbiaceae

- *Euphorbia* (Subfamily Euphorbioideae): Known for its cup-like cyathium inflorescence, which has one female bloom surrounded by numerous male flowers, each with a single stamen.
- Acalyphoideae: Lacks milky latex compared to other subfamilies.
- *Phyllanthus*: Produces drupaceous fruits instead of capsules often.
- *Manihot* & *Ricinus*: Characterized by non-milky sap and characteristic palmate leaves.
- Succulent Types: Xerophytic *Euphorbia* species have decreased or missing leaves to limit water loss.

12. Fabaceae (Leguminosae- Legume/Pea Family)

1. Leaf Structure (Exceptions to Compound Leaves)
 - Although most Fabaceae have pinnately compound leaves, some have evolved to have simple or reduced leaves.
 - Simple Leaves: Cercis (redbud).
 - Phyllodes (Modified Petioles): Many Australian Acacia species lack true leaves as adults, with leaf-like, flattened petioles (phyllodes) taking their place.
 - Spiny/Reduced Leaves: Ulex europaeus (Gorse) has leaves reduced to spines.
2. Flower Symmetry (Exceptions to Zygomorphic)

- Although most Fabaceae flowers are zygomorphic (bilateral symmetry), some show radial symmetry or have different petal arrangements.
 - Radial/Actinomorphic Symmetry: The subfamily Mimosoideae (e.g., *Mimosa*, *Acacia*) typically has radially symmetric flowers with long, showy stamens.
 - Variation in Caesalpinioideae: Many in this subfamily have irregular or nearly radial flowers, such as *Bauhinia* (orchid trees).
 - Radially Symmetric Exceptions: *Cadia* is a genus within the normally papilionoid tribe that has evolved radial flowers.
3. Nodule Formation (Exceptions to Nitrogen-Fixing)
- Although the ability to form nitrogen-fixing root nodules with *Rhizobium* bacteria is a defining feature, it is not universal.
 - Non-nodulating Species: Many species within the subfamily Caesalpinioideae do not form nodules.
 - Specific Examples: *Senegalia pentagona* (formerly in Mimosoideae) does not form nodules, despite others in the same group doing so.
4. Fruit Type (Exceptions to Dry Pods)
- Indehiscent Pods: Although legumes typically split open (dehiscent), some produce pods that do not split (indehiscent), such as in *Ceratonia siliqua* (carob).
 - Samaras: *Tipuana tipu* produces winged, one-seeded pods (samaras).
5. Other Notable Exceptions
- Underground Fruiting: *Arachis hypogaea* (peanut) produces flowers above ground, but the fruit matures underground.
 - Toxicity: Although many are staples, some seeds are highly poisonous, such as the *Abrus precatorius* (jequirity bean or rosary pea).
 - Habit Exception: Although mostly herbs/shrubs/trees, some are aquatic, like *Sesbania rostrata*, which nodulates on its stems, not just roots.
 - The Caesalpinioideae and Mimosoideae subfamilies exhibit irregular or actinomorphic (radial) symmetry instead of zygomorphic symmetry.
 - Herbs in Mimosaceae (e.g., *Neptunia*); Fruit woody, coiled, or spiraling (like *Pithecellobium dulce*); lomentaceous fruit in *Mimosa pudica*, *Entada*, *Desmodium*, *Hedysarum*, *Zornia*;
 - Stamens in Mimosoideae: Many (sometimes infinite) stamens, not 10 or 9+1.
 - Root Nodules: Although recognized for nitrogen-fixing, certain members like *Cercis* (Redbud) do not generate root nodules.
 - Mimosaceae (Subfamily): Australian *Acacia* species often have phyllodes (modified petioles) instead of compound leaves, appearing simple.

- Caesalpiniaceae (Subfamily): *Cercis* has simple leaves, and some have almost radial flowers, deviating from the typical zygomorphic legume, e.g., *Bauhinia*.
- Woody climbers in Caesalpiniaceae (e.g., *Caesalpinia*); stamens connate (e.g., *Tamarindus*); anemochory - *Tipuana tipu*; hydrochory - *Caesalpinia crista*;
- Papilionaceae (Subfamily): *Indigofera* and *Indigo* genus sometimes have only one petal (the banner/standard) instead of five.
- Stamens monadelphous (*Crotalaria*), or very rarely 9 (*Abrus*);
- Root System: *Cercis* (redbud) lacks the typical rhizobial root nodules found in most other Fabaceae.

13. Lamiaceae

Although the Lamiaceae is characterized by square stems, opposite leaves, and aromatic, two-lipped flowers, several, exceptions to these rules exist within the family:

- Flower Shape: *Mentha* (Mint) has almost regular (actinomorphic) flowers, not two-lipped.
- Symmetry: Some exceptions to the opposite leaf arrangement (e.g., whorled).
- Deviation: Mostly aromatic herbs with opposite leaves, But *Tinnea* have actinomorphic flowers, and *Mentha* has nearly radial flowers.
- Spike- *Teucrium*, Axillary cyme - *Leucas prostrate*, Racemose- *Scutellaria*; corolla bilabiate 4/1 arrangement in *Ocimum*, *Hyptis*; & 0/5 arrangement in *Teucrium*;
- Stamens 4, (2 in *Salvia*, *Meriandra*; Monadelphous in *Coleus*);
- Non-Square Stems: Although most Lamiaceae have square stems, some species within the family exhibit rounded or differently shaped stems.
- Non-Aromatic Species: Although famously aromatic (containing volatile oils like menthol or thymol), not all species possess a strong fragrance.
- Tree/Shrub Habit: Although predominantly herbs or subshrubs, some members deviate to woody forms, such as *Tectona* (teak), which is a large tree, or woody undershrubs like *Royalea*.
- Staminal Variation (*Salvia*): The genus *Salvia* is an exception to the typical four-stamen structure of the family, as they have evolved to have only two functional stamens with a unique, elongated connective lever mechanism.
- Fruit Structure: Although the typical fruit is a dry nutlet, *Prassium* and *Stenogyne* are exceptions that produce fleshy, drupaceous nutlets.
- Seed Characteristics: Most Lamiaceae have non-endospermic seeds, but members of the subfamily Prostantheroideae (e.g., *Prostanthera*, *Wixonia*) are exceptions, having endospermic seeds.

Examples of Notable Exceptions:

- **Teak (*Tectona grandis*):** A large tree, unlike the typical herbaceous mint.
- **Sage (*Salvia* spp.):** Deviates from standard staminal structure.
- ***Scutellaria*:** Known for having a distinct, non-traditional calyx and nutlet structure compared to typical mints.

Summary Table of Exceptional characteristics in Lamiaceae

Characteristic	Typical Feature of Lamiaceae	Exceptions / Variations	Examples of Exceptions
Habit	Herbs or shrubs	Trees, woody vines (lianas)	<i>Volkameria</i> (climbing shrubs), <i>Tectona</i> (teak), <i>Plectranthus</i>
Stem Shape	Quadrangular (4-angled)	Cylindrical or circular in cross-section	<i>Volkameria</i> , some <i>Clerodendrum</i> species
Phyllotaxy	Opposite and decussate	Alternate, whorled, or spiral	<i>Volkameria</i> (3 per node), <i>Scutellaria</i> (sometimes spiral)
Aroma	Aromatic (glandular hairs)	Non-aromatic	<i>Scutellaria</i> species
Corolla	Bilabiate (2-lipped)	Actinomorphic (regular), 4-5 lobed, or salverform	<i>Mentha</i> (sometimes nearly regular), <i>Volkameria</i> (salverform)
Stamens	4(Didynamous)	2 (with 2 staminodes) or rarely 5	<i>Salvia</i> (2), <i>Lycopus</i> (2)
Ovary/Style	Deeply 4-lobed, Gynobasic style	Entire or shallowly 4-lobed; Terminal style	Subfamily Ajugoideae, Prostantheroideae
Fruit	4 Nutlets (Schizocarp)	Drupes, fleshy, or capsules	<i>Volkameria</i> (Drupes), <i>Clerodendrum</i>

Important Remarks on Significant Exceptions in Lamiaceae

- **Habit/Stem:** Mostly herbaceous and square-stemmed, the family also contains tropical climbers and woody trees (e.g., Teak) with cylindrical stems.
- **Flowers:** The two-lipped flower is typical, although certain taxa exhibit actinomorphic (radial) symmetry (e.g., *Mentha*) or Salverform (long-tubed, *Volkameria*).

- *Style Position*: Common "gynobasic" style from ovary base, but "terminal" style from top found in primitive Lamiales, distinguishing them from other Lamiales.
- *Fruits*: Some species of the Clerodendroideae subfamily produce juicy drupes instead of dry nutlets.

14. Magnoliaceae

An overview of instances of exceptions in Magnoliaceae family:

- *Pollination Method (Liriodendron vs. Others)*: Most Magnoliaceae, such as *Magnolia* and *Michelia*, are beetle-pollinated, featuring robust carpels that withstand damage. However, the tulip tree (*Liriodendron tulipifera*) is an exception, relying on bees for pollination.
- *Pollinator Adaptation*: The carpels of most *Magnolia* flowers are especially thick to avoid damage by beetles, whereas other related taxa might not share this extreme adaptation.
- *Flower Sexuality*: Although most members have bisexual flowers, some species in the *Magnolia* section *Gynopodium* and the genus *Kmeria* (sometimes considered a subgroup of *Magnolia*) have unisexual flowers.
- *Fruit and Seed Characteristics*: Most Magnoliaceae produces follicles that form an aggregate of fruit (etaerio). The seeds typically have a fleshy, red-to-orange coating (aril). *Liriodendron* is an exception, having wind-dispersed, samara-like fruits that do not open (indehiscent).
- *Leaf Shape and Bud Structure*: The Tulip Tree (*Liriodendron*) is a major exception in that it never has a pointed leaf apex; the leaves are truncate or notched. Furthermore, its terminal buds are flattened and valve-like, distinct from the hairy buds found in many *Magnolia* species.
- Although primarily trees/shrubs with woody carpels, *Michelia* has axillary flowers, while *Magnolia* has terminal flowers.
- Unisexual (*Drimys*); Introrse (*Magnolia*, *Manglietia*) or Extrorse (*Michelia*, *Liriodendron*); syncarpous (*Zygogynum*);
- Aggregate of Follicles (woody or leathery) in *Magnolia grandiflora*, *Magnolia campbellii*; Aggregate of Samaras (papery/dry) in *Liriodendron tulipifera*; Fleshy/Berry-like Aggregate in *Talauma candollei*;

Summary Table of Exceptional characteristics in Magnoliaceae

Characteristics	Typical Features of Magnoliaceae	Exceptions/Exceptions to the Rule
Leaf/Bud Shape	Pointed/Hairy (<i>Magnolia</i>)	<i>Liriodendron</i> (Truncate/Flattened)
Floral Sexuality	Bisexual (Hermaphrodite)	<i>Kmeria</i> and some species of <i>Magnolia</i> section <i>Gynopodium</i> are unisexual.
Fruit Type	Aggregate of follicles (etaerio)	<i>Liriodendron</i> produces a samara-cetum (aggregate of samaras).
Carpel Fusion	Apocarpous (separate)	<i>Talauma</i> and many Neotropical species are syncarpous (fused).
Perianth Arrangement	Spiral/Whorled (indistinguishable)	Mostly trimerous (whorls of 3), but some are irregular.
Stipule Attachment	Free/Caducous	<i>Magnolia</i> section <i>Talauma</i> and <i>Macrophylla</i> have stipules adnate to the petiole.
Leaf Habit	Generally Evergreen	Deciduous in <i>Yulania</i> and some <i>Magnolia</i> sections.
Seed Dispersal	Fleshy sarcotesta (bird)	<i>Liriodendron</i> seeds are dry (wind-dispersed).
Pollination	Beetle pollination (<i>Magnolia</i>)	<i>Liriodendron</i> (bee pollinated)

Important Remarks on Significant Exceptions in Magnoliaceae

- Subfamily Magnolioideae (e.g., *Magnolia*): Typically have follicular aggregates and spirally organized, free carpels.
- Subfamily Liriodendroidae (*Liriodendron*): Characterized by lobed apices, free stipules, and samaras.
- The section *Talauma* is characterized by fused carpels that separate in circumscissile manner.

15. Malvaceae

An overview of instances of exceptions in Malvaceae family:

- **Habit Variations:** Although many are herbs or shrubs (*Hibiscus*, *Gossypium*), the family includes trees like *Adansonia* (Baobab), *Gossypium arboreum* and *Thespesia*.
- Spreading stem (*Sida*, *Malva parviflora*);

- **Stipules:** usually free lateral as in *Hibiscus rosa-sinensis*, *Sida*, stipules deciduous (i.e., short-lived and fall early) in *Malva*;
- **Inflorescences:** Usually Solitary axillary (*Hibiscus*, *Urena*), solitary terminal (*Abutilon*), raceme (*Althaea*), panicle (*Kydia*);
- **Unisexual Flowers:** The family is generally bisexual, but *Napaea* has unisexual flowers. *Kydia* is noted as being polygamodioecious.
- **Irregular (Zygomorphic) Flowers:** Almost all Malvaceae have actinomorphic (regular) flowers, but some Hawaiian species, specifically in the genus *Hibiscadelphus* (endemic to Hawaii), have curved, slightly zygomorphic flowers.
- **Epicalyx Variations:** Mostly with epicalyx, but some, like *Sida* and *Abutilon* lack epicalyx.
- The number of epicalyx segments varies from 3 in *Gossypium*, *Malva*, 5 or more in *Hibiscus*, 7 to 9 (*Althaea*), and it is large/foliaceous in *Gossypium* (cotton).
- **Staminal Tube Variations:** Although the stamens form a tube, *Sida* shows the top of the staminal tube branched into several filaments.
- **The number of Carpels:** usually 5 (*Hibiscus*), 10 (*Althaea*), many (*Abutilon*) or 3 (*Kydia*);
- **Fruit Variations:** Schizocarpic (*Abutilon*, *Malva*, *Sida*), loculicidal capsule (*Hibiscus*, *Gossypium*), berry (*Malvaviscus*).
- **Seed coat:** densely tomentose in *Gossypium*.

16. Myrtaceae

An overview of instances of exceptions in Myrtaceae (Myrtle) family:

1. Leaf Arrangement Exceptions (Mostly Opposite vs. Alternate)
 - Although the family is known for opposite leaves, several species exhibit alternative or spiral arrangements.
 - Example: *Eucalyptus* species: Although young seedlings often have opposite leaves, mature trees frequently have alternate, petiolate leaves.
 - Example: *Callistemon* (Bottlebrush): Often shows alternate leaves, distinguishing it from the typical opposite leaf structure of other genera like *Psidium* (Guava).
2. Fruit Type Exceptions (Berry vs. Capsule)
 - Myrtaceae is split into two major groups: *Myrtoideae* (fleshy fruit/berries) and *Leptospermoideae* (dry fruit/capsules).
 - Capsule Producing (Non-fleshy): *Eucalyptus* (Gum trees), *Callistemon* and *Melaleuca* (Paperbarks) are famous for dry, dehiscent capsules rather than the fleshy berries typical of guava.

- Drupe-like (Fleshy): *Eugenia* and *Syzygium* can produce fruits that are drupaceous or intermediate between berries and drupes.

Summary Table of Exceptional characteristics in Myrtaceae

<i>Characteristics</i>	<i>Typical Features of Myrtaceae</i>	<i>Exceptions/Exceptions to the Rule</i>
<i>Habit</i>	Trees or shrubs	Scrambling shrubs, or, rarely, subshrubs
<i>Leaf Arrangement</i>	Opposite	Alternate or spiral in some taxa (e.g., <i>Eucalyptus</i> species, <i>Melaleuca</i>)
<i>Leaf Venation</i>	Pinnate	Parallel or longitudinal in some taxa (e.g., <i>Eucalyptus</i>)
<i>Stipules</i>	Absent (Exstipulate)	Rarely present, or tiny/rudimentary
<i>Flower Symmetry</i>	Actinomorphic	Occasionally zygomorphic
<i>Petals</i>	4-5, present	Petals minute, absent, or forming a calyptra (cap) in <i>Eucalyptus</i> and <i>Corymbia</i>
<i>Stamens</i>	Numerous, free	Few in some, or arranged in bundles (phalanges)
<i>Ovary Position</i>	Inferior	Half-inferior to inferior
<i>Fruit Type</i>	Fleshy berry/Drupe (Myrtoideae)	Woody capsule (Leptospermoideae)
<i>Seed Number</i>	Variable	Can be 1-2 (in some berries) or numerous (in capsules)
<i>Pollen</i>	Monad, tricolporate	Rare tetrahedral occurrences

3. Floral Structure and Symmetry Exceptions

- Calyptra (Lid) Forming: In most plants, sepals and petals are distinct. In *Eucalyptus* and some *Corymbia*, the sepals and petals are fused into a cap (calyptra) that falls off as a single lid.
- Petal-less Flowers: Although mostly 4–5 merous, some genera in the family have minute or completely absent petals.
- Stamen Arrangement: Although stamens are usually numerous, in *Melaleuca leucadendron*, the stamens are grouped into five distinct bundles opposite the petals.

4. Reproductive and Breeding System Exceptions

- Andromonoecy: Many species (e.g., *Eucalyptus*, *Melaleuca*, *Leptospermum*) have both male and hermaphroditic flowers on the same plant, contrary to the general assumption of only hermaphroditic flowers.
- Dioecy: In some rare exceptions within Myrtaceae, male and female flowers are on separate plants (e.g., *Pimenta guatemalensis*, *Myrcia almasensis*).
- Polyembryony: In *Eugenia*, multiple embryos can occur in a single seed, which is unusual for the family.

5. Ecological Adaptations

- Lignotubers: Although not a "botanical" violation, the development of lignotubers in *Eucalyptus* is an exceptional adaptation to fire, allowing for rapid regeneration from the base, which is not found in most other members.
- Pneumatophores: Although most are terrestrial, the mangrove species *Osbornia octodonta* possesses adaptations to salt marsh environments, unlike the typical forest-dwelling members.

Important Remarks on Significant Exceptions in Myrtaceae

- Myrtoideae (Fleshy-fruited): Characterized by berries, but with exceptions in stamen whorls.
- Leptospermoideae (Capsular-fruited): Characterized by woody capsules, often with alternate, narrow leaves.
- Genus *Eugenia*: *Eugenia splendens* is noted for an apparent lack of bracteoles.
- Genus *Eucalyptus*: Petals and sepals fuse to form an operculum (cap).
- Staminal Connective Glands: typically present, but may be underdeveloped.
- Solitary axillary (*Myrtus communis*); trichotomous cyme (*Syzygium*); panicle cyme (*Eucalyptus*).
- Flower Pedicellate (*Eucalyptus*) or sessile (*Callistemon*); usually with two bracteoles (*Callistemon*), ebracteate (*Eucalyptus*);
- Corolla forming cap (*Eucalyptus*);
- Placentation parietal (*Rhodamnia*);
- Berry (*Psidium*, *Syzygium cumini*, *Eugenia uniflora*) and capsule (*Callistemon citrinus*, *Eucalyptus*);

17. Ranunculaceae

Major exceptions in the Ranunculaceae family with examples are as follows:

1. **Habit:** Woody Vines (Lianas)

- Although mostly herbaceous, *Xanthorhiza* (yellowroot) is a shrubby exception.
 - Deviation: other climbing shrubs include *Clematis gouriana*, *Naravelia*;
 - Root tuberous (*Ranunculus* spp. and *Aconitum*);
2. **Leaf Arrangement: Opposite Leaves**
 - In contrast to the predominantly alternate, compound, or lobed leaves in the family, *Clematis* species typically have opposite leaf arrangements.
 - Stipulate (*Thalictrum*), sessile leaf (*Delphinium*);
 - Leaves show dimorphy (*Ranunculus aquatilis*);
 3. **Floral Symmetry: Bilateral (Zygomorphic)**
 - Mainly regular (*Ranunculus*), Exceptions include zygomorphic (*Delphinium*, *Aconitum*);
 4. **Perianth (Petals/Sepals): Absent or Reduced**
 - Although many members have both petals and sepals, some lack true petals, with sepals taking on a petal-like (petaloid) appearance:
 - *Clematis*: These species have no true petals, using colored sepals instead.
 - *Thalictrum* (meadow-rue): Often lacks petals and relies on sepals.
 - *Caltha palustris* (marsh marigold): Lacks petals; its yellow "petals" are actually sepals.
 - Petals are united to form spur in *Delphinium*;
 5. **Inflorescence: Solitary Flowers**
 - Many Ranunculaceae feature inflorescences (clusters of flowers). A noteworthy deviation is the *Anemone nemorosa*, which is solitary terminal
 - axillary in *Clematis*, raceme in *Aconitum*, *Delphinium*, and cymose in *Ranunculus* spp.;
 6. **Sexual Expression: Unisexual Flowers**
 - Most family members have bisexual (perfect) flowers.
 - Exception: *Hamadryas*, *Thalictrum* have unisexual flowers (dioecious).
 7. **Other Notable Anomalies**
 - *Ficaria verna* (lesser celandine): Produces root tubers in the leaf axils for vegetative reproduction.
 - *Myosurus*: Exceptionally, this genus has ovaries with only one ovule.
 - *Aquilegia* (columbine): Known for having highly modified, spurred petals, unlike the simple, cup-shaped petals of typical buttercups.

- A rain pollinated plant - *Ranunculus repens* (rain washes pollen to the base of glossy petals & capillary action draws it up to stigmas);
- *Aquilegia* contains 50 stamens arranged in radial rows; *Nigella* has 32 stamens in 8 rows; 80 to 150 stamens in *Caltha*; stamens of *Thalictrum* are brightly coloured;
- Carpel one in *Delphinium*, 3 to 5 in *Aconitum*; unilocular with 1 (*Clematis*) to many (*Caltha*) ovules; placentation axile in *Nigella*.
- **Fruit** Etaerio of Achenes (*Ranunculus*, *Anemone*, *Clematis*), Etaerio of Follicles (*Aconitum*, *Helleborus*, *Aquilegia*), Etaerio of Drupes (*Adonis*), etario of berries (*Hydrastis*), single follicle (not in an aggregate cluster) as in *Delphinium*, berry (*Actaea*), Septicidal Capsule (*Nigella*), or Simple Pod (*Xanthorhiza*).
- Deviation: Although apocarpous is standard, *Nigella* has a syncarpous gynoecium.
- Deviation: *Aconitum* and *Delphinium* are strongly zygomorphic (bilateral) due to specialized spurred petals/sepals, unlike the radial flower norm, e.g., *Ranunculus*.

Summary Table of Exceptional characteristics in Ranunculaceae

Characteristics	Typical Features of Ranunculaceae	Exceptions/Exceptions to the Rule
<i>Habit</i>	<i>Herbs (annual/perennial)</i>	<i>Woody climbers (Clematis), shrubs (Xanthorhiza)</i>
<i>Phyllotaxy</i>	<i>Alternate/Basal leaves</i>	<i>Opposite leaves in Clematis</i>
<i>Stipules</i>	<i>Absent (exstipulate)</i>	<i>Present in Thalictrum, Caltha, Ranunculus</i>
<i>Symmetry</i>	<i>Actinomorphic (Radial)</i>	<i>Zygomorphic (Bilateral) in Delphinium, Aconitum</i>
<i>Perianth</i>	<i>Distinct calyx & corolla</i>	<i>Simple perianth (petaloid sepals) in Anemone, Caltha, Thalictrum</i>
<i>Petals</i>	<i>Present (often 5)</i>	<i>Absent in Thalictrum, Anemone</i>
<i>Carpels</i>	<i>Apocarpous (numerous)</i>	<i>Syncarpous (fused) in Nigella; Single carpel in Actaea</i>
<i>Placentation</i>	<i>Marginal</i>	<i>Axile in Nigella</i>
<i>Fruit</i>	<i>Aggregate (Achenes/Follicles)</i>	<i>Berry in Actaea</i>
<i>Flower Sex</i>	<i>Bisexual</i>	<i>Unisexual in Thalictrum, Hamadryas</i>

18. Rosaceae

An overview of instances of exceptions are as follows

- General Character: 5 petals, 5 sepals, numerous stamens, alternate leaves.

Exceptions to the general characters:

- Petal Number: Some species have lost petals or have varying numbers of petals.
- Ovary Position: Varies significantly from superior (*Prunus*) to inferior (*Pyrus*).
- Deviation: Although mostly with actinomorphic flowers, some *Sanguisorba* are wind-pollinated and lack petals.
- Deviation: *Rubus* and *Rosa* are commonly thorny, but many are not.
- Habit: Annual (*Neurada*); trees (e.g. *Prunus amygdalus*, *Prunus persica*, *Pyrus communis*, *Pyrus mains*); *Cydonia* sp are bush-like;
- Leaves & stipules: opposite (*Rhodotypos*); stipule may be minute and caducous (*Spiraea*, *Pyrus*), adnate and persistent (*Rosa*, *Rubus*);
- Inflorescences: Solitary (*Potentilla*, *Rosa sericea*) or racemose (*Agrimonia*); terminal corymbose (*Rosa moschata*), terminal cyme (*Geum*) or corymbose cyme (*Potentilla sibbaldi*).
- zygomorphic (*Chrysobalanoideae*), epigynous (*Pyrus*), perigynous (*Rosa*);
- epicalyx present in *Potentilla*,
- Petals entirely absent (*Pygeum gardneria*, *Poterium*), petals numerous (*Rosa*);
- Apricot (peach/plum), *Rosa* have many stamens; stamens 1 to 4 (*Alchemilla*)
- Carpel 1 (*Prunus*, *Prinsepia*), 5 (*Pyrus*) or indefinite (*Fragaria* and *Rosa*), apocarpous (*Rosa*, *Fragaria*), syncarpous (*Pyrus*),
- **Fruits:** Pome (Apples, pears), Drupe (Peaches, plums, cherries), berry (*Eriobotrya japonica*), Aggregate fruits for example, Raspberries & Blackberries (*Rubus* spp.), Cloudberry & Loganberry (*Rubus* spp.) are etaerio of drupelets; Strawberries (*Fragaria* spp.), *Rosa* spp are etaerio of achenes;

19. Rubiaceae

Major exceptions in the Rubiaceae family with examples:

1. Superior Ovary (Instead of Inferior)
 - Although the family is known for an inferior ovary, a few genera are exceptions.
 - Examples: Gaertnera and Pagamea.
2. Leaf Phyllotaxis (Whorled or Alternate instead of Opposite)
 - Most species have opposite, decussate leaves, but some exceptions exist.
 - Whorled leaves: *Fadogia*.

- Seemingly alternate leaves: *Sabicea sthenula* (due to reduction of one leaf at the node).
 - Whorled (Tribal exception): The tribe Rubieae (e.g., *Galium*) is known for appearing to have whorled leaves, which are technically leaf-like stipules.
3. Ovaries with Different Placentation or Locules
 - Parietal Placentation: Contrary to the typical axile placentation, *Gardenia* exhibits parietal placentation.
 - Unilocular Ovary: *Gardenia*.
 - Half-inferior Ovary: *Synaptantha*.
 4. Flower Morphology and Structure
 - Calix Absent: The calyx is absent in some taxa, such as *Theligonum*.
 - Unequal or Enlarged Calyx Lobes: *Mussaenda* is a major exception where one calyx lobe is significantly enlarged and colored (a "semaphyl").
 - Poricidal Anthers: Instead of the typical longitudinal dehiscence, *Rustia* and *Tresanthera* have poricidal anthers.
 5. Habit
 - Succulent Epiphytes: Although mostly terrestrial trees or shrubs, some have adapted to become succulent epiphytes with ant-inhabited tubers.
 - Examples: *Myrmecodia*, *Hydnophytum*, *Anthorrhiza*.
 6. Leaves (Compound instead of Simple)
 - Pinnately Compound: Although leaves are generally simple, *Pentagonia osapinnata* is a notable exception with compound leaves.
 7. Ecological Exceptions
 - Anemophilous (Wind-pollinated): Most are insect-pollinated (zoophilous), but tribes Anthospermeae and Theligoneae are adapted for wind pollination.
 - Habitat: Although mainly tropical, the tribe Rubieae is centered in temperate regions.
 8. Other Chemical/Structural Exceptions
 - Bacterial Nodules: *Pavetta*, *Psychotria*, and *Sericanthe* possess bacterial leaf nodules.
 - Blue Fruits: Generally red or black, but blue fruits are found in Psychotrieae.
- Deviation: Mostly opposite/decussate leaves, but *Galium* has whorled leaves.
 - Deviation: Mostly actinomorphic, *Borreria* often has slightly zygomorphic flowers.

- Trees (*Cinchona*, *Coffea*, *Neolamarckia*, *Adina*), Shrubs (*Ixora*, *Gardenia*, *Mussaenda*, *Hamelia*); Herbs (*Galium*, *Rubia*, *Oldenlandia*), Climbers/woody Vines (or lianas- *Paederia*, *Uncaria*); epiphytes (*Neohymenopogon parasiticus*, *Hydnophytum formicarum*, *Myrmecodia tuberosa*, *Squamellaria*, *Schradera*).

Twinning (*Manettia*), climbing by hooks (*Uncaria*), Interpetiolar stipules (Most Common type) Examples: *Coffea*, *Ixora*, and *Gardenia*; Intrapetiolar (e.g., *Gardenia*); Foliaceous (leaf-like) Examples: *Rubia* and *Galium*; Ochreate: Examples: *Richardia*, *Diodia*, *Borreria*; Fimbriate/Laciniate: (e.g., *Palicourea*, *Damnacanthus*, *Pentas*); Caducous/Withering (e.g., *Didymaea*).

- Solitary (*Gardenia*), globose head (*Adina*), axillary (*Coffea arabica*), terminal cyme (*Mussaenda glabra*).
- Sessile flower (*Greenia*, *Randia*), one sepal modified into coloured bract like structure (*Mussaenda*), tubular (*Ixora*), salver shaped (*Gardenia*), funnel-shaped (*Cinchona*, *Coffea*); Stamens usually 4 or 5, rarely many (*Gardenia*), usually free from one another, but can occasionally be connected via their anthers (e.g., *Argostemma*); Specialized crystal deposits may be seen in the anther septa of *Cephalanthus glabratus*.
- Half inferior (*Synaptanthera*), superior (*Paganea*), 1-locular (*Gardenia*), parietal placentation in *Gardenia*.

20. Rutaceae

- Habit: Normally shrubs (*Murraya*, *Limonia*, *Zanthoxylum*), trees (*Aegle*, *Citrus*, *Feronia*), rarely herbs (*Ruta graveolens*) with strong fragrance; shrubby climbers like *Paramignya* (*P.monophylla*, *P. armata*, *P.scandens*) Woody (*Citrus*, *Feronia*)
- Leaves: arranged in Alternate phyllotaxy in *Citrus*, *Murraya* or opposite in *Evodia*, petiole may be winged (*Citrus aurantium*), simple or compound-pinnate (*Murraya*), palmate (*Aegle and Citrus*)
- Flowers: unisexual (*Zanthoxylum*, *Evodia*, *Feronia*), zygomorphic (*Dictamnus and Correa*), gamopetalous (*Correa speciosa*) or absent (*Zanthoxylum*).
- Fruit: Mostly with dry/drupaceous fruits, Deviation: *Citrus* has a highly modified berry (hesperidium).

21. Scrophulariaceae

- Mostly herbs, Deviation: *Paulownia* is a large tree. Climbers (*Maurandia*) or root parasites (*Pedicularis*). woody (*Paulownia*)
- Mostly zygomorphic, Deviation: *Verbascum* has almost actinomorphic flowers.

- Whorled (*Veronica*), in *Limnophila* leaves are dimorphic, solitary axillary (*Scoparia*, *Striga densiflora*).
- Flowers sessile (*Lindenbergia*), actinomorphic (*Verbascum*, *Veronica*). Bilabiate (Two-lipped) in *Mimulus* (Monkey flower), *Penstemon* (Beardtongue);
- Personate (Masked) in *Antirrhinum majus* (Snapdragon), *Linaria vulgaris* (Toadflax), *Lindenbergia*; Campanulate (Bell-shaped) in *Digitalis purpurea* (Common foxglove); Rotate (Wheel-shaped) as in *Verbascum* (Mullein), *Veronica* (Speedwell); Spurred in *Linaria* (Toadflax); Saccate/Gibbous in *Angelonia*;
- Stamens 4 in *Digitalis*, 5 in *Verbascum*, 2 in *Veronica*; when didynamous, there are 4 fertile stamens & 1 staminode seen in *Digitalis purpurea*, *D. lanata*, *Penstemon*;
- Septicidal Capsule as seen in *Digitalis* (Foxglove), *Verbascum* (Mullein); Loculicidal Capsule as seen in *Antirrhinum* (Snapdragon); Poricidal Capsule as seen in *Linaria* (Toadflax); or Berry as seen in Brahmi (*Bacopa monnieri*).

22. Solanaceae

Major exceptions in the in Solanaceae family with examples are:

1. Exceptions in Floral Structure and Symmetry: Although mostly are actinomorphic, some exceptions exist:
 - *Salpiglossis* and *Schizanthus*: These genera are known to have zygomorphic flowers instead of the typical actinomorphic flowers.
 - *Schizanthus*: The stamens are reduced to 2-4 instead of the usual 5.
 - *Browallia*: An ornamental genus characterized by 4 didynamous stamens.
 - *Datura*: Shows twisted aestivation in the corolla.
 - Calyx persistent, often enlarged (accrescent) in *Physalis peruviana*,
 - Corolla Campanulate in *Solanum tuberosum*, funnel-shaped (infundibuliform) in *Datura*, *Petunia*, or tubular/campanulate in *Nicotiana tabacum*, star shaped in *Solanum nigrum*.
 - Stamens 2 in *Salpiglossis* *Schizanthus*, Dehiscence by longitudinal slits (*Capsicum annuum*, *Petunia*) or by apical pores (*Solanum nigrum*).
2. Exceptions in Ovary and Carpel Structure: Typically bicarpellary, but exceptions are:
 - *Nicandra*: Ovary 3-5 carpels.
 - *Datura*: The ovary is often 4-celled due to the development of a false septum.
 - *Hemionia*, *Capsicum*: Ovary 1-locular
 - Stigma bifid/Bilobed: *Datura*, *Capsicum annuum*, *Solanum nigrum*, *Withania somnifera*/Ashwagandha)
 - Stigma capitate (Head-shaped) in Tomato, Brinjal, *Petunia*, Tobacco, Belladonna;

Summary Table of Exceptional characteristics of Solanaceae

Characteristics	General Features	Exceptions/Variations	Examples
<i>Habit</i>	Herbs, Annuals	Shrubs, Small trees, Vines/Lianas	<i>Solanum giganteum</i> (Tree), <i>Lycium</i> (Shrub)
<i>Stem</i>	Aerial, Erect	Underground Tubers, Creeping, Woody	Potato (<i>Solanum tuberosum</i>), <i>Solanum dulcamara</i>
<i>Leaves</i>	Simple, Alternate	Pinnately compound, Opposite/Sub-opposite	Tomato (<i>S. lycopersicum</i>), Potato
<i>Inflorescence</i>	Cymose (often axillary)	Solitary (terminal/axillary)	<i>Datura</i> , <i>Solanum</i>
<i>Floral Symmetry</i>	Actinomorphic	Zygomorphic	Schizanthus (bilabial corolla), <i>Salpiglossis</i>
<i>Stamens</i>	5, Epipetalous	4 (2+2), 2, or Staminodes	<i>Browallia</i> (4 stamens), <i>Salpiglossis</i>
<i>Gynoecium</i>	Bicarpellary, 2-locular	3 to 5 -locular	<i>Nicandra</i> , <i>Datura</i> (False septa)
<i>Fruit</i>	Berry	Capsule	<i>Datura</i> , <i>Petunia</i> (Capsule)

3. Exceptions in Habit and Growth Form: Mainly herbs, some are woody:
 - *Solanum xanthocarpum*: A spinous, xerophytic herb (not a typical mesophyte)
 - Shrubs (*Cestrum nocturnum*, *Lycium barbarum*, *Solanum rantonnetii*)
 - Small trees (*Solanum mauritianum*, *Nicotiana glauca*, *Cyphomandra betacea*)
 - Climbing (*Solanum jasminoides*),
 - Underground stem in *Solanum tuberosum*.
 - Leaf sessile in *Nicotiana tabacum*, *Solanum rantonnetii*
4. Exceptions in Fruit Type:
 - Berries vs. Capsules: Although the family is known for berries (tomato) and capsules (datura), the genus *Physalis* has a berry enclosed within a greatly enlarged, bladder-like persistent calyx.

Specific Examples of Exceptions

- *Schizanthus* (Butterfly Flower): Violates the regular actinomorphic flower rule by having a significantly zygomorphic (bilabial) corolla.
- *Browallia*: Breaks the 5-stamen rule by having only four didynamous stamens.

- *Withania somnifera* (Ashwagandha): Exhibits the "basic type" of anther wall development, whereas most Solanaceae follow the dicotyledonous type.
- *Datura and Nicandra*: The gynoecium is not always strictly bilocular; it can be multi-locular (3-5 locules) due to false septa.
- Tree Habit: Although generally herbaceous, *Solanum verbascifolium* and *Solanum giganteum* grow as trees.
- Leaves: Leaves are generally simple, but Tomato (*Solanum lycopersicum*) and Potato (*Solanum tuberosum*) possess pinnately compound leaves.
- *Datura* (4-celled ovary)
- *Cestrum* (Shrub)
- *Salpiglossis* (Zygomorphic flower)
- *Physalis* (Persistent bladder-like calyx)
- *Nicandra* (3-5 locules)

23. Sterculiaceae (Now mostly in Malvaceae)

Habit Exceptions (Herbaceous Members):

Although most are trees/ shrubs, *Pentapetes phoenicea* and species within the genus *Melochia* (e.g., *Melochia corchorifolia*) are herbaceous; Lianas (e.g., *Ayenia*).

Flower Exception (Unisexual Flowers):

- Although Sterculiaceae is known for bisexual flowers, the tribe Sterculieae—specifically *Sterculia*, *Brachychiton*, and *Heritiera*—are exceptions with unisexual (male or female) flowers.
- Pollination Exception (Bat Pollination): *Hildegardia baruensis* and *Guazuma ulmifolia* exhibit unique floral features to facilitate bat pollination, which is distinct from the insect pollination common in Sterculiaceae.

Fruit/Seed Dispersal Exceptions:

- *Cistanthera*: Unlike the distinctive carpel-winged fruits of the tribe Sterculieae, this genus has winged seeds.
- *Scaphium* and *Pterocymbium*: These exhibit a unique, single-seeded, winged membranous carpel.
- *Heritiera littoralis*: This species has evolved to produce large, water-dispersed, unwinged fruits (or with a reduced keel), separating it from the winged samaras of other Sterculieae.

Morphological Distinctions:

- *Pentapetes phoenicea*: Separates from other members due to its deltoid leaf base and the absence of fiber cells in the phloem layer at the internodal region.

- *Cola* subgenus *Distichae*: These species lack the typical stellate hairs, often possessing only simple hairs, and are often misidentified as belonging to other families.

Leaf Exception:

- Compound Leaf Exception (Palmate): *Sterculia foetida* has palmately compound leaves with 7–9 leaflets.
- Phyllotaxy Exception (Distichous): Typically, Sterculiaceae have spiral leaves; Deviation: *Cola* subgenus *Disticha* (e.g., *Cola philipi-jonesii*) has distichous (two-ranked) leaves.
- Leaf Margin and Surface Texture: Mostly simple & lobed, Deviation: *Heritiera species* have stiff, leathery leaves with silvery scales on the underside, differentiating them from the often herbaceous or soft-hairy leaves of other members.
- Reduced Petiole /Absent (Sessile Leaves): although mostly petiolate, sometimes, sessile reduced petioles are found.

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>
Habit	Tree/Shrub	Herbs/undershrubs, <i>Melochia corchorifolia</i> , <i>Waltheria indica</i>
Leaf Complexity	Simple	<i>Sterculia foetida</i> (Palmately compound)
Leaf Arrangement	Spiral	<i>Cola</i> subgenus <i>Disticha</i> (Distichous)
Leaf Shape	Lobed/Entire	<i>Fremontodendron californicum</i> (Distinct, reduced, leathery)
Flowers	Unisexual/Monoecious	Bisexual flowers, <i>Dombeya spp.</i> , <i>Pentapetes</i>
Symmetry	Actinomorphic	Zygomorphic (irregular), <i>Helicteres isora</i>
Petals	Present	Petals absent/reduced <i>Sterculia</i> spp. (e.g., <i>S. foetida</i>)
Fruit	Follicle	Capsule or samaroid <i>Theobroma cacao</i> (capsule), <i>Heritiera</i> (samaroid)
Stamens	Monadelphous tube	Stamens free or distinct, <i>Sterculia</i>
Stomata	Hypostomatic	Amphistomatic (stomata on both sides), <i>Waltheria indica</i> , <i>Mansonia altissima</i>

Summary of major Genera:

Sterculia/Brachychiton/Heritiera (Unisexual/Winged seeds or fruits); *Pentapetes* (Herbaceous); *Cola* (Simple hairs, distinct from family norm, unisexual); *Scaphium* (Winged, single-seeded carpels)

24. Tiliaceae (Now mostly in Malvaceae)

- Deviation: Mostly trees with fibrous bark, *Corchorus* is a herb; Stipule caducous (*Tilia*), unisexual (*Carpodiptera*), petals absent in *Prockia*,
- Deviation: Many have bisexual flowers, but some, like *Entelea*, have variable stamen numbers and sizes.
- Stamens united in groups (*Grewia*), dehiscent capsules (e.g., *Corchorus*) to bristly drupes (e.g., *Grewia*).

25. Verbenaceae

Major exceptions in the Verbenaceae family include:

1. Fruit and Ovary Exceptions

- Fleshy Fruits (Drupes): Although most Verbenaceae produce dry, four-parted fruits (schizocarps), many genera have evolved fleshy, drupaceous fruits. Examples include *Lantana*, *Citharexylum*, and *Duranta*.
- Four-Carpellate Ovary: Typically carpels 2; *Duranta* is a notable exception, with a 4-carpellate ovary that develops into a drupe with four 2-seeded pyrenes.
- Unicarpellate Ovary: Reduction to one carpel, arising from the abortion of one carpel, occurs in *Bouchea*, *Chascanum*, and *Stachytarpheta*.

2. Morphological and Floral Exceptions

- Ephedroid Habit (Reduced Leaves): Some species, particularly in the tribe Neospartoneae (e.g., *Neosparton aphyllum*, *Diostea juncea*), have an ephedroid habit (e.e., many-branched shrubs with leaves reduced to tiny scales or bracts).
- Succulent Leaves: *Lampaya* is an exception, being a low, spreading shrub with thick, fleshy leaves.
- Leaves pinnately compound (*Vitex*), Flower regular in *Callicarpa*, Carpels 4 (*Duranta*) or 5 (*Geunsia*).
- Actinomorphic (Regular) Flowers: Although the family is mostly zygomorphic (bilateral), some, such as *Neosparton*, have actinomorphic flowers.
- Reduced Stamens: mainly Verbenaceae have 4 fertile stamens, didynamous. *Stachytarpheta* is distinctive in having only 2-functional stamens, with the abaxial pair reduced to staminodes.

Summary Table of Exceptional characteristics in Verbenaceae

Features	Typical family Characteristics	Exceptions
Habit	Herbs, shrubs, trees	Ephedroid (leafless) habit in <i>Diostea</i> and <i>Neosparton</i> .
Leaves	Opposite or whorled, simple	Fleshy leaves in <i>Lampayo</i> .
Leaf development	Well-developed	Reduced/Absent (<i>Neosparton</i>)
Inflorescence	Cymose or Spiked	Rarely racemose in some <i>Cordia</i> sp.
Flower	Zygomorphic	Actinomorphic (<i>Neosparton</i>)
Stamens	4 (Didynamous)	5 stamens present in <i>Tectona</i> (Teak); 2 Fertile (<i>Stachytarpheta</i>)
Gynoecium	Bicarpellary	4 carpels in <i>Duranta</i> , 5 in <i>Geunsia</i> .
Placentation	Axile	Free central in <i>Avicennia</i> .
Fruit Type	Drupe (fleshy)	Schizocarpic capsule or mericarps in <i>Verbena</i> , <i>Phyla</i> , <i>Duranta</i> .
Style	Terminal	Gynobasic or eccentric in some, branching from base.
Phyllotaxis	Decussate	Fibonacci pattern in <i>Verbena officinalis</i> .

3. Habitat and Ecological Exceptions

- Mangrove Habitat: *Avicennia* (sometimes placed in its own family, Avicenniaceae, but related to Verbenaceae) is an exception, occurring as a mangrove tree in tidal areas with pneumatophores (breathing roots).
- Winged Fruits: although fruits are typically unwinged, *Svensonia hyderabadensis* (a segregate of *Chascanum*) produces winged fruits.

4. Excluded Genera

- Deviation: Over and over again confused with Lamiaceae, but commonly, their stamens are not normally didynamous in all genera, and they frequently lack the strong aromatic oil found in Lamiaceae.
- Many genera previously considered part of Verbenaceae, such as *Callicarpa*, *Clerodendrum*, *Tectona*, and *Vitex*, have been reclassified into the Lamiaceae family based on molecular evidence.

- Scandent (climbing/scrambling) shrub - *Holmskioldia sanguinea* (Chinese hat plant/Cup-and-saucer) - Now shifted to Lamiaceae from Verbenaceae;

Important Remarks on Significant Exceptions in Verbenaceae

- *Avicennia*: Often classified as a separate family (Avicenniaceae) or Acanthaceae due to its unusual embryology and free central placentation.
- Although fleshy fruits (drupes) are typically considered distinctive, their evolution within the *Lantana/Lippia* clade makes fruit type a changeable feature for categorization.
- Tribe Neospartoneae: *Diostea* and *Lampayo* exhibit unique fleshy, spiny, or ephedroid traits compared to the remainder of the family.

In Lantana, 4-lobed calyces or corollas are prevalent, despite the typical 5-lobed ones.

“In every walk with nature, one receives far more than he seeks.” – John Muir

CHAPTER 6

Study of Selected Monocotyledonous Families

Chapter Contents:

- Type genera of different Monocot families (Alismataceae, Amaryllidaceae, Araceae, Arecaceae, Commelinaceae, Cyperaceae, Liliaceae, Musaceae, Orchidaceae, Poaceae, and Zingiberaceae)
- General Botanical Characteristics of different Monocot families, their diagnostic features, and Systematic Position
- Why is Orchidaceae widely considered the most advanced family in monocotyledons?
- Deviations from the General Monocotyledonous Family characters
- Some Selected Questions with Answers

❖ THE TYPE GENERA FOR THE CHOSEN MONOCOT FAMILIES ARE LISTED BELOW, ACCORDING TO ICN:

- a) Alismataceae: *Alisma* L.
- b) Amaryllidaceae: *Amaryllis* L.
- c) Araceae: *Arum* L.
- d) Arecaceae: *Areca* L.
- e) Commelinaceae: *Commelina* L.
- f) Cyperaceae: *Cyperus* L.
- g) Liliaceae: *Lilium* L.
- h) Musaceae: *Musa* L.
- i) Orchidaceae: *Orchis* L.
- j) Poaceae: *Poa* L.
- k) Zingiberaceae: *Zingiber* Mill.

General Botanical Characteristics of Alismataceae (water-plantain family)

Vegetative Features:

Habit: Annual/perennial aquatic or marsh-dwelling erect herbs, often bears stolons for clonal propagation

Stem: rhizomatous or corm-like, often with laticifers producing latex, occasionally specialized idioblasts.

Leaves: Basal, sheathing, and often dimorphic (submerged linear, emerged linear to sagittate/ovate).

Floral characters:

Inflorescence: Bracteates, Scapose, compound, flowers arranged in whorls, usually in panicles or racemes.

Flowers: Regular, bisexual, 3-merous (3 sepals + 3 petals), hypogynous.

Perianth: Tepals 6 (3+3), Outer 3 sepaloid (green) and persistent; inner 3 petaloid (white, pink, or purple) and caducous.

Androecium: Stamens 3, 6, 9, or many, free.

Gynoecium: carpels 3 to many, apocarpous, superior ovary, 1-chambered with basal anatrous ovules, placentation marginal/superficial

Floral Formula: $\text{Br or Ebr} \oplus \overset{\curvearrowright}{\text{P}}_{3+3} \text{A}_{6-\infty} \underline{\text{G}}_{3-\infty}$

Fruit and Seeds:

Fruit: - Etaerion of Achenes or follicles

Seeds: - lack endosperm (exalbuminous)

Embryo: - straight/curved/ horse shoe-shaped

Main Diagnostic features:

- Herbaceous plants highly adapted to aquatic or marshy habitat
- Basal, petiolate leaves (often shows heterophyly),
- Laticifers producing latex/white sap,
- Whorled, showy, 3-merous flowers
- Perianth 6 (3+3), outer sepaloid & inner petaloid
- Stamens 6 to many
- Apocarpous pistil
- Fruit etaerion of Achenes or follicles with exalbuminous seeds
- Specialized aerenchyma tissue present to survive in wetland habitats

General Botanical Characteristics of Amaryllidaceae

Amaryllidaceae family is commonly divided into 3 basic subfamilies, based on molecular phylogenetic research and the 2009/2016 APG classification:

- a) Agapanthoideae (formerly Agapanthaceae): Contains only one genus, *Agapanthus*
- b) Allioideae (formerly Alliaceae, which includes onion, garlic, and chives)
- c) Amaryllidoideae (formerly Amaryllidaceae sensu stricto): The biggest subfamily, with roughly 58-60 genera (e.g., *Narcissus*, *Hippeastrum*, *Crinum*). They produce distinctive isoquinoline alkaloids (Amaryllidaceae alkaloids) and have inferior ovaries.

According to the APG classification, these 3-subfamilies compose the wide definition of the family Amaryllidaceae (Amaryllidaceae *sensu lato*)

Vegetative Features:

Habit: Mostly perennial, scapose herbs, occasionally fleshy bulbous/rhizomatous (often toxic), rarely shrubs, often adapted to xeric (dry) climate.

Roots: Adventitious, often contractile.

Leaves: Basal, simple, fleshy, linear/lorate to strap-shaped, distichous and sheathing at the base.

Inflorescence: Scapose (flowers on a leafless stem), typically umbellate cyme subtended by 2 or more spatheaceous, membranous bracts.

Floral characters:

Flowers: Regular/medianly zygomorphic, bisexual, epigynous

Perianth: Tepals 6 (3+3), arranged in two whorls, often connate at the base forming a tube (hypanthium), bears corona.

Androecium: Stamens 6, usually in two whorls, epiphyllous, anthers versatile, 2-celled, staminal corona present.

Gynoecium: Carpels 3, syncarpous, ovary inferior, trilocular with axile placentation.

Corona: A staminal corona (cup-like structure) is present in some genera (e.g., *Narcissus*).

Floral Formula: $\text{Br } \% \text{ or } \oplus \quad \varnothing \quad P_{6(3+3)} \quad A_{6(3+3)} \quad \overline{G}_{(3)}$

Fruit and Seeds:

Fruit: - a loculicidal capsule, rarely a berry.

Seeds: - endospermic (fleshy)

Main Diagnostic features:

- Mostly perennial, scapose herbs of xeric habitat
- Flowers regular, bisexual, epigynous

- Tepals 6 (3+3), often connate at the base forming a tube (hypanthium)
- Presence of staminal corona
- Carpels 3, syncarpous, ovary inferior, trilocular with axile placentation
- Fruit a loculicidal capsule

Systematic Position of Amaryllidaceae (APG System):

According to the APG IV (2016) system, its systematic position is as follows:

- **Clade:** Monocots
- **Order:** Asparagales
- **Family:** Amaryllidaceae (often referred to as the amaryllis or onion family)
- **Subfamilies Included:** Amaryllidoideae (includes *Amaryllis*, *Narcissus*), Allioideae (includes *Allium*), and Agapanthoideae (includes *Agapanthus*).

The APG IV system uses a wider definition of this family, shifting away from splitting it into separate families (Amaryllidaceae, Alliaceae, Agapanthaceae) as was formerly regarded in earlier classifications.

General Botanical Characteristics of Araceae

Vegetative Features:

Habit: Mostly herbaceous, but highly varied, including tropical climbers (e.g., *Monstera*), aquatic plants (e.g., *Pistia*), tuberous herbs (e.g., *Amorphophallus*), and epiphytes (e.g., *Anthurium*). Almost all parts contain calcium oxalate crystals (raphides) for defense, causing severe irritation if ingested.

Leaves: Often large, simple, or variously divided (pinnate/palmate), featuring sheathing petiole bases and reticulate (net-like) leaf venation. Despite being monocots, leaves vary greatly, frequently having a petiole and large, complex, occasionally divided (as in *Monstera*) or palmately split blades with a unique reticulate (net-like) venation.

Floral characters:

Inflorescence: Spadix (a dense spike bearing tiny unisexual flowers) usually covered/subtended by a leafy (may be colored) spathe.

Flowers (thermogenic): small, bisexual or unisexual (monoecious) with female flowers at the base and male flowers above, although some are bisexual. The flowers are tiny, sessile, and lack perianth segments. Several species are monoecious (different male/female flowers on one plant), frequently with the female flowers emerging first (protogyny) to avoid self-fertilization.

Perianth: 4-6 in two whorls (in Bisexual flowers), usually absent in unisexual flowers;

Androecium: 2,4,6 or 8-9, rarely 1, opposite to the perianth leaves, anthers 2-celled

Gynoecium: Carpels 2 or 3, (syncarpous) or 1; ovary superior, 1-3 chambered, Parietal or axile placentation.

Floral Formula: Br P₍₄₋₆₎ or 6 A₍₂₋₈₎ or 1 G₍₁₋₃₎

Fruit and Seeds:

Fruit: Generally a berry. Seeds: - usually endospermic

Main Diagnostic features:

- Large petiolate leaves, often with sheathing bases
- Both stem and leaves contain calcium oxalate (raphides) that make tissues irritating.
- Inflorescence Spadix with a leafy/colored spathe
- Thermogenic flowers small, unisexual (monoecious) or bisexual
- Presence of protogyny to avoid self-fertilization
- Tepals 4-6 in two whorls (in Bisexual flowers), absent in unisexual flowers
- Fruit commonly a berry
- Seeds usually endospermic

General Botanical Characteristics of Arecaceae

Vegetative Features:

Habit: Mostly erect, perennial, unbranched (exception: *Hyphaene* is a notable branched genus) trees (e.g., *Cocos nucifera*), though some are shrubs, or climbers (rattan/lianas); some are stemless; *Nypa fruticans* is a unique, low-growing, rhizomatous mangrove palm.

Root: Fibrous, adventitious, originating from base of stem.

Stem: typically unbranched, sturdy, column-like woody trunk, often bear scars of old leaves; Secondary growth is absent.

Leaves: Large, alternate, often compound, pinnate (feather-like) or palmate (fan-like), evergreen, arranged in a terminal crown. Young leaves are folded (plicate); the base is characteristically sheathing, sometimes possess a Ligule or Hastula.

Floral characters:

Inflorescence: usually a compound panicle or spike often protected by a large, woody or papery, spathe which may be occasionally persistent.

Flowers: Small, almost sessile, regular, often unisexual (dioecious or monoecious), and arranged in a large, branching inflorescence (spadix) protected by a bract (spathe), usually 3-merous

Perianth: 6 (3+3), persistent, sepaloid, free, imbricate/valvate

Androecium: Stamens 6 (3+3), rarely 3 or more, free,

Gynoecium: Carpels 3, syncarpous, superior ovary, 3-chambered, 1-ovuled, style short.

Floral Formula:

Male: $\text{Br} \oplus \text{♂ } P_{6(3+3)} A_{6(3+3)} \overline{G}_0$

Female: $\text{Br} \oplus \text{♀ } P_{6(3+3)} A_0 \overline{G}_{(3)}$

Fruit and Seeds: Fruit: commonly one-seeded drupe or berry, endocarp attached with seed coat. Seeds: contain rich endosperm. Embryo:- small, embedded oily, ruminant/horny endosperm

Main Diagnostic features:

- Erect, perennial, unbranched trees
- Root: Fibrous, adventitious
- Stem: sturdy, column-like woody trunk bearing leaf-scars
- Large, alternate, evergreen leaves in a terminal crown
- Flowers small, unisexual, monoecious/ dioecious, regular
- Spadix - simple or compound with boat-shaped spathaceous bract
- Perianth 6, free, persistent
- Stamens 6 (3+3)
- Carpels 3, syncarpous, superior ovary, 3-chambered, 1-ovuled
- One-seeded drupe or berry

General Botanical Characteristics of Commelinaceae:

Vegetative Features:

Habit: Plants herb with a jointed stem, either erect or creeping of marshy places.

Leaves: alternate, simple, entire, sheathing, parallel veined.

Floral characters:

Inflorescence: monochasial (helicoid) cyme or solitary, enclosed by boat shaped leaf sheath or foliaceous bract.

Flowers: Irregular, bisexual or polygamous, hypogynous, often enclosed in spathes.

Perianth: Tepals 6 (3+3), free outer sepaloid & inner petaloid, petals are generally blue in color, imbricate.

Androecium: Stamens - 6 (3+3) in two whorls of 3 each, all perfect (*Cyanotis*, *Polia*, *Tradescantia*), or outer 3 being reduced to staminodes or staminodes absent (*Collisea*); filaments bear moniliform hairs; anther basifixed. Extrose or introse.

Gynoecium: Carpels-3, syncarpous, ovary superior, 3-celled, (2-celled in *Floscopa*) with 1 to few orthotropous ovules on axile placentation; style terminal; stigma generally capitate/trifid.

Floral Formula: Br % ♂ P₆₍₃₊₃₎ A₆₍₃₊₃₎ G₍₃₎

Fruit and Seeds: Fruit: Capsule. Seeds: Angled, albuminous;

Embryo:- small, located beneath a disc like callosity (Embryostega) on seed coat.

Main Diagnostic features:

- Erect/creeping herbs of marshy places, with a jointed stem
- Leaves alternate, simple, entire, with sheathing base
- Monochasial/helicoid cyme, enclosed by boat-shaped spathaceous bract
- Tepals 6 (3+3), free, outer sepaloid & inner petaloid
- Stamens - 6 (3+3) in two whorls
- Carpels 3, syncarpous, ovary superior, 3-celled
- Fruit capsule

General Botanical Characteristics of Cyperaceae (sedge family)

Vegetative Features:

Habit: Primarily perennial herbs with creeping rhizomes, stolons, or tubers;

Roots: fibrous, adventitious, or sometimes dauciform (nutrient-absorbing, carrot-like).

Stem (Culm): Often solid, smooth or scabrid (rough), lacking distinct nodes (nodes are not jointed), and triangular in cross-section (3-ranked in a 1/3rd phyllotaxy).

Leaves: Simple, linear, and arranged in three rows (tristichous), with a closed sheath, ligule absent.

Floral characters:

Inflorescence: Composed of spikelets, arranged in terminal spikes, panicles, or anthelae; involucre bract present.

Flowers: Small, inconspicuous, sessile, and subtended by a single glume (bract). They are bisexual or unisexual

Perianth: Usually absent, or modified into 1–6 scales or bristles.

Androecium: with 1–6 stamens, anthers basifixed.

Gynoecium: Carpels 2/3, superior, 1-locular ovary; style one, stigmas 2-3, plumose.

Floral Formula: $\text{Br} \oplus \text{P}_0 \text{A}_3 \underline{\text{G}}_{(2)} \text{ or } (3)$

Fruit and Seeds: Fruit: a 3-sided or lens-shaped, hard achene (nut).

Embryo: surrounded by mealy endosperm, lies at the base of grain.

Main Diagnostic features:

- Perennial, rhizomatous herbs having grass-like appearances, often found in wetlands
- Solid, 3-angled stems (culms), nodes are not jointed
- Tristichous leaves with closed leaf sheaths and no ligule
- Inflorescence spikelets, arranged in terminal spikes, panicles, or anthelae
- Involucral bract present; Glumes & lemma are absent
- Stamens 3
- Carpels 2 or 3 with superior, 1-locular ovary
- Fruit a 3-sided hard achene (nut)

General Botanical Characteristics of Liliaceae (Lily family)

Vegetative Features:

Habit: Mainly perennial herbs with underground bulbs, some are trees (*Dracaena*, *Yucca*), shrubby/climbers (e.g., *Smilax*).

Root: Adventitious, fibrous, or fasciculated roots, usually contractile roots.

Stem: erect/climbing, mostly modified to underground bulbs, corms, or rhizomes

Leaves: simple, radical/cauline, alternate, linear/strap- shaped, parallel veined, exstipulate.

Floral characters:

Inflorescence: various, commonly scapose, solitary, or in cymose/umbellate clusters.

Flowers: Usually large, showy, trimerous, regular, bisexual, rarely unisexual (*Smilax*), hypogynous.

Perianth: Tepals 6 (3+3), often petaloid, polyphyllous/gamophyllous, often spotted/with lines, nectar gland present at the tepal base.

Androecium: Stamens 6, (3+3), commonly epiphyllous, filaments free, anther 2-celled.

Gynoecium: Carpel-3, syncarpous, superior many ovuled trilocular ovary, axile placentation.

Floral Formula: Br. $\oplus \text{ } \overline{\text{P}}_{3+3} \text{ } \overline{\text{A}}_{1-2} \text{ } \overline{\text{G}}_{(3)}$

Fruit and Seeds: Fruit: Generally loculicidal capsule, occasionally berry.

Seed: Endospermic (fleshy/cartilaginous), usually flat.

Main Diagnostic features:

- Perennial herbs/shrubs with underground bulbs, corms, or rhizomes
- Leaves: simple, radical (basal) or cauline
- Flowers: trimerous
- Perianth: 6 tepals (3+3), often petaloid
- Androecium with 6 stamens, epiphyllous
- Tricarpellary, syncarpous, superior many ovuled trilocular ovary, axile placentation
- Fruit: Generally loculicidal capsule

General Botanical Characteristics of Musaceae (Banana family)

Vegetative Features:

Habit: Perennial herbs, often tree-like, arising from an underground rhizome or corm.

Roots: Adventitious, arising from the rhizome.

Stem: Pseudostem with tightly wrapped, overlapping leaf sheaths, unbranched, stout.

Leaves: Extremely large, simple, spirally arranged, with a thick, prominent midrib and parallel, pinnate veins that often tear in the wind, giving a ragged appearance.

Floral characters:

Inflorescence: A large, terminal mixed spadix (thyse) (where cymosely arranged flowers are racemosely arranged on fleshy axis) often drooping, subtended by large, frequently brightly colored, leathery, or papery bracts (spathes).

Flowers: Zygomorphic, unisexual, often monoecious, female & male flowers are located on the lower/proximal and distal (upper) part of the inflorescence respectively; epigynous.

Perianth: Tepals 6(3+3), usually arranged in two whorls, petaloid; in *Musa*, 5 are fused into a toothed tube Although the inner posterior one is free; imbricate.

Androecium: usually stamens 6, but often only 5 are fertile, the 6th being a staminode (rudimentary), in *Ravenala*, all the 6 stamens are fertile; anthers 2-celled.

Gynoecium: Tricarpellary, syncarpous, 3-locular, many ovuled, inferior ovary, style-1, stigma 3-lobed or capitate; axile placentation.

Floral Formula: $\text{Br } \% \text{ } \text{P}_{3+3} \text{A}_{6-\infty} \underline{\text{G}}_{(3)}$

Fruit and Seeds: Fruit: A fleshy, elongated, 3-locular berry, which is parthenocarpic (seedless) in many cultivated species (e.g., *Musa*), or a capsule in other genera like *Ravenala*.

Seeds: hard (testa), angled, or sub-spherical, (when present), often surrounded by pulp & arillate. **Embryo:** straight

Main Diagnostic features:

- Perennial herbaceous plants
- Tall, watery pseudostem formed by overlapping, sheath-like leaf bases
- Large, spirally arranged leaves, half-alternate, long stem clasping sheaths, without ligule
- Inflorescence terminal mixed spadix
- Flowers zygomorphic, unisexual, monoecious, epigynous
- Tepals 6 (3+3)
- Stamens 6
- Tricarpellary, syncarpous, inferior, 3-locular ovary
- Fleshy, seeded or seedless berries

General Botanical Characteristics of Orchidaceae:

Vegetative Features:

Habit: Mostly epiphytic, some are saprophytes & terrestrial plants.

Leaves: Simple with parallel venation, alternate, often distichous, rarely opposite, sometimes reduced to achlorophyllous scales [saprophytic species], usually fleshy, & linear to ovate in shape, entire, leaf sheathing at base, sheath closed & encircling the stem, exstipulate, stomata tetracytic; foliage leaves are absent in *Dendrophylax*, *Epipogon*; only a single leaf per shoot is present in *Pleurothallis*.

Floral characters:

Inflorescence: Variable from racemose (raceme), paniculate (*Oncidium*), spicate or flowers solitary (*Cypripedium*).

Flowers: Usually bracteates, bisexual, rarely unisexual, irregular, epigynous, showy, beautifully colored & extraordinarily diverse in shape, size & color; mostly resupinate i.e., twisted 180 degree or upside down.

Perianth: *Segments 6*, biseriate (i.e., differentiated into calyx & corolla) the tepals of outer whorl (sepals) are smaller than those of the inner (petals); Tepals are polyphyllous (free).

Sepals are equal in size or the odd one which is always anterior in position may be larger or smaller than the pair. In *Disa* the anterior sepal is spurred.

Petals 3, free, fully developed & colorful; posterior median tepal of inner whorl (petal) is bigger & forms labellum. It is of variable shape and function as a landing station for pollinating insects; bracts tiny, bracteoles lacking.

Resupination: Prolonged inferior ovary that outwardly appears like a pedicel undergoes a clockwise twisting through 180 degrees. This shifts the posterior side of the flower towards the anterior side & vice versa. This is called resupination. As a result, the labellum serves as a very efficient landing place for pollinating insects.

Androecium: consists of 2 fused, lateral stamens or 1 terminal stamen; anthers 2-celled, introse Pollens are in *pollinia* having *caudicles*; Pollen monocolpate in *Cypripedium*.

Column or Gynostemium: - Stigma, style and stamens are united to form a single, highly complex structure called column or Gynostemium.

Gynoecium: *Tricarpellary*, syncarpous, Ovary inferior, twisted, unilocular many-ovuled, anatropous, parietal placentation; style 1 (part of column);

Rostellum: In most orchids, Stigmas-3 of which 2 are fertile & 3rd one is sterile forming a beak like structure [pocket] called rostellum; It lies between the anther & the other 2 functional stigmas; a part of rostellum is modified into a viscid disc, the viscidium to which the caudicles are attached. The lowest part of the anther may be drawn out on each side into a slender process which surrounds the lower sterile portion, the caudicle of the pollinium.

Floral Formula: Br. % ♂ $P_{3+3} A_{1-2} \overline{G}_{(3)}$

Fruit and Seeds: **Fruit:** - Dry, dehiscent capsule breaking by 6 slits.

Seeds: minute, numerous, light (each weighing as low as 0.004 mg), and non-endospermic.

Main Diagnostic features:

- Perennial herbs, epiphytic or saprophytic or terrestrial
- Flowers – Bracteate, bisexual, irregular, epigynous, showy, beautifully colored & extraordinarily diverse in shape, size & color; mostly resupinate (i.e., twisted 180 degree or upside down)
- Perianth – 6, biseriate, free, tepals of outer whorl (sepals) are smaller than those of inner whorl [petals]

- Stamens 2, fused, anthers 2-celled, introse
- Pollens are in pollinia having caudicles
- Stigma, style & stamens are united to form Column or Gynostemium
- Tricarpellary Gynoecium, syncarpous, Ovary inferior, twisted, unilocular with many, anatropous ovules on parietal placentation; style 1 (part of column)
- Stigmas- 3 of which 2 are fertile & 3rd one is sterile forming a beak like structure [pocket] called rostellum
- Fruit- Dry, dehiscent capsule breaking by 6 slits
- Seeds minute, light, numerous & non-endospermic

General Botanical Characteristics of Poaceae

Vegetative Features:

Habit: Mostly herbs (annual or perennial), with some woody, evergreen trees or shrubs as exceptions like bamboo.

Leaves: Simple, lanceolate to linear, alternate, distichous (two-ranked). Each leaf consists of a sheath that wraps around the stem, a long blade, and a small, membranous, or hairy extension called a ligule at the junction of the sheath and blade, exstipulate.

Stem: Jointed with distinct nodes and internodes, usually hollow at the nodes and solid at internodes (fistular), cylindrical (round), and rarely flattened.

Floral characters:

Inflorescence: Usually spikelet, which are further arranged in panicles, racemes, or spikes.

Flowers: Small, inconspicuous, Bisexual (rarely unisexual), actinomorphic, and trimerous.

Perianth: Generally represented by 2-3 minute, fleshy scales called lodicules.

Androecium: Stamens 6 (3+3) or 3; anthers 2-celled, versatile

Gynoecium: carpel 1, with a superior ovary and 2 or 3 feathery (plumose) stigmas, 1-chambered, 1-ovuled.

Floral Formula: $\text{Br } \% \text{ } \overline{\text{P}}_2 \text{A}_3 \underline{\text{G}}_{(1)}$

Fruit and Seeds: Fruit: caryopsis. Seeds: endospermic (starchy).

Main Diagnostic features:

- Cylindrical stem with hollow internodes
- Simple leaves arranged in two ranks (distichous), ligulate

- Flowers Small, reduced, often greenish, arranged in spikelets
- Stamens 6 (3+3) or 3, anthers versatile
- Carpel 1
- Style 2, with feathery stigmas
- Fruit caryopsis

General Botanical Characteristics of Zingiberaceae

Vegetative Features:

Habit: Mostly Perennial, aromatic herbs with creeping, fleshy, or tuberous rhizomes.

Root: Adventitious, fibrous.

Stem: mostly underground; aerial "stems" (pseudostems) are formed by tightly rolled, overlapping leaf sheaths. tuberous or horizontal Rhizome present, bracted, scapose or leafy. In *Curcuma* the aerial stem is very short or even absent;

Leaves: Radical or cauline; Simple, entire, exstipulate, ligulate, petiolate or sessile, usually distichous (two-ranked), spiral in *Costus*, leaf base sheathing in some (*Curcuma*); Leaf blades are typically linear to lanceolate, apex acute or obtuse; parallel unicostate.

Floral characters:

Inflorescence: Terminal spike or racemose or panicle.

Flowers: Bracteate; pedicellate or sessile; complete; zygomorphic; irregular; bisexual; epigynous; cyclic; calyx and corolla are distinct; flowers usually large in size and brightly coloured, aromatic, except in *Costus*, *Monocostus*, *Dimerocostus* and *Tapeinocostus*; Entomophilous.

Calyx: Sepals 3; gamosepalous; tubular or spathe like; generally 3-toothed; green; superior. In *Globba* the calyx tube is very short; odd sepal anterior.

Corolla: Petals 3, free or more or less united; tubular or funnel-shaped; three-lobed, lobes unequal; linear or broad. In *Roscoea* the corolla tube is long and slender with upper lobe broad, cucullate, and erects, the two lateral lobes spreading and narrower. Corolla tube as long as or longer than the calyx tube.

Androecium: Stumens 6, arranged in two whorls, the median posterior stamen of inner whorl is only fertile and epipetalous and antipetalous, the other two stamens of the inner whorl are sterile and mostly petaloid and are fused together to form the petaloid lip or labellum, which may be two or three lobed (not equivalent to the labellum of Orchidaceae).

The anterior stamen of the outer whorl is always suppressed or absent, the other two may be absent (Renealmia) or may be present as large leafy staminodes right and left of the fertile stamen. In *Curcuma*, *Roscoeia* and *Zingiber* the two anther lobes are joined by a wide spurred connective, the spurs standing above the lip; in *Roscoeia* the connective has two basal spurs.

Gynoecium: Carpels 3, syncarpous; inferior; 3-chambered with axile placentation (*Zingiber*; *Curcuma*, *Hedychium*, *Roscoeia*, *Amomum* etc.); ovules many and superposed in each loculus; in *Globba* the ovary is 1-chambered (unilocular) with parietal placentation; in *Monocostus* the ovary is 2-chambered (bilocular) with parietal placentation (third loculus is suppressed); in *Haplochorema* the ovary is 1-chambered (unilocular) with a few basal ovules. Ovules are usually anatropous or semi-anatropous. Style-1, simple, typically slender; stigma-1, simple, variously developed, capitate or 3-lobed.

Floral Formula: Br % ♂ $P_{3+3} A_6 \overline{G}_{(3)}$

Fruit and Seeds: Fruit: dehiscent, 3-valved loculicidal capsule.

Seeds: many, arillate with abundant mealy perisperm.

Main Diagnostic features:

- Aromatic herbs with rhizomes
- Simple leaves, distichous, ligulate.
- Flowers solitary or in racemose/paniculate.
- Perianth 6 (3+3), differentiated into calyx & corolla
- Calyx fused in a tube, 3-toothed
- Corolla 3-lobed and tubular at the base
- Only 1 stamen fertile, other 2 stamens (staminodes) are sterile, petaloid, fused together forming lip or labellum
- Carpel 3, syncarpous, Style 1, inferior ovary, 3-locular with axile placentation
- Fruit dehiscent, 3-valved loculicidal capsule with many, arillate seeds.

Why is Orchidaceae widely considered the most advanced family in monocotyledons?

Orchidaceae is recognized as the most evolved monocot family because of the following features:

- a) **Gynostemium (Column):** One of the most advanced floral adaptations, stamens and pistil merging into a single reproductive structure.
- b) **Pollinia:** Pollen grains form waxy pollinia, assisting in insect pollination.
- c) **Resupination:** The flower pedicel rotates 180 degrees during development, putting the labellum (lip) for pollinators.

- d) **Labellum Modification:** The median petal (labellum) is altered in form, size, and color to attract pollinators.
- e) **Seed Structure:** Orchids generate millions of tiny, dust-like seeds that lack endosperm
- f) **Mycorrhizal Dependency:** Seeds require symbiotic mycorrhizal fungus for germination, a highly sophisticated survival strategy.
- g) **Epiphytic adaptations:** Many plants have aerial roots coated in velamen, a multi-layered water-absorbing tissue.
- h) **Vegetative specialization:** Pseudobulbs (swollen stems) store water and nutrients for epiphytic or dry survival.
- i) **Pollination Mechanisms:** They replicate fragrance, form, and color to attract certain insects, birds, and bees.
- j) **Reduced Stamens:** The number of stamens is reduced to one or two to focus on complicated, focused pollination.

SYSTEMATIC POSITIONS OF MONOCOT FAMILIES:

1. Alismataceae

Bentham & Hooker: Monocotyledones→Series Apocarpeae.

Engler-Prantl: Monocotyledoneae→Order Helobiae.

Hutchinson: Monocotyledones→Order Alismatales.

Cronquist: Liliopsida→Subclass Alismatidae→Order Alismatales.

APG IV: Angiosperms, →Monocots→Order Alismatales.

2. Amaryllidaceae

Bentham & Hooker: Monocotyledones→Series Epigynae.

Engler-Prantl: Monocotyledoneae→Order Liliiflorae.

Hutchinson: Monocotyledones→Order Amaryllidales.

Cronquist: Liliopsida, →Subclass Liliidae→Order Liliales.

APG IV: Angiosperms→Monocots→Order Asparagales (Note: Now includes former Alliaceae and Agapanthaceae).

3. Araceae

Bentham & Hooker: Monocotyledones→Series Nudiflorae.

Engler-Prantl: Monocotyledoneae, →Order Arales.

Hutchinson: Monocotyledones→Order Arales.

Cronquist: Liliopsida→Subclass Arecidae, →Order Arales.

APG IV: Angiosperms→Monocots→Order Alismatales.

4. Arecaceae (Palmae)

Bentham & Hooker: Monocotyledones→Series Calycinae.

Engler-Prantl: Monocotyledoneae→Order Principes.
Hutchinson: Monocotyledones→Order Arecales.
Cronquist: Liliopsida→Subclass Arecidae→Order Arecales.
APG IV: Angiosperms→Monocots →Order Arecales.

5. Commelinaceae

Bentham & Hooker: Monocotyledones→Series Coronarieae.
Engler-Prantl: Monocotyledoneae →Order Farinosae.
Hutchinson: Monocotyledones→Order Commelinales.
Cronquist: Liliopsida→Subclass Commelinidae→Order Commelinales.
APG IV: Angiosperms→Monocots→Order Commelinales.

6. Cyperaceae

Bentham & Hooker: Monocotyledones→Series Glumaceae.
Engler-Prantl: Monocotyledoneae→Order Glumiflorae.
Hutchinson: Monocotyledones→Order Cyperales.
Cronquist: Liliopsida→Subclass Commelinidae→Order Cyperales.
APG IV: Angiosperms→Monocots→Order Poales.

7. Liliaceae

Bentham & Hooker: Monocotyledones→Series Coronarieae.
Engler-Prantl: Monocotyledoneae→Order Liliiflorae.
Hutchinson: Monocotyledones→Order Liliales.
Cronquist: Liliopsida→Subclass Liliidae→Order Liliales.
APG IV: Angiosperms, Monocots→Order Liliales
(Note: Highly restricted compared to earlier definitions).

8. Musaceae

Bentham & Hooker: Monocotyledones→Series Epigynae (under Scitamineae).
Engler-Prantl: Monocotyledoneae→Order Scitamineae.
Hutchinson: Monocotyledones→Order Zingiberales.
Cronquist: Liliopsida→Subclass Zingiberidae→Order Zingiberales.
APG IV: Angiosperms→Monocots→Order Zingiberales.

9. Orchidaceae

Bentham & Hooker: Monocotyledones→Series Microspermae.
Engler-Prantl: Monocotyledoneae→Order Microspermae.
Hutchinson: Monocotyledones →Order Orchidales.
Cronquist: Liliopsida→Subclass Liliidae, →Order Orchidales.

APG IV: Angiosperms, →Monocots, →Order Asparagales.

SYSTEMATIC POSITION OF ORCHIDACEAE:

Classification Systems: Bentham and Hooker placed them in Microspermae, but modern molecular phylogenetic studies (APG I, II, III, IV) place them in Asparagales, often sister to Boryaceae or a specialized branch.

Subfamilies of Orchidaceae: Currently (reflecting modern phylogenetic studies) it is divided into 5 major subfamilies:

- a) **Apostasioideae (most basal):** Considered basal, with two fertile stamens, found in Asia.
- b) **Cypripedioideae (Lady's slippers):** Characterized by a pouch-like lip, with 2 lateral staminodes & 2-fertile stamens.
- c) **Vanilloideae:** Includes vanilla, mostly terrestrial or climbing, with unique pollination.
- d) **Orchidoideae (Terrestrial Orchids):** Mostly terrestrial, from tubers, with segmented pollinia (e.g., *Orchis*, *Dactylorhiza*).
- e) **Epidendroideae (Epiphytic Orchids, largest subfamily, ~80% of species):** The biggest group, diverse, includes several common epiphytes like *Cymbidium*, *Dendrobium*, and *Vanda*.

Classification's Evolution (Placement of Orchids):

Early classifications based on morphology, placed orchids with grasses (Gramineae). Modern approaches, however, are using molecular data to decide the current phylogenetic grouping into these five subfamilies, displaying a more precise understanding of how they have evolved.

❖ Systematic Position (According to the APG):

Kingdom: Plantae

Clade: Tracheophytes (Vascular plants)

Clade: Angiosperms (Flowering plants)

Clade: Monocots

Order: Asparagales

Family: Orchidaceae Juss. (1789)

10. Poaceae (Gramineae)

Bentham & Hooker: Monocotyledones, →Series Glumaceae.

Engler-Prantl: Monocotyledoneae→Order Glumiflorae.

Hutchinson: Monocotyledones, →Order Graminales.

Cronquist: Liliopsida→Subclass Commelinidae, → Order Cyperales.

APG IV: Angiosperms→Monocots→Order Poales.

11. Zingiberaceae

Bentham & Hooker: Monocotyledones, →Series Epigynae (under Scitamineae).

Engler-Prantl: Monocotyledoneae→Order Scitamineae.

Hutchinson: Monocotyledones→Order Zingiberales.

Cronquist: Liliopsida, →Subclass Zingiberidae, →Order Zingiberales.

APG IV: Angiosperms→Monocots→Order Zingiberales.

Overall Summary of Differences in different classification (monocot):

- Bentham & Hooker (1862–1883): Families were arranged according to morphological, non-phylogenetic affinities, frequently utilizing habit (e.g., Glumaceae for grasses).
- Engler-Prantl (1887–1915): Prioritized monocots above dicots and placed more "primitive" unisexually bloomed plants first, emphasizing evolutionary links.
- Hutchinson (1926–1934): Attempted a more stringent phylogenetic categorization, frequently dividing families using vegetative and floral characteristics.
- Cronquist (1968, 1981): introduced subclasses and concentrated on the phylogeny of angiosperms, utilizing a variety of data sets, including chemistry and ultrastructure.
- APG IV (2016): Completely molecular (DNA) based, considering families as monophyletic groupings, leading to a major restructuring (e.g., Araceae to Alismatales, Orchidaceae to Asparagales).

EXCEPTIONS/ DEVIATIONS (MONOCOT)

1. Alismataceae (Water-Plantain Family)

Important Remarks on Significant Exceptions in Alismataceae

- a) **Pollination:** Although most species are pollinated by insects, some are suited for wind or self-pollination.
- b) **Vegetative Features:** In dry conditions, the aerenchyma tissue seen in plants may vanish.
- c) **Apocarpous Gynoecium:** Uncharacteristic for most monocots, which typically have syncarpous (fused) ovaries, this family features many free carpels.
- d) **Laticifers:** One of the few monocot families to possess milky latex.
- e) **Leaf Dimorphism:** Often produces different leaf shapes (submerged vs. emergent) on the same plant.
- f) The Alismataceae family has a number of morphological, reproductive, and life cycle exceptions, such as:

Summary Table of Exceptional characteristics in Alismataceae

Features	Typical family Characteristics	Exceptions
<i>Habit/Life Span</i>	Perennial	Many species can behave as annuals, particularly in seasonal water conditions.
<i>Leaf Shape</i>	Basal, petiolate, often dimorphic (linear submerged, ovate/sagittate emergent)	Leaves may be sessile or have very short petioles (e.g., <i>Sagittaria pygmaea</i>).
<i>Inflorescence</i>	Compound, with whorls of branches	Inflorescences can be simple, paniculate, or rarely umbel-like/solitary flowers.
<i>Floral Sexuality</i>	Bisexual	Frequently monoecious (separate male/female on same plant) or rarely dioecious.
<i>Petal Condition</i>	Three, conspicuous, white/pink, deciduous	In <i>Burnatia</i> and <i>Wiesneria</i> , petals are minute; they can be absent in female flowers.
<i>Stamen Number</i>	6 or 9 (whorled)	Can be as few as 3 or, in <i>Sagittaria</i> , numerous.
<i>Ovary Structure</i>	Superior, carpels in a single whorl	Carpels can be in a clustered, spiral head in <i>Sagittaria</i> .
<i>Seed Endosperm</i>	Absent	The family is known for having embryos that are often green.
<i>Stolons</i>	Present in many species (<i>Sagittaria</i>)	Frequently lacking in certain <i>Sagittaria</i> species (e.g., <i>S. guayanensis</i> , <i>S. lichuanensis</i>).
<i>Sepal Behavior</i>	Persist in fruit	Sepals may be reflexed or not reflexed after anthesis, depending on the species.

- Unisexual Flowers (Derived Trait):** Although the majority of Alismataceae have bisexual flowers, some are dioecious or monoecious, meaning that the male and female flowers are separate on the same plant.
- For instance, the arrowhead sign of *Sagittaria* is often either monoecious or dioecious. The uncommon annual *Wiesneria triandra* has blooms that are unisexual. The flowers of *Limnophyton* species are frequently unisexual.
- Androecium Structure in *Wiesneria*:** *Wiesneria triandra* has a derived, typical alternation of stamens with petals, in contrast to the usual Alismataceae stamens in antipetalous pairs.
- Annual Habit:** Some species act like annuals, especially under seasonal water circumstances, although the majority are hardy perennials.

- e) **Fruit Type Variation in *Damasonium*:** Although the family's normal fruit is an achenese head, the starfruit, or *Damasonium*, is an anomaly, with follicles.
- f) **Winged Scapes in *Echinodorus*:** In *Echinodorus*, some species have unique winged expansions, although many have rounded or triangular scapes. For instance, the pentagonal shape of *Echinodorus palaeifolius* features five winged expansions. The clawed petals of *Echinodorus berteroi* are distinctive.
- g) **Reduced/Absent Petals:** Female blooms of *Burnatia* and *Wiesneria* have little or nonexistent petals.

Polyphyletic/Paraphyletic Genera: The paraphyletic *Limnophyton* and the polyphyletic *Caldesia* are examples of taxonomic exceptions, in which molecular evidence deviates from conventional morphology.

2. Amaryllidaceae (Amaryllis Family)

In Amaryllidaceae family major exceptions with examples are:

- a) **Inferior Ovary:** A key deviation from the closely related Liliaceae, which has a superior ovary.
- b) **Corona/Paraperigone:** Features a specialized outgrowth of the perianth (e.g., the cup in Daffodils).
- c) **Unique Alkaloids:** Contains specialized norbelladine alkaloids not found in other plant groups.
- d) **Non-Bulbous Roots (Rhizomatous/Fleshy Roots):** though mostly bulbous, certain genera lack true bulbs e.g.,
 - *Clivia* species have large, fleshy, white-and-yellow roots instead of bulbs.
 - *Agave* species (subfamily Agavoideae) typically possess rhizomes.
- e) **Leaf Arrangement:** Leaves are generally alternate, but some exhibit unique arrangements. Example: *Clivia* leaves are two-ranked, arising from the soil directly opposite one another.
- f) **Androecium Exceptions (Stamen Number):** The standard is 6 stamens (3+3), but exceptions exist. Example: *Gethyllis* species can have 12 to 18 stamens.
- g) **Flower Symmetry:** Flowers are generally actinomorphic (radially symmetrical), but some are not. Example: *Sprekelia* has zygomorphic flowers.
- h) **Aerial Stems:** Most are herbaceous with leafless scapes, but some have leafy stems. Example: *Agave* species can have aerial, leafy stems.
- i) **Superior/Semi-Inferior Ovary:** The family is largely defined by an inferior ovary, but some taxa differ. Example: *Agapanthus* is considered a connecting link with a superior ovary, although it is often placed within this family.

- j) **Unique Floral Structure (Corona Variation):** Although the corona is common (e.g., in *Narcissus*), its structure varies or is absent in other genera like *Amaryllis*.

3. Araceae (Arum Family)

The primary exceptions in the Araceae family are:

1. Temperate & Non-Tropical Exceptions
 - Although most Araceae are tropical, some species are adapted to cold climates.
 - *Symplocarpus foetidus*: Native to cold marshy habitats in North America and Russia.
 - *Lysichiton*: Found in temperate East Asia and Western North America.
 - *Arisaema triphyllum*: A North American temperate species.
2. Aquatic vs. Terrestrial/Epiphytic Habits
 - Most aroids are terrestrial or epiphytic, but several are specialized for water.
 - *Pistia stratiotes*: A floating, stoloniferous aquatic plant.
 - *Orontium*: An aquatic genus found in North America.
3. Unique Inflorescence and Flower Exceptions
 - Although aroids are known for the spadix/spathe, variations exist.
 - *Wolffia* spp.: These are unique in having the smallest flowers of any angiosperm, lacking traditional large spathes and having highly reduced vegetative structures.
 - *Amorphophallus titanum*: Features a massive, rapidly developing inflorescence rather than the smaller, delicate structures of other aroids.
4. Morphological and Chemical Exceptions
 - *Gymnostachys*: A rare terrestrial, non-aquatic genus found in Australia that differs from its closely related aquatic relatives.
 - Acoraceae Family (formerly Araceae): *Acorus* (sweet flag) was shifted out of Araceae because it lacks raphide crystals (present in almost all Araceae) and has unifacial leaves.
 - Latex Production: Although many aroids contain latex, some genera like *Pothos* are specifically noted for lacking it.
 - Spadix & Spathe: Flowers are reduced and packed onto a fleshy spike (spadix) subtended by a large bract (spathe).
 - Thermogenesis: Several species can generate metabolic heat to volatilize scents and attract pollinators.
 - Raphide Crystals: Contains needle-like calcium oxalate crystals (raphides) that act as a chemical defense mechanism.

Summary Table of Exceptions

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>
Climate	Tropical	Symplocarpus (Cold marshy)
Habitat	Terrestrial/Epiphytic	Pistia (Floating aquatic)
Size	Small/Medium	Amorphophallus titanum (Massive)
Flow er Size	Distinctive	Wolffia (Smallest in the world)
Chemistry	Raphide Crystals	Acorus (Lacks raphide crystals)

4. Arecaceae (Palm Family)

Following are the major exceptions within the Arecaceae family and their examples:

1. Branched Palms (Exceptions to Unbranched Rule)

- Mostly grow as a single, unbranched trunk.
- *Hyphaene* (Doom Palm): This genus is a notable exception as it habitually branches, often dichotomously (forking into two), particularly *Hyphaene thebaica*.
- *Nypa fruticans* (*Nypa* Palm): Known to have a dichotomously branching underground stem.

2. Climbing Palms (Rattans)

- Instead of upright, stout trunks, these are slender, scrambling, vine-like, or climbing plants.
- *Calamus* species: Known as true rattans, these have long, flexible stems that climb using specialized organs (cirri/flagella).
- *Desmoncus*: A climbing palm found in the Neotropics that uses modified leaflets (acanthophylls) to climb.

3. Stemless or Short-Stemmed Palms

- Many palms are characterized by having no aerial trunk, or an extremely short one.
- *Nypa fruticans* (Mangrove Palm): Grows in salt water with an underground, horizontal stem (rhizome).
- *Phoenix acaulis*: A dwarf date palm with a very short or stumpy stem.
- *Asterogyne martiana*: A type of "litter-trapping" palm that is often stemless or very low-growing.

4. Cold-Hardy/Non-Tropical Palms (Exceptions to Tropical Habitat)

- Although restricted to warm climates, some species thrive in much colder areas.
 - *Jubaea chilensis*: Capable of withstanding significant cold.
 - *Trachycarpus fortunei*: Highly cold-hardy, capable of surviving well below freezing.
5. Unique Leaf Structure
- *Caryota*: An exception to the usual pinnate or palmate leaf structure, the *Caryota* has bipinnate leaves (twice-divided), making it look distinct from other palms.
6. Unique Reproductive and Growth Behaviors
- *Corypha umbraculifera* (Talipot Palm): A monocarpic plant, meaning it flowers only once at the end of its life, producing a massive terminal inflorescence, and then dies.
 - *Ravenea musicalis*: A unique palm that lives in riverbeds (rheophyte) and is viviparous, meaning the seed germinates although still on the parent plant.
 - *Lodoicea maldivica* (Double Coconut/Coco de Mer): Known for producing the largest seed in the plant kingdom.
7. Non-Palm "Imposters" (Common Misconceptions)
- Some plants with "palm" in their name are not in the Arecaceae family:
 - Sago Palm (*Cycas revoluta*): A Cycad, not a palm, and an ancient relative of conifers.
 - Ponytail Palm (*Beaucarnea recurvata*): Member of the Agave/Asparagaceae family.
 - Traveller's Palm (*Ravenala madagascariensis*): Not a palm, but in the Bird of Paradise family (Strelitziaceae).
 - Arborescent Habit: Although most monocots are herbaceous, palms develop a massive, woody-like unbranched stem (caudex).
 - Plicate Leaves: Leaves are folded in a fan-like or feather-like manner (plicate) during development.

Summary Table of Exceptional characteristics in Arecaceae

<i>Characteristic</i>	<i>Typical Feature</i>	<i>Exceptions (Exceptions to the Rule)</i>
Habit	Single-stemmed trees	Clumping/suckering stems; lianas (climbing vines, e.g., <i>Calamus</i>); acaulescent (trunkless)
Branching	Unbranched (monopodial)	Dichotomous (forked) branching in <i>Hyphaene</i> and <i>Nypa</i>
Stem Diameter	Tapered or	Swollen (e.g., Bottle Palm, <i>Hyophorbe lagenicaulis</i>)

	uniform	
Leaf Type	Palmately or pinnately compound	Simple or bifid leaves (e.g., some <i>Geonoma</i> or <i>Chamaedorea</i>)
Inflorescence	Interfoliar (among leaves)	Infrafoliar (below leaves, e.g., Royal Palm) or Suprafoliar (above leaves)
Sexual System	Monoecious	Dioecious (e.g., Phoenix, Borassus); hermaphroditic
Flower Parts	Trimerous (parts in 3s)	Multi-parted, e.g., Phytelephas (5-10+ carpels)
Fruit Type	Single-seeded drupe	Multi-seeded berries (e.g., Salacca, Phytelephas)
Fruit Surface	Smooth/Fleshy	Scaly (Calamoideae) or spiny
Pollination	Insect/Wind	Bat or bird pollination

Important Remarks on Significant Exceptions in Areaceae

- **Stem Branching:** *Hyphaene* (dour palm) and *Nypa* are renowned for their dichotomous branching, although the majority of palms are unbranched.
- **Climbing Habit:** Many species are thin lianas that use hook-like spines to climb, especially those in the subfamily Calamoideae (*Calamus*, rattan, etc.).
- **Flowers:** Although most are dioecious (separate male and female plants) or bisexual, a significant portion are monoecious (male and female on one plant).
- **Fruit Structure:** Unlike the usual one-seeded drupe, *Salacca* (snake fruit) has scaly, multi-seeded fruits.
- **Gigantism:** The biggest seed in the plant kingdom is produced by *Lodoicea maldivica*, an exception.
- **Ecological Niche:** Although tropical, certain palms, such as *Nypa*, are suited to arid environments, although others are suited to tidal mangroves.

5. Commelinaceae (Spiderwort Family)

Following are the major exceptions within the Commelinaceae family:

1. Habit Exceptions (Climbers/Epiphytes)
 - Although mostly erect/scrambling terrestrial herbs, some are adapted to climbing or epiphytic lifestyles:

- Climbers: Genera like *Streptolirion*, *Aetheolirion*, and certain species of *Spatholirion* are climbers.
 - Epiphytes: The genus *Cochliostema* consists of epiphytic plants (growing on other plants).
 - Succulent Stems: Characterized by soft, fleshy, and often jointed stems.
2. Habitat Exceptions (Aquatic/Semi-Aquatic)
- Although mostly terrestrial, some members are specialized for wet environments:
 - *Commelina benghalensis*: Often found in ditches and moist places, this species is described as semi-aquatic.
 - *Cyanotis axillaris*: Another example of a semi-aquatic herb.
3. Floral and Stamen Exceptions (Structural Variations)
- Commelinaceae has two main subfamilies, *Commelinoideae* (zygomorphic flowers, 4 guard cells) and *Tradescantoideae* (actinomorphic flowers, 2 guard cells), which provide further exceptions:
 - Stamen Variation (*Triandreae*): Although many have 6 stamens, members of the Triandreae tribe, such as *Murdannia* and *Palisota*, have only 3 fertile stamens, with the rest being sterile or absent.
 - Ephemeral Flowers: Individual flowers often last only a few hours or a single day.
 - Flower Color/Type: *Commelina benghalensis* is notable for producing underground cleistogamous flowers (self-pollinating, white flowers that do not open) in addition to normal aerial flowers.
 - Cincinnus Inflorescence: Features a specific type of Scorpioid cyme known as a cincinnus.
4. Root System Variation
- Though many have fibrous roots, some have tubers, like *Commelina benghalensis*.

Important Remarks on Significant Exceptions in Commelinaceae

- a) ***Cartonema***: This genus features yellow flowers, actinomorphic blooms with six stamens, and no glandular microhairs like the rest of the family.
- b) ***Siderasis***: Dimorphic branches (one kind leafless and ascending, another leafy and reproductive) are what make *Siderasis* unique.
- c) ***Commelina***: Known for producing both typical aerial blooms and subterranean (underground) cleistogamous flowers.

- d) ***Dichorisandra***: Not like other members of the family, it is renowned for having an odd, odorous sap.

Summary Table of Exceptional characteristics in Commelinaceae

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>
Habit	Herbs, sometimes succulent	<i>Dichorisandra</i> , <i>Elasis</i> , & <i>Siderasis</i> (scramblers or twining vines that can reach ± 5 m); Epiphyte (<i>Cochliostema</i>), Semi-Aquatic (<i>Commelina benghalensis</i> , <i>Cyanotis axillaris</i>); Underground Flowers (<i>Commelina benghalensis</i>)
Roots	Fibrous, adventitious	Tuberous roots are present in some species of <i>Dichorisandra</i> and <i>Siderasis</i> .
Inflorescence	Terminal/Axillary cymes (cincinni)	Basal inflorescences in <i>Geogenanthus</i> . Solitary flowers in <i>Cartonema</i> and <i>Sauvallea</i> .
Spathe	Present, boat-shaped	Absent or much reduced in many genera like <i>Tradescantia</i> and <i>Gibasis</i> .
Flowers	Bisexual (hermaphrodite)	Andromonoecious (male + bisexual) or gynomonoecious (female + bisexual) in some species.
Symmetry	Actinomorphic (regular)	Zygomorphic (bilateral) in <i>Commelina</i> , <i>Floscopa</i> , <i>Dichorisandra</i> .
Petals	Blue, purple, or white	Yellow in <i>Cartonema</i> .
Stamens	6, in 2 whorls of 3	Reduced number (1–5) in some genera. Only 1 fertile in some, or up to 6. e.g., <i>Murdannia</i> , <i>Palisota</i> (3 fertile)
Filaments	Bearded (with hairs)	Glabrous (hairless) in <i>Dichorisandra</i> , <i>Siderasis</i> , <i>Commelina</i> .
Anthers	Longitudinal slits (rimose)	Poricidal (opening by pores) in <i>Dichorisandra</i> and some <i>Murdannia</i> .
Ovary	Superior, 3-loculed	Bilocular (2-loculed) in <i>Commelina badamica</i> var. <i>palkondensis</i> .
Fruit	Loculicidal Capsule	Berry in <i>Pollia</i> . Fleshy, berry-like capsules in <i>Dichorisandra</i> .
Seeds	Without Aril	Arillate (with arils) in <i>Dichorisandra</i> and <i>Siderasis</i> .

6. Cyperaceae (Sedge Family)

Summary Table of Exceptional characteristics in Cyperaceae

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>
Stem Shape	Triangular ("Sedges have edges")	Round/terete in <i>Eleocharis</i> , <i>Schoenoplectus</i> (tule)
Stem Structure	Solid, rarely hollow	Hollow in some species
Leaves	3-ranked (tristichous)	Sometimes 2-ranked or spirally arranged
Leaf Sheath	Closed	Occasionally open in certain species
Ligule	Absent or membranous flap	Generally absent, often missing entirely
Inflorescence	Spikelet (subtended by a single glume)	Occasionally solitary terminal (<i>Oreobolus</i>)
Flower Type	Bisexual or Unisexual	<i>Carex</i> has exclusively unisexual flowers
Pollination	Wind-pollinated	Insect-pollinated (<i>Cyperus niveus</i>)
Perianth	Absent or reduced to bristles/hairs	Represented by scales (<i>Oreobolus</i>)
Stamens	3	1–6 (commonly 1 in <i>Hemicarpha</i>)
Style/Stigma	2-3 branches	Sometimes undivided

Important Remarks on Significant Exceptions in Cyperaceae

- **Vegetative Exceptions:** Although the adage "sedges have edges" is usually accurate, some bulrushes, such as, *Schoenoplectus*, and the genus *Eleocharis* have rounded, smooth stems.
- **Floral Structure:** The biggest genus, *Carex*, is specialized to have unisexual flowers, with male and female flowers on the same or distinct spikes, in contrast to the majority of sedges, which have bisexual flowers.
- **Pollination Changes:** Species such as *Cyperus niveus* have evolved to entomophily, or insect pollination, while being primarily anemophilous.
- **Photosynthetic Pathways:** This family of plants is a significant but sometimes disregarded category. There are over 1,400 species spread across 21 genera, especially in open, tropical environments.

- **Roots:** Although they are often fibrous, several species have dauciform (carrot-like) roots to help absorb nutrients in soil that is low in nutrients.

7. Liliaceae (Lily Family)

Few exceptions in the Liliaceae family with examples are given below:

1. Leaf Venation Exception: Reticulate Venation
 - Exception: although monocots naturally show parallel leaf venation, certain members exhibit reticulate venation, Example: *Smilax*.
2. Leaf Type/Structure Exceptions
 - Stipulate Leaves: Mostly exstipulate, but *Smilax* has stipules, which are often modified into tendrils.
 - Modified Leaves (Cladodes/Phylloclades): In some genera, leaves are reduced to scales, and branches take over photosynthesis.
 - Example: *Ruscus* (leaves modified into cladodes).
 - Example: *Asparagus* (leaves reduced to spines/scales).
 - Tendril Formation:
 - Example: *Gloriosa* (leaf tips are modified into tendrils).
3. Habit Exceptions (Non-Herbaceous)
 - Exception: Although mostly perennial herbs, some members are woody, shrubs, or climbing plants.
 - Example: *Dracaena* (tree).
 - Example: *Yucca* (tree).
 - Example: *Smilax* (climber).
4. Anatomical Exceptions (Secondary Growth)
 - Exception: Normal monocots do not exhibit secondary growth, but some Liliaceae members do; e.g., *Dracaena* and *Yucca*
5. Floral Exceptions
 - Style: Although most have a single style, some have divided styles or different, unusual gynoecium structures.
 - Example: *Allium* can have a gynobasic style.
 - Example: *Lilium apertum* (formerly *Nomocharis*) has been shown to have both bisexual & male flowers in the same population.

Summary Table of Exceptional characteristics in Liliaceae

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>	<i>Representative Genera</i>
Venation	Parallel	Reticulate	<i>Smilax</i>
Leaves	Sessile/Simple	Stipulate/Tendrils	<i>Smilax, Gloriosa</i>
Stem	Herbaceous	Woody/Shrub/Tree	<i>Dracaena, Yucca</i>
Growth	Primary only	Secondary Growth	<i>Dracaena, Yucca</i>
Photosynthesis	Leaves	Cladodes/Spines	<i>Ruscus, Asparagus</i>

8. Musaceae (Banana Family)

Following are the major exceptions within the Musaceae family and their examples:

1. Reproductive and Morphological Exceptions

- Monocarpic vs. Polycarpic: Although most *Musa* species are perennial & stooling (producing suckers), *Ensete ventricosum* (Ethiopian banana) is typically monocarpic—it flowers once and then dies.
- Unisexual vs. Bisexual Flowers: Although flowers in the family are generally arranged with female flowers on proximal parts and male on distal, some species, such as *Ensete glaucum*, may exhibit bisexual flowers.
- Fruit Type Variation: Most Musaceae produce berries, but some *Ensete* species produce fruits that are more like a dry, leathery nut.
- Seed Size Difference: *Ensete* species are distinguished from *Musa* by having significantly larger seeds.

2. Genetic and Taxonomical Exceptions

- Unusual Genomic Compositions: Most edible bananas are derived from *M. acuminata* and *M. balbisiana*. Exceptions include Fe'i bananas (*Musa troglodytarum*), which are derived from the Australimusa series and possess distinct orange/red pulp and erect bunches.
- Hybridization with *M. schizocarpa*: Some Papua New Guinea cultivars are exceptions to the normal parentage, showing ancestry from *Musa schizocarpa*.
- Rare Tetraploids: Although most cultivated bananas are diploid or triploid, natural tetraploids (e.g., AAAA, AAAB, AABB) are rare exceptions, found specifically in regions like Papua New Guinea.

3. Structural and Ecological Exceptions

- Unique Stigma Shape: *Musella lasiocarpa* (Chinese dwarf banana) is an exception in the family for having a capitate stigma, whereas most *Musa* and *Ensete* have clavate stigmas.
 - Ecological Tolerance (Cold/Dry): *Musella lasiocarpa* is highly adapted to colder and drier habitats, unlike the typical tropical, humid preference of *Musa*.
 - Leaf Arrangement: In contrast to the strictly spiral phyllotaxy of *Musa*, some members of the formerly included genera (like *Ravenala*) had distichous or half-alternate leaf arrangements.
4. Morphological Exceptions in *Musa* Section
- Unique Tepal Shape: Although most Musaceae have a free median inner tepal, *Musa nanensis* is an exception.
 - Variation in Tepal Fusing: In the Section *Musa* (including *Rhodochlamys*), some members show a fusion of the median tepal with other tepals, which is a divergence from the general, separate tepal structure.
 - Rarely Observed Hybrids: *Musa beccarii* is an exception that is very closely related to *Musa acuminata* but often classified in a different section, whereas *Musa boman* is exceptionally placed in the *Australimusa* section.
5. Historical/Fossil Exceptions
- Dubious Fossils: *Scitamineites musaeformis* is considered a potential exception or questionable fossil that might not be a true angiosperm, despite being referred to as a Musaceae ancestor.

Summary Table of Exceptional characteristics in Musaceae

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>	<i>Examples/Notes</i>
<i>Inflorescence Position</i>	Pendulous (drooping)	Erect (upright)	<i>Musa</i> sections <i>Rhodochlamys</i> & <i>Callimusa</i> ; <i>Musella lasiocarpa</i>
<i>Flower Symmetry</i>	Zygomorphic	Nearly Actinomorphic	<i>Musa nanensis</i>
<i>Stamen Number</i>	5 functional + 1 staminode	6 functional stamens (fused)	<i>Musa nanensis</i>
<i>Tepal Fusion</i>	3 outer + 2 inner fused; 1 free	All 3 outer + 3 inner fused	<i>Musa nanensis</i>
<i>Bract Behavior</i>	Revolute	Non-revolute	<i>Musa balbisiana</i> & <i>Australimusa</i> sp

<i>Chromosome Number</i>	<i>Musa</i> sect. <i>Musa</i> ; <i>Ensete</i> and <i>Musella</i> are consistently $2n = 18$	<i>Section Ingentimusa</i> : $2n = 14$ (Exception) <i>Musa beccarii</i> (<i>Section Callimusa</i>): $2n = 18, 20$ (Variability, 18 is an exception) <i>Section Australimusa</i> : $2n = 20$ (Common for the section) <i>Eumusa/Rhodochlamys</i> : $2n = 22$ (Common, but $3x=33$ is common in cultivated types)	<i>Musa</i> sections <i>Callimusa</i> & <i>Ingentimusa</i>
<i>rowth Habit</i>	Soft-wooded herb	"Woody" appearance	<i>Ensete</i> species & some large <i>Musa</i>
<i>Seed Morphology</i>	Sub-globose	Cylindrical/Barrel-shaped	<i>Musa</i> section <i>Callimusa</i>
<i>Habitat</i>	Tropical/Subtropical	High elevation cold tolerance	<i>Ensete ventricosum</i>

Important Remarks on Significant Exceptions in Musaceae

- Defying the Diploid Norm: Due to their high heterozygosity and decreased fertility, cultivated bananas are often seedless and parthenocarpic, often displaying triploidy ($3x$) or sometimes tetraploidy ($4x$), such as AAAA or AAAB.
- Genus Differences: Although *Musa* and *Ensete* have similar habits, *Musa* is perennial and produces suckers, whereas *Ensete* is monocarpic (died after blooming).
- Fruit Edibility: *Ensete* and certain *Musa* sections (like *Callimusa*) have tiny, hard, seed-filled fruits, although many *Musa* produce edible parthenocarpic fruit.

9. Orchidaceae (Orchid Family)

Following are notable exceptions in Orchidaceae to the general rules:

- Exceptions in Floral Symmetry (Non-Resupinate or Regular Flowers)
 - Non-Resupinate Orchids: Most orchids twist their flowers 180 degrees during development (resupination) so the lip is at the bottom, but some, like the Bog Orchid (*Hammarbya paludosa*) and Fen Orchid (*Liparis loeselii*), do not properly rotate or rotate 360 degrees, making them appear upside down.
 - Actinomorphic Flowers: Although nearly all orchids are zygomorphic, Apostasia and Neuwiedia are primitive genera that have more regular, radial symmetry.

- Lip Placement: In the Fen Orchid (*Liparis loeselii*), the flower is tilted backwards, placing the lip above the rest of the flower, rather than below.
2. Exceptions in Nutrition (Non-Photosynthetic)
 - Mycoheterotrophic Orchids: Unlike most orchids that produce their own food, these species are entirely dependent on fungi for nutrients throughout their lives and lack chlorophyll.
 - Examples: *Neottia nidus-avis*, *Epipogium aphyllum*, and *Corallorhiza trifida*.
 3. Exceptions in Pollen Structure
 - Loose Pollen: Generally orchids have waxy, sticky pollen (pollinia). But, primitive orchids like *Apostasia* and *Neuwiedia* possess loose, granular pollen.
 - Exine Variation: Although mostly orchids have specific exine structures, the genus *Anacamptis* shows very little, uniform variation (psilate–scabrate), whereas others in the same tribe have highly varied patterns.
 4. Exceptions in Reproductive Habits
 - Vegetative Reproduction: Although orchids normally reproduce via seeds *Hammarbya paludos* can produce small bulbils on its leaf margins.
 - Stoloniferous Growth: *Herminium monorchis* produce new, plants by stolons.
 5. Exceptions in Column/Stamen Structure
 - Diandroideae Subfamily: Although most orchids have one fertile stamen (Monandreae), the Cypripedeae tribe (e.g., *Paphiopedilum*, *Cypripedium*) has 2 fertile anthers, a significant structural departure from the rest of the family.
 6. Exceptions in Fruit/Seed Dispersal
 - Fleshy Fruits: Although most orchids have dry capsules, some genera like *Vanilla* produce fleshy, aromatic fruits designed for animal dispersal.

Summary Table of Exceptional characteristics in Orchidaceae

<i>Features</i>	<i>Typical family Characteristics</i>	<i>Exceptions</i>
<i>Habit/Life Form</i>	Perennial herbs (Terrestrial or Epiphytic)	Rarely annual; some are climbers or vines; many are saprophytic/myco-heterotrophic (no chlorophyll)
<i>Photosynthesis</i>	Autotrophic (Green)	~200+ species are achlorophyllous myco-heterotrophs, relying entirely on fungus for carbon
<i>Leaves</i>	Simple with parallel veins	A few species show net-like (reticulate)

		venation, e.g., in subfamily Vanilloideae. Some are leafless, e.g., <i>Taeniophyllum</i>
<i>Floral Symmetry</i>	Zygomorphic (Bilaterally Symmetric)	Rarely actinomorphic, e.g., some <i>Nilssonia</i> or abnormal flowers
<i>Resupination</i>	180° twist of pedicel/ovary	Non-resupinate orchids (flowers stay upright), e.g., some <i>Epidendrum</i>
<i>Stamens</i>	One fertile stamen (Monandry)	Two fertile stamens in Subfamily Cypripedioideae (Lady's Slippers)
<i>Pollen Structure</i>	Pollinia	Some basal, primitive species have powdery pollen (farinaceous)
<i>Habit (Growth)</i>	Sympodial (most common) or Monopodial	Diverse, from tiny 5mm plants (<i>Bulbophyllum</i>) to 3.5m+ tall (<i>Grammatophyllum</i>)

Important Remarks on Significant Exceptions in Orchidaceae

- Habit:** *Taeniophyllum* species do not have leaves or stems; instead, photosynthesis and blooming are only carried out on the flattened aerial roots.
- Vanilloideae Leaves:** In contrast to most monocots, *Vanilla* and related genera have net-like venation, a typically dicot feature.
- Chlorophyllous Orchids:** Plants that live as parasites on fungus (myco-heterotrophy), like *Neottia nidus-avis* (bird's nest orchid), have no green leaves or chlorophyll at all.
- The "Two-Stamen" Exception:** The lady's slipper orchids (Cypripedioideae) contain 2 functional stamens, indicating a more primitive condition than the majority of orchids, which are monandrous (1 stamen).
- Absence of the Rostellum:** Not all subfamilies have the rostellum, a trait that inhibits self-pollination.

10. Poaceae (Grass Family)

Major Exceptions in the Poaceae Family are as follows:

- **Unisexual Flowers (Monoecious/Dioecious):** Although most grasses have bisexual (hermaphrodite) flowers, maize (*Zea mays*) has separate male (tassel) and female (ear) flowers on the same plant (monoecious). Buffalo grass (*Buchloe dactyloides*) is another exception, often having separate male and female plants (dioecious).
- **Solid Stems:** The typical grass stem is hollow, but some exceptions have solid stems, such as maize, sugarcane, and some sorghum species.
- **Fleshy Fruit:** Instead of the typical dry caryopsis (grain), some bamboos have a berry-like fruit with a fleshy, thick pericarp.

- **Vivipary/Pseudovivipary:** Bulbous bluegrass (*Poa bulbosa*) is an exception that reproduces using asexual bulbils (small plants) that grow in place of seeds, a condition known as pseudovivipary.
- **Leaf Arrangement:** Although typically two-ranked (distichous), some primitive grasses, such as *Anomochloa*, have leaves arranged in a spiral pattern.
- **Flower Structure (Lodicules):** Although most grass flowers have 2 lodicules, some bamboo species can have 0 to 3 or more.
- **Growth Habit:** Although most are herbaceous, bamboo (Bambusoideae) grows into woody, tree-like structures.

Examples of Specific Exception Species

- **Maize (*Zea mays*):** Solid stems, bisexual spikelets, monoecious.
- **Bamboo (various species):** Woody, solid stems, fleshy fruit.
- **Bulbous Bluegrass (*Poa bulbosa*):** Produces asexual bulbils instead of seeds.
- **Buffalo Grass (*Buchloe dactyloides*):** Dioecious (separate male/female plants).
- **Sugarcane (*Saccharum officinarum*):** Solid stems.
- **Rice (*Oryza sativa*):** Possesses some, though rare, hermaphroditic flowers, yet in many, the spikelet is highly modified.

Summary Table of Exceptional characteristics in Poaceae

<i>Feature</i>	<i>Typical family Characteristic</i>	<i>Exceptions</i>
<i>Habit/Stem</i>	Herbaceous, annual/perennial herbs	Woody and tree-like in Bamboos (<i>Bambusa</i> , <i>Dendrocalamus</i>)
<i>Stem Structure</i>	Hollow at internodes (fistular)	Solid stems in some species (e.g., <i>Andropogon</i> spp.)
<i>Leaf Arrangement</i>	Distichous (two rows)	Spiral arrangement in some species.
<i>Stem Shape</i>	Cylindrical	Flattened or angular in some grasses.
<i>Flower Sex</i>	Bisexual (Hermaphrodite)	Unisexual in some, e.g., Maize (<i>Zea mays</i>), Buffalo grass
<i>Stamen Number</i>	Usually 3	Can be 1, 2, or 6 (e.g., Rice, Bamboos)
<i>Perianth</i>	Reduced to 2–3 Lodicules	Many lodicules in <i>Ochlandra</i>
<i>Stigmas</i>	2-3 feathery	Stigmas modified in some species for different pollination strategies
<i>Fruit Type</i>	Caryopsis (dry grain)	Nut-like in some bamboos; berry-like in some <i>Melocalamus</i> .

- ***Streptogyna*:** A tribe that sometimes shows more than 2 stamens.
- The 12 subfamilies of Poaceae vary, although the Bambusoideae (bamboos), Panicoideae (maize/sugarcane), and particular genera like *Poa* differ.

Important Remarks on Significant Exceptions in Poaceae

- **Woody Habit (Bamboos):** Although the majority of grasses are herbs, members of the Bambusoideae subfamily (e.g., *Bambusa*) develop woody, tall, tree-like stems.
- **Monoecious/Unisexual Flowers:** Although most grasses are hermaphrodite, maize (*Zea mays*) is a notable exception, which produces distinct male and female flowers on the same plant.
- **Fruit Modification:** The pericarp (caryopsis) and seed coat are united in normal grasses. Some bamboos have a berry-like fleshy fruit wall.
- **Stamen Number:** Three stamens is the norm. However, some species are reduced to one or two, although rice (*Oryza*) has six.
- **Leaf Modification:** Certain bamboos have leaves with a characteristic petiole-like base rather of being strictly linear.

These anomalies demonstrate the Poaceae family's great degree of evolutionary adaptation to a variety of habitats.

11. Zingiberaceae (Ginger Family)

Major Exceptions in Zingiberaceae with Examples are as follows:

- **Unilocular Ovary (Instead of 3-locular):** Although most Zingiberaceae have a 3-locular ovary, the tribe Globbeae (e.g., *Globba*) has a unilocular ovary with parietal placentation.
- **Partially Unilocular Ovary:** Exceptions to the trilocular rule also include *Caulokaempferia*, *Paracautleya*, *Scaphochlamys*, *Siphonochilus*, and *Riedelia*, which are partially unilocular.
- **Absence of Staminodes:** Lateral staminodes are typically well-developed or petaloid, but they are completely absent in the genus *Rhynchanthus*.
- **Non-Aromatic Habit:** Most members are aromatic, but the subfamily Costoideae (which includes *Costus*, often treated in the closely related Costaceae family but sometimes associated) is generally not aromatic.
- **Spiral Leaf Arrangement:** Most Zingiberaceae have distichous leaves, but the Costoideae subfamily (e.g., *Costus*) has spiral, monistichous leaves.
- **Inflorescence Exception:** *Zingiber clarkii* is noted as an exception within the *Zingiber* genus for having 2–4 flowers per bract instead of the typical single flower.
- **Sterility:** *Curcuma longa* (turmeric) is an example of an exception in reproduction, as it is often sterile and incapable of producing seeds, relying on vegetative propagation.
- **Exceptions in Subfamily/Tribal Characteristics:**
- *Siphonochilus* (Tribe *Hedychieae*): Unlike many in its tribe, *Siphonochilus* has lateral staminodes fused to the central labellum.

- *Tamijia* (Tribe *Alpinieae*): *Tamijia* is a narrow endemic from Borneo that acts as an exception in the *Alpinieae* by having a unilocular ovary.

Summary Table of Exceptional characteristics in Zingiberaceae

<i>Feature</i>	<i>Typical family Characteristic</i>	<i>Exceptions</i>
Habit	Terrestrial herbs	Epiphytic
Stem	Pseudostem (wrapped leaf sheaths)	<i>Costus</i> species have aerial stems with non-overlapping leaf sheaths (true stem)
Leaf Arrangement	Distichous (2-ranked)	<i>Costus</i> species exhibit a spiral, or single-row, arrangement
Aroma	Aromatic (essential oils)	Costaceae (closely related) are not aromatic
Leaf Structure	No pulvinus (joint)	A distinct pulvinus is present at the petiole-ligule junction in <i>Zingiber</i>
Inflorescence Position	Terminal (on leafy stem)	<i>Curcuma</i> , <i>Zingiber</i> , & <i>Etlingera</i> often have separate, ground-level (scapose) inflorescences
Inflorescence Type	Spike or Raceme	Panicles exist, particularly in some <i>Alpinia</i> species
Flowers per Bract	Usually 1 (monochasial)	<i>Zingiber clarkei</i> has 2–4 flowers per bract
Ovary Locules	3-locular (tricarpellary)	Unilocular with parietal placentation in <i>Globba</i>
Staminodes	2-4, often petaloid	Lateral staminodes are often absent or reduced to small teeth in <i>Curcuma</i> and <i>Zingiber</i>
Labellum	Formed by 2 fused staminodes	Sometimes the labellum is deeply 2-cleft (e.g., <i>Zingiber</i>)
Fruit Type	Loculicidal Capsule	Some species bear fleshy, berry-like fruits (e.g., <i>Aframomum</i>)
Seeds	Arillate (with aril)	Aril may be absent or rudimentary in some, such as <i>Renealmia</i> or <i>Costus</i> .

Important Remarks on Significant Exceptions in Zingiberaceae

- **Staminode/Labellum Variation:** The labellum is the most variable component; it frequently has lateral staminodes and a three-lobed shape, but it can also be decreased or completely fused with the labellum.
- **Ovary Structure:** *Globba* & *Haplochorema* are recognized for being unilocular, whereas the majority of Zingiberaceae are 3-locular.

- The *Costus* Case: *Costus*, which is now a member of the Costaceae family, is very different from "true" gingers (Zingiberoideae) in that it lacks ligules, has a spirally organized, non-sheathing stem, and lacks aromatic chemicals.
- *Zingiber* Exceptions: *Zingiber clarkei* stands apart among the other plants in the *Zingiber* genus because it produces several blooms on each bract.

'Your work is not to drag the world kicking and screaming into a new awareness. Your job is to simply do your work... sacredly, secretly, silently ... and those with "eyes to see and ears to hear' will respond.' – The Arturians

CHAPTER 7

Some Practical Aspects

Chapter Contents:

- Guidelines for Field Notebook preparation
- Botanical Excursion (Educational Tour)
- Some Exceptional features observed in Plants
- List for the types of phyllotaxy, aestivation, inflorescence, fruit, ovary, and placentation, in the families (Dicot): (Acanthaceae, Annonaceae, Apiaceae, Apocynaceae, Asclepiadaceae, Asteraceae, Brassicaceae, Cucurbitaceae, Dipterocarpaceae, Ericaceae, Euphorbiaceae, Fabaceae (Mimosaceae, Caesalpinaceae, Papilionaceae), Lamiaceae, Magnoliaceae, Myrtaceae, Malvaceae, Ranunculaceae, Rosaceae, Rubiaceae, Rutaceae, Scrophulariaceae, Solanaceae, Sterculiaceae, Tiliaceae, Verbenaceae)
- List for the types of phyllotaxy, aestivation, inflorescence, fruit, ovary, placentation, in the families (Monocot): (Alismataceae, Amaryllidaceae, Araceae, Arecaceae, Commelinaceae, Cyperaceae, Liliaceae, Musaceae, Orchidaceae, Poaceae, and Zingiberaceae)
- Description of some selected plants for practical (work out)
- A quick look at a few fascinating flowering plants

❖ GUIDELINES FOR FIELD NOTEBOOK PREPARATION

In plant Taxonomy, a field notebook is an essential document of a plant specimen's natural surroundings. As plants usually lose its original color, fragrance, and posture after pressing (drying), these characteristics are vital for scientific Validation.

1. Fundamental Equipment & Formatting

- a) **Selection of Notebook:** Take a compact notebook (about 4" x 6") with ruled pages that is firmly bonded. To avoid missing pages, stay away from loose-leaf binders.
- b) **Ink:** Use indelible (waterproof) ink or a hard-lead pencil. Standard ink can smear if the notebook gets wet in the field.
- c) **Collection Numbers:** Assign each specimen a unique, sequential number (beginning at 1). This number must also be put on the plant's tag and the newspaper fold.

2. Basic Data Points for Every Entry

Every specimen entry should include the following:

- a) **Collection Date:** Format as DD-MMM-YYYY (e.g., 09 Oct 2026) to prevent ambiguity.
- b) **Collector(s):** List your entire name and the names of any companions.
- c) **Locality:** Be precise. Include nation, state, county, and distance/direction from a permanent landmark (e.g., "2 miles South of Jct. Hwy 231").
- d) **GPS Location:** Note the exact latitude, longitude, and elevation.
- e) **Habitat:** Describe the slope aspect, light exposure (full sun, shade), soil type (sand, clay, loam), and wetness (wet, mesic, xeric).
- f) **Associated Species:** List additional plants occurring in the local neighborhood to define the vegetative community.

3. Morphological Observations (The "Unpreservables")

- a) Record characteristics that will be lost or altered during the drying process.
- b) **Plant Habit:** Note whether it is a tree/shrub/herb/climber, and determine its height/diameter.
- c) **Color:** Describe the precise color of petals, sepals, and fruit. If feasible, standardize using a color chart.
- d) **Scent and Exudate:** Take note of the color and consistency of any sap or latex, such as milky or clear, as well as any characteristic odor, particularly when leaves are crushed.
- e) **Abundance:** Indicate if the plant is dominating, common, or rare in the area.
- f) **Local Names & usage:** Record indigenous names and traditional usage if supplied by local inhabitants.

4. Best Practices for Fieldwork

- a) **Durable Notebook:** Use a sturdy notebook or binder (like an 8.5"x11" 3-ring binder) with sturdy paper.
- b) **One Page/Entry:** Dedicate one page (or section) per collection for clarity.
- c) **Ink & Pencil:** Write in ink but use a pencil for sketching and initial notes; don't erase, just cross out errors.
- d) **Real-Time Recording:** Write your notes before collecting the plant when the specimen is still in its natural condition. Never rely on memory to fill in information later.
- e) **No Recopying:** Your field notebook is the main document. To make it "more tidy," don't recopy it because this will generate transcription problems.

- f) **Sketching:** Add short realistic drawings of fruits, leaves, flowers, cross-sections of flower, leaf groupings or general habits that highlight anatomical features like veins or reproductive organs. Sketches frequently reveal subtleties unseen by photography.
- g) **One Side Only:** Write on only one side of the page to allow for later additions or comments.
- h) **Chronological:** Record entries as soon as possible, preferably during observation in a chronological order.
- i) **Add Questions:** Also write down any queries or original ideas that come to your mind.
- j) **Numbering System:** To make tracking specimens and comments simple, use a uniform numbering System.
- k) **Data Sheets:** If necessary, use distinct data sheets for quantitative information (counts, measurements).

❖ BOTANICAL EXCURSION (EDUCATIONAL TOUR)

The process of education is taking or giving organized lessons, especially at a college or university. Students use the ideas they just learned at institutes to learn more and improve their skills. Teachers use a lot of different ways to teach their lessons to their students. One way is to plan educational tours. Educational tours are important for teaching students in an interesting and useful way. It is a natural fact that we can understand something better when we see it than when we read about it or try to remember it from a book. It is much better to learn something by doing it than by reading about it in a book. Also, learning by doing helps us remember things better. Taking students on field trips with an educational focus can help them learn the material much better. Educational tours can be fun, relaxing, and a way for students to deal with stress. Every school should try to get students to go on field trips that teach them something. Educational tours are a good idea to add to the curriculum because they help students learn more. Educational tours are meant to improve students' overall learning and growth by focusing on their interests. When students go on an educational tour, they are energised, thrilled, and excited to see new things and relax in new places. It's fun and interesting to go from one city to another with your classmates and friends. It gives students a chance to look at things from a different point of view while trying to learn more about new situations in a relaxed setting. Educational tours are common in schools and colleges today because they help students learn more.

Significance of educational trips or, the objectives of the educational tour

Thoughts about Educational trips are popular during the formative years, in part because they give both students and teachers a break from the usual routine. Even though their main goal is to teach, they can also be a fun way for everyone to get to know each other better.

Improving Classroom Learning:

The main goal of educational trips is to improve learning in the classroom. They let students experience what they have learned in the classroom by seeing, touching, and doing it. One way for students to learn more about art, history, and society is to go to a museum or art gallery. Science museums and study facilities can also be visited on educational trips to help students learn more about science and technology.

Students can also experience themes in the real world on educational trips. This can help them understand how the ideas they learn in class are used in the real world. On the other hand, going to a farm can help students learn about gardening and how it affects the food they eat.

Reinforcement

The trip can help students understand a subject better and remind them of what the teacher has been teaching about it in class.

Engagement

Teachers use field trips as mobile classrooms by telling students to collect data and then quizzing them or giving them a project based on what they learned.

Socialization

By taking students to new places, they learn how to travel as a group with respect.

Exposure

The students get to go somewhere they've never been before. This can be especially helpful for students who don't have much money and can't afford to travel.

Curiosity

When students go on trips that teach them something, they often want to learn more.

Retention

Educational trips help children make "episodic memories," to remember things for longer.

New sights

When teachers and students are together outside of the classroom, they can learn in and about new places and situations. If the educational trip is to a planetarium, students may be able to see many things they can't see at school, like exotic animals, rare plants, and maybe even the stars. Talking about the Educational trip before it happens is a good idea because it lets the students know what they will do while they are away from school.

Bonding

Getting out of the usual classroom setting gives students a chance to spend time with each other in a new place. They might be able to get to know each other better if they don't have to follow the rules of a school day. Students might be able to spend most of the day on an educational trip in small groups, watching, talking, and getting to know each other. A field trip early in the school year is a good idea because it gives students a chance to get to know classmates they might not know very well.

Establishments to learn informally

Educational trips are a great way to learn outside of the classroom, without textbooks and other tools that are usually used in school. On educational trips, students can often learn and have fun in a less formal setting. If the educational trip destination, like a science centre or historical museum, has staff members who teach students directly, the kids will be excited to learn from someone new.

Perspective

Educational trips help students learn about the world from different points of view. This is especially true for longer school trips that take students farther from home. By living in a different place or learning a new culture or language, students can learn more about their place in the world and become more accepting of others' differences.

Variety

Lesson plans can also be made more interesting by including educational trips. Students don't have to spend every day in the classroom. Instead, they get to learn in a new place with different teachers. Educational trips may also give students the chance to learn with or do group activities with students from other schools.

Styles of Learning

Educational trips often fit more than one way of learning, which makes them great ways to teach some students. Classroom lectures are mostly for people who learn best by listening, which is most people. Visual learners can benefit from visual aids, which are sometimes used

in the classroom but much more often on an educational trip. Lastly, educational trips give people who learn best through touch a rare chance to learn by doing.

Classroom Supplement

It's important for teachers and school administrators to choose field trips that add to and go along with what students are learning in the classroom. When teachers choose an educational trip for these reasons, it can help them explain difficult ideas or add more detail to a general lesson by giving them more information. Specialists who take school groups on educational trips may also be able to give professional advice that teachers could never give on their own, based on their advanced education or direct experience.

Reward

Students can start to benefit from an educational trip even before it happens. By not letting students on an educational trip who have problems with their behavior or grades, teachers can encourage good behavior and get students to work hard so they can go on an educational trip. Even the most educational trips usually include some time for fun, so they are a way for all students to relax.

It is fun and teaches a lot.

Because their minds are at ease, students are more likely to learn on an educational trip. They don't worry about being in a competitive classroom. Even if students learn a lot on an educational trip, they may remember the day best because they had fun. Students are always excited to get out of school for a day or even half a day, and educational trips are always very much looked forward to. Students will have fun with their friends, and when they go back to school, they may be more ready to do their work.

Get out of your rut

Students think of educational trips as longer times to play. If you find that your students are getting tired of a topic, you could use a relevant educational trip to make the topic more fun.

Find Out Something

There are interesting facts that aren't in the textbooks that would be great to know. Many experts can share what they know about your topic to help you learn more.

Shows how to be a professional

During school trips, teachers expect their students to be on their best behaviour. This is a way to teach students how to act in a professional setting and how to be polite.

Sense of community grows

If your educational trip is somewhere close to home, students will learn more about where they live. This sometimes makes the students want to be more involved in their communities and help protect the things that make them special.

Gets people interested in new jobs

Most educational trips have a tour guide or a person in charge who leads the group. These people can tell students about the kinds of jobs that are out there for people who are interested in that topic.

Experience in the real world

When you go on an educational trip, you can fully immerse yourself in the natural environment and social setting. Students get to use their social skills and critical thinking outside of the controlled classroom setting. It takes some thought to be able to ask experts about their field of study on the spot. He can learn lessons from the real world.

Ideas for the classroom

When a student sees, touches, and smells historical relics, ancient artifacts, and the original sources of a text, it makes him want to learn more when he goes back to class. Educational trips help students learn more than what they can get from books and videos. This doesn't mean that all educational trips are equally interesting, but well-planned trips lead to higher levels of academic achievement in every subject. When he is on an educational trip led by a professional, like to a museum or science centre, he is learning in an informal setting. This lets everyone learn without realising it, so more students from different learning backgrounds and styles can take part.

Connection to the Neighbourhood

For students with low incomes or who are new to the school, field trips that use local resources help them connect with the community. For example, a student may never be able to go to a local park or bank, which are both important places for the student and his family to use. Students whose families don't speak English or who just moved to the area can learn about the neighbourhood with the help of their school and then share what they've learned with their families when they get back home.

Permission Slips

At least a month before the trip, give out permission slips. So, you don't have to bug your students until the last minute, offer a class reward like extra recess time if all permission slips come back at least a week before the trip.

Parent Chaperones

Send a note to the parents explaining how your trip will help them learn and asking for help.

Give each of your students a number.

If there are a lot of students, you might want to give each one a number at the start of the trip. Then, instead of checking off a list of people who are there or counting heads, you can ask students to quickly call out their numbers in order.

Conclusion:

In conclusion, it can be said that educational tours are very important for learning. They help pupils learn more in the classroom, grow socially and emotionally, and experience things that happen in real life. Tours for educational institutions give pupils a unique chance to learn in a new place and discover new hobbies and skills. Therefore, educational tours should be an integral part of every student's education.

Plant families are often defined by a collection of consistent, distinguishing features. However, because of evolution, environmental adaptation, or parasitic lives, many plants differ from these standards.

❖ IMPORTANT EXCEPTIONAL FEATURES FOUND IN PLANTS

Monocot Exceptions (Generally Parallel Venation)

- a) Monocots usually have fibrous roots and parallel leaf venation, however others have characteristics similar to dicots:
- b) Reticulate (Net-like) Venation: Rather than parallel, *Smilax zeylanica* and *Colocasia esculenta* have reticulate venation.
- c) Non-endospermic Seeds: Orchidaceae (orchids) and *Alisma* have non-endospermic seeds, whereas monocots are usually endospermic.
- d) Secondary Growth: While most lack cambium, some monocots like *Dracaena* and *Aloe* display anomalous secondary growth.

Dicot Exceptions (Generally Reticulate Venation)

Parallel Venation: *Calophyllum inophyllum*, *Aciphylla* and *Eryngium yuccifolium* have parallel venation, a characteristically monocot characteristic. Despite this, they are dicots.

Note: Eryngium and Aciphylla are significant deviations within the Apiaceae family, as they display leaves with parallel venation, comparable to monocotyledonous plants, even though they are dicots.

Deviations from the Root and Habit

Photosynthetic Roots: Although roots are normally non-green, *Tinospora* contains green, photosynthetic roots.

- a) **Rootless Plants:** *Utricularia* (bladderwort) and *Wolffia* (duckweed) have no roots.
- b) **Parasitic Habits:** *Cuscuta* (dodder) is a parasitic plant that lacks cotyledons and chlorophyll.

Particular Environmental Modifications

- a) **Mangrove Roots:** Roots are normally geotropic (develop downwards), however mangroves like *Rhizophora* and *Avicennia* feature negatively geotropic pneumatophores (roots that develop upward seeking oxygen).
- b) **Carnivorous Plants:** In contrast to the majority of autotrophic plants, families such as Nepenthaceae (pitcher plants) and Droseraceae (sundews) have evolved to capture insects in order to get nutrients in soils that lack nitrogen.

Floral and Reproductive Deviations

- a) **Vesselless Angiosperms:** Although vessels are a feature of angiosperm xylem, families like Winteraceae lack vessel components.
- b) **Cauliflory:** In several woody species of Sterculiaceae (now part of Malvaceae, e.g., *Theobroma cacao*), flowers develop straight from the main, thick branches (cauliflory) rather than immature, green branches.
- c) **Androgynophore:** In Caryophyllaceae (carnation family), a stalk termed an androgynophore sometimes holds both the androecium and gynoecium above the petals.

<i>Exception to the General Rule with examples</i>			
<i>Feature</i>	<i>General Monocot Character</i>	<i>Exception / Deviation</i>	<i>Examples</i>
Leaf Venation	Parallel Venation	Reticulate (Net-like) Venation	<i>Smilax, Alocasia, Dioscorea (Yams), Trillium</i>
Secondary Growth	Absent (Herbaceous)	Present (Anomalous Secondary Growth)	<i>Palms, Dracaena, Yucca, Aloe</i>
Flower Merosity	Trimerous (3s)	Tetramerous (4s) or Polymerous	<i>Paris quadrifolia (4s), Potamogeton</i>
Root System	Fibrous (Adventitious)	Bulbous/Tuberous/Thickened Roots	<i>Dioscorea, Ginger, many Orchidaceae</i>
Cotyledons	One (Single)	Two (appearing/fused)	<i>Nymphaea (Water Lily - actually a basal angiosperm, sometimes misclassified)</i>
Habit	Herbaceous	Woody/Arborescent (Tree-like)	<i>Bamboo, Palms (Arecaceae), Bananas</i>

Exception to the General Rule with examples		
Dicot Character	Deviation/Exception	Examples
Number of Cotyledons	One cotyledon instead of two (Monocot-like)	<i>Persoonia, Ranunculus ficaria</i>
Number of Cotyledons	More than two cotyledons	<i>Proteales</i> (3-8 cotyledons)
Number of Cotyledons	No cotyledons (Acotyledonous)	<i>Cuscuta</i> (parasitic)
Leaf Venation	Parallel Venation (Monocot-like)	<i>Calophyllum</i> <i>inophyllum, Eryngium yuccifolium</i>
Flower Merosity	Trimerous (3-part) flowers (Monocot-like)	<i>Berberis, Ranunculus</i> (some species)
Stem Anatomy	Scattered Vascular Bundles (Monocot-like)	<i>Ranunculus, Thalictrum, Piper</i>
Root System	Fibrous Roots (Monocot-like)	<i>Ranunculus</i>
Root Function	Photosynthetic (Green) Roots	<i>Tinospora</i>
Seed Endosperm	Endospermic (Albuminous) Seeds	<i>Castor, Sunflower, Solanaceae</i>
Parasitism	No roots	<i>Cuscuta</i>

Phyllotaxy, Aestivation, Inflorescence, Fruit, Ovary, Placentation Types in Dicot families:

Family	Phyllotaxy	Aestivation	Inflorescence	Fruit	Ovary	Placentation
Acanthaceae	opposite and decussate	Calyx imbricate or valvate; Corolla imbricate or contorted (twisted)	Cymose, raceme, or spike (often with large, colorful bracts). Common types: terminal or axillary spikes	Loculicidal capsule (explosively dehiscent) seeds with jaculato (helps in seed dispersal)	superior bilocular	Placentation axile
Annonaceae	Alternate	Valvate or Imbricate	Solitary or Fascicle	Aggregate (Etaerio of Berries)	Superior (Apocarpous)	Marginal or Basal
Apiaceae	alternate, rarely opposite on upper stems	Both calyx & corolla valvate or imbricate	simple or compound umbel, involucrate	Cremocarp (splits into 2 one-seeded mericarps.)	inferior, bicarpellary	apical-axile (1-pendulous anatropous ovule per locule)
Apocynaceae	Opposite or Whorled	Valvate or Twisted (Convolute)	Cymose	Follicle, Berry, or Drupe	Superior or Semi-inferior	Marginal or Axile
Asteraceae	Alternate or Opposite	Valvate (Calyx as Pappus)	Capitulum (Head)	Cypsela	Inferior	Basal
Brassicaceae	Alternate	Valvate	Racemose or Corymb	Siliqua or Silicula	Superior	Parietal
Cucurbitaceae	Alternate	Imbricate	Solitary or Racemose	Pepo	Inferior	Parietal
Dipterocarpaceae	Alternate	Twisted (Contorted)	Racemose or Panicle	Nut (usually winged)	Superior	Axile
Fabaceae (Papilionaceae)	Alternate	Vexillary (Descending Imbricate)	Racemose	Legume (Pod)	Superior	Marginal
(Caesalpinaceae)	Alternate	Imbricate (Ascending)	Raceme or Panicle	Legume	Superior	Marginal
(Mimosaceae)	Alternate	Valvate	Globose Head or Spike	Legume	Superior	Marginal
Lamiaceae	Opposite	Valvate or	Verticillaster	Carcerulus	Superior	Axile

	Decussate	Imbricate		(4 Nutlets)	(Gynobasic style)	
Magnoliaceae	Alternate	Imbricate	Solitary Terminal	Etaerio of Follicles or Samaras	Superior	Marginal
Malvaceae	Alternate	Valvate (Sepals), Twisted (Petals)	Solitary or Cymose	Capsule or Schizocarp	Superior	Axile
Myrtaceae	Opposite, sometimes alternate	calyx valvate; corolla imbricate or quincuncial	cymose, appearing as panicles, or cymes	berry (guava) or loculicidal capsule	Inferior, 2 to 5 locules	Axile
Ranunculaceae	Alternate	Imbricate	Solitary or Cymose	Etaerio of Achenes or Follicles	Superior	Marginal
Rosaceae	Alternate	Imbricate	Solitary, Racemose, or Cymose	Drupe, Pome, or Etaerio	Superior or Inferior	Axile or Marginal
Rubiaceae	Opposite Decussate	Valvate, Imbricate, or Twisted	Cymose	Capsule, Berry, or Drupe	Inferior	Axile
Rutaceae	Alternate or Opposite	Imbricate	Solitary or Cymose	Hesperidium or Capsule	Superior	Axile
Scrophulariaceae	Alternate (sometimes opposite or whorled)	Calyx valvate or imbricate; Corolla imbricate	Raceme, spike, or panicle,	Septicidal/loculicidal capsule; rarely berry	Superior, bicarpellary	Axile
Solanaceae	Alternate	Valvate	Cymose or Solitary	Berry or Capsule	Superior	Axile
Sterculiaceae	Alternate	Calyx valvate; Corolla twisted or valvate	Mainly cymose, axillary/terminal panicles, or sometimes solitary	capsule (loculicidal or septicidal) or schizocarp of follicles	Superior, 2 to 5-locular	Axile

Tiliaceae	Alternate	Calyx valvate; Corolla imbricate or contorted	Mainly cymose, often in axillary or terminal panicles, or cymes	Highly variable, from capsules to drupes	Superior, 2-10 locular	Axile
Verbenaceae	Opposite or Whorled	Imbricate	Spike, Raceme, or Cyme	Drupe or Schizocarp	Superior	Axile

Phyllotaxy, Aestivation, Inflorescence, Fruit, Ovary, Placentation Types in Monocot families:

Families	Phyllotaxy	Aestivation	Inflorescence	Fruit	Ovary	Placentation
Alismataceae	Basal, alternate, or whorled	Valvate (calyx) imbricate (corolla).	Scapose panicle or raceme, often with whorled branches	Aggregate of achenes or follicles	Superior, Apocarpous (carpels 3-numerous, free)	Basal
Amaryllidaceae	Basal, distichous (two-ranked), linear or strap-shaped	Valvate (tepals)	Umbellate cyme, often subtended by a spathaceous bract	Capsule (loculicidal) or rarely a berry	Inferior (usually) or Superior (in Alliioideae/Agapanthoideae)	Axile
Araceae	Simple or lobed leaves, usually basal or alternate	Generally absent or valvate (in bisexual flowers)	Spadix (fleshy spike) surrounded by a leafy spathe	Berry, often aggregated into a syncarp	Superior, syncarpous (sometimes reduced to 1 carpel)	Parietal, Basal, or Axile
Arecaceae	Alternate, often crowded at the apex, pinnate or palmate	Valvate or imbricate (tepals)	Large, branched spadix enclosed in a woody spathe	Drupe (often fibrous) or Berry	Superior, syncarpous or apocarpous	Basal or Axile
Commelinaceae	Alternate, often with sheathing bases	Imbricate or valvate	Thyrse, with scorpion tail-like clusters (cincinni)	Capsule (loculicidal)	Superior, syncarpous (3 carpels)	Axile
Cyperaceae	Three-ranked (tristichous), linear, closed leaf sheath	N/A (small, wind-pollinated, or hidden by glumes)	Spikelet (panicle or head)	Achene or nutlet	Superior, Syncarpous	Basal
Liliaceae	Alternate or basal, simple	Valvate (tepals)	Raceme, solitary, or umbellate		Superior, Tricarpellary, Syncarpous	Axile

			cluster			
Musaceae	Large leaves, spirally arranged, with sheathing bases forming a pseudostem	Valvate (petaloid tepals)	Large, terminal, hanging spadix, covered by large bracts	Fleshy Berry	Inferior, Syncarpous (3 carpels)	Axile
Orchidaceae	Alternate, simple, sheathing	Imbricate	Spike or raceme	Capsule (rarely berry)	Inferior, Tricarpellary, Syncarpous	Parietal
Poaceae	Alternate, distichous (two-ranked), sheathing	Valvate (lodicules, if considered perianth)	Spikelet, arranged in spikes or panicles	Caryopsis	Superior, Monocarpellary (often 1 cell, 1 ovule)	Basal
Zingiberaceae	Alternate, distichous, with sheathing bases	Imbricate	Spike or panicle, with bracts	Loculicidal capsule	Inferior, Syncarpous	Axile (rarely parietal)

Taxonomic study of *Brassica campestris* (Brassicaceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Root: Not supplied.

Stem: Aerial, branched, erect, solid, round, smooth, differentiated into nodes & internodes, Color (greenish) & measurement (length of internodes $\pm$ cm).

Leaf: Cauline and ramal; alternate, exstipulate, sessile, simple (pinnate), lower ones lyrate and upper ones oblong or lanceolate with deeply cut margins, acute, glabrous, reticulate - unicastate, green, Size of lamina $\pm$ A x B cm.

Inflorescence: Raceme.

Flower: Ebracteate, pedicelled, complete, regular, dichlamydeous, bisexual, tetramerous, hypogynous, cyclic, Color (yellow) & measurement.

Calyx: Sepals 4, polysepalous, regular, slightly petaloid, valvate, Color & measurement.

Corolla: Petals 4, polypetalous, regular, cruciform, each petal has a distinct claw and limb, deciduous, valvate, hairy, Color (violet) & measurement.

Androecium: Stamens 6 in two whorls (2+4), tetradynamous, 4 inner long and 2 outer short, inserted, basifixed, ditheous, introse, glands occur at the base of 4 stamens, Color & measurement.

Gynoecium: Carpels (2), syncarpous, ovary superior, unilocular but becomes bilocular due to false septum (replum) with many ovules in each chamber, placentation parietal, Style short, Stigma bilobed, Color & measurement.

Fruit: Simple, dry, dehiscent, Siliqua (many seeded 2-celled long, narrow fruit dehiscing from below upwards), Color & measurement.

Floral Formula: $Ebr \oplus \overline{\sigma} K_{2+2} C_4 A_{2+4} \underline{G}_{(2)}$

Taxonomic study of *Callistemon citrinus* (Myrtaceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be small tree.

Root: Not supplied.

Stem: Woody, aerial, branched, erect, solid, round, glabrous (smooth), differentiated into nodes & internodes, length of internodes $\pm$ cm; bark flaky, brownish.

Leaf: Cauline and ramal; alternate, exstipulate, simple (pinnate), subsessile, entire, acute, linear-lanceolate, Size of lamina $\pm$ A x B cm, leathery, gland dotted, reticulate (unicostate), infra-marginal (submarginal veins), green.

Inflorescence: Racemose, pendent intercalary (sub-terminal) spike, proliferating into vegetative shoot.

Flower: Ebracteate, sessile, complete, regular, dichlamydeous, bisexual, penta-merous, epigynous, Color & measurement.

Calyx: Sepals (5), gamosepalous, campanulate, persistent, imbricate, color.

Corolla: Petals (5), gamopetalous, regular; deciduous, imbricate, boat shaped, color (whitish green) & measurement.

Androecium: Stamens numerous, monadelphous (united at base), exerted, versatile, ditheous, filaments long, introse, dehiscence longitudinal, color (bright red), give measurement.

Gynoecium: Carpels (3), syncarpous, fused with hypanthium, ovary inferior, trilocular, Placentation axile, Style long, Stigma capitate, Color & measurement.

Fruit: Simple, dry, capsule, Color & measurement.

Floral Formula: Br. Brl. $\oplus \varnothing$ K (4+5) C₄₋₅ A _{∞} $\overline{G}$ (2- ∞)

Taxonomic study of *Eclipta prostrata* (Asteraceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Root: Not supplied.

Stem: Aerial, branched, erect, solid, terete, glabrous (not hairy), without any exudates, differentiated into nodes & internodes, length of internodes $\pm$ x cm; light brown.

Leaf: Cauline and ramal; opposite-decussate, exstipulate, simple (pinnate), sessile, elliptic-lanceolate, crenulate, acute, Size of lamina $\pm$ A x B cm, reticulate - unicostate, presence of dense hairs, green.

Inflorescence: Capitulum, terminal, heterogamous heads and surrounded by green involucre of bracts which are much hairy.

Flower: Spirally arranged much reduced florets are of 2 types: Ray Florets and Disc Florets, Color & measurement.

Ray Florets: Outer whorl (3-6), bracteates, ligulate, incomplete, Irregular, unisexual, pistillate (female), cyclic and epigynous.

Calyx: Sepals 4, polysepalous, modified into plumose bristle like long pappus, persistent, valvate, Color & measurement ($\pm$ 0.3cm).

Corolla: Petals (4), gamopetalous, irregular; ligulate, tube long, narrow, deciduous, **posterior 2 petals reduced to dentate structures**, valvate, Color & measurement.

Androecium: Absent.

Gynoecium: Carpels (2), syncarpous, ovary inferior, uni-locular, one ovuled ($\pm$ 0.09cm long), erect, anatropous, Placentation basal, Style ($\pm$ 0.4 cm long) slender, terete, terminal and exerted, Stigma bifid and papillose, Color & measurement.

Disc Florets: Numerous, centrally located, spirally arranged, **complete**, bisexual, regular, tetramerous, cyclic, epigynous.

Calyx: Sepals 4, polysepalous, modified into plumose bristle like long pappus, persistent, valvate, Color & measurement (± 0.3 cm). [As in Ray florets]

Corolla: Petals (4), gamopetalous, tubular (± 0.65 cm long), tube cylindric, narrow (± 0.3 cm in diameter), irregular, ovate, erect, deciduous, hairy, 5-lobed, valvate, Color.

Androecium: Stamens 4, syngenesious, epipetalous, (± 0.3 cm long) inserted, basifixed, ditheous, introse, dehiscence by apical pores, Color & measurement.

Gynoecium: Carpels (2), syncarpous, ovary inferior, uni-locular, one ovuled (± 0.09 cm long), erect, anatropous, Placentation basal, Style (± 0.4 cm long) slender, terete, terminal and exerted, Stigma bifid and papillose, Color & measurement. [As in Ray florets]

Fruit: Simple, dry, Cypsella, crowned by bristly pappus, Color (black) & measurement ($\pm 0.2 \times 0.07$ cm). *Floral Formula:* Ray Floret: Br. $\% \text{ } \varnothing K_{\text{pappus}} C_{(5-4)} A_0 \bar{G}_{(2)}$

Disc Floret: Br. $\oplus \text{ } \varnothing K_{\text{pappus}} C_{(5-4)} A_{(5-4)} \bar{G}_{(2)}$

Taxonomic study of *Ageratum conyzoides* (Asteraceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Stem: Aerial, branched, erect, solid, round, hairy, differentiated into nodes & internodes, length of internodes $\pm$ cm; purple green.

Leaf: Cauline and ramal; lower leaves opposite, upper leaves alternate, exstipulate, simple (pinnate), petiolate, subsessile, ovate, serrate, acute, Size of lamina $\pm A \times B$ cm, reticulate - unicostate, green.

Inflorescence: Compound homogamous capitulum, heads are arranged in cymose pattern and surrounded by green involucre of bracts.

Flower: Bracteate, sessile, complete, regular, dichlamydeous, bisexual, penta-merous, epigynous, cyclic, Color & measurement.

Calyx: Sepals 5, polysepalous, modified into plumose bristle like long pappus, persistent, valvate, Color & measurement.

Corolla: Petals (5), gamopetalous, regular; tubular, deciduous, valvate, hairy, Color (violet) & measurement.

Androecium: Stamens 5, syngenesious, inserted, basifixed, ditheous, introse, Color & measurement.

Gynoecium: Carpels (2), syncarpous, ovary inferior, uni-locular, Placentation basal, Style long, Stigma bifid and hairy, Color & measurement.

Fruit: Simple, dry, indehiscent, Cypsella (one-seeded fruit where pericarp & seed coat are free), crowned by bristly pappus, Color & measurement.

Floral Formula: Br. $\oplus \text{ } \overline{\text{K}}_{\text{pappus}} \text{C}_{(5)} \text{A}_{(5)} \overline{\text{G}}_{(2)}$

Taxonomic study of *Tridax procumbens* (Asteraceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Stem: Aerial, branched, erect, solid, terete, hairy (hispid), without any exudates, differentiated into nodes & internodes, length of internodes $\pm$ cm; green.

Leaf: Cauline and ramal; opposite-decussate, exstipulate, simple (pinnate), petiolate, base narrowly half-amplexicaul, lamina ovate-ovate-elliptic or ovate-lanceolate, lower ones pinnatisect, upper ones sinuate & dentate to dentate-serrate, acute, abruptly narrowed to the petiole, Size of lamina $\pm$ A x B cm, reticulate - unicostate, 3-nerved at base, presence of dense hairs having glandular bases, green.

Inflorescence: Capitulum, terminal, heterogamous heads and surrounded by green involucre of bracts which are much hairy.

Flower: Spirally arranged much reduced florets are of 2 types: Ray Florets and Disc Florets, Color & measurement.

Ray Florets: 3-6 in single outer whorl. Irregular, epigynous, female.

Calyx: Sepals 4, polysepalous, modified into plumose bristle like long pappus, persistent, valvate, Color & measurement ($\pm$ 0.3cm).

Corolla: Petals (4), gamopetalous, irregular; ligulate, tube long, narrow, deciduous, upper 1/4th hairy, limb laterally expaned, 2-3 unequally lobed, middle lobe smallest, a total of 5 nerves unequally distributed, valvate, Color (dull yellow) & measurement.

Androecium: Absent.

Gynoecium: Carpels (2), syncarpous, ovary inferior, uni-locular, one ovuled ($\pm$ 0.09cm long), erect, anatropous, Placentation basal, Style ($\pm$ 0.4 cm long) slender, terete, terminal and exerted, Stigma bifid and papillose, Color (yellow) & measurement.

Disc Florets: Numerous, spirally arranged, regular, epigynous, bisexual.

Calyx: Sepals 4, polysepalous, modified into plumose bristle like long pappus, persistent, valvate, Color & measurement (± 0.3 cm). [As in Ray florets]

Corolla: Petals (4), gamopetalous, tubular (± 0.65 cm long), tube cylindric, narrow (± 0.3 cm in diameter), irregular, ovate, erect, deciduous, hairy, 5-lobed, valvate, Color (light yellow).

Androecium: Stamens 5, syngenesious, epipetalous, (± 0.3 cm long) inserted, basifixed, dithecal, introse, dehiscence by apical pores, Color (yellow) & measurement.

Gynoecium: Carpels (2), syncarpous, ovary inferior, uni-locular, one ovuled (± 0.09 cm long), erect, anatropous, Placentation basal, Style (± 0.4 cm long) slender, terete, terminal and exerted, Stigma bifid and papillose, Color (yellow) & measurement. [As in Ray florets]

Fruit: Simple, dry, Cypsella, slightly compressed, silky, crowned by bristly pappus, Color (black) & measurement ($\pm 0.2 \times 0.07$ cm).

Floral Formula: Ray Floret: Br. $\% \overline{\text{K}}_{\text{pappus}} C_{(5)} A_0 \overline{G}_{(2)}$

Disc Floret: Br. $\oplus \overline{\text{K}}_{\text{pappus}} C_{(5)} A_{(5)} \overline{G}_{(2)}$

Taxonomic study of *Ocimum sanctum* (Lamiaceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Stem: Aerial, branched, erect, solid, quadrangular, hairy, differentiated into nodes & internodes, Color (greenish) & measurement (length of internodes $\pm$ cm).

Leaf: Cauline and ramal; opposite decussate, exstipulate, simple (pinnate), petiolate, ovate, serrate, acute, pubescent, reticulate - unicostate, green, Size of lamina $\pm A \times B$ cm.

Inflorescence: Verticillaster.

Flower: Bracteate, shortly pedicelled, complete, irregular, dichlamydeous, bisexual, pentamerous, hypogynous, cyclic, Color & measurement.

Calyx: Sepals (5), gamosepalous, irregular, $\frac{1}{4}$ labiate, persistent, valvate, Color & measurement.

Corolla: Petals (5), gamopetalous, irregular, 4/1 labiate, deciduous, valvate, hairy, Color (violet) & measurement.

Androecium: Stamens 4, didynamous, epipetalous, inserted, dorsifixed, dithealous, introse, dehiscence longitudinal, anterior pair longer, Color & measurement.

Gynoecium: Carpels (2), syncarpous, ovary superior, tetra-locular with one ovule in each chamber, Placentation axile, Style gynobasic, Stigma bifid and filiform, disc present below the ovary, Color & measurement.

Fruit: Simple, dry, dehiscent, carcerule (one seeded 4 nutlets), Color & measurement.

Floral Formula: Br. % $\overset{\circ}{\text{K}}_{(5) \text{ or } (1/4)} \text{C}_{(4/1)}^{\wedge} \text{A}_{2+2} \underline{\text{G}}_{(2)}$

Taxonomic study of *Leucas indica* (Lamiaceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Stem: Aerial, branched, erect, solid, quadrangular, hairy, differentiated into nodes & internodes, Color (greenish) & measurement (length of internodes $\pm$ cm).

Leaf: Cauline and ramal; opposite decussate, exstipulate, simple (pinnate), petiolate, ovate, serrate, acute, pubescent, reticulate - unicostate, green, Size of lamina $\pm$ A x B cm.

Inflorescence: Verticillaster, clustering at the nodes.

Flower: Bracteate, shortly pedicelled, complete, irregular, dichlamydeous, bisexual, pentamerous, hypogynous, cyclic, Color (white) & measurement.

Calyx: Sepals (5), gamosepalous, irregular, mouth oblique, persistent, valvate, Color & measurement.

Corolla: Petals (5), gamopetalous, irregular, 3/2 labiate, deciduous, imbricate, hairy, upper lip longer, Color (violet) & measurement.

Androecium: Stamens 4, didynamous, epipetalous, inserted, dorsifixed, dithealous, introse, dehiscence longitudinal, anterior pair longer, anther divergent, Color & measurement.

Gynoecium: Carpels (2), syncarpous, ovary superior, tetra-locular with one ovule in each chamber, Placentation axile, Style gynobasic, Stigma bifid and filiform, disc present below the ovary, Color & measurement.

Fruit: Simple, dry, dehiscent, carcerule (one seeded 4 nutlets), Color & measurement.

Floral Formula: Br. % $\overset{\circ}{\text{K}}_{(5)} \text{C}_{(2+3)}^{\wedge} \text{A}_{2+2} \underline{\text{G}}_{(2)}$

Taxonomic study of *Croton bonplandianum* (Euphorbiaceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Stem: Aerial, branched, erect, solid, lower portion woody, terete, covered with stalked stellate hairs, differentiated into nodes & internodes, lower internode much longer (± 5 cm), Color (greenish) & measurement (length of internodes $\pm$ cm).

Leaf: Cauline and ramal; alternate, crowded towards the tips of branches (falsely whorled), exstipulate, simple (pinnate), petiolate (± 0.8 cm), ovate-lanceolate, serrate, acuminate, base attenuate, dorsiventral, glabrous above, lower surface with few stellate hairs, reticulate - unicostate, green, Size of lamina $\pm A \times B$ cm.

Inflorescence: Terminal mixed racemes (catkin like but erect), female flowers towards the base & few in number while male flowers are clustered towards the upper side, bracteate.

Flower: Shortly pedicelled, complete, regular, dichlamydeous, unisexual, pentamerous, hypogynous, cyclic.

Male Flower:

Calyx: Sepals 5, polysepalous, regular, small, ovate, acute, imbricate, Color (green) & measurement.

Corolla: Petals 5, polypetalous, regular, smaller than sepals, alternating with petals, ovate-oblong, acute, deciduous, valvate, Color (white) & measurement.

Androecium: Stamens many, free, inserted, inflexed in bud, straight in flower, anther dithecal, adnate, lobes parallel, introse, Color (white) & measurement.

Gynoecium: Absent.

Female Flower:

Perianth: Tepals 5, polysepalous, regular, small, ovate, acute, one nerved, imbricate, persistent, Color (green) & measurement.

Androecium: Absent.

Gynoecium: Carpels (3), syncarpous, ovary superior, oblong, glandular, hairy, 3-locular with one pendulous ovule in each chamber, Placentation axile, Style 3, Stigma bifid, disc annular, Color & measurement.

Fruit: Simple, dry, schizocarpic, regma with persistent style and perianth, stellate hairs present throughout the surface, breaks into 1-seeded three cocci, endocarp horny, Color & measurement.

Floral Formula: Male Flower: $\text{Br brl} \oplus \text{♂ } K_5 C_5 A_{(5+5)} G_0$;

Female Flower: $\text{Br} \oplus \text{K}_5 \text{C}_5 \text{A}_0 \underline{\text{G}}_{(3)}$

Taxonomic study of *Solanum nigrum* (Solanaceae)

Specimen: A flowering twig with fruits was supplied in the laboratory.

Habitat: Appears to be terrestrial.

Habit: Appears to be herbaceous.

Stem: Aerial, herbaceous, branched, erect, solid, round, smooth, differentiated into nodes & internodes, Color (greenish) & measurement (length of internodes $\pm$ cm).

Leaf: Cauline and ramal; alternate but due to fusion of the petiole with stem axis the leaves seem to be opposite at some places, exstipulate, simple (pinnate), petiolate, ovate, entire or slightly lobed, acute, glabrous, reticulate - unicostate, green, Size of lamina $\pm$ A x B cm.

Inflorescence: Extra-axillary cyme.

Flower: Ebracteate, pedicelled, complete, regular, dichlamydeous, bisexual, pentamerous, hypogynous, cyclic, Color & measurement.

Calyx: Sepals (5), gamosepalous, regular, persistent, valvate, Color & measurement.

Corolla: Petals (5), gamopetalous, regular, rotate, deciduous, valvate, Color (white) & measurement.

Androecium: Stamens 5, epipetalous, inserted, basifixed, dithecal, introse, dehiscence by apical pores, color & measurement.

Gynoecium: Carpels (2), syncarpous, ovary superior, bi-locular with many ovules in each chamber, Placentation axile, septum oblique, Style long and hairy, Stigma bilobed, Color & measurement.

Fruit: Simple, fleshy, indehiscent, globose berry, Color (blackish green) & measurement.

Floral Formula: $\text{Br} \oplus \text{K}_{(5)} \text{C}_{(5)} \text{A}_5 \underline{\text{G}}_{(2)}$

“Tell me and I forget, teach me and I may remember, involve me and I learn.”

— Benjamin Franklin

CHAPTER 8

Specific Focus for Economic Botany

Chapter Contents:

- Some economically important plants of Different Dicot Families: (families are arranged alphabetically) (*Acanthaceae, Annonaceae, Apiaceae, Apocynaceae, Asclepiadaceae, Asteraceae, Brassicaceae, Cucurbitaceae, Dipterocarpaceae, Ericaceae, Euphorbiaceae, Fabaceae (Mimosaceae, Caesalpiniaceae, Papilionaceae), Lamiaceae, Magnoliaceae, Malvaceae, Myrtaceae, Ranunculaceae, Rosaceae, Rubiaceae, Rutaceae, Scrophulariaceae, Solanaceae, Sterculiaceae, Tiliaceae, Verbenaceae*)
- Some economically important plants of Different Monocot Families: (*Alismataceae, Amaryllidaceae, Araceae, Arecaceae, Commelinaceae, Cyperaceae, Liliaceae, Musaceae, Orchidaceae, Poaceae, and Zingiberaceae*)
- ⊖ Economic importance, parts used, and medicinal properties of some Medicinal/Aromatic Plants (*Cinchona, Ipecac, Adhatoda, Curcuma, Cardamom, Neem, Cannabis, and Trichosanthes dioica*)

The following plant families are expressly listed for study in the WBCS Main Examination syllabus for Botany (Optional Paper) and Agriculture. These families are examined in light of their economic significance, systematic location, and diagnostic characteristics.

Core Families (Taxonomy of Angiosperms):

1. Brassicaceae (Mustard/Cruciferae family)
2. Fabaceae (Leguminosae family)
3. Solanaceae (Potato/Nightshade family)
4. Malvaceae (Cotton/Mallow family)
5. Ranunculaceae (Buttercup family)
6. Apiaceae (Umbelliferae/Carrot family)
7. Rubiaceae (Coffee family)
8. Lamiaceae (Mint family)
9. Euphorbiaceae (Spurge family)
10. Commelinaceae (Spiderwort family)
11. Araceae (Arum family)
12. Liliaceae (Lily family)
13. Poaceae (Grass family)

14. Orchidaceae (Orchid family)

Specific Focus for Economic Botany

The WBCS Main Examination syllabus emphasizes the economic importance, parts used, and medicinal properties of plants within these families, particularly with reference to:

- a) **Medicinal/Aromatic Plants:** *Cinchona*, *Ipecac*, *Adhatoda*, and *Curcuma longa* (Turmeric).
- b) **Other Important Taxa:** *Elettaria cardamomum* (Cardamom), *Azadirachta indica* (Neem), *Cannabis sativa*, and *Trichosanthes dioica* (Pointed gourd/Potol).
- c) **Gymnosperms:** Pinaceae, or pine cone, *Gnetum*, *Cycas*

❖ SOME ECONOMICALLY IMPORTANT PLANTS (DICOT):

(1) Some economically important plants of Acanthaceae:

➤ Medicinal Plants

- ***Justicia adhatoda* (Vasaka):** used in Ayurvedic and Unani medicine (for over 2000 years) to treat cough, bronchitis, and respiratory ailments.
- ***Andrographis paniculata* (Kalmegh):** Known as the "King of Bitters & used for treating liver disorders and fevers; also as an antimicrobial.
- ***Barleria prionitis* (Katsareya):** Used in traditional medicine for various ailments.
- ***Rhinacanthus communis*:** Used to treat skin diseases.
- ***Asteracantha longifolia* (Syn. *Hygrophila auriculata*):** Used for treating jaundice and liver ailments.
- ***Ecbolium viride*:** Roots are used to treat jaundice.
- ***Hemigraphis colorata*:** used in wound healing.

➤ Ornamental Plants

- a) ***Acanthus mollis* (Bear's-breech):** Known for large leaves and decorative spikes.
- b) ***Thunbergia alata* (Black-eyed Susan vine) & *T. grandiflora*:** Popular climbing plants cultivated for year-round flowering.
- c) ***Justicia brandegeana* (Shrimp Plant):** Popular garden shrub.
- d) ***Crossandra infundibuliformis* (Firecracker Flower):** Cultivated for ornamental flowers & used in traditional medicine for its antimicrobial properties.
- e) ***Fittonia* spp.:** Popular ornamental groundcover.

➤ **Other Uses**

- ***Avicennia* spp.:** Ecologically important mangrove trees that provide habitat and coastal protection.
- ***Peristrophe bivalvis*:** used as a natural dye, source for food, textiles, & matting, specially in Southeast Asia.
- ***Strobilanthes cusia*:** Leaves are used to produce indigo dye.
- ***Aechnanthera wallichii*:** Leaves used by natives to make clothing.
- ***Justicia betonica* & *Barleria*:** used for Fencing or as Hedge plants

(2) Some economically important plants of Annonaceae:

A. Edible Fruits (*Annona* & others):

- a) Custard Apple / Sweetsop (*Annona squamosa*): A widely cultivated, highly prized tropical fruit.
- b) Soursop / Graviola (*Annona muricata*): Used in beverages and desserts.
- c) Cherimoya (*Annona cherimola*): Known for its creamy, sweet fruit.
- d) Pawpaw (*Asimina triloba*): Native to North America.
- e) Biriba (*Rollinia mucosa*): A South American fruit.

B. Essential Oils & Perfumes:

- a) Ylang-ylang (*Cananga odorata*): Cultivated for high-value fragrant oil used in perfumery.
- b) *Desmos chinensis*: Flowers are used for perfume, similar to Macassar oil.

C. Timber & Utility:

- a) Debdru / False Ashok (*Polyalthia longifolia*): Widely used as an ornamental avenue tree.
- b) Lancewood (*Oxandra lanceolata*): Provides strong, elastic timber.
- c) Other Timber Species: *Bocagea virgata*, *Cyathocalyx zeylanicus*, and *Duguetia quitarensis*.

D. Medicinal & Other Uses:

- a) *Xylopia aethiopica*: Known as African pepper, used as a spice.
- b) *Goniothalamus wightii*: Bark is used for producing strong fibres.
- c) *Annona* seeds: Used as insecticidal powder.

(3) Economic importance of Apiaceae family

a) Vegetables & Food: Leaf stalks and root crops are essential vegetables.

- **Root vegetables** include Arracacha (*Arracacia xanthorrhiza*), Hamburg parsley (*Petroselinum crispum*), celeriac (*Daucus carota*), and parsnip (*Pastinaca sativa*).

- **Leafy greens and stalks** include chervil (*Anthriscus cerefolium*), fennel (*Foeniculum vulgare*), cilantro (*Coriander sativum*), celery (*Apium graveolens*), parsley (*Petroselinum crispum*), and loveage (*Levisticum officinale*).
- b) **Examples** are Arracacha (*Arracacia xanthorrhiza*), Parsnip (*Pastinaca sativa*), Celery (*Apium graveolens*), and Carrot (*Daucus carota*).
- c) **Culinary Herbs and Spices:** Due to their fragrant ingredients, often used as condiments, flavorings, and fragrances. Examples are caraway (*Carum carvi*), dill (*Anethum graveolens*), fennel (*Foeniculum vulgare*), cumin (*Cuminum cyminum*), and coriander (*Coriandrum sativum*).
- d) **Therapeutic Uses:** Numerous species have anti-inflammatory and digestive qualities and are abundant in phenolic compounds and antioxidants. e.g., Gotu Kola (*Centella asiatica*), Ajwain (*Carum copticum*), and Asafoetida/Hing (*Ferula foetida*).
- e) **Industrial and Ornamental:** Used as aromatic, ornamental plants and in fragrances and cosmetics. e.g., Blue Lace Flower (*Trachymene caerulea*) and Masterwort (*Astrantia*).
- f) **Additional Applications:** Some varieties are used as companion plants for beneficial insects, as well as fodder (*Daucus carota*, *Angelica sylvestris*), and in herbal teas (*Levisticum officinale*, *Angelica sylvestris* / *A. archangelica*).

Levisticum officinale has a strong, sweet, savory taste akin to celery; traditionally used to cure kidney stones, reduce inflammation, alleviate digestive problems, and act as a diuretic. Precautions: Avoid using this product during pregnancy.

Note: Poison hemlock (*Conium maculatum*) is one of the toxic species in the family.

(4) Some economically important plants of Apocynaceae:

Medicinal Plants

- a) ***Rauvolfia serpentina* (Indian Snakeroot):** Roots contain reserpine, used to treat hypertension and mental disorders.
- b) ***Catharanthus roseus* (Madagascar Periwinkle):** Produces vincristine and vinblastine, crucial for treating childhood leukemia.
- c) ***Alstonia scholaris* (Devil Tree):** Bark is used for treating malaria and skin diseases.
- d) ***Wrightia tinctoria* (Candor):** Bark and seeds possess medicinal properties, also source of a blue dye.
- e) ***Tabernanthe iboga*:** Known for ibogaine, studied for treating drug addiction.

Ornamental Plants

- a) ***Nerium oleander* (Oleander):** A common evergreen shrub with vibrant flowers.

- b) *Plumeria rubra* (Frangipani): Highly fragrant, popular ornamental tree.
- c) *Allamanda cathartica* (Golden Trumpet): A popular climbing ornamental.
- d) *Adenium obesum* (Desert Rose): Cultivated for its thick stem and attractive flowers.

Industrial and Edible Plants

- a) *Carissa carandas* (Karaunda): Spiny shrub with fruits used in pickles and jams.
- b) *Landolphia* species: Historically used as a source of rubber.
- c) *Apocynum cannabinum* (Dogbane): Utilized for fiber.
- d) *Saba comorensis*: Used for its aromatic fruit juice.

Toxic/Other Uses

- a) *Thevetia peruviana* (Yellow Oleander): Contains poisonous, bitter latex but is grown as an ornamental.
- b) *Acokanthera* species: Used to make arrow poisons.

(5) Some economically important plants of Asclepiadaceae

Medicinal Plants:

- a) *Gymnema sylvestre* (Gymnema): Known for anti-diabetic properties (gymnemic acid), leaves are used to treat sugar-related issues.
- b) *Tylophora indica* (Indian Ipecacuanha): Roots used for asthma, bronchitis, and respiratory disorders.
- c) *Hemidesmus indicus* (Indian Sarsaparilla): Roots used as a blood purifier and for skin/urinary diseases.
- d) *Calotropis gigantea* / *C. procera* (Madar/Akanda): Latex used in traditional medicine for skin diseases, while roots are used for various ailments.
- e) *Oxystelma esculentum*: Roots are used in treatments for jaundice.

Fiber and Industrial Use:

- a) *Calotropis* species: Yield strong, white, silky fiber used for making ropes, mats, fishing nets, and sewing threads. The floss from the fruit is used to stuff pillows.
- b) *Cryptostegia grandiflora* (Rubber Vine): A source of natural rubber.
- c) *Leptadenia pyrotechnica*: Used for fiber and cordage.

Ornamental Plants:

- a) *Asclepias curassavica* (Milkweed): Widely grown for its orange-red flowers and as a host plant for monarch butterflies.

- b) ***Hoya carnosa* (Wax Plant):** Popular ornamental, cultivated for its shiny leaves and fragrant flowers.
- c) ***Stapelia gigantea* (Carrion Flower):** Grown for its unique, large star-shaped flowers.

Food Source:

- a) ***Caralluma fimbriata*:** Fleshy stems are eaten as a vegetable in some regions.
- b) ***Ceropegia species*:** Tubers are often edible.

Some economically important plants of Mimosaceae:

1. **Gum-Yielding Plants:** *Acacia senegal* (Gum Arabic), *Acacia nilotica* (Babool gum), and *Albizia lebbek* (Sirish) provide commercially valuable gums used in textiles, confectionery, and pharmaceutical industries.
2. **Timber and Wood:** *Acacia catechu* (Katha), *Acacia melanoxylon* (Australian Acacia), and *Xylia xylocarpa* (Iron wood) are prized for durable timber, furniture, and agricultural implements.
3. **Tannin and Dye:** Bark of *Acacia nilotica*, *A. catechu*, and *A. decurrens* are rich in tannins, widely used for tanning leather. *Adenanthera pavonina* (Red wood) yields a red dye.
4. **Medicinal and Cosmetic:** *Mimosa pudica* (Touch-me-not/Lazzabati) has diuretic and medicinal properties. *Acacia concinna* (Shikakai) pods are used for washing hair and in shampoos.
5. **Fodder and Agroforestry:** *Prosopis cineraria* and *Prosopis juliflora* are crucial for soil reclamation, fuel, and fodder in arid regions. *Leucaena leucocephala* (Subabul) is used as fodder.
6. **Ornamental:** *Calliandra haematocephala* (Red powder puff) and *Mimosa pudica* are grown for their unique flowers.

(6) Some economically important plants of Asteraceae:

Food & Oil Crops:

- a) **Sunflower (*Helianthus annuus*):** Extensively cultivated for edible oil, seeds, and fodder.
- b) **Lettuce (*Lactuca sativa*):** Major leafy vegetable used worldwide.
- c) **Safflower (*Carthamus tinctorius*):** Source of edible oil and used in paints/soaps.
- d) **Jerusalem Artichoke (*Helianthus tuberosus*):** Cultivated for its edible tubers.
- e) **Globe Artichoke (*Cynara scolymus*):** Cultivated for edible flower buds.
- f) **Chicory (*Cichorium intybus*):** Roots are used as a coffee substitute or additive.
- g) **Yacón (*Smallanthus sonchifolius*):** Grown for its crisp, sweet, edible tubers.

Medicinal Plants:

- a) **Chamomile** (*Matricaria chamomilla*/*Anthemis* spp.): Used for tea and medicinal purposes.
- b) **Echinacea** (*Echinacea* spp.): Used in herbal remedies to boost immunity.
- c) **Artemisia** (*Artemisia* spp.): Known for medicinal uses, including anti-malarial compounds.
- d) **Marigold** (*Tagetes patula/erecta*): Used for essential oils, insecticides, and in medicinal, traditional uses.
- e) **Dandelion** (*Taraxacum* spp.): Used in traditional medicine.

Ornamental Plants:

- a) **Chrysanthemum** (*Chrysanthemum* spp.): Major commercial flower.
- b) **Dahlia** (*Dahlia* spp.): Popular garden flower.
- c) **Aster** (*Aster* spp.): Garden flower used for horticulture.
- d) **Cosmos** (*Cosmos* spp.): Ornamental garden plant.

Industrial & Other Uses:

- a) **Pyrethrum** (*Tanacetum* spp.): Source of natural insecticides.
- b) **Guayule** (*Parthenium argentatum*): A source of natural rubber.
- c) **Burdock** (*Arctium* spp.): Used in food and medicinally, with hooked bracts that inspired Velcro.

(7) Some economically important plants of Brassicaceae:

1. Primary Food Source (Vegetables)

The family provides a vast array of high-fiber, vitamin-rich vegetables, many of which are cultivars of a single species, *Brassica oleracea*.

- **Leafy Vegetables:** Cabbage (var. *capitata*), Kale (var. *acephala*), and Brussels sprouts (var. *gemmifera*).
- **Flower Buds/Inflorescence:** Broccoli (var. *italica*) and Cauliflower (var. *botrytis*).
- **Edible Roots/Stems:** Radish (*Raphanus sativus*), Turnip (*Brassica rapa*), and Kohlrabi (var. *gongylodes*).
- **Condiments & Spices:** Includes Black mustard (*B. nigra*), White mustard (*Sinapis alba*), Horseradish (*Armoracia rusticana*), and Wasabi (*Eutrema japonicum*).

2. Edible and Industrial Oils:

Brassicaceae seeds are high in oil content, ranking as the third most important oil source globally after soybean and palm oil.

- **Canola/Rapeseed Oil:** Extracted from *Brassica napus*, it accounts for roughly 12-14% of the world's edible vegetable oil production.
- **Mustard Oil:** Derived from species like *B. campestris* and *B. juncea*, widely used for cooking and traditional massage.
- **Biofuels:** Camelina (*Camelina sativa*) and *B. carinata* are used to produce biodiesel and aviation fuel, which can reduce greenhouse gas emissions by up to 75% compared to petroleum.

3. Medicinal and Health Benefits:

Members of this family are "nutritional goldmines" containing unique secondary metabolites like glucosinolates and isothiocyanates.

- **Anticancer Properties:** Compounds like sulforaphane and indole-3-carbinol are studied for reducing tumor growth and preventing cancers.
- **Traditional Uses:** *Lepidium sativum* is used to treat asthma and liver complaints; *Iberis amara* (candytuft) is used for rheumatism and gout.

4. Scientific and Industrial Importance:

- **Model Organism:** *Arabidopsis thaliana* is the premier model for plant genetics and molecular biology, being the first plant to have its genome fully sequenced.
- **Phytoremediation:** Some species are "hyper-accumulators" that can absorb heavy metals like zinc, cadmium, and nickel from contaminated soils.
- **Ornamentals:** Flowers like Wallflower (*Erysimum*), Candytuft (*Iberis*), and Honesty (*Lunaria*) are grown for aesthetic value.
- **Cattle Feed:** The "oil cake" residue left after oil extraction is a highly nutritious protein source for livestock.

(8) Some economically important plants of Cucurbitaceae:

- a) **Food Crops:** *Cucumis sativus* (Cucumber), *Citrullus lanatus* (Watermelon), *Cucumis melo* (Muskmelon/Melon), *Cucurbita pepo* (Pumpkin/Squash), *Cucurbita maxima* (Red Pumpkin), *Lagenaria siceraria* (Bottle Gourd), *Trichosanthes dioica* (Pointed Gourd), and *Luffa acutangula* (Ribbed Gourd).

- b) **Medicinal & Utility Plants:** *Momordica charantia* (Bitter Gourd/Melon - used for diabetes), *Luffa cylindrica* (Loofah - used as a bath sponge), and *Lagenaria siceraria* (used for containers).
- c) **Economic Value:** These plants are significant for their high water content, vitamins, seeds, and as popular, versatile vegetables consumed worldwide.

(9) Some economically important plants of Dipterocarpaceae:

1. *Shorea* Species (Meranti, Balau, Sal)

Shorea is one of the largest and most valuable genera in this family, used for timber and, in some cases, seed oil.

- a) ***Shorea robusta* (Sal):** A major timber species in India, used for railway sleepers, house construction, and furniture.
- b) ***Shorea leprosula* (Light Red Meranti):** A fast-growing tree, highly valued in the plywood and timber industry.
- c) ***Shorea macrophylla* (Tengkawang/Illipe nut):** Known for producing seeds that are high in fat, used as a substitute for cocoa butter in the confectionery and cosmetic industries.
- d) ***Shorea laevis* (Balau/Damar Laut):** Known for producing very hard, heavy, and durable timber suitable for heavy construction.
- e) ***Shorea faguetiana* (Yellow Meranti):** Known for producing yellow meranti timber and holding records for being the tallest tropical trees.

2. *Dipterocarpus* Species (Keruing, Garjan)

Dipterocarpus species are major sources of timber, generally known as Keruing (Malaysia) or Garjan (India).

- a) ***Dipterocarpus turbinatus* (Garjan):** Extensively used in boat-building, construction, and for producing balsams/resins used in varnishes.
- b) ***Dipterocarpus grandiflorus* (Apitong):** A major timber species in the Philippines and Malaysia.
- c) ***Dipterocarpus alatus*:** Important for timber and resin production in South and Southeast Asia.

3. *Hopea* Species (Giam, Telsur)

Hopea species are often prized for their extremely durable, heavy hardwood.

- a) **Hopea odorata (Telsur):** Used for timber in construction, particularly in maritime environments, and sometimes as an ornamental.
- b) **Hopea parviflora:** Yields excellent timber used in bridges and piles.
- c) **Hopea micrantha:** Produces a valuable resin known as 'mata Kuching'.

4. *Dryobalanops* Species (Kapur)

- o ***Dryobalanops aromatica* (Borneo Camphor):** Famous for yielding "Borneo camphor" (used in medicine and incense) and high-quality "Kapur" timber.

5. *Vateria* Species (Piney)

- a) ***Vateria indica* (Indian Copal/Piney):** Important for producing "piney varnish" (resins) and edible seeds (Indian tallow).

6. *Neobalanocarpus* Species

- a) ***Neobalanocarpus heimii* (Chengal):** Produces one of the most durable and expensive heavy hardwood timbers in Malaysia.

7. *Anisoptera* Species (Mersawa)

- a) ***Anisoptera costata* (Mersawa):** A large, commercial timber tree.

These trees are not only economically vital for timber but are also crucial for ecological stability. Due to overexploitation, many of these species are now considered threatened or endangered.

(10) Some economically important plants of Ericaceae:

Fruit Crops:

- a) Blueberry (*Vaccinium angustifolium*, *V. corymbosum*)
- b) Cranberry (*Vaccinium macrocarpon*, *V. oxycoccos*)
- c) Bilberry/Whortleberry (*Vaccinium myrtillus*)
- d) Huckleberry (*Gaylussacia* spp.)
- e) Lingonberry/Cowberry (*Vaccinium vitis-idaea*)
- f) Strawberry tree (*Arbutus unedo*)

Ornamentals:

- a) Rhododendron/Azalea (*Rhododendron* spp.)
- b) Heather (*Calluna vulgaris*)
- c) Heath (*Erica* spp.)

- d) Mountain laurel (*Kalmia latifolia*)

Medicinal/Commercial:

- a) Wintergreen (*Gaultheria procumbens* - used for oil of wintergreen)
- b) Manzanita (*Arctostaphylos* spp.)
- c) Briar (*Erica arborea* - used for making tobacco pipes)
- d) Sourwood (*Oxydendrum arboreum* - ornamental and nectar source)

These plants are predominantly found in acidic soils and are valuable for their edible fruits, showy flowers, and, in some cases, wood and medicinal oils.

(11) Some economically important plants of Euphorbiaceae:

Food Crops:

- Cassava (*Manihot esculenta*), a tropical food crop with starchy tuberous roots, is vital.
- Vitamin C-rich Amla/Gooseberry is *Phyllanthus emblica*.

Rubber: *Hevea brasiliensis* (Para rubber tree) produces most natural rubber. *Manihot glaziovii* (Manicoba rubber) also yields latex.

Industrial oil:

- Castor oil from *Ricinus communis* (Castor) seeds, used as lubricant, purgative, & in paints.
- *Vernicia fordii* (Tung oil tree), formerly known as *Aleurites fordii*: generates valuable paint-drying oil.
- *Jatropha curcas* used in biodiesel & medicine.

Medicinal uses:

- *Phyllanthus amarus*: Used for treating jaundice.
- *Croton tiglium*: Seeds are used as a purgative.
- *Mallotus philippensis*: Used for medicinal purposes.
- *Euphorbia hirta*: Used in respiratory ailments, skin treatments and as diuretics.
- *Croton bonplandianum* purges.

Ornamentals: *Ponsettia*, *Codiaeum variegatum*, *Euphorbia milii*, *Euphorbia splendens* etc.

Other uses:

- *Chrozophora* species are used as a source of dye.

- *Euphorbia antisyphilitica* makes candelilla wax.
- *Excoecaria agallocha* (blinding tree) produces toxic, milky latex used in medicine and repellents.

(12) Some economically important plants of Mimosaceae:

1. Gum and Resin Production

- *Acacia senegal* (Kumta): Primary source of high-quality gum arabic used in confectionery and pharmaceuticals.
- *Acacia nilotica* (Babul/Kikar): Produces edible gum and provides, along with *Albizia lebbek* (Sareh), valuable industrial gum.

2. Timber and Wood

- *Acacia catechu* (Khair): Heartwood provides "Katha," used in pan masala, and serves as a host for lac insects.
- *Xylia xylocarpa* (Iron wood): Provides durable timber.
- *Albizia lebbek* (Siris) & *Acacia melanoxylon* (Australian Acacia): Utilized for furniture and cabinetry.
- *Mimosa scabrella* (Bracatinga): Used for fuel-wood, lumber, and charcoal.

3. Tannins and Dyes

- *Acacia catechu* & *Acacia nilotica*: Bark is rich in tannin, used for tanning leather.
- *Adenanthera pavonina* (Red wood): The wood is used to produce a red dye.

4. Medicinal and Miscellaneous Uses

- *Mimosa pudica* (Touch-me-not plant): Used in traditional medicine to treat wounds, piles, and urogenital disorders.
- *Acacia concinna* (Shikakai): Pods are used as a natural detergent for hair and fabrics.
- *Prosopis cineraria*: Used for sand dune stabilization, windbreaks, and fodder in arid regions.
- *Leucaena leucocephala* (Subabul): Grown for fodder and fuel.

(13) Some economically important plants of Caesalpiniaceae:

1. Food and Condiments:

- *Tamarindus indica* (Tamarind/Imli): Fruits are widely used as a popular condiment, flavoring, and in chutneys due to high tartaric acid content.
- *Bauhinia variegata* (Kachanar): Flowers and flower buds are used as vegetables, while seeds provide edible starch.
- *Senna tora* (Pamaar): Young leaves are eaten as a vegetable.

2. Medicinal Plants:

- *Cassia fistula* (Amaltas): Fruit pulp is a well-known, safe laxative and purgative.
- *Saraca indica* (Ashoka): Bark is highly valued in traditional medicine for treating uterine disorders and as a tonic.
- *Caesalpinia bonduc* (Fever nut/Latakaranja): Seeds are used for treating fevers, inflammation, and digestive issues.
- *Senna alata* (Dadmurdan): Leaves are used to treat skin diseases, particularly ringworm.

3. Dyes, Tans, and Industrial Use:

- *Caesalpinia spinosa* (Tara): Pods are a major source of tannins used for leather tanning and dye production.
- *Haematoxylon campechianum* (Logwood): Heartwood yields a dye known as *Haematoxylin*.
- *Cassia auriculata* (Tarvar): Bark is used in the tanning industry.

4. Ornamental and Timber Trees:

- *Delonix regia* (Gulmohar): A prominent, widely planted ornamental tree with bright red flowers

(14) Some economically important plants of Papilionaceae:

1. Pulses and Food Crops:

- Soybean (*Glycine max*): Source of protein and oil.
- Peanut/Groundnut (*Arachis hypogaea*): Major oilseed crop.
- Gram/Chickpea (*Cicer arietinum*): Major pulse.
- Pea (*Pisum sativum*): Important food legume.
- Pigeon Pea/Arhar (*Cajanus cajan*): Widely consumed pulse.
- Beans (*Phaseolus vulgaris*, *Vigna mungo*, *Vigna radiata*): beans and pulses.

- Lentil (*Lens culinaris*): Source of food.

2. Fodder and Forage Crops:

- Alfalfa/Lucerne (*Medicago sativa*): High-quality fodder.
- Clover (*Trifolium* species): Important pasture plant.
- White Sweet Clover (*Melilotus alba*): Fodder.

3. Fiber and Industrial Crops:

- Sunn Hemp (*Crotalaria juncea*): Yields fiber for ropes and bags.
- Guar (*Cyamopsis tetragonoloba*): Source of guar gum.
- Indian Rosewood (*Dalbergia sissoo* & *D. latifolia*): High-quality timber.

4. Dyes, Medicine, and Ornamentals:

- Indigo (*Indigofera tinctoria*): Yields natural dye.
- Liquorice/Mulethi (*Glycyrrhiza glabra*): Medicinal plant.
- Sweet Pea (*Lathyrus odoratus*): Ornamental garden plant.
- Flame of the Forest (*Butea monosperma*): Medicinal gum and dye source.
- Indian Coral Tree (*Erythrina*): Ornamental.

5. Soil Amendment:

- Many species, like, *Sesbania*, are used as green manure for nitrogen fixation in agriculture.

(15) Some economically important plants of Lamiaceae:

The Lamiaceae (mint family) holds immense economic value, primarily for culinary herbs, essential oils, and medicines. Major species include mint (*Mentha* spp.), basil (*Ocimum basilicum*), lavender (*Lavandula*), rosemary (*Salvia rosmarinus*), thyme (*Thymus vulgaris*), sage (*Salvia officinalis*), oregano (*Origanum vulgare*), and chia (*Salvia hispanica*).

Culinary Herbs: Mint, basil, oregano, thyme, and marjoram are globally traded for flavoring.

Essential Oils & Fragrances: Lavender, rosemary, patchouli (*Pogostemon cablin*), and peppermint are used for perfumes, cosmetics, and aromatherapy.

Medicinal Plants: Holy basil (*Ocimum tenuiflorum* or Tulsi), catnip (*Nepeta cataria*), and lemon balm (*Melissa officinalis*) are widely used in traditional medicine.

Timber: *Tectona grandis* (Teak) is a major timber tree.

Ornamentals: *Coleus*, *Salvia*, and *Monarda* (bee balm) are popular garden plants.

Edible Tubers: *Plectranthus edulis* (Madagascar potato) and *Stachys affinis* (Chinese artichoke) are grown for food.

(16) Some economically important plants of Magnoliaceae:

1. Ornamental & Fragrant Plants:

- *Magnolia grandiflora* (Southern Magnolia): Widely cultivated for large, fragrant white flowers and evergreen foliage.
- *Michelia champaca* (Champa): Known for highly fragrant, yellow-tinted flowers used in perfumery and for religious offerings.
- ⊖ *Magnolia* × *soulangeana* (Saucer Magnolia): Popular ornamental with large flowers.
- *Magnolia denudata* (Yulan Magnolia): Cultivated for early, fragrant white blooms.

2. Timber Producing Trees:

- *Liriodendron tulipifera* (Tulip Tree/Yellow Poplar): Provides high-quality, lightweight timber used for furniture, crates, and musical instruments.
- *Magnolia acuminata* (Cucumber Tree): Known for soft, durable wood used in construction.
- *Michelia doltsopa*: Produces valuable timber for furniture and indoor work.
- *Manglietia hookeri*: Used for timber in furniture production.
- Medicinal Plants:
- *Magnolia officinalis* (Houpo Magnolia): The bark is used in traditional Chinese medicine to treat respiratory, gastrointestinal, and anxiety disorders.
- *Magnolia liliiflora*: Buds are used for treating sinus and respiratory infections.
- *Drimys winteri* (winter's Bark): Used as an astringent and stimulant.

3. Essential Oils & Others:

- *Michelia champaca*: Yields champaca oil from flowers.
- *Illicium anisatum* (Star Anise - Note: Often classified under Schisandraceae now, but sometimes historically associated): Used in spices and medicine.

(17) Some economically important plants of Malvaceae:

1. Fiber Plants:

- Cotton (*Gossypium* spp.): The most significant source of textile fiber worldwide, obtained from seed hairs.
- Jute (*Corchorus capsularis/olitorius*): Used for making gunny bags and textiles.
- Kenaf (*Hibiscus cannabinus*): Used for ropes and paper.
- Roselle (*Hibiscus sabdariffa*): Provides bast fiber.
- Urena (*Urena lobata*): Used as a substitute for jute.

2. Food and Beverages:

- Okra (*Abelmoschus esculentus*): Widely cultivated vegetable (bhindi).
- Cacao (*Theobroma cacao*): Source of cocoa beans for chocolate.
- Durian (*Durio zibethinus*): Tropical fruit known for its strong scent.
- Kola Nut (*Cola nitida/acuminata*): Used as a flavoring in drinks.

3. Timber and Wood:

- Balsa (*Ochroma pyramidale*): Known for its extremely lightweight wood.
- Kapok (*Ceiba pentandra*): Produces fiber and wood.
- Portia Tree (*Thespesia populnea*): Used for furniture and boat building.

4. Medicinal and Ornaments:

- Marsh-mallow (*Althaea officinalis*): Roots used for medicinal, demulcent properties.
- Hibiscus (*Hibiscus rosa-sinensis*): Popular ornamental plant.
- Hollyhock (*Alcea rosea*): Garden plant.
- Sida (*Sida cordifolia*): Used in traditional medicine.

(18) Some economically important plants of Myrtaceae:

- 1. Timber and Pulp:** *Eucalyptus* species are globally used for timber, pulp, and paper, mainly *Eucalyptus regnans* (mountain ash). *Melaleuca* and *Syncarpia* (Turpentine tree) also yield timber.

2. Spices and Flavoring:

- Clove (*Syzygium aromaticum*): Dried flower buds are source of spice and oil.
- Allspice (*Pimenta dioica*): Leaves and berries are used as spices.
- Bay Rum Tree (*Pimenta racemosa*): Leaves are used for fragrance & oil.

3. Fruits:

- **Guava (*Psidium guajava*):** Widely consumed, rich in Vitamin C.
- **Jamun/Java Plum (*Syzygium cumini*):** Edible fruit with medicinal properties.
- **Rose Apple/Wax Jambu (*Syzygium jambos*):** Edible, popular in tropical regions.
- **Surinam Cherry (*Eugenia uniflora*):** Used in jams and jellies.

4. Essential Oils and Medicine:

- **Eucalyptus Oil :** as antiseptic, decongestant, and in pharmaceutical products.
- **Tea Tree Oil (*Melaleuca alternifolia*):** antibacterial and antifungal properties
- **Manuka (*Leptospermum scoparium*):** Famed for medicinal honey.
- **Ornamentals:** *Callistemon* and *Myrtus communis* cultivated as ornamental

(19) Some economically important plants of Ranunculaceae:

1. Medicinal Plants:

- ***Aconitum napellus/heterophyllum* (Aconite/Atis):** Roots yield aconitine, used for blood pressure, rheumatism, and in traditional medicine.
- ***Hydrastis canadensis* (Goldenseal):** as a tonic and to cure inflammation.
- ***Anemone pulsatilla* (Pulsatilla):** to treat nerve, gynecological, & gastric disorders
- ***Thalictrum foliolosum* (Mamira):** Roots used as a tonic.
- ***Delphinium staphisagria*:** Used as an anti-parasitic ointment.
- ***Helleborus niger* (Black Hellebore):** Roots in veterinary medicine (purgative)

2. Ornamental Plants:

- ***Ranunculus asiaticus* (Persian Buttercup):** Widely cultivated for cut flowers.
- ***Delphinium ajacis* (Rocket Larkspur):** Popular garden ornamental.
- ***Clematis paniculata*:** Grown for beautiful flowers.
- ***Aquilegia vulgaris* (Columbine):** Cultivated in gardens.

3. Culinary/Condiment Plants:

- *Nigella sativa* (Black Cumin): Seeds as spice & for cough, rheumatism

4. Other Uses:

- *Delphinium caeruleum*: Roots are used as an insecticide.
- *Thalictrum javanicum*: Serves as an alternate host for wheat rust research.

(20) Some economically important plants of Rosaceae:

1. Fruit Crops (Pome Fruits):

- Apple (*Malus domestica*)
- Pear (*Pyrus communis*)
- Loquat (*Eriobotrya japonica*)
- Quince (*Cydonia oblonga*)

2. Fruit Crops (Stone Fruits/Drupes - *Prunus species*):

- Peach and Nectarine (*Prunus persica*)
- Plum (*Prunus domestica*)
- Cherry (Sweet - *P. avium*, Tart - *P. cerasus*)
- Apricot (*Prunus armeniaca*)
- Almond (*Prunus dulcis*)

3. Berries:

- Strawberry (*Fragaria* × *ananassa*)
- Raspberry (*Rubus idaeus*)
- Blackberry (*Rubus fruticosus*)

4. Ornamental Plants:

- Roses (*Rosa species*)
- Spiraea (*Spiraea* spp.)
- Firethorn (*Pyracantha* spp.)
- Hawthorn (*Crataegus* spp.)

5. Medicinal/Commercial Use:

- Rose (petals used for rose oil and gulkand)
- Wood: *Crataegus* (hardwood for tool handles)

(21) Some economically important plants of Rubiaceae:

1. Beverages: *Coffea arabica* and *Coffea canephora* sources of commercial coffee

2. Medicinal:

- *Cinchona officinalis* (and other spp.): Bark yields quinine, (antimalarial)
- *Carapichea ipecacuanha* (Ipecac): Roots used as an emetic.
- *Mitragyna speciosa* (Kratom): Leaves in traditional medicine (stimulant effects)
- *Pausinystalia johimbe* (Yohimbe): Source of yohimbine, a stimulant.

3. Dyes: *Rubia tinctorum* (Madder): Roots historically used to produce red dye (alizarin).

4. Ornamentals:

- *Gardenia jasminoides*: Cultivated for fragrant, white flowers.
- *Ixora coccinea* (Ixora/West Indian Jasmine): Popular flowering shrub.
- *Pentas lanceolata*: Popular garden bedding plant.

5. Other Uses:

- *Uncaria gambir* (Gambier): Produces extracts used in tanning.
- *Morinda citrifolia* (Noni): Fruits are used locally for food.
- *Galium odoratum* (Sweet Woodruff): Contains coumarin, used for fragrance.

(22) Some economically important plants of Rutaceae:

1. Citrus Species (Fruits):

- *Citrus × sinensis* (Sweet orange) - Major fruit crop.
- *Citrus × limon* (Lemon) - Used for juice and oil.
- *Citrus × paradisi* (Grapefruit) - Commercial fruit.
- *Citrus × aurantifolia* (Lime) - Rich in citric acid.
- *Citrus reticulata* (Mandarin/Santara) - Highly nutritive.
- *Citrus maxima* (Chakotra/Pomelo) - Edible fruit.
- *Citrus medica* (Citron) - Cultivated for fruit.

2. Medicinal and Aromatic Plants:

- *Aegle marmelos* (Bael) - Known for stomach disorders; fruit is edible.
- *Ruta graveolens* (Rue) - Used for herbal medicinal purposes.
- *Pilocarpus jaborandi* - Source of pilocarpine to treat glaucoma.
- *Toddalia asiatica* - Roots used for medicine.

3. Spices and Culinary Herbs:

- *Murraya koenigii* (Curry leaf) - Used as a spice/condiment.
- *Zanthoxylum piperitum* (Japanese pepper) - Culinary spice.
- *Zanthoxylum limonella* - Used for aromatic oils.

4. Other Uses:

- *Boronia* species - Used in the perfume industry.
- *Chloroxylon swietenia* (Ceylon satinwood) - Valued for timber.
- *Murraya paniculata* (Orange jasmine) - Grown as an ornamental hedge.
- *Feronia limonia* (Wood apple) - Edible fruit and medicine.

(23) Some economically important plants of Scrophulariaceae:

1. Medicinal Plants

- ***Digitalis purpurea* (Foxglove):** Historically crucial medicinal member, source of digitalin (cardiac glycosides), which is used to treat heart conditions.
- ***Verbascum thapsus*:** Used in asthma, coughs, respiratory complaints.
- ***Scrophularia* (Figworts):** Species like *Scrophularia ningpoensis* are used in traditional medicine for their antipyretic and anti-inflammatory properties.
- ***Picrorhiza kurrooa*:** roots used to treat liver disorders, fever, jaundice.
- ***Lindenbergia indica*:** Used in traditional medicine to treat bronchitis.
- ***Anticharis* spp.:** Used in the treatment of diabetes.

2. Ornamental Plants

- ***Buddleja* (Butterfly Bush):** Cultivated for its flowers (attract butterflies)
- ***Antirrhinum majus* (Snapdragon):** popular, cultivated ornamental plant
- ***Penstemon* (Beardtongue):** A diverse genus with many spp cultivated in gardens for their showy, tubular flowers.
- ***Calceolaria* (Slipperwort/Pocketbook plant):** Popular, ornamental plants
- ***Mimulus* (Monkey flower):** Used as ornamental herbs in gardening.
- ***Verbascum* (Mullein):** medicinal, some spp are cultivated as ornamental

- ***Diascia* (Twinspur):** Popular, low-growing ornamental plants.
- ***Torenia* (Wishbone flower):** Commonly grown as an ornamental.

3. Other Uses

- ***Paulownia* spp.:** Cultivated for high-quality wood production, with flowers sometimes used for medicinal products.
- ***Eremophila* (Poverty bushes):** Used in Australian environments for ecological, medicinal, and ornamental purposes.
- ***Limosella* (Mudwort):** Used in aquaria and for specific ecological settings.

4. Note on Taxonomic Changes

- **Moved to Plantaginaceae:** *Veronica* (Speedwells), *Digitalis* (Foxglove), *Antirrhinum* (Snapdragon), *Linaria* (Toadflax), *Bacopa*.
- **Moved to Orobanchaceae:** *Striga* (Witchweed), *Pedicularis* (Lousewort), *Euphrasia* (Eyebright), *Castilleja*.

The above listed plants belong to the modern, narrower, and more phylogenetically accurate definition of the Scrophulariaceae (**Scrophulariaceae s.s.**).

(24) Some economically important plants of Solanaceae:

1. Major Food Staples

- The family includes a number of "global staples" that serve as the foundation for numerous diets.
- **Potato (*Solanum tuberosum*):** One of the world's most significant non-cereal crops, delivering high levels of carbohydrates and starch.
- **Tomato (*Solanum lycopersicum*):** A widely cultivated fruit used as a vegetable, necessary for manufacturing sauces, ketchups, and powders.
- **Eggplant/Brinjal (*Solanum melongena*):** A prominent fleshy fruit used in cuisines worldwide.
- **Chilli & Peppers (*Capsicum* species):** Provides both mild vegetables (bell peppers) and strong spices (chilli) rich in capsaicin.

2. Medicinal Importance

- Solanaceae members are notable for their high alkaloid content, which is utilized in numerous medications.
- ***Atropa belladonna* (Deadly Nightshade):** The source of atropine, used to dilate pupils during eye tests and to treat muscle spasms.

- Ashwagandha, or *Withania somnifera*, is an essential plant used in Ayurvedic therapy because of its adaptogenic qualities.
- Parkinson's disease and asthma medications are extracted from *Datura stramonium*.
- ***Hyoscyamus niger* (Henbane):** Provides henbane, which works as a sedative for respiratory diseases including whooping cough.

3. Commercial and Industrial Uses

- **Tobacco (*Nicotiana tabacum*):** A large commercial cash crop used for cigarettes, cigars, and other narcotics.
- **Industrial Extracts:** Potatoes used to make dextrin, syrup & industrial alcohols.
- **Pesticides:** Nicotine, derived from tobacco, a natural insecticide and pesticide.

4. Ornamental Plants

Many species are cultivated for their aesthetic value in gardens and landscapes:

- ***Petunia*:** A popular garden flower with different colours.
- ***Cestrum* (Night-blooming jasmine):** Known for its aromatic blossoms.
- ***Solanum jasminoides*:** A climber grown for its fragrant white or blue-tinted blooms.

(25) Some economically important plants of Sterculiaceae:

- a) ***Theobroma cacao* (Cocoa Tree):** Perhaps the most economically vital, it is the source of cocoa beans, which are used for producing chocolate, cocoa butter, and cocoa powder.
- b) ***Cola nitida* and *Cola acuminata* (Kola Nut):** These produce the kola nuts, which contain caffeine and are used in traditional medicine and in the production of refreshing beverages.
- c) ***Sterculia urens* (Gum Karaya Tree):** A major source of "Karaya gum" or "Indian Tragacanth," which is used in the food industry as a thickener and stabilizer (E416), in pharmaceuticals as a bulk laxative, and as a denture adhesive.
- d) ***Sterculia foetida* (Java Olive/Sterculia):** Known as "jangali badam," its seeds are edible, and it produces a similar gum to *S. urens*. It is also studied as a potential source for biodiesel.
- e) ***Heritiera fomes* (Sundri):** Known as the most commercially valuable timber in the Sundarbans, offering wood that is superior in properties to teak.
- f) ***Abroma augusta* (Devil's Cotton):** Widely used in traditional medicine, particularly for treating menstrual disorders (amenorrhea, dysmenorrhea) and as a fiber source (a substitute for hemp).
- g) ***Helicteres isora* (East Indian Screw Tree):** Used for its fiber and in traditional medicine ("Jamu") in Indonesia and China for treating stomach ailments, snake bites, and as a gastrospasm treatment.
- h) ***Guazuma ulmifolia* (Mutamba):** Used for its medicinal bark and fruit, and recently studied as a natural coagulant for dairy wastewater treatment.
- i) ***Pterospermum acerifolium* (Dinner Plate Tree):** An ornamental tree often planted for its fragrant flowers, with bark used in traditional medicine for treating diabetes and tumors.
- j) ***Mansonia dipikae* and *Mansonia altissima*:** Known to yield durable, high-quality timber for furniture.
- k) ***Scaphium* species (e.g., *Scaphium macropodum*):** Known as "Malva nut," used in traditional medicine for treating throat ailments, fever, and constipation.

Summary of Uses:

- a) **Food & Beverages:** *Theobroma cacao*, *Cola* spp., *Sterculia foetida* (seeds).
- b) **Gums & Additives:** *Sterculia urens* (Gum Karaya), *Sterculia villosa*.
- c) **Timber:** *Heritiera fomes*, *Mansonia* spp..

- d) **Medicine:** *Abroma augusta*, *Helicteres isora*, *Pterospermum*.
- e) **Fibers:** *Sterculia villosa* (rope making), *Abroma*.

(26) Some economically important plants of Tiliaceae:

- a) ***Corchorus capsularis* (White Jute) & *Corchorus olitorius* (Tossa Jute):** These are the most economically significant members, cultivated extensively for their tenacious bast fibers used in making gunny bags, ropes, and textiles.
- b) ***Grewia asiatica* (Phalsa):** A shrub widely cultivated in India for its small, edible berry-like fruits (drupes) that are used to make refreshing syrups and drinks.
- c) ***Tilia americana* (American Linden/Basswood) & *Tilia europaea* (Lime Tree):** These trees are valuable for their high-quality, lightweight timber, which is used in carving and cabinet making.
- d) ***Grewia tenax* (Gangeti/Phalsa Cherry):** Used in traditional medicine for treating infections and as a food source (fruits) in Africa and Asia.
- e) ***Triumfetta rhomboidea* (Chinese Burr):** Known for its fibers, and its roots/leaves are used medicinally to treat conditions like diarrhea and dysentery.
- f) ***Berrya cordifolia* (Trincomalee Wood):** A valuable timber tree, often planted as an avenue tree in India.
- g) ***Muntingia calabura* (Strawberry Tree):** Cultivated in gardens for its edible fruit and ornamental value.
- h) ***Abroma augusta* (Devil's Cotton):** Cultivated for the medicinal properties of its roots.

These plants are generally found in tropical and subtropical regions.

(27) Some economically important plants of Verbenaceae:

1. Timber/Wood:

- **Teak/Segun (*Tectona grandis*):** One of the most prized timber species for furniture and construction.
- **White Mangrove (*Avicennia alba*):** A mangrove tree with durable, light-colored wood.
- **Gmelina/Gamari/Gamhar (*Gmelina arborea*):** Known for its wood.

2. Medicinal Plants:

- ***Vitex/Nishinda (*Vitex negundo*):*** is a highly significant medicinal plant whose branches are used to keep flies away from grains that have been kept and whose

leaves are used as a febrifuge (fever reliever); also used for treating respiratory issues, rheumatism, and as a tonic.

- **Lantana (*Lantana camara*):** Roots used for treating stomachic issues; leaves for cuts and skin diseases.
- **Verbena (*Verbena officinalis*):** used in traditional medicine for its calming, diuretic, and anti-inflammatory qualities.
- **Clerodendrum (Glory-bower/Ghetu):** Roots of various species, like *Clerodendrum inerme*, are frequently used in traditional medicine to treat respiratory ailments.
- **Porterweed (*Stachytarpheta*):** is used in many traditional medicines.
- **Lippia (*Lippia* spp.):** Known for aromatic, medicinal oil.

3. Ornamental Plants:

- **Golden Dew Drop (*Duranta repens*):** a common hedge and decorative garden plant.
- **Sandpaper Vine (*Petrea volubilis*):** Grown for its beautiful purple Flowers.
- **Bleeding Heart (*Clerodendrum thomsonae*):** is a widespread Ornamental vine/climber.
- **Verbena (*Verbena* spp.):** Widely cultivated for flowers.

4. Tannin and Natural Dye Plants

- ***Lantana camara*:** In addition to essential oils, provide a safe natural dye for cotton and silk fabrics.
- ***Avicennia* (Mangrove):** The tanning business uses its bark
- ***Vitex* species:** Bark of many species of *Vitex* contains tannins.

5. Essential Oil and Fragrance Plants

- ***Aloysia triphylla* (Lemon Verbena):** grown for its aromatic leaves, which are used to make teas, culinary flavorings, and essential oils.
- ***Lippia alba* (Candy Bush):** yields a priceless essential oil that is utilized in the fragrance business.
- ***Lantana camara* (Wild Sage):** is well-known for being a rich source of essential oils; "Lantana oil" is sold commercially. It is also utilized for its antibacterial qualities and in the perfume business.
- ***Vitex negundo* (Nirgundi/Nishinda):** medicinally used and produces oil

❖ MONOCOT FAMILIES: (ECONOMIC IMPORTANCE)

(1) Some economically important plants of Alismataceae:

a) *Sagittaria* spp. (Arrowhead/Wapato):

- *Sagittaria latifolia* (Broadleaf Arrowhead): Known for its edible starchy tubers, which are consumed as food (often called "swamp potato" or "wapato").
- *Sagittaria sagittifolia* (Arrowhead): Cultivated in China and Japan for its edible corms and also used as livestock fodder.
- *Sagittaria trifolia* (Threeleaf Arrowhead): Collected as a food source, used for animal fodder, and also used as green fertilizer in Asia.
- *Sagittaria subulata* (Dwarf Sagittaria): Popular as an aquarium ornamental plant due to its grass-like,, submerged foliage.

b) *Alisma* spp. (Water-plantain):

- *Alisma plantago-aquatica* (European Water-plantain): Used in traditional medicine for its diuretic, astringent, and anti-inflammatory properties.
- *Alisma orientale*: A well-known traditional Chinese medicinal herb used to treat edema, urinary issues, and diarrhea.

c) *Limnocharis* spp. (Yellow Velvetleaf):

- *Limnocharis flava*: Highly esteemed in Southeast Asia, where the leaves and flower buds are eaten as a vegetable ("poor people's vegetable"). It is also used as fodder for cattle and pigs.

d) *Echinodorus* spp. (Burhead/Amazon Sword Plant):

- *Echinodorus grandiflorus* & *Echinodorus macrophyllus*: Extensively used as ornamental plants in aquariums and water gardens. They also have medicinal applications, with leaves reported to have anti-hypertensive, diuretic, and anti-arthritic properties.

Summary of Economic Uses of Alismataceae plants:

- a) **Food:** Tubers, corms, and leaves of *Sagittaria* and *Limnocharis* are edible.
- b) **Medicinal:** *Alisma* and *Echinodorus* species are used in traditional medicine, especially in Asia and South America.
- c) **Ornamental:** Many species are cultivated for aquariums and water gardens.
- d) **Fodder & Fertilizer:** Used in agricultural areas for livestock and soil improvement.

(2) Some economically important plants of Amaryllidaceae:

1. Food and Culinary Crops (Subfamily Allioideae):

- **Onion (*Allium cepa*):** A major global vegetable crop.
- **Garlic (*Allium sativum*):** Important for culinary and medicinal uses (anti-inflammatory properties).
- **Leek (*Allium porrum*), Chives (*A. schoenoprasum*), and Shallot (*A. cepa* var. *aggregatum*):** Widely cultivated in agriculture.

2. Ornamentals (Floriculture):

- **Narcissus (Daffodils/Jonquils):** Major commercial bulb crop.
- **Hippeastrum (Amaryllis):** Extremely popular pot and garden plant.
- **Galanthus & Leucojum:** Important early spring-flowering plants.
- **Clivia, Nerine, and Zephyranthes:** Popular for landscaping and indoor containers.

3. Medicinal and Pharmaceutical:

- **Galanthus (*G. nivalis*) & Narcissus:** Sources of galanthamine, used to treat Alzheimer's disease.
- **Crinum spp.:** Used in traditional medicine (anti-cancer/alkaloid properties)
- **Agave americana (American aloe):** Used for fiber and production of alcoholic drinks.
- These plants, with over 500 alkaloids, are decorative and produce antiviral, antiparasitic, and anti-tumor chemicals.

(3) Some economically important plants of Araceae:

- **Colocasia esculenta (Taro/Arbi):** A staple food for 400-500 million people, cultivated for its edible corms, leaves, and stems.
- **Amorphophallus paeoniifolius (Elephant Foot Yam):** A major tropical tuber crop.
- **Xanthosoma sagittifolium (Tannia/Elephant Ear):** cultivated for its starchy corms.
- **Cyrtosperma merkusii (Giant Swamp Taro):** Cultivated in the Pacific.

Economically Important Ornamental Aroids (Houseplants)

- **Monstera deliciosa:** Highly prized for its large, perforated leaves.
- **Anthurium:** Known for its vibrant spathes and glossy leaves.
- **Philodendron:** A major genus for interior decorating and foliage.
- **Aglaonema:** Popular for variegated leaves and tolerance of low light.

- ***Dieffenbachia* (Dumb Cane):** A popular, large-leaved houseplant.
- ***Epipremnum aureum* (Money Plant/Pothos):** Widely used in interior decoration.
- ***Zantedeschia* (Calla Lily):** Cultivated for its ornamental flowers.
- ***Caladium* (Heart of Jesus):** Known for colorful foliage.

Medicinal and Other Uses

- **Medicinal Purposes:** Various species in the Amazon are used for treating fevers, malaria, and liver disorders, particularly in the *Philodendron* genus.
- **Aquarium Plants:** Genera such as *Cryptocoryne*, *Anubias*, *Bucephalandra* are highly popular in aquascaping.
- **Unique Specimens:** *Amorphophallus titanum* (Titan arum) is famous for its massive, unique inflorescence.

The horticulture sector and global food supply benefit from these tropical and subtropical plants.

(4) Some economically important plants of Arecaceae:

- Cocos nucifera* (Coconut Palm):** A "multipurpose tree," & provides copra (oil), coir fiber, food, and fuel.
- Elaeis guineensis* (African Oil Palm):** Major source of commercial vegetable oil.
- Phoenix dactylifera* (Date Palm):** Cultivated for edible fruit.
- Metroxylon sagu* (Sago Palm):** Starch extracted from stem pith, used as a staple food.
- Areca catechu* (Betel Nut Palm):** Nuts are chewed for stimulating effects.
- Calamus rotang* (Rattan Palm):** (Stems) used in furniture and basket making.
- Borassus flabellifer* (Palmyra Palm):** Used for timber, handicrafts (leaves) & for toddy (sap).
- Copernicia cerifera* (Carnauba Wax Palm):** Source of valuable carnauba wax.
- Nypa fruticans* (Nipa Palm):** Leaves used for thatching; sap used for sugar.
- Roystonea regia* (Royal Palm):** Widely used for ornamental landscaping.

These plants are primarily cultivated in tropical and subtropical regions for both subsistence and commercial trade.

(5) Some economically important plants of Commelinaceae:

1. Ornamentals:

- Tradescantia* spp. (Spiderwort):** Extensively cultivated as houseplants and garden groundcover, including popular variegated varieties.

- b) *Rhoeo spathacea* (Moses-in-the-cradle/Boat Lily): ornamental with purple-backed leaves.
- c) *Zebrina pendula* (Wandering Dude/Inch Plant): used trailing hanging plant.
- d) *Gibasis pellucida* (Bridal Veil): With beautiful trailing growth & tiny white flowers.

2. Medicinal and Edible Plants:

- a) *Commelina benghalensis* L.: Seed flour for food and traditional medicine.
- b) *Commelina diffusa*: Employed in traditional medicine to treat various ailments.
- c) *Floscopa scandens*: treats gynecological and musculoskeletal issues.
- d) *Cyanotis axillaris*: The seeds are used for food.

3. Agricultural Weeds (Economic Impact):

- a) *Commelina benghalensis*: Considered a major weed in over 25 crops (e.g., peanuts, cotton) across many countries.
- b) *Commelina diffusa*: A common, persistent weed in agricultural systems.
- c) *Murdannia nudiflora*: Identified as a weed in several crop systems.

4. Scientific Utility:

- a) *Tradescantia*: Frequently used in science for demonstrating protoplasmic circulation and as a bioassay for detecting environmental pollution.

(6) Some economically important plants of Cyperaceae:

1. Food Source:

- a) Chinese Water Chestnut (*Eleocharis dulcis*): Cultivated extensively for its edible, crunchy tubers.
- b) Chufa or Tiger Nut (*Cyperus esculentus*): Grown in Africa for high-oil content tubers, used in beverages like horchata.
- c) Nutgrass (*Cyperus rotundus*): Tubers are used as food during famine.

2. Weaving, Matting, and Construction:

- a) Papyrus (*Cyperus papyrus*): Historically used for paper and construction of boats.
- b) Mat Sedges (*Cyperus tegetum*, *Schoenoplectus* sp.): Used for making mats, baskets, and sandals.
- c) Totorá (*Schoenoplectus tatora*): Used for constructing boats.

3. Medicinal Uses:

- a) **Rhizomes/Tubers (*Cyperus* sp.):** *Cyperus articulatus*, *C. iria*, and *C. longus* are used for carminative, stimulant, and tonic properties.
- b) **Beach Star (*Remirea maritima*):** Rhizomes for diuretic and sudorific purposes.

4. Other Uses:

- a) **Fodder:** Many *Carex* and *Cyperus* species serve as grazing food for cattle.
- b) **Ornamentals:** *Cyperus alternifolius* (umbrella plant) is used in gardening.
- c) **Environmental:** *Carex arenaria* is used as a sand binder.

(7) Some Economically Important Plants of Liliaceae:

1. Food and Condiments:

- a) *Allium cepa* (Onion): Widely consumed bulb.
- b) *Allium sativum* (Garlic): Used for flavoring and medicinal purposes.
- c) *Asparagus officinalis* (Garden asparagus): Edible shoots.
- d) *Asparagus racemosus* (Satavar): Used as a vegetable and tonic.

2. Medicinal Plants:

- a) *Aloe vera* (Aloe): Known for skin treatment and, for Aloin, used as a purgative.
- b) *Colchicum luteum* (Meadow saffron): Source of colchicine, used for gout treatment.
- c) *Smilax* spp.: Used for medicines, including those acting as tonics.
- d) *Urginea indica* (Indian squill): Used for medicinal purposes and as a rodenticide.
- e) *Gloriosa superba* (Flame lily): Medicinal, but also known to be poisonous.

3. Ornamental Plants (Floriculture):

- a) *Tulipa* (Tulip): Popular garden flower.
- b) *Lilium* (Lily): Major ornamental, used as a cut flower.
- c) *Gloriosa* (Glory lily): Ornamental climber.
- d) *Dracaena* (Dragon tree): Used in landscaping and interior decor.
- e) *Convallaria majalis* (Lily of the valley): Valued for fragrance.

4. Fiber and Industrial Plants:

- a) *Yucca* (Dagger plant): Provides fiber for cordage and rope.
- b) *Phormium tenax* (New Zealand flax): Yields strong fiber.

- c) *Xanthorrhoea*: Yields resin used for varnish and sealing wax.

(8) Some economically important plants of Musaceae:

1. Edible Fruits & Food Security:

- a) *Musa paradisiaca* (**Banana/Plantain**): The most significant species, consumed worldwide as ripe fruit, cooked green fruit, or processed flour.
- b) *Musa acuminata* & *Musa balbisiana*: The primary wild ancestors of most cultivated banana varieties.
- c) *Ensete ventricosum* (**Abyssinian Banana/False Banana**): A crucial food source in Ethiopia, where its corm is used for food.

2. Fiber & Industrial Use:

- a) *Musa textilis* (**Abacá/Manila Hemp**): fiber used in paper, clothing, and cordage.
- b) *Musa basjoo*: Used for fiber in Japan.
- c) *Musa sapientum*: Fruit skin used in soap industry (high potash content).

3. Medicinal Uses:

- a) *Musa spp.*: Sap is used for treating nervous system disorders (hysteria, epilepsy) and in traditional medicines for dysentery and diarrhea.
- b) **Ornamental**: *Musa ornata* (Flowering Banana), *Musa velutina* (Velvet Banana), and *Musella lasiocarpa* (Chinese Dwarf Banana): Cultivated for their aesthetic foliage and flowers.

4. Other Uses:

- a) **Leaves**: Used extensively for wrapping food, as plates, and for roofing materials.
- b) **Ash**: Used in dyeing, and the plant has applications in leather and wood processing.

(9) Some economically important plants of Orchidaceae:

- 1. Flavoring (*Vanilla*):** *Vanilla planifolia* and *V. tahitensis*: Produce vanilla beans for flavoring food and confectionery.

- a) **Horticulture/Ornamental** (Cut Flowers & Pot Plants): *Cattleya*, *Phalaenopsis*, *Dendrobium*, *Cymbidium*, *Odontoglossum*, *Vanda*, *Paphiopedilum*.
- b) *Epidendrum* (Green-fly orchid) and *Oncidium* (Butterfly orchid).

2. Medicinal & Herbal:

- a) ***Gastrodia elata***: Tubers used in traditional medicine for headaches and vertigo.
- b) ***Dendrobium officinale***: Used in herbal health products and drinks.
- c) ***Eulophia campestris*, *Vanda roxburghii*, and *Orchis latifolia***: Used for various medicinal purposes (e.g., rheumatism, tonics).
- d) Ashtavarga plants (e.g., Riddhi, Vriddhi): Used in Ayurvedic preparations like Chyawanprash.

3. Food/Tuber Products:

- a) **Salep (derived from tubers of *Orchis* and *Ophrys* species)**: Used in hot beverages and ice cream.
- b) ***Habenaria susannae***: Tubers used as food.

Summary Table of Uses of orchids

Genus/Species	Economic Use
<i>Vanilla planifolia</i>	Primary source of vanilla
<i>Phalaenopsis</i> spp.	Highly popular ornamental pot plant
<i>Dendrobium</i> spp.	Ornamental and herbal medicine
<i>Cattleya</i> spp.	High-value cut flower
<i>Cymbidium</i> spp.	Cut flower and tea
<i>Orchis</i> spp.	Salep production (tuber)

Orchids are also heavily traded for, with over 100,000 artificial hybrids created for their aesthetic appeal.

(10) Some economically important plants of Poaceae:

1. Cereals (Staple Foods):

- Rice (*Oryza sativa*): Major global food source.
- Wheat (*Triticum aestivum*): Primary staple in many regions.
- Corn/Maize (*Zea mays*): Food, industrial raw material, and animal feed.
- Barley (*Hordeum vulgare*): Used in food and beverages.
- Oats (*Avena sativa*): Human consumption and livestock feed.
- Rye (*Secale cereale*): Food grain.

2. Millets (Nutritious Grains):

Millets are warm-weather, annual, small-grained cereals that are members of the grass family. They have a nutritious level comparable with other main grains and are extremely resilient to drought and other harsh weather.

Due to its excellent grain output and resistance to drought, pearl millet is frequently cultivated. Often referred to as the "great millet," sorghum is utilized for both food and feed. Finger millet, which is frequently farmed in Africa and India, is well-known for having high calcium content.

- a) **Pearl Millet (Bajra):** *Pennisetum glaucum / typhoideum* - The most widely cultivated, high in iron and protein.
- b) **Sorghum (Jowar):** *Sorghum bicolor* - A major, versatile grain often used as Food, fodder, and syrup
- c) **Finger Millet (Ragi):** *Eleusine coracana* - Known for exceptionally high calcium content, crucial for bone health.
- d) **Foxtail Millet (Kangni/Thinai):** *Setaria italica* - Rich in dietary fiber and low in glycemic index, excellent for blood sugar management.
- e) **Little Millet (Kutki/Samai):** High in antioxidants and fiber, often used as a direct rice substitute.
- f) **Barnyard Millet (Sawan/Sanwa):** Rich in iron and good for weight loss.
- g) **Kodo Millet (Kodra/Varagu):** High in fiber and protein, often recommended for managing diabetes.
- h) **Proso Millet (Chena/Barri):** A mild, nutty-flavored grain high in protein and essential minerals.
- i) **Browntop Millet (Korle):** Bears high fiber content & digestive health benefits.

Classification Summary of millets

Major Millets:

- a) **Pearl Millet (Bajra):** *Cenchrus americanus* (synonym *Pennisetum glaucum*)
- b) **Sorghum (Jowar):** *Sorghum bicolor*
- c) **Finger Millet (Ragi):** *Eleusine coracana*

Minor Millets

- a) **Foxtail Millet (Kakum/Kangni):** *Setaria italica*
- b) **Little Millet (Kutki):** *Panicum sumatrense*
- c) **Kodo Millet (Kodra):** *Paspalum scrobiculatum*

- d) **Barnyard Millet (Sanwa):** *Echinochloa esculenta* (Japanese), *Echinochloa frumentacea* (Indian)
- e) **Proso Millet (Cheena):** *Panicum miliaceum*
- f) **Browntop Millet (Korle):** *Urochloa ramosa* (formerly *Brachiaria ramosa*)



Pearl millet
(*Pennisetum glaucum*)



Finger millet
(*Eleusine coracana*)



Proso millet
(*Panicum miliaceum*)



Kodo millet
(*Paspalum scrobiculatum*)

Millets are valued for sustaining nourishment and tolerance to hot, dry regions.

Sugar & Industrial Crops:

- a) **Sugarcane (*Saccharum officinarum*):** Primary source of sugar.
- b) **Bamboo (*Bambusa* spp.):** Construction, paper, and furniture.
- c) **Broomcorn (*Sorghum vulgare* var. *technicum*):** Used for brooms.

Aromatic & Other Uses:

- a) **Lemon grass (*Cymbopogon citratus*):** Essential oil production.
- b) **Vetiver/Khus grass (*Chrysopogon zizanioides*):** Aromatic oil and soil conservation.
- c) **Turf grasses (*Cynodon dactylon* - Bermuda grass):** Lawns and landscaping.

Major Economic Impacts:

- a) **Food Security:** Cereals provide the bulk of calories for the human population.
- b) **Livestock Industry:** Provides essential fodder and grazing, supporting meat and dairy production.
- c) **Industry:** Source of biofuel, alcohol (beer/whisky), and building materials.

(11) Some economically important plants of Zingiberaceae:

- a) **Ginger (*Zingiber officinale*):** globally used as spice, food, and medicinally.
- b) **Turmeric (*Curcuma longa*):** Cultivated for its rhizome, which is used as a spice (curry powder), yellow dye, in cosmetics, and in medicine for its antioxidant and anti-inflammatory properties.
- c) **Cardamom (*Elettaria cardamomum*):** Known as the "queen of spices," it is a major economic crop for its aromatic seeds.

- d) **Galangal / Thai Ginger (*Alpinia galanga*)**: Used in Southeast Asian cuisine and for medicinal purposes.
- e) **Mango Ginger (*Curcuma amada*)**: A rhizome with a mango-like flavor, used for pickles and in traditional medicine.
- f) **Shampoo Ginger / Pinecone Ginger (*Zingiber zerumbet*)**: Used for its medicinal properties and in traditional shampoos.
- g) **Black Cardamom (*Amomum subulatum*)**: A major spice used in savory dishes.
- h) **Ornamental Ginger (*Hedychium coronatum* - Ginger Lily)**: Cultivated in gardens and greenhouses for their fragrant flowers.

Key Economic Uses:

- a) **Spices & Food**: Ginger, Turmeric, Cardamom, Galangal, Myoga (*Zingiber mioga*).
- b) **Medicinal**: Used for nausea, anti-inflammatory, & digestive disorders.
- c) **Ornamental**: *Alpinia*, *Hedychium*, and *Curcuma* species.
- d) **Aromatic/Cosmetic**: Used in perfumes, soaps, and traditional hair care.

Important Genera: *Zingiber* (Ginger), *Curcuma* (Turmeric), *Elettaria* (Cardamom), *Alpinia* (Galangal), *Amomum* (Black Cardamom), *Hedychium* (Ginger Lily), *Kaempferia* (Aromatic ginger)

The starch and fragrant oils in these plants' rhizomes make them valuable fresh, dried, or as extracts.

ECONOMIC IMPORTANCE, PARTS USED, AND MEDICINAL PROPERTIES OF SOME MEDICINAL/AROMATIC PLANTS

***Cinchona*:**

Cinchona is a genus of trees and shrubs in the family Rubiaceae, historically significant as the primary source of the anti-malarial drug quinine. Known as "fever trees," these plants have a deep-rooted impact on global health and tropical exploration.

1. Economic Importance of *Cinchona*

- a) **Source of Quinine:** *Cinchona* is the only economically practical, natural source of quinine, which remained the sole effective treatment for malaria for centuries.

- b) **Pharmaceutical Industry:** The bark is used to produce quinine, quinidine, and other alkaloids, used in pharmaceuticals for anti-malarial, anti-arrhythmic, and other medicinal applications.
- c) **Beverage Industry:** *Cinchona* bark extract is used as a bittering agent in tonic water, bitter lemon, and various alcoholic aperitifs (e.g., quinquina or Cap Corse).
- d) **Colonial History:** The demand for *Cinchona* bark during the 19th century was critical for European colonial expansion into tropical, mosquito-infested areas.
- e) **Raw Material & Trade:** In Indonesia & India it's a source of non-oil & gas foreign exchange.

2. Parts Used

- a) **Bark (Primary):** The bark of the trunk, branches, and especially the roots is harvested.
- b) **Root Bark:** Generally considered superior to stem bark, as it contains the highest concentration of alkaloids.
- c) **Method of Harvesting:** Coppicing or uprooting produces bark, frequently with "mossing" to promote thicker, better bark.

3. Medicinal Properties of *Cinchona*

The medicinal properties are attributed to over 25 alkaloids present in the bark. The Four Major Alkaloids are- Quinine, Quinidine, Cinchonidine, and Cinchonine. Other Minor Alkaloids and Related Compounds are Quinamine, Epiquinidine, Epiquinine, Cinchonamine, Cinchophyllamine, Quinicine, Cinchonicine, Chairamidine, Chairamine etc. The bark contains quinovin, quinic acid, cinchotannic acid (a phlobatannin), and "cinchona red" in addition to alkaloids. The two main alkaloids are pseudoenantiomeric pairs (Quinine-Quinidine and Cinchonidine-Cinchonine), which are frequently employed for asymmetric catalysis in modern chemistry.

Anti-malarial: Highly effective against *Plasmodium falciparum*, particularly for treating chloroquine-resistant malaria.

Anti-pyretic (Anti-fever): Used to reduce fever, particularly in malaria.

Bitter Stomachic: Stimulates saliva and gastric juices, aiding in digestion and appetite improvement.

Cardiac Depressant (Quinidine): Quinidine (a key alkaloid) is used to treat irregular cardiac rhythms (arrhythmias) and atrial fibrillation.

Anti-inflammatory/Anti-spasmodic: Used to treat leg cramps, neuralgia, and rheumatism.

Antiseptic/Astringent: Used in gargles for sore throats and in lotions for burns.

Other Potentialities: Studies suggest potential anti-cancer, anti-oxidant, anti-obesity, and anti-microbial activities.

Note: *Cinchona* alkaloids can cause "cinchonism" (headaches, vertigo, and ringing in the ears) and deadly heart issues in high doses.

Ipecac

Ipecac is a tropical shrub with strong therapeutic qualities, especially for treating poisoning. It is derived from *Carapichea ipecacuanha* and *Cephaelis acuminata*. It contains **isoquinoline** alkaloids, mainly *cephaeline* and *emetine*, which are expectorant and rapid-acting emetics (cause vomiting).

1. Economic Importance of *Ipecac*

- a) **Medicinal Production:** Historically used to produce Ipecac syrup, a staple in first-aid for inducing vomiting in cases of suspected poisoning.
- b) **Pharmaceutical Trade:** It is a valuable medicinal plant, with roots traded for extracting emetine and cephaeline for pharmaceutical use in cough mixtures and treating amoebic dysentery.
- c) **Cultivation:** Primarily grown in Brazil and parts of Central America.
- d) **Decline in Use:** Due to a lack of evidence of effectiveness, its routine use as an emetic has been discontinued in Western medicine, leading to a significant decrease in commercial demand for, and production of, the syrup.

2. Parts Used

- a) **Roots and Rhizomes:** The dried roots and rhizomes (underground stems) are the main parts used to prepare the medicine.
- b) **Characteristics:** The roots are typically annulated (ringed) and yellowish-brown to dark brown in color.

3. Medicinal Properties of *Ipecac*

Ipecac contains major alkaloids: emetine and cephaeline.

- a) **Emetic:** It acts by irritating the stomach lining and stimulating the brain's chemoreceptor trigger zone to induce vomiting, typically within 15–60 minutes.
- b) **Expectorant:** In low doses, it is used to thin mucus and facilitate coughing in cases of bronchitis and croup.

- c) **Amoebicide:** Emetine, in particular, is effective against *Entamoeba histolytica*, the cause of amoebic dysentery.
- d) **Diaphoretic:** Historically used to induce sweating.
- e) **Antiviral Potential:** Recent studies have suggested that emetine may have potential as an antiviral agent against coronaviruses (SARS and MERS) and other viruses like Zika.

4. Precautions and Safety

- a) **Toxicity:** Overuse can cause severe heart issues, cardiomyopathy, and death.
- b) **Contraindications:** Should not be used for corrosive substance ingestion (e.g., lye) or if the patient is drowsy/unconscious.
- c) **Recommendation:** It is generally no longer recommended for routine emergency use.

Adhatoda

Adhatoda (scientific name: *Justicia adhatoda* L.), commonly known as Vasaka, Adulsa, or Malabar Nut, is a highly significant medicinal shrub in the Acanthaceae family, used for over 2,000 years in Ayurvedic and Unani medicine, primarily to treat respiratory disorders.

1. Medicinal Properties and Therapeutic Uses of *Adhatoda*

The plant is a rich source of alkaloids, particularly vasicine and vasicinone, which provide a wide range of pharmacological effects.

- a) **Respiratory Care:** It is a well-known, potent expectorant, bronchodilator, and antitussive agent used to treat asthma, chronic bronchitis, cough, cold, and tuberculosis. It helps loosen thick, sticky phlegm.
- b) **Anti-inflammatory & Anti-allergic:** It possesses significant anti-inflammatory and anti-allergic properties.
- c) **Wound Healing & Antiseptic:** Leaf paste is used as a poultice for wounds, rheumatic joints, and skin infections.
- d) **Other Properties:** It is used as an abortifacient/uterotonic (to speed up childbirth), anti-diabetic, antipyretic (fever reducer), and for treating bleeding piles, jaundice, and gonorrhea.

2. Parts Used of *Adhatoda*

- a) **Leaves:** Most widely used, greatest medicinal chemical concentration.
- b) **Roots:** Used in decoctions for bronchial and chest disorders.
- c) **Flowers:** Used to treat eye diseases (ophthalmia) and as a cooling agent.
- d) **Bark:** Used in treating bleeding piles and intestinal worms.

- e) **Fruit:** Sometimes utilized in treating diarrhea and dysentery.

3. Economic Importance of *Adhatoda*

- a) **Pharmaceutical Industry:** The active alkaloid, vasicine, is used to manufacture modern medicines, including the widely used mucolytics bromhexine and ambroxol.
- b) **Commercial Formulations:** It is a key ingredient in many Ayurvedic, Unani, and herbal cough syrups and remedies (e.g., Vasasav, Kada, Kan Jang).
- c) **Agricultural Utility:** Acts as a larvicidal, and antifeedant against agricultural pests like the tomato fruit borer (*Helicoverpa armigera*).
- d) **Environmental & Agrarian:** The leaves are utilized as green manure to boost compost nitrogen. Soil binding, phytoremediation (removing mercury and chromium from water), and land restoration are other ecological advantages.

Curcuma longa (Turmeric)

Turmeric, or *Curcuma longa*, is a perennial herb that belongs to the ginger family (Zingiberaceae) and has enormous uses as a spice, color, and industrial, culinary, and medical ingredient. It is referred to as the "**Golden Spice of India**" because of the vivid yellow hue that comes from the active ingredient *curcumin*.

1. Economic Importance of Turmeric

Turmeric is a major commercial crop, with India accounting for over 80% of global production and 60% of world exports.

- a) **Food Industry:** Used as a staple ingredient in curry powder, providing flavor and a yellow tinge to mustard, cheese, butter, and pickles.
- b) **Medicinal/Nutraceutical Industry:** High demand for curcumin-based supplements to treat chronic diseases, with the market growing rapidly.
- c) **Cosmetics & Beauty:** Used in skincare for products targeting acne, rashes, and as a skin brightener.
- d) **Dye Industry:** Serves as a natural, non-toxic dye for textiles, including fabrics and traditional robes.
- e) **Cultural Significance:** Used in religious ceremonies, particularly in Hinduism, symbolizing purity and prosperity.

2. Parts Used

- a) **Rhizomes (Underground Stem):** This is the primary part used. It is harvested, boiled, dried, and ground into a fine, deep orange-yellow powder.

- b) **Leaves:** Sometimes used in traditional, local, or specialized cuisine for flavoring.

3. Medicinal Properties and Health Benefits of Turmeric

Turmeric contains over 100 chemical compounds, including curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin) and volatile oils (atlantone, turmerone).

- a) **Anti-inflammatory:** A highly potent anti-inflammatory, inhibiting enzymes like COX-2 and 5-LOX. It is used to treat arthritis, rheumatism, and general pain.
- b) **Antioxidant:** Scavenges free radicals and increases antioxidant enzyme levels, comparable to vitamins C and E.
- c) **Anticarcinogenic/Anti-tumor:** Inhibits cancer progression at various stages (initiation, promotion, angiogenesis) and promotes apoptosis (cell death) in cancer cells.
- d) **Hepatoprotective:** Protects the liver against toxins, cirrhosis, and fatty liver disease, acting similarly to silymarin.
- e) **Antimicrobial & Antiviral:** Inhibits the growth of various bacteria, parasites, and fungi (e.g., *H. pylori*, dermatophytes).
- f) **Gastrointestinal Health:** Acts as a carminative and helps manage irritable bowel syndrome (IBS), ulcers, and improves fat digestion.
- g) **Neuroprotective:** Research suggests it may help in treating Alzheimer's disease by reducing amyloid plaques and inflammation in the brain.
- h) **Wound Healing:** Applied topically treat cut, burn, skin infection.

4. Important Chemical Constituents of Turmeric

- a) **Curcumin (Curcumin I):** The main bioactive component (94% of curcuminoids) responsible for the yellow color.
- b) **Curcuminoids:** Comprising Curcumin, Demethoxycurcumin, and Bisdemethoxycurcumin.
- c) **Volatile Oils:** Including turmerone, arturmerone, and zingiberene.

5. Safety and Usage

Although the FDA has classified high-dose turmeric supplements as generally recognized as safe (GRAS), taking them in excess can interfere with blood thinners or induce digestive problems like nausea or diarrhea. It is regarded as harmless and is frequently included in the diet on a daily basis in India.

Elettaria cardamomum (Cardamom)

The "Queen of Spices," Cardamom, is a highly prized and fragrant spice crop that is mostly cultivated in Guatemala and India for use in the global perfumery, medicine, and culinary

sectors. Its essential oil, which is high in 1,8-cineole, is used to treat respiratory problems, digestive disorders, and bad breath, while the dried fruit seeds and capsules are used for flavoring.

1. Economic Importance of Cardamom

- a) **High-Value Spice:** It is one of the world's most expensive spices by weight, making it a critical cash crop for farmers in India and Guatemala.
- b) **Culinary Usage:** Used extensively in spice blends (garam masala), desserts, beverages, and as a flavoring agent in tobacco.
- c) **Industrial Applications:** Essential oil extracted from seeds is used in the pharmaceutical, food, and perfume industries.
- d) **Pharmaceuticals:** Used in Ayurvedic and modern medicine for preparing herbal, digestive, and oral care products.

2. Parts Used

- a) **Dried Fruit Capsule (Pod):** Uses seeds whole or ground for taste and medicinal.
- b) **Seeds:** The primary source of essential oil, containing compounds like terpinyl acetate, 1,8-cineole, and linalool.
- c) **Rhizomes:** Sometimes used in traditional remedies.

3. Medicinal Properties of Cardamom

- a) **Digestive Aid:** Promotes digestion, treats indigestion, flatulence, and colic.
- b) **Respiratory Health:** Used to alleviate asthma, bronchitis, and clear lung congestion.
- c) **Antimicrobial & Antiseptic:** Contains 1,8-cineole, which acts as a potent antiseptic, particularly for oral hygiene to treat bad breath and gum infections.
- d) **Anti-inflammatory & Antioxidant:** Helps reduce inflammation and is used to treat nausea, diarrhea, and vomiting.
- e) **Cardiac Support:** Functions as a cardiac stimulant and tonic.

4. Other Potential Uses:

Known to have diuretic properties, aid in treating kidney stones, and provide relief from hypertension and stress-related disorders.

Cardamom is also utilized in Ayurvedic, Unani, and Chinese traditional medicines for various ailments including, but not limited to, headaches, anorexia, and cardiovascular diseases.

***Azadirachta indica* (Neem)**

Neem, or *Azadirachta indica*, is a highly prized tree because of its many industrial, agricultural, and medicinal uses. Because of its strong antiseptic, antibacterial, antifungal, and antipyretic qualities, practically every part—leaves, bark, seeds, fruit, roots, and flowers—is used. Economically, it supplies fertilizer, oil, soap, biopesticides, and feed. It is also essential to traditional Indian medicine.

1. Economic Importance of Neem

- a) **Agriculture:** Leaves and neem oil are used as potent natural pesticides, fertilizers, and soil conditioners (bio-pesticide, neem cake).
- b) **Medicinal/Cosmetic Industry:** Extracts are used in manufacturing soaps, toothpaste, shampoos, lotions, and anti-acne products.
- c) **Industrial Use:** Seed oil is used in the manufacturing of lubricants and lighting.
- d) **Environmental Benefits:** It acts as an air purifier and is often planted for reforestation and to check desertification.

2. Parts Used and Medicinal Properties of Neem

- a) **Leaves:** Contain antibacterial and anti-inflammatory properties, used to treat skin infections, acne, dandruff, and to boost immunity. They are used as fodder and for preserving grains.
- b) **Bark:** Possesses strong antiseptic properties, used to treat fever, malaria, skin diseases, and in treating leprosy.
- c) **Seeds/Oil:** Used for oil production, which acts as a powerful insecticide, antiseptic, and to treat skin infections.
- d) **Flowers:** Used for treating intestinal worms, vomiting, anorexia, and in traditional, nutrient-rich, or bitter culinary dishes.
- e) **Fruit/Roots:** Used as purgatives and in the treatment of hemorrhoids and urinary tract diseases.

3. Key Medicinal Properties of Neem

- a) **Leaves:** Contain antibacterial and anti-inflammatory properties, u
- b) **Antimicrobial & Antiseptic:** Effective against various fungi, bacteria, and viruses.
- c) **Anti-inflammatory & Analgesic:** Used to treat pain and chronic inflammation, sometimes considered more effective than synthetic drugs.
- d) **Dermatological:** Excellent for treating acne, eczema, and other skin disorders.
- e) **Dental Health:** Bark and leaf extracts are used to prevent plaque and gingivitis.
- f) *Azadirachta indica* is a vital, sustainable resource for health and agriculture, often referred to as a "panacea for all ailments".

Cannabis sativa

Cannabis sativa L., an annual dioecious plant with great economic, industrial, and therapeutic significance, is frequently divided into two types according to its cannabinoid content: industrial (hemp) and drug (marijuana). It is known to produce more than 500 chemical components, such as flavonoids, terpenes, and cannabinoids.

Etymology: The Latin word "cannabis," which was borrowed from Greek, became Proto-Germanic, giving rise to many Germanic forms, including Old Norse "hampr," Old English "haenep," Old Saxon "hanup," and Old High German "hanaf," until finally becoming modern British English "hemp."

Spiritual note on *Cannabis*: Several religions have revered *Cannabis* as an entheogen in the Indian subcontinent since the Vedic period. The Atharva Veda, written approximately 1400 BCE, has the first recorded references to *Cannabis*' revered position in India. Shiva is called the "Lord of bhang" for using *Cannabis*. The Rastafari movement has popularized *Cannabis* as a sacrament and meditation aid in modern culture.

1. Economic Importance

- a) *Cannabis sativa* is a "thousand and one molecules" plant, capable of being used in thousands of products.
- b) **Industrial Hemp (Fiber & Bast):** Used for textiles, clothing, durable rope, canvas, and specialized paper. It provides a sustainable, biodegradable alternative to fiberglass and plastics (biocomposites).
- c) **Construction:** Hemp hurd (woody core) combined with lime creates "hempcrete," a sustainable, insulating, and mold-resistant building material.
- d) **Automotive:** Hemp fibers are used in biocomposites to reinforce door panels and dashboards in vehicles.
- e) **Food and Nutrition:** Seeds are considered a superfood, rich in essential fatty acids (Omega-3 and 6) and digestible proteins, used in protein powders, oils, and snacks.
- f) **Environmental Benefits:** Used for bioremediation of contaminated soil and water.
- g) **Cosmetics:** Seed oil is used in lotions, soaps, and anti-aging creams.

2. Parts Used and Their Applications

- a) **Flowers (Inflorescence):** The primary source of cannabinoids (THC, CBD) and terpenoids, used in medicine and high-end essential oils.
- b) **Leaves:** Used traditionally in medicine to treat skin conditions (eczema), inflammation, and central nervous system disorders. Also used for teas and extracts.

- c) **Stems (Fiber/Bast & Hurds):** The outer bast fiber is used for textiles, while the inner woody hurds are used for animal bedding, mulch, and insulation.
- d) **Seeds (Fruits):** Used for food (hemp hearts), oil, and animal feed.
- e) **Roots:** Used in traditional medicine to treat joint pain, inflammation, and skin burns.
- f) **Trichomes:** Glandular hairs that coat the flowers and leaves, containing the highest concentration of cannabinoids and terpenes.

3. Medicinal Properties

More than 100 cannabinoids and several terpenes/flavonoids are responsible for the therapeutic potential.

- a) **Analgesic and Anti-inflammatory:** Used for chronic pain management, rheumatism, arthritis, and joint pain.
- b) **Neurological Disorders:** CBD (cannabidiol) is used in treating refractory epilepsy (e.g., Dravet syndrome) and multiple sclerosis (MS) spasticity.
- c) **Antiemetic and Appetite Stimulant:** Treats nausea, vomiting in cancer chemotherapy patients, and wasting syndrome in AIDS patients.
- d) **Psychological and Sleep Aid:** Used for alleviating anxiety, PTSD-related nightmares, and insomnia.
- e) **Anticancer Potential:** Research indicates that some cannabinoids (CBC, CBG) show tumor-inhibiting and anti-neoplastic effects.
- f) **Antimicrobial and Antioxidant:** Hemp components show antibacterial properties against bacteria like *E. coli* and possess strong antioxidant activities.
- g) **Note on Regulation:** While its therapeutic value is widely recognized, *Cannabis sativa* remains subject to strict regulations and is illegal or heavily controlled in many countries due to its psychoactive THC content.

What Is Bhang?

Ans: Dry *Cannabis sativa* leaves and buds are pulverized and soaked to make bhang. This Lord Shiva-related drink is highly popular during Indian occasions like Holi. Bhang is commonly eaten as goli or lassi.

What Is Ganja?

Ganja—marijuana, weed, or pot—is made from dried *Cannabis* flowers, leaves, and resin. Ganja is smoked rather than eaten like bhang because of its greater and quicker effects.

How do Bhang & Ganja affect our Mind & Body?

The psychoactive ingredient THC is present in both ganja and bhang, albeit (although) in different amounts.

- a) **THC (Tetrahydrocannabinol):** it is the main substance that causes the "high" sensation. It has an impact on motor skills, emotions, and memory.
- b) **CBD (Cannabidiol):** It can lessen some of the euphoric effects of THC while also having a soothing and anti-inflammatory impact.

Important Details About Bhang:

- a) **Origin & Definition:** Usually added to beverages like thandai or lassi, this paste is formed from the leaves and buds of the cannabis plant.
- b) **Traditional Significance:** It has deep cultural roots in India and is customarily consumed during the Holi and Maha Shivaratri festivities.
- c) **Religious Association:** Connected to Lord Shiva, the "Lord of Bhang"
- d) **Preparation:** Bhang is a gentler kind of cannabis than charas or ganja since it is made from leaves rather than resin or blooming tops.
- e) **History:** It was first used in ancient India around 1000 BCE.
- f) **Medicinal/Spiritual Use:** Traditionally used as a sacrament and for a variety of diseases in Ayurveda.
- g) **Effects:** Because bhang is edible, its effects may take longer to show up, but they are frequently strong and long-lasting.

Important Information about Ganja (*Cannabis*):

- a) **Active Ingredients:** Tetrahydrocannabinol (THC) is the primary psychoactive component, while cannabidiol (CBD) is another significant, non-intoxicating substance.
- b) **Species:** Cannabis sativa, Cannabis indica, and Cannabis ruderalis are the three commonly recognized species.
- c) **Origin and Use:** Entheogenic (spiritual), medical and recreational uses date back centuries, and it is native to Central or South Asia.
- d) **Methods of Consumption:** Ganja can be smoked, vaporized, or ingested through food.
- e) **Legal Status:** Varies greatly; in certain nations, it is legal for medical or recreational purposes, whereas in many other countries, it is outlawed.
- f) **Effects:** renowned for its psychoactive properties, which can lead to changes in perception, mood, and thought processes.

Comparison between Bhang & Ganja

Features	Bhang	Ganja
Preparation	Made from the leaves & buds of Cannabis Sativa	Made from dried flowers, leaves, & resin of Cannabis plant
Consumption Method	Ingested in food and drinks (like bhang lassi)	Typically smoked or vaporized
Potency	Mild, less intoxicating	High potency, contains more THC
Legal Status	Tolerated in certain areas for medicinal & cultural use	Strictly illegal under the Narcotic Drugs & Psychotropic Substances Act
Time to Take Effect	2-3 hrs (due to digestion)	30 minutes (rapid effects while smoked)
Cultural Significance	Consumed during festivals like Holi, associated with Lord Shiva	Used historically by ascetics; recent recreational use
Active Compounds	mainly contains lesser levels of THC	elevated levels of THC, yielding stronger effects
Common Forms	Bhang lassi, bhang goli (balls)	Smoked in joints, pipes, or bongs

Trichosanthes dioica (Pointed gourd/Potol)

Trichosanthes dioica Roxb., a perennial, dioecious vine in the Cucurbitaceae family, is sometimes referred to as Pointed Gourd, Parwal (Hindi), or Potol (Bengali/Odia). Because of its culinary and therapeutic qualities, it is widely prized throughout the Indian subcontinent.

1. Economic Importance

- Nutrient-Dense Food:** The green, tender fruits are widely consumed as a popular, nutritious, and easily digestible vegetable, particularly in India and Bangladesh.
- Commercial Value:** It is a profitable, high-yield vegetable crop that is in high demand, often grown in the summer and monsoon seasons.
- Nutraceutical/Medicinal Use:** Due to its rich phytochemical profile, it is used to produce Ayurvedic medicines and is considered a "wonder plant" with significant therapeutic potential.
- Culinary Versatility:** It is used in curries, stews, fries, and even sweets.

2. Parts Used

All parts of the *T. dioica* plant, (fruit, leaves, and roots), are used in traditional medicine:

- Fruit:** Used primarily as a vegetable, but also for its juice and pulp to treat digestive issues.

- b) **Leaves/Tender Shoots:** Used in traditional medicine as a tonic, to treat fever (febrifuge), and for topical application on skin diseases.
- c) **Roots:** Possess purgative (laxative) properties.
- d) **Seeds:** Used in extracts to manage cholesterol and blood sugar levels.

3. Medicinal Properties

T. dioica acts as a "storehouse" of bioactive compounds (trichosanthin, cucurbitacins, flavonoids, saponins) and possesses the following medicinal properties:

- a) **Antidiabetic/Hypoglycemic:** The juice of the fruit and leaf extracts can lower blood sugar levels, with studies showing a reduction of up to 14% in fasting blood glucose over 8 weeks.
- b) **Hepatoprotective (Liver Health):** It is a well-known remedy for jaundice, liver disorders, and reducing the enlargement of the liver and spleen.
- c) **Hypolipidemic (Cholesterol Lowering):** Fruit extracts reduce high-density lipoproteins (LDL) and triglycerides
- d) **Digestive and Laxative:** Improves digestion, boosts appetite, and a mild laxative
- e) **Antioxidant & Anti-inflammatory:** Rich in vitamins A, C, and flavonoids (quercetin, kaempferol), which fight free radicals and reduce inflammation.
- f) **Blood Purifier & Skin Care:** To treat infections, edema, boils, and alopecia/hair loss
- g) **Anti-tumor/Anti-cancer:** Root extracts can reduce tumor volume
- h) **Immunity Booster:** Due to the presence of Vitamin C and other nutrients.

4. Important Nutrients

- a) **Vitamins & Minerals:** Rich in Vit-A, C, Ca, Mg, K, and P
- b) **Fiber:** High dietary fiber content that aids in digestion.
- c) **Warning:** Although typically safe, excessive use of concentrated extracts or juice may produce moderate gastrointestinal difficulties. Use the plant under advice, especially for individuals taking additional diabetic treatments.

❖ Examples of various types of vegetables

1. Root Vegetables

These are underground plant parts (swollen taproots or storage roots).

- **Carrot (*Daucus carota* – Apiaceae):** Native to Central Asia and the Mediterranean.
- **Radish (*Raphanus sativus* – Brassicaceae):** Native to Europe or Asia (India/China).
- **Beetroot (*Beta vulgaris* – Amaranthaceae):** Native to the Mediterranean region.

- **Sweet Potato (*Ipomoea batatas* – Convolvulaceae):** Native to tropical America (Central/South America).
- **Cassava/Yuca (*Manihot esculenta* – Euphorbiaceae):** Native to South America.
- **Turnip (*Brassica rapa* – Brassicaceae):** Native to Europe and temperate Asia.

2. Underground Stem Vegetables

These are modified stems (tubers, rhizomes, corms, bulbs) that grow below ground.

- **Potato (*Solanum tuberosum* – Solanaceae):** Native to the Andean region of South America.
- **Ginger (*Zingiber officinale* – Zingiberaceae):** Native to Southeast Asia.
- **Onion (*Allium cepa* – Amaryllidaceae):** Native to Central Asia.
- **Garlic (*Allium sativum* – Amaryllidaceae):** Native to Central Asia.
- **Taro/Colocasia (*Colocasia esculenta* – Araceae):** Native to Southeast Asia and Southern India.
- **Jerusalem Artichoke (*Helianthus tuberosus* – Asteraceae):** Native to North America.

3. Herbage Vegetables (Leafy & Stem)

These include leaves, stalks, and shoots (culinary greens).

- **Spinach (*Spinacia oleracea* – Amaranthaceae/Chenopodiaceae):** Native to Central/Southwestern Asia.
- **Cabbage (*Brassica oleracea* var. *capitata* – Brassicaceae):** Native to Mediterranean Europe.
- **Lettuce (*Lactuca sativa* – Asteraceae):** Native to the Mediterranean region.
- **Celery (*Apium graveolens* – Apiaceae):** Native to the Mediterranean and North Africa.
- **Fenugreek Leaves (*Trigonella foenum-graecum* – Fabaceae):** Native to the Mediterranean and Western Asia.
- **Asparagus (*Asparagus officinalis* – Asparagaceae):** Native to Europe, North Africa, and Western Asia.

4. Fruit Vegetables

Botanically fruits, but used as vegetables in cooking.

- **Tomato (*Solanum lycopersicum* – Solanaceae):** Native to South America.
- **Brinjal/Eggplant (*Solanum melongena* – Solanaceae):** Native to India and Asia.
- **Cucumber (*Cucumis sativus* – Cucurbitaceae):** Native to India.
- **Okra/Lady Finger (*Abelmoschus esculentus* – Malvaceae):** Native to Tropical Africa.

- Pumpkin (*Cucurbita pepo* – Cucurbitaceae): Native to North America.
- Bottle Gourd (*Lagenaria siceraria* – Cucurbitaceae): Native to Africa/Asia.

5. Other Vegetables (Flower/Podded)

- **Cauliflower** (*Brassica oleracea* var. *botrytis* – Brassicaceae): Native to the Mediterranean region.
- **Broccoli** (*Brassica oleracea* var. *italica* – Brassicaceae): Native to the Mediterranean region.
- **Peas** (*Pisum sativum* – Fabaceae): Native to the Mediterranean and Western Asia.
- **Green Beans** (*Phaseolus vulgaris* – Fabaceae): Native to Central and South America.
- **Moringa/Drumstick** (*Moringa oleifera* – Moringaceae): Native to India.

❖ By-Products of Sugar Industry & their Important Uses:

The sugar industry produces 3 main by-products—bagasse, molasses, and press mud—which make up around 88% of the processed sugarcane, and have substantial economic value in addition to sugar production. These are mostly used for the production of organic fertilizers, animal feed, ethanol/alcohol, and renewable energy (cogeneration).

1. Bagasse (Fibrous Residue):

Biofuel: Used as the primary fuel source in sugar factories to generate steam.

Paper & Pulp: Used as raw material to produce paper, cardboard, packaging materials.

Building Materials: Used to produce particle boards and other construction materials.

2. Molasses (Dark Syrup):

Ethanol Production: Fermented to produce industrial alcohol, ethanol for fuel blending, and potable spirits (rum).

Animal Feed: Highly nutritious component for livestock feed.

Chemical/Food Industry: Used in the production of citric acid, vinegar, and yeast.

3. Press Mud / Filter Cake (Clarification Waste):

Fertilizer: Used as a nutrient-rich soil conditioner/organic manure for farms.

Wax Production: Extracted to produce sugarcane wax for industrial applications.

Biogas: Used in generating biogas.

4. Other Minor By-Products:

Ash: Used as fertilizer for potassium content.

Green Cane Trash: Used for mulching (soil covering) and biomass energy.

❖ Important Fruits with their botanical names, Families, Types, Edible Parts, and Native place

- **Mango (*Mangifera indica*):** Drupe; Family: Anacardiaceae; Edible: Mesocarp; Native: India.
- **Banana (*Musa paradisiaca*):** Berry; Family: Musaceae; Edible: Pericarp and Placenta; Native: South East Asia.
- **Apple (I):** Pome; Family: Rosaceae; Edible: Fleshy Thalamus; Native: Caucasus Mountains/Central Asia.
- **Guava (*Psidium guajava*):** Berry; Family: Myrtaceae; Edible: Pericarp and Placenta; Native: Tropical America.
- **Citrus/Orange (*Citrus spp*):** Hesperidium; Family: Rutaceae; Edible: Succulent hairs (mesocarp/endocarp); Native: Tropical Asia.
- **Grapes (*Vitis vinifera*):** Berry; Family: Vitaceae; Edible: Pericarp; Native: Mediterranean region.
- **Papaya (*Carica papaya*):** Berry; Family: Caricaceae; Edible: Mesocarp; Native: Tropical America.
- **Pineapple (*Ananas comosus*):** Sorosis; Family: Bromeliaceae; Edible: Fleshy axis and bracts; Native: South America.
- **Jackfruit (*Artocarpus heterophyllus*):** Sorosis; Family: Moraceae; Edible: Fleshy perianth; Native: India.
- **Coconut (*Cocos nucifera*):** Drupe; Family: Arecaceae; Edible: Endosperm; Native: Southeast Asia.

An explanation of the 5 common fruit types

1. **Drupe:** Thin skin, fleshy middle, hard inner shell (e.g., Mango, Peach, Coconut).
2. **Berry:** Fleshy fruit developed from a single ovary (e.g., Banana, Grape, Guava).
3. **Pome:** Accessory fruit where the edible part is a swollen receptacle (e.g., Apple, Pear).
4. **Hesperidium:** Specialized berry with a leathery rind (e.g., *Citrus*).
5. **Sorosis:** Multiple fruit derived from a spike or raceme (e.g., Pineapple, Jackfruit).

❖ TYPES OF ESSENTIAL OILS USED IN PERFUMES:

Plant parts used (Source) - Flowers:

- a) Rose (*Rosa damascena/centifolia*): Petals; Family: Rosaceae
- b) Jasmine (*Jasminum grandiflorum*): Flowers; Family: Oleaceae
- c) Ylang-Ylang (*Cananga odorata*): Flowers; Family: Annonaceae
- d) Geranium (*Pelargonium graveolens*): Leaves/Aerial Parts; Family: Geraniaceae
- e) Neroli (*Citrus aurantium* var. *amara*): Flowers; Family: Rutaceae
- f) Lavender (*Lavandula angustifolia*): Flowers; Family: Lamiaceae
- g) Tuberose (*Polianthes tuberosa*): Flowers; Family: Asparagaceae

Citrus:

- 1. Bergamot (*Citrus bergamia*): Rind/Peel; Family: Rutaceae
- 2. Lemon (*Citrus limon*): Peel; Family: Rutaceae
- 3. Sweet Orange (*Citrus sinensis*): Peel; Family: Rutaceae
- 4. Grapefruit (*Citrus paradisi*): Peel; Family: Rutaceae
- 5. Lime (*Citrus aurantiifolia*): Peel; Family: Rutaceae
- 6. Lemongrass (*Cymbopogon citratus*): Grass Leaves; Family: Poaceae

Woody & Earthy parts:

- a) Sandalwood (*Santalum album*): Heartwood/Roots; Family: Santalaceae
- b) Patchouli (*Pogostemon cablin*): Leaves; Family: Lamiaceae
- c) Cedarwood (*Cedrus atlantica/Juniperus virginiana*): Wood; Family: Pinaceae/Cupressaceae
- d) Vetiver (*Vetiveria zizanoides*): Roots/Rhizomes; Family: Poaceae
- e) Rosewood (*Aniba rosaeodora*): Wood; Family: Lauraceae
- f) Agarwood/Oud (*Aquilaria malaccensis*): Heartwood/Resin; Family: Thymelaeaceae

Spicy & Resinous Source:

- a) Frankincense (*Boswellia sacra/carterii*): Resin/Gum; Family: Burseraceae
- b) Myrrh (*Commiphora myrrha*): Resin/Gum; Family: Burseraceae
- c) Cinnamon (*Cinnamomum verum*): Bark; Family: Lauraceae
- d) Clove (*Syzygium aromaticum*): Flower Buds; Family: Myrtaceae
- e) Cardamom (*Elettaria cardamomum*): Seeds/Fruits; Family: Zingiberaceae
- f) Ginger (*Zingiber officinale*): Rhizome; Family: Zingiberaceae
- g) Black Pepper (*Piper nigrum*): Fruit; Family: Piperaceae

Herbal & Green source:

- a) Rosemary (*Rosmarinus officinalis*): Leaves/Flowering Tops; Family: Lamiaceae
- b) Clary Sage (*Salvia sclarea*): Leaves/Flowering Tops; Family: Lamiaceae
- c) Basil (*Ocimum basilicum*): Leaves; Family: Lamiaceae
- d) Tea Tree (*Melaleuca alternifolia*): Leaves; Family: Myrtaceae

<i>Essential Oil</i>	<i>Botanical Name</i>	<i>Plant Family</i>	<i>Part(s) Used</i>	<i>Medicinal Uses & Properties</i>
Lavender	<i>Lavandula angustifolia</i>	Lamiaceae	Flowers	Relaxation, sleep aid, anti-inflammatory, antiseptic
Tea Tree	<i>Melaleuca alternifolia</i>	Myrtaceae	Leaves	Potent antimicrobial, antifungal, acne treatment
Peppermint	<i>Mentha x piperita</i>	Lamiaceae	Leaves	Digestion aid, headache relief, mental alertness
Eucalyptus	<i>Eucalyptus globulus</i>	Myrtaceae	Leaves	Respiratory support, decongestant, air purifier
Clove	<i>Syzygium aromaticum</i>	Myrtaceae	Bud	Anesthetic (dental), antibacterial, antioxidant
Rosemary	<i>Rosmarinus officinalis</i>	Lamiaceae	Leaves/ Flowers	Memory enhancement, hair growth, antiseptic
Lemon	<i>Citrus limon</i>	Rutaceae	Peel	Antimicrobial, mood-lifting, cleaning agent
Chamomile (German)	<i>Matricaria chamomilla</i>	Asteraceae	Flowers	Anti-inflammatory, calming, skin soothing
Sandalwood	<i>Santalum album</i>	Santalaceae	Wood/ Roots	Meditation (calming), skin hydration, perfumery
Cinnamon	<i>Cinnamomum verum</i>	Lauraceae	Bark/ Leaves	Antimicrobial, warming, food flavoring
Frankincense	<i>Boswellia carterii</i>	Burseraceae	Gum/Resin	Anti-inflammatory, skin regeneration, meditation
Lemongrass	<i>Cymbopogon citratus</i>	Poaceae	Leaves/	Antifungal, insect

Essential Oil	Botanical Name	Plant Family	Part(s) Used	Medicinal Uses & Properties
			Grass	repellent, flavoring
Ylang Ylang	<i>Cananga odorata</i>	Annonaceae	Flowers	Perfumery, anxiety reduction, aphrodisiac
Patchouli	<i>Pogostemon cablin</i>	Lamiaceae	Leaves	Perfumery fixative, skin elasticity, insecticide
Bergamot	<i>Citrus bergamia</i>	Rutaceae	Peel	Antidepressant, anxiety relief, perfumery
Ginger	<i>Zingiber officinale</i>	Zingiberaceae	Rhizome	Digestive comfort, anti-inflammatory, flavoring
Vetiver	<i>Vetiveria zizanioides</i>	Poaceae	Roots	Perfumery fixative, grounding, skincare
Thyme	<i>Thymus vulgaris</i>	Lamiaceae	Leaves/ Flowers	Immune support, antibacterial, respiratory health
Fennel	<i>Foeniculum vulgare</i>	Apiaceae	Seeds	Carminative, digestive, antispasmodic
Cade	<i>Juniperus oxycedrus</i>	Cupressaceae	Wood/ Branches	Antiseptic, skin treatments (eczema)

❖ ESSENTIAL OILS WITH MEDICINAL USES, THEIR SOURCE PLANTS, PLANT PARTS AND PLANT FAMILIES

- 1) **Flowers:** Lavender (Lamiaceae), Rose (Rosaceae), Jasmine (Oleaceae), Ylang Ylang (Annonaceae), Chamomile (Asteraceae).
- 2) **Leaves/Herbs:** Peppermint (Lamiaceae), Eucalyptus (Myrtaceae), Tea Tree (Myrtaceae), Rosemary (Lamiaceae), Basil (Lamiaceae), Lemongrass (Poaceae).
- 3) **Bark/Wood:** Cinnamon (Lauraceae), Sandalwood (Santalaceae), Cedarwood (Cupressaceae), Camphor (Lauraceae).
- 4) **Roots/Rhizomes:** Vetiver (Poaceae), Ginger (Zingiberaceae), Angelica (Apiaceae), Valerian (Valerianaceae).
- 5) **Seeds/Fruits:** Fennel (Apiaceae), Coriander (Apiaceae), Cardamom (Zingiberaceae), Nutmeg (Myristicaceae), Orange/Lemon (Rutaceae).

6) **Resins:** Frankincense (Burseraceae), Myrrh (Burseraceae), Balsam of Peru (Fabaceae).

❖ PRINCIPAL VEGETABLE FATS AND FATTY OILS: PLANT NAME, FAMILY, PARTS USED

<i>Oil Name</i>	<i>Plant Name</i>	<i>Plant Part Used</i>	<i>Family</i>
Palm/Palm Kernel Oil	<i>Elaeis guineensis</i>	Fruit Mesocarp/Kernel	Arecaceae
Soybean Oil	<i>Glycine max</i>	Seed	Fabaceae
Sunflower Oil	<i>Helianthus annuus</i>	Seed	Asteraceae
Canola/Rapeseed Oil	<i>Brassica napus</i>	Seed	Brassicaceae
Coconut Oil	<i>Cocos nucifera</i>	Endosperm (Kernel)	Arecaceae
Olive Oil	<i>Olea europaea</i>	Fruit	Oleaceae
Peanut/Groundnut Oil	<i>Arachis hypogaea</i>	Seed (Nut)	Fabaceae
Cottonseed Oil	<i>Gossypium spp.</i>	Seed	Malvaceae
Sesame Oil	<i>Sesamum indicum</i>	Seed	Pedaliaceae
Linseed/Flax Oil	<i>Linum usitatissimum</i>	Seed	Linaceae
Corn Oil	<i>Zea mays</i>	Germ of seed	Poaceae
Castor Oil	<i>Ricinus communis</i>	Seed	Euphorbiaceae
Safflower Oil	<i>Carthamus tinctorius</i>	Seed	Asteraceae
Rice Bran Oil	<i>Oryza sativa</i>	Bran/Germ	Poaceae
Grape Seed Oil	<i>Vitis vinifera</i>	Seed	Vitaceae
Cocoa Butter	<i>Theobroma cacao</i>	Seed	Malvaceae
Shea Butter	<i>Vitellaria paradoxa</i>	Nut	Sapotaceae
Almond Oil	<i>Prunus dulcis</i>	Kernel (Nut)	Rosaceae

Points to Remember:

1. **Edible Oils:** The majority of important edible oils, including sunflower and soybean, are high in polyunsaturated or monounsaturated fats and low in saturated fats.
2. **Saturated Fats:** Notably, cocoa butter, coconut oil, and palm oil are heavy in saturated fats.
3. **Manufacturing:** Oil palm accounts for more than one-third of global vegetable oil output, making it the primary source.

Important rubber yielding plants, their common names, botanical names, families, & parts used, families

Important rubber-yielding plants, categorized by their commercial importance:

1. Major Commercial Rubber Producer

- **Common Name:** Pará Rubber Tree, Rubber Tree, Seringueira
- **Botanical Name:** *Hevea brasiliensis*
- **Family:** Euphorbiaceae (Spurge family)
- **Parts Used:** Latex (extracted from the bark of the trunk via tapping)

2. Significant Alternative/Historical Rubber Producers

- **Common Name:** Panama Rubber Tree, Castilla Rubber
- **Botanical Name:** *Castilla elastica*
- **Family:** Moraceae (Mulberry family)
- **Parts Used:** Latex (harvested from the bark)
- **Common Name:** Ceara Rubber, Maniçoba
- **Botanical Name:** *Manihot glaziovii* (closely related to Cassava)
- **Family:** Euphorbiaceae
- **Parts Used:** Latex (tapped from the bark)
- **Common Name:** Assam Rubber, Indian Rubber Tree, Rubber Fig
- **Botanical Name:** *Ficus elastica*
- **Family:** Moraceae
- **Parts Used:** Latex (found in the stem and bark)

Note: Widely grown as an ornamental plant today, but was once a major rubber source before Hevea took over.

- **Common Name:** Lagos Silk Rubber
- **Botanical Name:** *Funtumia elastica*
- **Family:** Apocynaceae (Dogbane family)
- **Parts Used:** Latex
- **Common Name:** Congo Rubber (Vine)
- **Botanical Name:** *Landolphia owariensis*
- **Family:** Apocynaceae
- **Parts Used:** Latex

3. Emerging Alternative/Non-Tree Sources

- **Common Name:** Guayule
- **Botanical Name:** *Parthenium argentatum*

- **Family:** Asteraceae (Sunflower family)
- **Parts Used:** Whole plant (shrub), specialized latex in tissues
- **Common Name:** Russian Dandelion, Kok-saghyz
- **Botanical Name:** *Taraxacum kok-saghyz*
- **Family:** Asteraceae
- **Parts Used:** Roots (containing latex)

Summary Table of Important rubber-yielding plants

Common Name	Botanical Name	Family	Part Used
Pará Rubber Tree	<i>Hevea brasiliensis</i>	Euphorbiaceae	Trunk Bark (Latex)
Panama Rubber	<i>Castilla elastica</i>	Moraceae	Trunk Bark (Latex)
Assam Rubber	<i>Ficus elastica</i>	Moraceae	Bark & Stem (Latex)
Guayule	<i>Parthenium argentatum</i>	Asteraceae	Whole Plant (Shrub)
Russian Dandelion	<i>Taraxacum kok-saghyz</i>	Asteraceae	Roots
Congo Rubber	<i>Landolphia owariensis</i>	Apocynaceae	Vine (Latex)

❖ PETRO CROP SPECIES:

1. Major Oil/Hydrocarbon Producing Petrocrops

- Physic Nut / Barbados Nut / Purging Nut
- Botanical Name: *Jatropha curcas*
- Family: Euphorbiaceae
- Parts Used: Seeds (for oil/biodiesel), sap
- Rubber Tree
- Botanical Name: *Hevea brasiliensis*
- Family: Euphorbiaceae
- Parts Used: Latex from the stem
- Gopher Plant
- Botanical Name: *Euphorbia lathyris*
- Family: Euphorbiaceae
- Parts Used: Entire plant/latex
- Milk Bush / Sehund
- Botanical Name: *Euphorbia tirucalli*
- Family: Euphorbiaceae
- Parts Used: Latex
- Aak / Milkweed

- Botanical Name: *Calotropis procera*
- Family: Asclepiadaceae
- Parts Used: Latex (high hydrocarbon content)
- Candle Bush / Slipper Plant
- Botanical Name: *Pedilanthus macrocarpus*
- Family: Euphorbiaceae
- Parts Used: Latex
- Copaiba
- Botanical Name: *Copaifera langsdorfii*
- Family: Leguminosae (Fabaceae)
- Parts Used: Oleoresin (from trunk)

2. Rubber-Producing Petrocrops (Compositae Family)

- Guayule
- Botanical Name: *Parthenium argentatum*
- Family: Compositae (Asteraceae)
- Parts Used: Whole plant (latex)
- Russian Dandelion
- Botanical Name: *Taraxacum koksaghyz*
- Family: Compositae (Asteraceae)
- Parts Used: Latex

3. Algal Sources

- Algae
- Botanical Name: *Botryococcus braunii*
- Family: Chlorophyta (Green Algae)
- Parts Used: Whole cells (produce hydrocarbon globules)

Summary of Main features of petrocrops

- 1) **Family Focus:** Most, but not all, belong to Euphorbiaceae.
- 2) **Product:** The extracted milky latex, often called "biocrude," yields roughly 70.6% energy (approx. 22% kerosene and 44.6% gasoline).
- 3) **Advantage:** These crops can be grown on marginal or waste lands unsuitable for conventional agriculture.

❖ FOR POWER PROJECTS AND ENERGY PLANTATIONS

The following are significant plant species for India's power projects and energy plantations:

1. Woody species that grow quickly (for biomass/fuelwood)

As these species produce large amounts of biomass in short rotation cycles (three to five years), they are mostly utilized to generate producer gas, wood pellets, and thermal energy.

<i>Common Name</i>	<i>Botanical Name</i>	<i>Family</i>	<i>Parts Used</i>
Eucalyptus	<i>Eucalyptus tereticornis</i>	Myrtaceae	Stem (wood), branches, bark
Casuarina	<i>Casuarina equisetifolia</i>	Casuarinaceae	Stem, branches (high fuel value)
Subabul	<i>Leucaena leucocephala</i>	Fabaceae	Wood, branches
Poplar	<i>Populus ciliata</i>	Salicaceae	Whole tree/stem
Melia	<i>Melia dubia</i>	Meliaceae	Wood
Kassod Tree	<i>Cassia siamea</i>	Fabaceae	Wood
Willow	<i>Salix alba</i>	Salicaceae	Stem
Siris	<i>Albizia lebbek</i>	Fabaceae	Wood
Teak	<i>Tectona grandis</i>	Verbenaceae	Wood

2. Oilseed Plants (For Biodiesel/Power)

These plants produce non-edible oils that can be converted into biodiesel for transport or power generation.

<i>Common Name</i>	<i>Botanical Name</i>	<i>Family</i>	<i>Parts Used</i>
Jatropha	<i>Jatropha curcas</i>	Euphorbiaceae	Seeds (oil), stem
Karanja	<i>Pongamia pinnata</i>	Fabaceae	Seeds (oil)
Mahua	<i>Madhuca indica</i>	Sapotaceae	Seeds (oil)
Neem	<i>Azadirachta indica</i>	Meliaceae	Seeds (oil)
Castor	<i>Ricinus communis</i>	Euphorbiaceae	Seeds (oil)

3. Petrocrop & High-Calorific Plants (For Liquid Fuel/Biogas)

These species, often called petroplants, accumulate hydrocarbons that can substitute for conventional petroleum sources.

<i>Common Name</i>	<i>Botanical Name</i>	<i>Family</i>	<i>Parts Used</i>
Akado/Aak	<i>Calotropis gigantea</i>	Asclepiadaceae	Whole plant (latex/oil)

Agave	Agave americana	Asparagaceae	Sap, leaves
Rubber Plant	Hevea brasiliensis	Euphorbiaceae	Latex/wood
Euphorbia	Euphorbia lathyris	Euphorbiaceae	Latex/seeds
Yellow Oleander	Thevetia neriifolia	Apocynaceae	Seeds

4. Perennial Grasses (For Biomass Pelletization)

These are used for quick biomass accumulation, particularly on degraded sites.

<i>Common Name</i>	<i>Botanical Name</i>	<i>Family</i>	<i>Parts Used</i>
Napier Grass	Pennisetum purpureum	Poaceae	Whole plant (stem/leaves)
Switchgrass	Panicum virgatum	Poaceae	Whole plant
Miscanthus	Miscanthus spp.	Poaceae	Whole plant

Features of Important Species (for India's power projects and energy plantations):

1. **Eucalyptus:** Excellent for fuel and has the highest production (125–150 tonnes/ha in 3 years).
2. **Casuarina:** Excellent for sandy coastal soils and extremely resistant to drought. Jatropha: Known as a "rock star" in the biodiesel industry, it can thrive on dry, low-fertility soils and produces seeds with 40% oil.
3. **Calotropis:** A resilient, untamed plant that is frequently found on wasteland and serves as a great, easily accessible source of biomass.

Important Medicinal Plants and Their Applications:

1. **Immunity & Respiratory:** Tulsi (*Ocimum sanctum*), Giloy (*Tinospora cordifolia*), Vasa (*Justicia adhatoda*), Pippali (*Piper longum*), and Badi Elaichi (*Amomum subulatum*).
2. **Skin & Blood Purification:** Neem (*Azadirachta indica*), Aloe Vera (*Aloe barbadensis*), Manjistha (*Rubia cordifolia*), and Amaltas (*Cassia fistula*).
3. **Digestion & Metabolism:** Amla (*Phyllanthus emblica*), Ginger (*Zingiber officinale*), Bael (*Aegle marmelos*), Curry Leaves (*Murraya koenigii*), Pudina (*Mentha piperita*), and Kutaj (*Holarrhena antidysenterica*).
4. **Stress, Sleep & Cognition:** Ashwagandha (*Withania somnifera*), Brahmi (*Bacopa monnieri*), Gotu Kola (*Centella asiatica*), and Sarpagandha (*Rauvolfia serpentina*).
5. **Joint & Pain Management:** Turmeric (*Curcuma longa*), Guggulu (*C. mukul*), Nirgundi (*Vitex negundo*), and Chitrak (*Pouzolzia zeylanica*).
6. **Cardiovascular & Women's Health:** Arjun (*Terminalia arjuna*), Shatavari (*Asparagus racemosus*), and Ashoka (*Saraca asoca*).

7. **Other Significant Plants:** Garlic (*Allium sativum*), Mulethi (*G. glabra*), Punarnava (*Boerhaavia diffusa*), Kalmegh (*Andrographis paniculata*), Haritaki (*Terminalia chebula*), Baheda (*T. bellirica*), Senna (*Cassia angustifolia*), Jamun (*Syzygium cumini*), Papaya (*Carica papaya*), Bhojpatra (*Betula utilis*), Shunthi (*Zingiber officinale*), and Akarkara (*Anacyclus pyrethrum*).

The following list covers a range of medical ailments and contains 30 significant medicinal plants that are often utilized in traditional, contemporary, and Ayurvedic herbal therapy.

Table: 30 significant Medicinal Plants

<i>Common Name</i>	<i>Botanical Name</i>	<i>Family</i>	<i>Parts Used</i>	<i>Uses</i>
1. Tulsi/Holy Basil	<i>Ocimum sanctum</i>	Lamiaceae	Leaves, Seeds	Cough, cold, fever, immune booster
2. Aloe Vera	<i>Aloe barbadensis</i>	Asphodelaceae	Gel (leaves)	Skin burns, acne, constipation, liver health
3. Turmeric	<i>Curcuma longa</i>	Zingiberaceae	Rhizome	Anti-inflammatory, antiseptic, blood purifier
4. Ashwagandha	<i>Withania somnifera</i>	Solanaceae	Roots	Stress relief, immunity, joint pains, anxiety
5. Amla/ Gooseberry	<i>Phyllanthus emblica</i>	Phyllanthaceae	Fruit	Antioxidant, digestion, hair health, Vitamin C
6. Neem	<i>Azadirachta indica</i>	Meliaceae	Leaves, Bark	Skin infections, acne, blood purifier, diabetes
7. Giloy	<i>Tinospora cordifolia</i>	Menispermaceae	Stem	Chronic fever, immunity, arthritis
8. Bael/Stone Apple	<i>Aegle marmelos</i>	Rutaceae	Fruit, Leaves	Diarrhea, constipation, gut health
9. Ginger	<i>Zingiber officinale</i>	Zingiberaceae	Rhizome	Nausea, indigestion, cold, cough
10. Brahmi	<i>Bacopa monnieri</i>	Scrophulariaceae	Whole Plant	Memory enhancer, anxiety, nervous disorders
11. Vasaka	<i>Justicia adhatoda</i>	Acanthaceae	Leaves	Cough, asthma, bronchitis, expectorant
12. Ashoka	<i>Saraca asoca</i>	Fabaceae	Bark	Gynecological problems, menstrual disorders
13. Plants Arjun	<i>Terminalia arjuna</i>	Combretaceae	Bark	Cardiovascular health, blood pressure

Common Name	Botanical Name	Family	Parts Used	Uses
14. Gotu Kola	<i>Centella asiatica</i>	Mackinlayaceae	Whole Plant	Brain tonic, skin diseases, wounds
15. Garlic	<i>Allium sativum</i>	Amaryllidaceae	Bulb	Hypertension, cholesterol, antifungal
16. Kalmegh	<i>Andrographis paniculata</i>	Acanthaceae	Whole Plant	Liver diseases, indigestion, fever
17. Punarnava	<i>Boerhaavia diffusa</i>	Nyctaginaceae	Roots/Whole	Kidney health, diuretic, jaundice
18. Shatavari	<i>Asparagus racemosus</i>	Asparagaceae	Tuberous Root	Female reproductive health, lactation
19. Moringa	<i>Moringa oleifera</i>	Moringaceae	Leaves, Pods	Malnutrition, immunity, joint pain
20. Jamun	<i>Syzygium cumini</i>	Myrtaceae	Seeds, Bark	Diabetes management, diarrhea
21. Guava	<i>Psidium guajava</i>	Myrtaceae	Leaves	Diarrhea, blood purification, vomiting
22. Coriander	<i>Coriandrum sativum</i>	Apiaceae	Seeds, Leaves	Indigestion, flatulence, blood sugar
23. Fenugreek	<i>Trigonella foenum-graecum</i>	Fabaceae	Seeds, Leaves	Diabetes, joint pain, lactation
24. Papaya	<i>Carica papaya</i>	Caricaceae	Leaves, Fruit	Dengue (platelet count), digestion
25. Cinnamon	<i>Cinnamomum verum</i>	Lauraceae	Bark	Digestion, diabetes, cold
26. Mint	<i>Mentha piperita</i>	Lamiaceae	Leaves	Indigestion, stomach pain, cold
27. Licorice	<i>Glycyrrhiza glabra</i>	Fabaceae	Roots	Cough, stomach ulcers, sore throat
28. Long Pepper	<i>Piper longum</i>	Piperaceae	Fruits/Roots	Bronchitis, respiratory issues, digestive
29. Nirgundi	<i>Vitex negundo</i>	Lamiaceae	Leaves, Roots	Pain reliever, swelling, arthritis
30. Senna	<i>Cassia angustifolia</i>	Fabaceae	Leaves, Pods	Laxative, constipation

“The best time to plant a tree was 20 years ago. The second best time is now.” – Chinese Proverb

CHAPTER 9

Comparison of Families

Chapter Contents:

Comparison between:

- 1) Rutaceae and Malvaceae
- 2) Papilionaceae, Caesalpiniaceae and Mimosaceae
- 3) Malvaceae, Sterculiaceae and Tiliaceae
- 4) Magnoliaceae and Annonaceae
- 5) Acanthaceae and Lamiaceae
- 6) Solanaceae and Scrophulariaceae
- 7) Apocynaceae and Asclepiadaceae
- 8) Asteraceae, Apiaceae and Rubiaceae
- 9) Rosaceae & Myrtaceae
- 10) Rutaceae & Malvaceae
- 11) Acanthaceae, Verbenaceae and Lamiaceae
- 12) Acanthaceae and Lamiaceae
- 13) Liliaceae & Amaryllidaceae
- 14) Liliaceae & Arecaceae
- 15) Poaceae & Cyperaceae
- 16) Poaceae & Orchidaceae
- 17) Musaceae and Zingiberaceae.
- 18) Musaceae and Araceae
- 19) Poaceae & Arecaceae

Compare Rutaceae and Malvaceae.

Features	Malvaceae	Rutaceae
<i>Plants</i>	Herbs, shrubs and trees.	Shrubs, trees rarely herbs
<i>Leaves</i>	Simple, palmately compound (Bombax).	Compound, alternate
<i>Inflorescence</i>	Solitary, axillary or terminal	Cymose
<i>Epicalyx</i>	Present	Absent
<i>Androecium</i>	Indefinite, monadelphous,	10 or 8 or less, polyandrous,

	monotheous, i.e. one celled, forming a staminal tube, epipetalous;	obdiplostemonous
<i>Disc</i>	Absent/Not so	A large cushion-like disc is present below the ovary
<i>Gynoecium</i>	Carpels (1 – α), usually (5), ovary 1 α chambered with 1 or more ovules in each chamber	
<i>Fruit</i>	Capsule or schizocarpic carcerulus	Capsule or berry hesperidium
<i>Floral Formula:</i>	Br. $\oplus$ $\overline{\sigma}$ Epik _∞ K ₍₅₎ C ₅ A _(∞) <u>G</u> ₍₅₎	Br. $\oplus$ $\overline{\sigma}$ K ₄₋₅ C _{4 or 5} A _{8 or 10} <u>G</u> ₍₄₎ or (5)

Comparison among Papilionaceae, Caesalpiniaceae and Mimosaceae.

Features	Papilionaceae	Caesalpiniaceae	Mimosaceae
<i>Habit</i>	Mostly herbs, rarely shrubs and a few trees	Mostly shrubs and trees rarely herbs	Mostly shrubs and trees rarely herbs
<i>Leaves</i>	Imparipinnate, sometimes simple	Paripinnate, never simple	Bipinnate, never simple
<i>Inflorescence</i>	Racemose	Raceme or panicle	Cymose head/spike
<i>Flower</i>	Zygomorphic	Slightly zygomorphic	Actinomorphic and regular
<i>Calyx</i>	Sepals 5, gamosepalous, odd sepal anterior	Sepals 5, free or slightly fused, odd sepal anterior	Sepals 5, gamosepalous, odd sepal posterior
<i>Corolla</i>	Pelals 5, papilionaceous, with posterior largest, standard, 2 lateral wings and 2 anterior united keel. Aestivation descending imbricate or vexillary	Petals 5, odd petal smallest and innermost. Aestivation ascending imbricate, odd petal innermost	Petals 4 or 5, fused/free, valvate, rarely imbricate
<i>Androecium</i>	Stamens 10, usually diadelphous (9)+1, rarely monadelphous	Stamens 10 (5+5), with staminodes, rarely fewer free, variable in length.	Stamens Numerous, free
<i>Gynoecium</i>	Monocarpellary, unilocular, marginal placentation	Same	Same
<i>Fruit</i>	Legume/pod	Legume/pod	Lomentum/Legume

<i>Floral Formula:</i>	Clitoria: Br. % ♂ Epik. K (5) C ₁₊₂₊₍₂₎ A ₍₉₎ +1 <u>G</u> ₁	Br. % ♂ K ₍₅₎ C ₅ A ₅₊₅ <u>G</u> ₁	Br. ⊕ ♂ K ₍₄₎ or (5) C ₄ or 5 A _∞ <u>G</u> ₁

Compare Malvaceae, Sterculiaceae and Tiliaceae

Features	Malvaceae	Sterculiaceae	Tiliaceae
<i>Plants</i>	Herbs, shrubs and trees.	Usually trees or shrubs, very few herbs	Usually trees or shrubs, very few herbs
<i>Leaves</i>	Simple, palmately compound (Bombax).	Simple or palmately compound	Simple with entire or dentate margin
<i>Flowers</i>	Regular, bisexual, epicalyx present.	Regular or irregular, bisexual; no epicalyx	Regular, bi-or unisexual, no epicalyx
<i>Calyx</i>	Sepals 5, united.	Sepals 5, free or united	Sepals 4-5, free or united
<i>Corolla</i>	Petals 5, free, twisted	Petals 5, reduced in size very often, sometimes absent, twisted	Petals 5, or fewer or absent, imbricate
<i>Androecium</i>	Stamens α, monadelphous, epipetalous; anther 1-celled	Stamens α or few in two whorls, outer staminodes or absent, inner fertile, anther 2-celled	Stamens α, free or united at the base, inserted at the base of the petals or raised on andro-gynophore. anther 2-celled
<i>Gynoecium</i>	Carpels (1 – α), usually (5), ovary 1 α chambered with 1 or more ovules in each chamber	Carpels (2 – 5), ovary 5-celled with 2-α ovules in each chamber. Ovary 1 – α-chambered with 1 or more ovules in each chamber	Carpels (2-5), ovary 2-5-celled with 1 or more ovules in each chamber
<i>Fruit</i>	Capsule or schizocarpic (carcerulus)	Capsule or schizocarpic	Capsule or usually schizocarpic, splitting
<i>Seeds</i>	Endosperm scanty	Endosperm fleshy	Endosperm fleshy
<i>Embryo</i>	Cotyledons folded	Cotyledons fleshy or folded	Cotyledons large or leafy
<i>Floral Formula</i>	Br. ⊕ ♂ Epik. K ₍₅₎ C ₅ A _(∞) <u>G</u> ₍₅₎	Br. ⊕ ♂ K ₅ C ₅ A _(∞) or ∞ <u>G</u> ₍₅₎	Br. ⊕ ♂ K ₅ C ₅ A _{5-∞} <u>G</u> ₍₅₋₁₀₎

Comparison between Magnoliaceae and Annonaceae.

Features	Magnoliaceae	Annonaceae
<i>Wood</i>	Not aromatic	Usually aromatic
<i>Leaves</i>	thick and stipulate	with glands, exstipulate
<i>Flower</i>	large and gaudy	Small, not showy
<i>Calyx/Perianth</i>	Perianth usually undifferentiated; outer whorl green or petaloid	Sepals & petals clearly differentiated
<i>Aestivation</i>	imbricate	Valvate
<i>Corolla</i>		
<i>Androecium</i>	Anthers are introse, filaments short or absent	Anthers are extrose, linear with peculiar elongated connective
<i>Style & stigma</i>	Absent in many cases	Present
<i>Fruit</i>	etaerio or follicles or drupes	etaerio of drupes or berries
<i>Sarcotesta</i>	Present in seeds	Absent
<i>Endosperms</i>	homogenous	Ruminated
<i>Floral Formula:</i>	$\text{Br.} \oplus \tilde{\text{P}} \text{K}_3 \text{C}_{3+3} \text{A}_{\infty} \underline{\text{G}_{\infty}}$	$\text{Br.} \oplus \tilde{\text{P}} \text{P}_{2+3+3} \text{A}_{\infty} \underline{\text{G}_{\infty}}$

Comparison between Acanthaceae and Lamiaceae.

Features	Acanthaceae	Lamiaceae
<i>Habit</i>	Herbs or shrubs with swollen nodes	Herbs or shrubs with squarish stem
<i>Leaves</i>	Opposite decussate and simple. Cystolith generally present	Simple, opposite and decussate
<i>Inflorescence</i>	Spike or cymose, Bracts and bracteoles prominent	Verticillaster
<i>Flower</i>	Zygomorphic, hermaphrodite and hypogynous	Zygomorphic, hermaphrodite, hypogynous
<i>Calyx</i>	Sepals 5, gamosepalous, unequal in size	Sepals 5, fused, bilabiate, persistent
<i>Corolla</i>	Petals 5, gamopetalous, personate	Petals 5, gamopetalous, bilabiate
<i>Androecium</i>	Stamens 2 or 2+2 epipetalous	Stamens 2+2 or 2 only, epipetalous
<i>Gynoecium</i>	Carpels 2, syncarpous, superior. Ovary biloculed with axile placentation, 8 to many ovules in each locule	Carpels 2, syncarpous, superior. Ovary tetralocular, axile placentation, each locule with one ovule Style Gynobasic
<i>Fruit</i>	Capsule	Schizocarpic carcerulus

<i>Seeds</i>	with jaculators	Jaculator absent
<i>Floral Formula:</i>	Br. Brl. % ♂ $K_{(4-5)}C_{(5)}\wedge A_{4 \text{ or } 2+2 \text{ or } 2} \underline{G}_{(2)}$	Br. % ♂ $K_{(5)}C_{(2+3)}\wedge A_{2+2} \underline{G}_{(2)}$

Comparison between Solanaceae and Scrophulariaceae.

Features	Solanaceae	Scrophulariaceae
<i>Habit</i>	Herbs or shrubs	Herbs or small shrubs
<i>Leaves</i>	Simple, alternate, exstipulate, entire or pinnatifid	Simple, alternate or opposite or whorled, exstipulate
<i>Inflorescence</i>	Cymose	Racemose, raceme or spike or cymose also
<i>Flower</i>	Actinomorphic rarely zygomorphic, hermaphrodite, hypogynous	Zygomorphic, hermaphrodite, hypogynous
<i>Calyx</i>	Sepals 5, gamosepalous, persistent	Sepals 5, gamosepalous, bilabiate
<i>Corolla</i>	Petals 5, gamopetalous, campanulate or rotate	Petals 5, gamopetalous, bilabiate spurred
<i>Androecium</i>	Stamens 5, epipetalous, Polyandrous	Stamens 4, didynamous, rarely 5, epipetalous
<i>Gynoecium</i>	Bicarpellary, syncarpous, ovary superior, obliquely placed, biloculed, axile placentation, swollen	Bicarpellary, syncarpous, ovary superior, medianally placed, biloculed, axile placentation, not swollen
<i>Fruit</i>	Berry rarely capsule	Capsule rarely berry
<i>Floral Formula:</i>	Br. ⊕ ♂ $K_{(5)}C_{(5)}\wedge A_5 \underline{G}_{(2)}$	Br. ⊕ or % ♂ $K_{4-(5)}C_4 \text{ or } 5 \underline{G}_{(2)}$

Comparison between Apocynaceae and Asclepiadaceae.

Features	Apocynaceae	Asclepiadaceae
<i>Habit</i>	Mostly herbs, shrubs, or vines with latex, includes more tree species	Mostly herbs, shrubs, or vines, with latex, includes more succulent species (e.g., Stapelia)
<i>Leaves</i>	Simple, opposite-decussate or whorled, exstipulate	Simple, opposite- decussate, exstipulate
<i>Inflorescence</i>	Generally cymose rarely solitary	Usually cymose umbel, sometimes racemose
<i>Flower</i>	Complete, hermaphrodite, actinomorphic, hypogynous	Same
<i>Calyx</i>	Sepals 4-5, gamosepalous, imbricate	Sepals 5, polysepalous, valvate or contorted
<i>Corolla</i>	Petals 5, gamopetalous,	Petals 5, gamopetalous, or slightly

	infundibuliform, twisted	fused at the base; -
<i>Corona</i>	Absent	Present
<i>Androecium</i>	Stamens 5, polyandrous, epipetalous	Stamens 5, adnate to gynoecium and forming gynostegium
<i>Pollinia & translators</i>	Absent; Pollen is discharged singly/s separately	Pollen is packaged into pollinia, & are transferred together by a translator apparatus
<i>Pollination mechanisms</i>	Standard	Highly specialized derived feature
<i>Gynoecium</i>	Carpels 2, syncarpous, placentation marginal or axile, stigma drum shaped	Carpels 2, syncarpous, placentation marginal, stigmatic disc 5 angled, united with the anthers to form gynostegium
<i>Fruit</i>	Variable i.e. capsule, drupe, berry, or follicle	Aggregate, an etacrio of follicles
<i>Floral Formula:</i>	$\text{Br} \oplus \text{♀} \text{K}_{(5)} \text{C}_{(5)} \text{A}_5 \underline{\text{G}_{(2)}}$	$\text{Br} \oplus \text{♀} \text{K}_{(5)} \text{C}_{(5)} \text{A}_5 \text{ } ^\wedge \underline{\text{G}_{(2)}}$

Taxonomic Note/classification: Both the families Apocynaceae and Asclepiadaceae are closely related. According to current phylogenetics, Asclepiadoideae is a subfamily of the larger Apocynaceae (s.l.). Although they both have follicular fruits, opposite leaves, and milky sap, their flower structures are very different, distinctively notable by their unique gynostegium and pollinia.

Comparison among Asteraceae, Apiaceae and Rubiaceae.

Features	Asteraceae	Apiaceae	Rubiaceae
<i>Habit</i>	Usually herbs with milky juice	Usually herbs	Herbs or woody shrubs
<i>Leaves</i>	Simple, alternate, exstipulate	Decompound, alternate	Simple, opposite and stipulate-interpetiolar
<i>Inflorescence</i>	Capitulum	Umbel	Cymose-biparous
<i>Flower</i>	Unisexual, or bisexual, actinomorphic, or zygomorphic epigynous	bisexual, actinomorphic and epigynous	generally bisexual, actinomorphic and epigynous
<i>Calyx</i>	Represented by pappus	Sepals 5	Sepals 4 or 5, gamosepalous
<i>Corolla</i>	Petals 5, gamopetalous, valvate	Petals 5, polypetalous	Petals 5 or 4, gamopetalous, valvate or imbrica

<i>Androecium</i>	Stamens 5, syngenesious, epipetalous, anthers introrse	Stamens 5, free, anthers versatile	Stamens 5 or 4, epipetalous, polyandrous anthers introrse
<i>Gynoecium</i>	Bicarpellary, syncarpous with basal placentation, Ovary inferior	Bicarpellary, syncarpous, bilocular, axile placentation, inferior	Bicarpellary, syncarpous, bilocular, axile placentation, inferior
<i>Fruit</i>	Cypsela	Cremocarp	Berry, drupe or capsule
<i>Floral Formula:</i>	Ray Floret: Br. $\% \text{ } \overline{\text{G}}_{(2)}$ $\text{K}_{\text{pappus}} \text{C}_{(2/3) \text{ or } 0/5} \text{A}_0 \overline{\text{G}}_{(2)}$ Disc Floret: Br. $\oplus \text{ } \overline{\text{G}}_{(2)}$ $\text{K}_{\text{pappus}} \text{C}_{(5)} \text{A}_{(5)} \overline{\text{G}}_{(2)}$	Central Flower: Br. $\oplus \text{ } \overline{\text{G}}_{(2)}$ $\text{K}_{(5)} \text{C}_5 \text{A}_5 \overline{\text{G}}_{(2)}$ Peripheral Flower: Br. $\% \text{ } \overline{\text{G}}_{(2)}$ $\text{K}_{(5)} \text{C}_5 \text{A}_5 \overline{\text{G}}_{(2)}$	Br. $\oplus \text{ } \overline{\text{G}}_{(2)}$ $\text{K}_{4-(5)} \text{C}_4 \text{ or } 5 \text{A}_8 \text{ or } 10 \overline{\text{G}}_{(4) \text{ or } (5)}$

Compare Rosaceae & Myrtaceae

Features	Rosaceae	Myrtaceae
<i>Habit</i>	Plants herbs, shrubs or trees	Plant mostly trees
<i>Leaves</i>	Simple, or compound, alternate, stipulate	Simple, opposite, exstipulate, aromatic with oil glands
<i>Inflorescence</i>	Variable-solitary, racemose, cymose	Variable-panicle, racemose, cymose
<i>Flower</i>	Actinomorphic, hermaphrodite or unisexual, perigynous or epigynous, epicalyx rarely present	Actinomorphic, hermaphrodite, perigynous to epigynous, disc present above the calyx tube
<i>Calyx</i>	Sepals 5 or 4, gamosepalous	Sepals 4-5, poly or gamosepalous
<i>Corolla</i>	Petals 4-5 or indefinite, polypetalous, imbricate or quincuncial	Petals 4-5 or 0, polypetalous, imbricate or united and thrown as a cap
<i>Androecium</i>	Stamens many, free	Stamens many, free/adelphous
<i>Gynoecium</i>	Carpels 1 to many, apocarpous or syncarpous ovary superior or inferior, placentation axile or marginal or basal	Carpels 2 to 5 to indefinite, syncarpous, ovary inferior, placentation axile or parietal
<i>Fruit</i>	Follicle, achene, drupe or pome	Berry or capsule
<i>Floral Formula:</i>	Br. $\oplus \text{ } \overline{\text{G}}_{(2)}$ $\text{K}_{(5) \text{ or } 5} \text{C}_5 \text{A}_{\infty} \overline{\text{G}}_{1-\infty}$	Br. Brl. $\oplus \text{ } \overline{\text{G}}_{(2-\infty)}$ $\text{K}_{(4+5)} \text{C}_{4-5} \text{A}_{\infty}$

Compare Rutaceae & Malvaceae

Features	Rutaceae	Malvaceae
<i>Habit</i>	shrubs or trees, rarely herbs	Herbs, shrubs, rarely trees

<i>Leaves</i>	Compound, alternate	Simple. Alternate
<i>Inflorescence</i>	Cymose	Solitary, axillary, or terminal
<i>Epicalyx</i>	Absent	Present
<i>Stamens</i>	10 or 8 or less, free, obdiplostemonous	Many, monadelphous, 1-celled, staminal tube
<i>Disc</i>	Large cushion like disc present below the ovary	Not so
<i>Fruit</i>	Capsule/berry	Capsule/schizocarpic carcerulus
<i>Floral Formula:</i>	Br. $\oplus$ $\overset{\curvearrowright}{\text{K}}_{4(5)} \text{C}_{4 \text{ or } 5} \text{A}_{8 \text{ or } 10} \underline{\text{G}}_{(4) \text{ or } (5)}$	Br. $\oplus$ $\overset{\curvearrowright}{\text{K}}_{\infty} \text{Epik.} \text{K}_{(5)} \text{C}_5 \wedge \text{A}_{(\infty)} \underline{\text{G}}_{(5)}$

Compare Acanthaceae, Verbenaceae and Lamiaceae

Features	Acanthaceae	Verbenaceae	Lamiaceae
<i>Habit</i>	Herbs, shrubs	Herbs, shrubs or trees	Herbs, shrubs, rarely trees, often aromatic
<i>Stem</i>	Often swollen nodes	Quadrangular	Quadrangular
<i>Leaves</i>	Opposite, simple, often with cystoliths	Simple, Opposite/whorled	Simple, Opposite - decussate
<i>Inflorescence</i>	Spike or cymose with prominent bracts & bracteoles	Racemose/cymose, often head-like	Verticillaster
<i>Flower</i>	Zygomorphic, bilabiate, often oblique	Zygomorphic, tubular	Zygomorphic, bilabiate
<i>Calyx</i>	Sepals 5, united, unequal	Sepals 5, united, tubular/campanulate, persistent	Sepals 5, united, tubular, persistent
<i>Corolla</i>	Petals 5, united, bilabiate, oblique	Petals 5, united, tubular/oblique	Petals 5, united, bilabiate
<i>Androecium</i>	Stamens 2+2 or 2, hairy or spurred anthers	Stamens 4 (2+2), didynamous or 2 only,	Stamens 4 (2+2), didynamous or 2 only,
<i>Gynoecium</i>	Carpels 2, syncarpous,	Carpels 2, syncarpous,	Carpels 2, syncarpous,
<i>Ovary</i>	Beaked, 2-celled, superior, many ovuled	2-4 celled, 1-2 ovuled, superior	4-celled, superior
<i>Fruit</i>	Capsule with jaculators	Drupe/berry	Schizocarpic, carcerulus (1-seeded 4 nutlets)
<i>Floral Formula:</i>	Br. Brl. $\% \overset{\curvearrowright}{\text{K}}_{(4-5)} \text{C}_{(5)} \wedge \text{A}_{4 \text{ or } 2+2 \text{ or } 2} \underline{\text{G}}_{(2)}$	Br. Brl. $\% \overset{\curvearrowright}{\text{K}}_{(5)} \text{C}_{(5)} \wedge \text{A}_{2+2} \underline{\text{G}}_{(2)}$	Br. $\% \overset{\curvearrowright}{\text{K}}_{(5)} \text{C}_{(2+3)} \wedge \text{A}_{2+2} \underline{\text{G}}_{(2)}$

Compare Acanthaceae and Lamiaceae

Features	Acanthaceae	Lamiaceae
<i>Habit</i>	Herbs, shrubs	Herbs, shrubs, rarely trees, often aromatic
<i>Stem</i>	Often with swollen nodes	Quadrangular
<i>Leaves</i>	Opposite, simple, often with cystoliths	Simple, Opposite-decussate
<i>Inflorescence</i>	Spike or cymose with prominent bracts & bracteoles	Verticillaster
<i>Flower</i>	Zygomorphic, bilabiate, often oblique	Zygomorphic, bilabiate
<i>Calyx</i>	Sepals 5, united, unequal	Sepals 5, united, tubular, persistent
<i>Corolla</i>	Petals 5, united, bilabiate/personate, oblique	Petals 5, united, bilabiate
<i>Androecium</i>	Stamens 2+2 or 2, hairy or spurred anthers	Stamens 4 (2+2), didynamous or 2 only,
<i>Gynoecium</i>	Carpels 2, syncarpous, superior	Carpels 2, syncarpous,
<i>Style</i>	Simple, terminal	Gynobasic
<i>Ovary</i>	Beaked, 2-celled, superior, 8-many ovuled	4-celled, superior, 1-ovuled
<i>Fruit</i>	Capsule	Schizocarpic, carcerulus (1-seeded 4 nutlets)
<i>Seeds</i>	with jaculators	Jaculators absent
<i>Floral Formula:</i>	Br. Brl. % ♂ $K_{(4-5)}C_{(5)}\wedge A_4 \text{ or } 2+2 \text{ or } 2 \underline{G}_{(2)}$	Br. % ♂ $K_{(5)}C_{(2+3)}\wedge A_{2+2} \underline{G}_{(2)}$

Compare Liliaceae & Amaryllidaceae

Features	Liliaceae	Amaryllidaceae
<i>Underground stem</i>	Various types- rhizomes, bulbs, tubers etc	Usually bulbs, rarely rhizomes
<i>Leaf distribution</i>	Often distributed along the main stem	Mostly basal, strap-shaped, and emerge directly from the bulb
<i>Leaf types</i>	Cauline or radical	Mostly radical
<i>Leaf habit</i>	Along stem	Basal/strap shaped
<i>Flowering Stalk (scape)</i>	Leafy	Often leafless (Scapose)
<i>Inflorescence</i>	Often Solitary/raceme	Umbel (like an umbrella)
<i>Flowers</i>	Hypogynous	Epigynous
<i>Corona</i>	Absent	Often present

<i>Anthers</i>	Versatile, both introrse & extrorse	Versatile,
<i>Ovary</i>	Superior	Inferior
<i>Endosperm</i>	Both fleshy & cartilaginous	Fleshy
<i>Floral Formula:</i>	$\text{Br. } \oplus \text{ } \overline{\text{P}}_{3+3} \text{ A}_{1-2} \overline{\text{G}}_{(3)}$	$\text{Br } \% \text{ or } \oplus \text{ } \overline{\text{P}}_{6(3+3)} \text{ A}_{6(3+3)} \overline{\text{G}}_{(3)}$

Compare Liliaceae & Arecaceae

Features	Liliaceae	Arecaceae
<i>Habit</i>	Mainly herbs, rarely shrubs or climbers (e.g., Smilax)	Tall trees, shrubs, or prickly climbers (e.g., Calamus)
<i>Underground stem</i>	Various types- rhizomes, bulbs, tubers etc; soft-stemmed herbs mainly	with large, unbranched stem (caudex)
<i>Leaves</i>	Cauline or radical, sessile, simple, linear, sheathing leaf base, exstipulate, rarely stipulate (Smilax), with parallel venation	Large, pinnately/palmately compound, leaf base sheathing, exstipulate
<i>Inflorescence</i>	Commonly raceme, panicle, or umbellate cyme.	Fleshy spadix enclosed in a spathe
<i>Flowers</i>	Bisexual, showy, trimerous, usually with 6 similar perianth parts (tepals) in two whorls, Hypogynous	Small, usually sessile and unisexual (monoecious or dioecious)
<i>Anthers</i>	Versatile, both introrse & extrorse	Versatile/dorsifixed
<i>Fruit</i>	Capsule or berry	Drupe or berry
<i>Floral Formula:</i>	$\text{Br. } \oplus \text{ } \overline{\text{P}}_{3+3} \text{ A}_{1-2} \overline{\text{G}}_{(3)}$	Male: $\text{Br } \oplus \text{ } \overline{\text{P}}_{6(3+3)} \text{ A}_{6(3+3)} \text{ G}_0$; Female: $\text{Br } \oplus \text{ } \overline{\text{P}}_{6(3+3)} \text{ A}_0 \overline{\text{G}}_{(3)}$

Compare Poaceae & Cyperaceae

Features	Poaceae	Cyperaceae
<i>Habitat</i>	Species are dominant in drier, open grasslands	Commonly found in wetlands, marshes, and shady, moist areas.
<i>Stem</i>	cylindrical (round), fistular (except maize & sugarcane)	Triangular with distinct edges, solid stems
<i>Node</i>	Distinct, swollen, jointed	Absent or inconspicuous, not jointed
<i>Leaf arrangement</i>	2- ranked (distichous).	3-ranked (tristichous)
<i>Leaf Sheath</i>	Typically split open.	Typically closed (fused).
<i>Ligule</i>	Almost always present at the leaf-sheath junction	Often absent or very reduced
<i>Flower</i>	Small, reduced, spiked, often greenish,	Flowers are subtended by a single

	arranged in spikelets	bract or scale
<i>Flower Symmetry</i>	Actinomorphic or irregular	Regular
<i>Flower structure</i>	Protected by two bracts: lemma and palea.	Subtended by a single chaffy bract
<i>Scales</i>	Glumes, lemma, palaea	Pistillate staminate scale
<i>Perianth</i>	Reduced to 2–3 scales called lodicules	Absent or reduced to bristles or scales
<i>Stamens</i>	6 (3+3), or 3, anthers versatile	3, anthers basifixed
<i>Carpels</i>	1 or 3, of which 2 are abortive	2 or 3
<i>Style</i>	2	1
<i>Stigma</i>	2, feathery	2-3, plumose
<i>Fruit</i>	Caryopsis (grain); seed coat fused to fruit wall.	achene or nutlet, which is often 3-sided
<i>Seed</i>	Seeds (caryopsis) are larger and endospermic (starchy)	Achene or nutlet; seed coat is separate from fruit wall
<i>Economic Value</i>	Most economically important plant family, providing staple food crops like rice, wheat, maize, and sugarcane	Includes species used for weaving, paper (papyrus), and some edible tubers (water chestnuts).
<i>Floral Formula:</i>	$\text{Br } \% \text{ } \overline{\text{P}}_2 \text{A}_3 \underline{\text{G}}_{(1)}$	$\text{Br } \oplus \text{P}_0 \text{A}_3 \underline{\text{G}}_{(2) \text{ or } (3)}$

Point to Remember:

Memorize the mnemonic to distinguish between Poaceae & Cyperaceae:

"Sedges have edges, rushes are round, and grasses are hollow, right from the ground".

Compare Poaceae & Orchidaceae

Features	Poaceae	Orchidaceae
<i>Habit</i>	Primarily terrestrial, herbs	Epiphytic or Terrestrial
<i>Stem</i>	Culm (hollow, jointed)	Fleshy, rhizomatous, or pseudobulbs
<i>Ligule</i>	Often present	Absent
<i>Inflorescence</i>	Mostly Spikelet	Ranges from solitary to raceme
<i>Root Type</i>	Fibrous, shallow	Thick, fleshy with fungi
<i>Flower</i>	Small, reduced, spiked, often greenish	complex, labellum, Showy
<i>Flower Symmetry</i>	Actinomorphic or irregular	Strongly Zygomorphic
<i>Perianth</i>	In the form of 2 or 3 lodicules	6(3+3), lodicules absent

<i>Stamens</i>	Usually 3	Usually 1, rarely 2
<i>Column</i>	Absent	Stamens and carpels fused into a column
<i>Stigmas</i>	2 or 3 feathery (plumose) stigmas	Not feathery; Stigmas-3 of which 2 are fertile & 3 rd one is sterile forming a beak like structure [pocket] called rostellum;
<i>Fruit</i>	Caryopsis	Capsule
<i>Seed</i>	Larger and endospermic (starchy)	extremely small, Non-endospermic (dust-like), requiring mycorrhizal fungi to germinate
<i>Pollination</i>	Wind (Anemophily)	Insect (Entomophily)
<i>Economic Value</i>	Food (rice/wheat), fodder	Horticultural (ornamental)
<i>Floral Formula:</i>	Br % ♂ P ₂ A ₃ <u>G</u> ₍₁₎	Br. % ♂ P ₃₊₃ A ₁₋₂ <u>G</u> ₍₃₎

Compare Musaceae and Zingiberaceae.

Features	Musaceae	Zingiberaceae
<i>Habit</i>	Large herbs, rarely trees with rhizomes	Aromatic herbs with rhizomes
<i>Leaves</i>	Large, spirally arranged, half-alternate with long stem clasping sheaths, without ligule	half-alternate with ligule
<i>Inflorescence</i>	Mostly spadix or cincinnus	Mostly Raceme or spike
<i>Flowers</i>	Bisexual, rarely unisexual, zygomorphic, epigynous	Bisexual, epigynous, medianly zygomorphic
<i>Perianth</i>	6(3+3), more or less united, rarely free, not differentiated into calyx & corolla, petaloid	6(3+3), differentiated into outer green calyx & inner coloured corolla; sepals are united in a tube
<i>Perianth lobes</i>	May be free or fused	Mostly fused
<i>Stamens and staminodes</i>	6 or 5 in two whorls, when 6, only 5 fertile, the sixth one metamorphosed into a staminode	Stamens-5 or 6, in two whorls, one (posterior stamen of the inner whorl) fertile (functional); 1 (anterior stamen of the outer whorl) suppressed; the remaining 3 or 4 are modified into petaloid staminodes, the two lateral staminodes of the inner whorl, fuse to form labellum.

<i>Fertile stamens</i>	6 or 5	Only one
<i>Carpel</i>	(3); ovary trilocular, many ovules, placentation axile.	Carpel (3); ovary 1-3 locular, placentation parietal
<i>Style</i>	Simple, not petaloid	Long, slender, passing through the groove of the fertile stamen.
<i>Stigma</i>	Slightly Lobed or capitate.	Variable
<i>Fruit</i>	Berry or woody capsule.	Capsule or indehiscent or fleshy
<i>Seed</i>	With mealy endosperm. No aril.	Arillate, endospermic.
<i>Floral Formula:</i>	Br % ♂ P ₃₊₃ A _{6-∞} <u>G</u> ₍₃₎	Br % ♀ P ₃₊₃ A ₆ <u>G</u> ₍₃₎

Compare Musaceae and Araceae

Features	Musaceae	Araceae
<i>Habit</i>	Large herbs, rarely trees (Ravenala) with rhizomes	Usually perennial herbs/woody trees/climbers with acrid/milky sap
<i>Roots</i>	Adventitious	Adventitious, aerial/epiphytic in climbers
<i>Stem</i>	Underground, rhizome	Underground, tubers/corms
<i>Leaves</i>	Large, spirally arranged, half-alternate with long stem clasping sheaths, without ligule	Simple, large, spiral, unicostate parallel, entire/lamina split, leaf sheath rolled up & overlapping, exstipulate
<i>Inflorescence</i>	Mostly spadix or cincinnus, surrounded by a long spathe	Terminal, pendulous spike/panicle, subtended by brilliantly colored spathaceous bracts
<i>Flowers</i>	Large, mostly colored, bisexual, rarely unisexual, zygomorphic, epigynous, 3-merous	Small, sessile, regular, unisexual, rarely bisexual,
<i>Perianth</i>	6(3+3), more or less united, rarely free, not differentiated into calyx & corolla, petaloid	Absent (Calla, Colocasia)) or 4 (Anthurium) or 6 (Acorus calamus)
<i>Stamens and staminodes</i>	6 or 5 in two whorls, when 6, only 5 fertile, the sixth one metamorphosed into a staminode	Many, or reduced to 4-10 or even 1 (Arisaema)
<i>Carpel</i>	(3); ovary trilocular, many ovules, placentation axile.	1 to many, ovary unilocular or trilocular, 1 to many ovuled, placentation basal
<i>Fruit</i>	Berry or woody capsule.	Berry
<i>Seed</i>	With mealy endosperm. No aril.	Few to many, endospermic/non-

		endospermic
<i>Floral Formula:</i>	Br % ♂ P ₃₊₃ A _{6-∞} <u>G</u> ₍₃₎	Br P ₍₄₋₆₎ or 6 A ₍₂₋₈₎ or 1 <u>G</u> ₍₁₋₃₎

Compare Poaceae & Arecaceae

Features	Poaceae	Arecaceae
<i>Habit</i>	Primarily terrestrial, herbs	Mainly trees, rarely shrubs
<i>Stem</i>	Culm (hollow, jointed)	Solid, often unbranched
<i>Leaves</i>	Narrow, simple, with sheath	Large, compound (fronds)
<i>Ligule</i>	Often present	Absent
<i>Inflorescence</i>	Mostly Spikelets arranged in panicles	Large panicle/spike enclosed in a spathe
<i>Root Type</i>	Thin, fine, fibrous roots arising from nodes or the base of the stem, shallow rooted, spreading horizontally.	Thick, adventitious, and woody, initiating from a specialized bole or the base of the stem. Usually shallow and fibrous, forming a thick mat that can spread wide
<i>Flower</i>	Small, reduced, spiked, often greenish, typically bisexual	Often unisexual
<i>Flower Symmetry</i>	Zygomorphic (bilateral symmetry)	Actinomorphic (radial symmetry)
<i>Perianth</i>	In the form of 2 or 3 lodicules	Tepals 6 (3+3)
<i>Stamens</i>	Usually 3	(3+3)
<i>Gynoecium</i>	Carpel 1, 1-locular	Carpels 3, uni-or trilocular ovary
<i>Stigmas</i>	2 or 3 feathery (plumose) stigmas	Small, inconspicuous, often 3-lobed
<i>Fruit</i>	Caryopsis	Berries/drupes
<i>Economic Value</i>	Food (rice/wheat), fodder	Food, oil, timber
<i>Pollination</i>	Excellently suited for anemophily, or wind pollination	Mainly suited for pollination by insects (entomophily), however sometimes pollinated by the wind.
<i>Floral Formula:</i>	Br % ♂ P ₂ A ₃ <u>G</u> ₍₁₎	Male: Br ⊕ ♂ P ₆₍₃₊₃₎ A ₆₍₃₊₃₎ G ₀ ; Female: Br ⊕ ♀ P ₆₍₃₊₃₎ A ₀ <u>G</u> ₍₃₎

“One hour per day of study in your chosen field is all it takes. One hour per day of study will put you at the top of your field within three years. Within five years you’ll be a national authority. In seven years, you can be one of the best people in the world at what you do.” — Earl Nightingale

CHAPTER 10

Phylogeny of Angiosperms

Chapter Contents:

- ❖ Origin and Evolution of Angiosperms
- ❖ Crucial Features of the Origin of Angiosperms
- ❖ Theories of angiosperm origin: Main Historical Theories of the Origin of Angiosperms: Bennettitalean (Anthostrobilus) Theory, Gnetales-Angiosperm Theory, The Isoetes-Monocotyledon Theory, Coniferales-Amentiferae Theory, Pteridosperm Theory: Distinctive sub-theories: Caytonialean & Pentoxylales Theory,
- ❖ Contemporary Views: Phylogenetic Consensus: "ANITA" Grade and Basal Angiosperms Origin: Pre-Cretaceous Options, Ancestry Beyond "Anthophytes", Origin Mechanisms,
- ❖ Summary of Current Theories
- ❖ Terms and concepts (primitive and advanced, homology and analogy, parallelism and convergence, monophyly, Paraphyly, polyphyly and clades)
- ❖ PRIMITIVE & ADVANCED Characters
 - HOMOLOGY & ANALOGY
 - PARALLELISM & CONVERGENCE: Examples of Convergent Evolution in Plants (unrelated taxa), Examples of Parallel Evolution in Plants (Related Taxa), Differences between Convergent Evolution & Parallel Evolution
 - Clades (Monophyletic Groups): Important Aspects of clades and their Roles, Importance of clades, briefly explain different kinds of plant phylogenetic groups with plant examples. Example of a Cladogram
- ❖ Definitions of selected terminologies often used in phylogenetics
- ❖ Methods of illustrating evolutionary relationship (phylogenetic tree, cladogram)
 - Phylogenetic trees: definition, major Characteristics, Types & Techniques for building phylogenetic trees, Applications with summary
 - Differentiate between Cladograms & Phylograms
 - Cladistics: definition, brief history & basic laws of cladistics
 - Brief explanations of the phylogeny of the Magnoliids, Eudicots, Core Eudicots, and Basal Angiosperms.

ORIGIN AND EVOLUTION OF ANGIOSPERMS:

Angiosperms, most likely appeared around 145–100 million years ago during the Early Cretaceous period, or even as early as the Triassic. They quickly emerged as the most varied group of terrestrial plants in the fossil record. They may have originated in Southeast Asia or other subtropical places, and they rapidly diversified after evolving from gymnosperm ancestors, probably by chimeric fusion of organs.

Crucial Features of the Origin of Angiosperms:

An "Abominable Mystery": Charles Darwin referred to the quick emergence and diversification of angiosperms as a "abominable mystery" because there were no distinct transitional fossils for millions of years prior to the Cretaceous, when they predominated.

Origin Time: Molecular evidence points to an earlier origin, with some research pointing to the Upper Triassic (247-242 million years ago), even though confirmed fossils date to the Lower Cretaceous (~130 million years ago), such as *Montsechia vidalii*.

Ancestry: Angiosperms are assumed to have descended from a group of extinct gymnosperms, which are sometimes regarded as seed ferns or pteridosperms. Pseudanthial (flower developed from fused, unisexual inflorescences) and Euanthial (flower generated from a bisexual strobilus) are two examples of theories.

Critical Developments: Double fertilization and the creation of the carpel, or encapsulated seed, were essential to their success. Like the contemporary Chloranthaceae, the earliest angiosperms were probably tiny, herbaceous plants.

Geographic Origin: Based on some research, the Pacific basin or Southeast Asia may be the "cradle" of several primitive groups, including the Magnoliaceae.

Evolutionary Acceleration: Coevolution with pollinators and their capacity for environmental adaptation propelled the angiosperms' explosive growth (dubbed the "Angiosperm Terrestrial Revolution").

THEORIES OF ANGIOSPERM ORIGIN:

Theories of angiosperm origin try to explain why flowering plants appeared so quickly, most likely in the Early Cretaceous (~130–135 mya), however certain evidence points to older, Jurassic origins. Major theories propose that they evolved from specialized, extinct groups like Caytoniales or Pteridosperms, or from gymnosperm predecessors like Bennettitales or Gnetales. Although there are polyphyletic ideas, the current consensus points to a monophyletic origin.

Main Historical Theories of the Origin of Angiosperms

1. **Bennettitalean (*Anthostrobilus*) Theory:** According to this idea, which was put out by Arber and Parkin in 1907, angiosperms descended from the extinct Bennettitales, which resembled the Magnolia type in their flower-like, bisexual structures.

Resemblances:

- i. The flower and strobili are both bisexual structures with an extended central axis;
- ii. In Magnolia, the perianth, stamens, and carpels are placed similarly to how the various sections of Cycadeoidea, such as bracts, microsporophylls, and megasporophylls, are ordered from the bottom towards the apex.

Despite the aforementioned surface-level similarities, a further analysis reveals several distinctions between the two groups.

Disparities

- i. **The stem:** In contrast to angiospermic plants, which have a thin cortex, a thick vascular cylinder, and tiny pith, benettitalean stems have a thick cortex, a relatively thin vascular cylinder, and huge pith.
- ii. **Stamens, or microsporophylls:** Whereas the stamens in Magnolia are free and spirally distributed on the axis, the microsporophylls in Benettitales are whorled and mostly connate.
- iii. **Carpels, or megasporophylls:** Megasporophylls are significantly diminished in Benettitales, which have a simple stalk with a single terminal ovule. Megasporophylls are protected by interseminal scales, also known as sterile scales. Magnolia flowers don't have these kinds of structures.
- iv. **Micropylar Tube:** Benettitales have a micropylar tube, whereas angiosperms do not have this structure.
- v. **Seed:** Primitive angiosperm seeds are albuminous, or endospermic, with a tiny embryo, whereas Benettitale seeds are exalbuminous, or non-endospermic, with a big embryo.

According to the information above, Benettitales cannot be regarded as the progenitor of angiosperms. There are more differences between the two groups than commonalities. Parallel evolution or shared ancestry might be the cause of the aforementioned similarities.

The evidence above proves Benettitales is not the progenitor of angiosperms. Both groups vary more than they agree. The aforementioned similarities may be attributable to common ancestry or parallel evolution.

According to Arber and Parkin (1907), both groups originated from seed ferns and may have diverged early. Later, Takhtajan (1980) classified Magnoliophyta as monophyletic, likely descended from Bennettitale-like stocks.

2. ***Gnetales-Angiosperm Theory***: Wettstein (1901) proposed this Theory, which identifies angiosperms with Gnetales (such as *Welwitschia*) due to similarities in vessel elements, leaf venation, and characteristics that resemble double fertilization.

Similarities between Angiosperms and Gnetales:

- i. Two cotyledons are present;
- ii. Ships made of secondary wood;
- iii. Reticulate venation;
- iv. Unisexual inflorescence (like many Amentifers' catkin);
- v. The male blooms of *Welwitschia* are truly bisexual, created by the elimination of female parts;
- vi. *Ephedra*, *Welwitschia*, and *Gnetum* stamens appear to resemble angiosperms;
- vii. Similar to angiosperm perianths, the female flowers of all three of the aforementioned taxa contain two or more envelopes around the nucellus;
- viii. Female flowers' well-developed micropylar tube, which is created by the ovule's inner wrap lengthening, resembles angiosperm flower style;
- ix. Unlike angiosperms, the female gametophyte of *Gnetum* is tetrasporic and lacks archegonia;
- x. Similar to angiosperms, the zygote's first division in *Gnetum* is accompanied by the creation of a cell wall.

Angiosperms and Gnetales differ in the following ways:

- i. *Gnetum* has vessels in secondary wood, although certain primitive dicots, such as *Trochodendron* and *Tetracentron*, have not;
- ii. The genesis of Gnetales' vessels differs completely from that of angiosperms;
- iii. *Gnetum*'s primary and secondary xylem lack the scalariform pitted tracheids that are a feature of primitive angiosperms. While *Gnetum* develops circular-bordered pits when secondary xylem grows;
- iv. In terms of vessel formation, *Gnetum* is likewise different from angiosperms.

The previous discussions suggest that the resemblance between Gnetales and some angiosperms is superficial and owing to evolution's convergence. Convergence also causes two cotyledon similarities. Angiosperms may have developed from polycots, not dicots. In the primitive angiosperm genus *Degeneria*, the polycotyledon (3-4 cotyledones) is found. *Gnetum*'s

lack of archegonia suggests parallelism with angiosperms. Vascular architecture substantially disproves any link between angiosperms and Gnetales.

3. ***The Isoetes-Monocotyledon Theory***: this theory put out by Campbell, postulates a direct—albeit mainly unsubstantiated—connection between monocotyledons and aquatic ferns such as Isoetes.

Highlighted similarities:

- a) Many monocots and isoetes flourish in watery or semi-aquatic settings.
- b) Their habits are herbaceous and geophilous (underground).
- c) The embryo, stalk, and vascular system of the older sporophyte are identical, including the absence of a cambium and the existence of a single cotyledon.

Evolutionary Route: Campbell proposed that herbaceous angiosperms evolved from Pteridophyte-like progenitors rather than woody Dicotyledons. Engler proposed a herbaceous intermediary called "Proangiosperms" to explain this.

Rejection and Criticism

- a) There is no fossil evidence linking Isoetes to early angiosperms.
- b) Modern phylogenetic studies imply the similarities are superficial or attributable to aquatic convergent evolution rather than direct ancestry.
- c) It is generally agreed that monocotyledons are advanced angiosperms that evolved from dicotyledonous progenitors, not Isoetes.

Modern botanical research rejects the hypothesis, despite its historical significance.

4. ***Coniferales-Amentiferae Theory***: Engler and Rendle backed the Coniferales-Amentiferae Theory, which proposes direct ancestry from conifers and specifically connects them to plants that grow catkins (Amentiferae).

The following characteristics of conifers are shared by the amentiferous members:

- a) Like conifers, flowers are simplistic and naked;
- b) Amentiferae stamens resemble conifer bisporangiate microsporophylls; Seeds are enclosed in angiosperms, which have also been found in *Araucaria* and *Agathis* of gymnosperm;
- c) Only pollen tubes reach the micropyle during fertilization in *Agathis*, *Araucaria*, and other conifers; pollens are deposited on the scale. This, trait is quite similar to the angiosperms (Doyle, 1945).

Drawbacks:

- a) The aforementioned similarities have recently been demonstrated to most likely result from parallelism between the two groups. The simple flowers found in amentiferous species are thought to have evolved as a result of reduction at a higher level rather than being primordial.
- b) Compared to conifers and amentifers, vessel-less angiosperms such as *Tetracentron*, *Trochodendron*, and others exhibit more primitive secondary xylem. At present, amentifers are viewed as more specialized rather than primitive.
- c) It is now known that the cones of conifers are unisexual, while the flowers of the primitive angiosperm are bisexual.
- d) Finally, it might be argued that this idea lacks adequate support due to the contemporary belief that amentifers are unquestionably advanced angiosperms.

5. *Pteridosperm Theory:*

According to the Pteridosperm (seed fern) theory, angiosperms descended from a group of gymnosperms that bore seeds throughout the Paleozoic and Mesozoic periods. According to proponents like Andrews (1947), these extinct plants are the most likely progenitors of flowering plants because of their physical similarities, including reticulate venation, cambium, and cupulate ovules (homologous to carpels). According to Cronquist (1968), "*it is a long way, morphologically, from any known seed fern to an angiosperm, but each of the differences could logically be bridged in the course of evolution*". Double fertilization with triploid (3n) endosperm in angiosperms may be caused to reduced female gametophyte. Sepals come from leaves and petals from sepals and stamens. Angiospermic flowers evolved from gymnosperm cones or cone-like features. Seed ferns and primitive angiosperms like *Magnolia* lack vessels in secondary woods. Thus, angiosperms may have developed from Pteridosperms. The reproductive branch of Glossopteridales (Pteridosperm) resembles Dichapetalum, according to Melville (1960).

Crucial Elements of the Pteridosperm Hypothesis:

- a) **Ancestral Group:** According to the idea, angiosperms originated from pteridosperms, such as Caytoniales and Corystospermaceae.

- b) **Proof of the Theory:**

Morphological Similarities: Pteridosperms and angiosperms have traits in common, such as reticulate venation in leaves, monopodial branching, and comparable wood structures (cambium).

Reproductive Structure: The cupule of Caytoniales, which offered a protective covering akin to an ovary, is thought to be related to the ovule of an angiosperm.

Fossil Evidence: Prior to being supplanted by angiosperms, these plants were common in marshy waterways, according to studies conducted by scientists such as H.H. Thomas (1936).

Distinctive sub-theories: Caytonialean & Pentoxylales Theory

Caytonialean Theory:

H. Hamshaw Thomas (1925, 1936) proposed Caytonialean theory. His proposal was based on comparative examinations of angiosperms and a middle Jurassic Caytoniales fossil.

Anthers evolved singly or in groups on pinnately branching sporophylls in prehistoric Caytoniales. The above structures resemble the branching stamens of *Ricinus* (Euphorbiaceae), *Calothamnus* (Myrtaceae), and *Hypericum*. His explanation included how Caytoniales produce angiosperms.

As Mesozoic relics of the Pteridosperms, the Caytoniales are related. The ovary-like pouches of the form-order Caytoniales cannot be regarded the progenitor of the angiosperm carpel since morphological investigations show that their ancestor should have open megasporophyll with exposed ovule.

Later, Stebbins (1974) backed the angiosperm-Caytoniales ovule homology idea. He believes angiosperm ovules are similar to Caytoniales cupules, including Caytoniaceae and Corytospermaceae.

Anatropous ovules with well-developed funiculus resemble cupules with stalks. Caytoniaceae cupules are multi-ovulate and dehiscent, whereas Corytospermaceae are uniovulate and indehiscent.

If the cupule of Corytospermaceae is homologous to the angiosperm ovule, then the outer integument matches the cupule wall and the inner one matches the single integument of Caytonia and other gymnosperm ovules.

Angiosperms have lateral ovules on flattened sporophylls, unlike Caytoniales, which have cupules on branching axes. Stebbins explains the above scenario using the structure of *Ligettonia*, a Permian fossil from South Africa associated with Glossopteris leaves. A branching cupule-bearing rachis may have attached to its subtending bract. So the carpel is a complex structure like the conifer ovule-bearing cone-scale. *Ligettonia*'s flattened, elliptical sporophyll may have two rows of dehiscent cupules.

According to this idea, angiosperms' ancestors were relatively recent pteridosperms from the Glossopteridalean-Caytonialean alliance available during Jurassic to Permian times.

Angiospermic plant carpel walls have two concrescent cupules, which he believes should be used to determine stigma's origin.

Pentoxylales Theory:

The theory of pentoxylales, which was promoted by A.D. According to J. Meeuse's 1961 theory, angiosperms, especially monocots like Pandanus, are descended from the extinct gymnospermous group Pentoxylales, which was found by Birbal Sahni. This theory is supported by common traits such as axillary, clustered inflorescences, dioecious nature, upright habit, and particular seed shape.

Important Pentoxylales Theory Aspects:

- a) **Proposed Ancestry:** Meeuse (1961) proposed that the distinctive characteristics of the Pentoxylales, particularly their female reproductive organs (Carnoconites), bridge the gap between gymnosperms and angiosperms by resembling a primitive, enclosed carpel. Comparability to Angiosperms:
- b) **Reproductive Structure:** Sarcotesta, which has been regarded as a primitive, enclosed carpel, encloses many seeds in stalked, berry-like formations called carnoconites. Their morphological characteristics included a tuft of leaves and, like certain monocots, an upright, shrub-like morphology in some species.
- c) **Anatomical Similarities:** Some monocotyledonous structures are similar to the vascular bundles in the stem.
- d) **Supporting Arguments:** The possible evolutionary connection is reinforced by the presence of monosulcate pollen, which is also present in early angiosperms and Bennetitales.
- e) **Counterarguments (Parallel Evolution):** According to Pant and Kidwai (1971), a number of botanists contend that parallel evolution, rather than direct ancestry, is most likely the cause of the similarities between Pandanus and Pentoxylales.
- f) **Unresolved Nature:** In spite of the idea, it is still unclear where the Pentoxylales belong in the evolutionary tree. They are sometimes regarded as a separate group of gymnosperms with fascinating but unidentified relationships.

The Pentoxylales are usually regarded in paleobotany as a distinct, specialized group that evolved comparable traits to angiosperms rather than being their direct progenitors, despite the fact that the notion offers an intriguing glimpse into early seed plants.

The Pteridosperm theory, which postulates a slow shift from open-ovule, seed-bearing plants to the enclosed, carpel-bearing structures of contemporary flowering plants, is still a significant idea.

Contemporary Views

The origins of angiosperms (flowering plants) has been reinterpreted to include "proangiosperms," fast diversification, and environmental causes. Although the fossil record is incomplete, contemporary molecular and fossil data suggests a complicated, multi-lineage history rather than a straight derivation from a gymnosperm group.

1. Phylogenetic Consensus: "ANITA" Grade and Basal Angiosperms

Molecular, embryological, and fossil research show that the first blooming plants were not Magnoliales.

The ANITA Grade: Molecular data identified a "basal grade" of extant lineages—Amborellales, Nymphaeales (water lilies), Illiciales, Trimeniaceae, and Austrobaileyales—as the earliest diverging lineages of present day angiosperms.

Amborella trichopoda: Amborella is the sister group to all extant flowering plants, suggesting that the original angiosperms were little understory shrubs with vessel-less wood anatomy.

The "Paleoherb" Hypothesis: Early fossils like *Archaeofructus* support the idea that the first angiosperms were tiny, watery or herbaceous plants.

2. Origin: Pre-Cretaceous Options

- a) **"Abominable Mystery" Continues:** Although "undisputed" fossils are found in the Lower Cretaceous (125–130 million years ago), molecular clocks frequently imply a Triassic or Jurassic origin.
- b) **Fossil Discoveries:** recent fossil discoveries, like *Nanjinganthus* (Early Jurassic, ~170 Ma) and *Taiyuanostachya* (Early Permian), suggest the existence of angiosperm-like plants even earlier.
- c) **The "Hidden Record":** Many botanists believe there existed a long, unfossilized "hidden record" of stem-group angiosperms before their prolific Cretaceous emergence.

3. Ancestry Beyond "Anthophytes"

Denying the "Anthophyte" Theory: Gnetales and Bennettitales (extinct) were once considered angiosperms' closest cousins (the "Anthophyte" theory). Modern molecular research suggests that Gnetales are closer to conifers and that angiosperm reproductive systems evolved separately.

Many experts now believe that angiosperms developed from a now-extinct, diversified group of Mesozoic Pteridosperms with enclosed seeds (cupules) and insect pollination, rather than gymnosperms.

4. Origin Mechanisms

- a) A prominent modern interpretation is that the carpel (the seed carrier) is a composite organ generated by the fusing of a leaf and a branch.
- b) **Rapid Diversification:** The "Cretaceous Terrestrial Revolution" saw angiosperms explode due to co-evolution with insects, the creation of novel vascular systems (vessels), and the capacity to survive in dry, seasonal conditions.
- c) **Polyphyletic Aspects:** Some experts believe that the numerous "angiosperm" traits (carpel, endosperm, double fertilization) may have evolved many times independently in distinct plant lineages, making them "polyphyletic" or at least very complex and reticulate.
- d) **Monophyletic Origin:** Most people agree that there was just one progenitor, as evidenced by tests of monosulcate pollen conducted by Hickey and Doyle in 1977.
- e) **Molecular Data:** By supporting a specialized, perhaps aquatic ancestry, the APG system (1998 forward) transformed knowledge.

Important Trends in Evolution

- a) **Flower Structure:** Small, reduced, unisexual blooms replaced huge, solitary, bisexual ones.
- b) **Carpel Development:** Megasporophylls, which resemble open leaves, give way to closed, protective carpels throughout the carpel development process.
- c) In conclusion, the current theory holds that the fast Cretaceous radiation was the result of a "stepwise" acquisition of traits (enclosed seeds, double fertilization, flowers) that may have taken place over 100 million years.
- ❖ **Phylogeny of angiosperms** tries to figure out how species evolved by using cladistics to find basic (ancestral) and advanced (derived) traits. Some important ideas are monophyly, homology, and the APG system (I–IV), which used genetic data to change the classification of blooming plants. Spiral, bisexual flowers are examples of primitive traits. More advanced traits have parts that are smaller, joined together, or specialized.

<i>Summary of Current Theories</i>	
Theory	Main Concept
<i>ANITA Grade</i>	Amborella and water lilies represent the earliest diverging lineages.
<i>Paleoherb</i>	Earliest angiosperms were small, herbaceous plants.
<i>Woody Magnoliid</i>	Earliest angiosperms were woody shrubs (favored by older molecular studies).
<i>Pteridosperm Origin</i>	Angiosperms arose from Mesozoic seed ferns, not conifers or cycads.

Concepts about the phylogeny of angiosperms

Primitive (Plesiomorphic) Characteristics: These are traits that ancestors and early groups shared, like big flowers that grow on their own, lots of petals or carpels that don't end, and parts that are grouped spirally (like *Magnolia*).

Advanced (Apomorphic) Characteristics: These are traits that show specialization and appeared later in evolution. For example, smaller ovaries, fewer flower parts, petals that join together (sympetaly), and zygomorphy (bilateral symmetry).

Homology: is the study of structures that are similar because they come from the same ancestors. For example, the tendril of *Passiflora* and the thorn of *Citrus* both grow from lateral buds.

Analogy: Similarities that come from useful adaptations rather than shared ancestry. For example, the thorns on *Opuntia* and the spines on *Berberis* are both used for protection, but they come from different places.

Convergence/"convergent evolution": when similar traits develop on their own in plants that are not related to each other but grow in similar conditions. For example, the succulent habit of plants in the Euphorbiaceae and Cactaceae families is not related.

Parallelism (Parallel Evolution): Similar traits have evolved separately in closely linked families, starting from similar ancestors. For instance, development of epigyny in different subgroups within the Rosidae.

Clades (Monophyletic Groups): They are like a single "branch" on the tree of life. They are made up of the most recent shared ancestor and its entire offspring. Angiosperms are a major group by themselves. In cladistic classification, a monophyletic group is the only valid unit. It is a group that includes all the children of a single parent.

Paraphyly: It is a group that shares a parent but doesn't include all its descendants. For instance, "dicots," which exclude monocots, are non-monophyletic.

Polyphyly: It is a group of taxa that don't share a direct ancestor. Rather than sharing an ancestor, these taxa are often put together based on similar traits.

○ **Characters those are PRIMITIVE & ADVANCED:**

The word "primitive character" was first used by Sporne in 1948 to describe a trait that an organism has and that its ancestors had as well. on the other hand, an "advanced character," is one that a modern taxon has but not its ancestor; it took the place of an ancestral character during evolution. Hutchinson put the plants into basic groups based on PRIMITIVE AND ADVANCED characters.

Some Primitive Characteristics (Ancestral Traits)

Habit: Woody habit (trees/shrubs).

Leaves: Simple, alternate, stipulate.

Flower: Large, solitary, actinomorphic, bisexual.

Perianth: Many, spirally arranged, not clearly differentiated into sepals and petals (tepals).

Androecium/Gynoecium: Many, stamens laminar (leaf-like), apocarpous.

Pollen: Monosulcate (single furrow).

Some Advanced Characteristics (Derived Traits)

Habit: Herbaceous (often considered derived from woody ancestors).

Leaves: Opposite/whorled, simple/compound, exstipulate.

Flower: Small, in inflorescences (capitulum, umbel), zygomorphic, unisexual.

Perianth: Few, fixed number, clearly differentiated into sepals and petals.

Androecium/Gynoecium: Reduced number, stamens differentiated, carpels fused.

Pollen: Trisulcate (three furrows).

HOMOLOGY & ANALOGY

Owen was the first person to use and explain these terms (1848). According to him, homology means that the same organ can be found in different animals in a wide range of shapes and sizes. on the other hand, according to him, an analogy is when a part or organ of one animal does the same job as a part or organ of a different animal.

If applied to plants, the rhizome of ginger, the corm of *Colocasia*, the potato (*Solanum tuberosum*) tuber, and runner/stolon of lawn grass/Bermuda grass (*Cynodon dactylon*) are all

homologous, as they all are stems. The potato tuber and the tuber of sweet potato (*Ipomoea batatas* - Convolvulaceae), on the other hand, are analogous as the latter represents a root.

PARALLELISM & CONVERGENCE

Based on Simpson's definition from 1961, parallelism is when similar changes happen on their own in groups that share a shared ancestor. *Ranunculus tripartitus* and *Ranunculus hederacea* are both water plants with leaves that can be cut into different pieces. These traits were developed at the same time through parallel evolution. Parallelism can also be seen in the way vessels grow in Gnetales and dicotyledons.

When two different phyletic lines become more alike, either in terms of a single organ or the whole body, this is called convergence. The convergence traits show up separately in two or more genetically different taxa or lineages that are not closely linked. Even though they don't have much in common, they do have some similarities. These similarities possibly come from different gene systems. Asclepiadaceae and Orchidaceae have pollinia, and *Equisetum*, *Ephedra*, and *Polygonum* have the "switch habit," which is a circle sheath at the nodes. Most of the time, convergence happens when climates and environments are similar and when plants spread or pollinate using similar ways.

Examples of Convergent Evolution in Plants (unrelated taxa):

Adapting to similar environments or biological roles, plants that are not closely related can develop similar traits through convergent evolution.

- **Desert Succulents:** Cacti in North America and Euphorbiaceae in South Africa both developed thick, spiny, succulent branches to protect themselves and store water.
- **Pollinia:** The unique, clumped pollen structures (pollinia) that are found in both Asclepiadaceae and Orchidaceae are a striking example of convergence. They make pollination quick and accurate.
- **Leaf Shapes:** Families of plants that live in similar dry or hard conditions have evolved similar leaf shapes on their own, such as needle-like and succulent leaves.
- **Wind Pollination:** Families that are not connected to each other, like Poaceae (grasses), Salicaceae (willows), and Urticaceae (nettles), came up with wind pollination on their own.
- **Carnivory:** Pitcher plants that catch insects emerged separately in the families Nepenthaceae, Sarraceniaceae, and Cephalotaceae.

Examples of Parallel Evolution in Plants (Related Taxa):

- a) Parallelism happens when two closely related species that share a shared ancestor develop the same trait at different times.

- b) **Leaf Variations in Ranunculus:** Several species of *Ranunculus* (buttercups), including *R. hederaceous*, *R. tripartitus*, and *R. fluitans*, changed their habits to live in water and cut up their leaves while they were underwater.
- c) **Indehiscence of Fruits and Seeds:** The development of traits like seed retention (loss of natural seed spread) in closely related domesticated cereal grains (e.g., wheat and barley).
- d) **Floral Symmetry:** The separate development of zygomorphy in a lot of plant families that are linked in the asterids.
- e) **C4 Photosynthesis:** The repeated development of C4 photosynthesis pathways in grasses and sedges that are closely linked to each other.

<i>Differences between Convergent Evolution & Parallel Evolution</i>		
Feature	Convergent Evolution	Parallel Evolution
<i>Relationship</i>	Distantly related or unrelated	Closely related i.e., having similar ancestors
<i>Mechanism</i>	Similar adaptations under same, independent, environmental pressure	Similar adaptations based on similar, inherited, genetic pathways
<i>Genetic Basis</i>	Non-homologous, different genetic processes are often used	homologous or orthologous genes are often used
<i>Examples in plants</i>	Cacti (America) vs. Euphorbia (Africa)	Ranunculus species developing aquatic leaves
<i>Examples in animals</i>	Wings of birds and bats, dolphins and sharks, eyes of vertebrates and cephalopods.	Marsupial wolves and placental wolves, placental moles and marsupial moles, New World and Old World monkeys.

Thus, both processes lead to adaptations (similar traits) that are akin to similar environmental forces, but they are fundamentally different in the species' shared past.

CLADES

The word "clade" comes from the Greek word "klados," which means "branch." Clades are the basic units of biological classification. They put species into groups based on their shared ancestry (monophyletic groups), which gives a more accurate picture of evolution than just physical similarities. Researchers can use them to find out about variety, which is important for protecting species and understanding the tree of life, and to figure out how evolution occurred.

Important Aspects of clades and their Roles:

- a) ***Accurate links in evolution:*** CLADES, also called monophyletic groups, make sure that all members are closely connected to a single shared ancestor. This is different from traditional classification methods, which might group organisms based only on how they look.
- b) ***Constructing Cladograms:*** When making cladograms, which are visual representations or "family trees" that show how species are related, clades are used. See how species changed and split up over time with these trees.
- c) ***Understanding Shared Traits:*** Clades help us figure out synapomorphies, which are traits that all members of a species share and that they got from a common parent. This makes it easier to tell the difference between groups that are closely related and ones that are not.
- d) ***Application in conservation biology:*** Conservators can use what they know about clades to figure out which parts of the food chain are under the most danger. This helps them conserve species and keep environmental diversity high.
- e) ***Mapping Evolutionary History:*** For example, clades show how smaller groups (like species) are nested within bigger, wider groups. This is called making a map of evolutionary history.

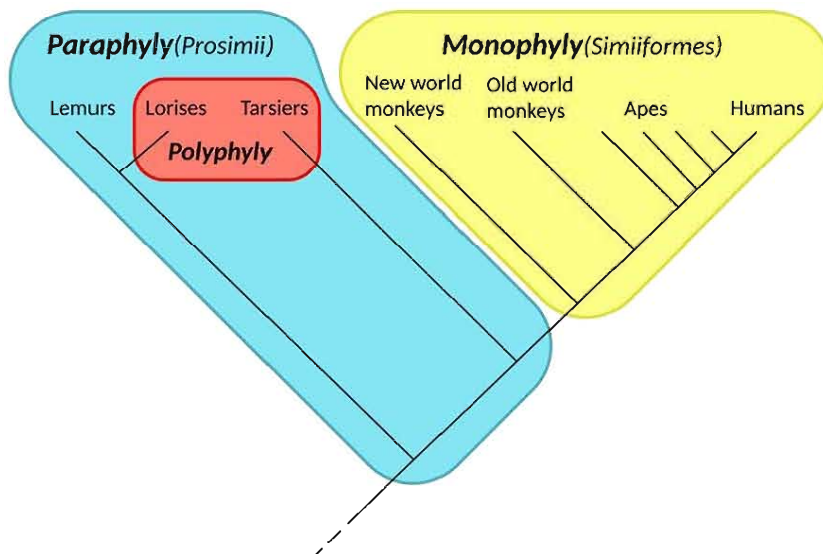


Figure: Primates' cladogram: In this cladogram of the primates, the simians are in yellow (showing monophyly), the prosimians are in blue/cyan with the red patch (showing paraphyly), and the night-active monkeys, lorises, and tarsiers are in red (showing polyphyly).

By showing surprising connections, like how birds and dinosaurs evolved together or how plants and animals are related, cladistics has completely changed biology.

Importance of clades:

Botanists use clades to figure out how traits (like fruits or vessels) developed instead of just looking the same over time. This helps with conservation, evolutionary studies, and figuring out how plants really evolved.

Briefly explain different kinds of plant phylogenetic groups with plant examples.

- **Monophyly (Clade):** All of a species' offspring share a shared ancestor, which is called monophyly. e.g., Plant Example: Embryophyta (Land Plants), Angiosperms, and Cycads are some examples.
- **Paraphyly (Grade):** It includes a shared ancestor and some of its offspring, but not all of them. e.g., Bryophyta includes mosses, liverworts, and hornworts but not vascular plants. Similarly, Dicotyledonae (dicots) excluding monocots.
- **Polyphyly:** It is a group of organisms that are not connected to each other but are descended from more than one parent. This is generally based on shared traits rather than shared history. e.g., All epiphytic plants or trees with bark structures that are alike and developed on their own.

Example of a Cladogram:

- **Monophyletic (A+B+C+D+E):** The whole group can be taken out with one cut (the root).
Explanation: It includes a common ancestor and all are descendents of that common ancestor

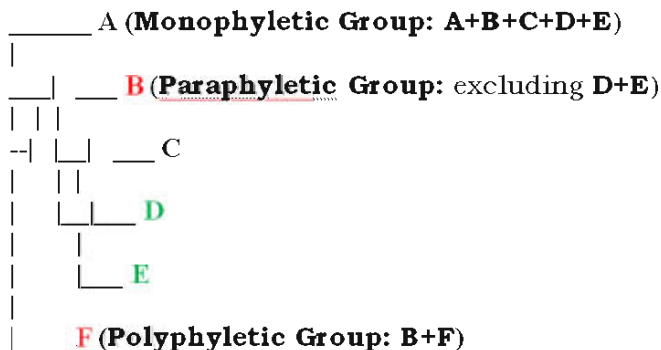


Figure: Example of a Cladogram (where A, B, C, D, and E are plant groups) showing monophyly, paraphyly, polyphyly.

- **Paraphyletic (A+B+C):** D and E are not descendants of the shared parent. Explanation: This group consists of common ancestor but not all the descendents.

- **Polyphyletic (B+F):** There are two plant taxa viz., B and F, that are grouped together, but their most recent shared parent is not in that group. Explanation: Taxa in this group share more than one parent. Some parts of a group share a common parent that is not in the group. It is possible for polyphyletic groups to split into monophyletic groups.

Definitions of selected terminologies often used in phylogenetics:

- a) **Apomorphy:** An apomorphy or homology is a trait that was passed down from a shared ancestor and is found in some or all of the terminal groups of a clade. It was an autapomorphy, meaning it wasn't present in the parent that it came from.
- b) **Autapomorphy:** A unique evolved trait that is only found in one taxon or group is called autapomorphy (within a single lineage).
- c) **Convergence:** It is when two or more taxa evolve a related trait without affecting each other.
- d) **Homoplasy:** When a trait has been acquired or lost separately in different lines during evolution, this is called homoplasy. (Similarity which is not the effect of homology)
- e) **Plesiomorphy:** It is a symplesiomorphy that is associated with a more evolved condition.
- f) **Pseudoplesiomorphy:** It is a trait that can't be told apart from either a plesiomorphy or an apomorphy, which means it's a reverse.
- g) **Reversal:** When a derived trait that was present in the parent is lost and a plesiomorphic trait is gained back, this is called reversal.
- h) **Symplesiomorphy:** It is a trait that two or more taxa share & that come from the same ancestor.
- i) **Synapomorphy:** It is a change in morphology that two or more groups share and got from a common parent (an apomorphy that unites 2 or more lineages).
- j) **Underlying synapomorphy:** A synapomorphy that many members of the group have lost again. It might be hard to distinguish from an autapomorphy if it's lost in all except one.

What is a Phylogenetic tree?

Ans: An illustration of the evolutionary relationships and histories between different biological species, organisms, or genes determined by shared ancestral lineages is called a phylogenetic tree. With nodes signifying shared ancestors and branches denoting lineages, it depicts how species diverge over time.

What are the major Characteristics of Phylogenetic Trees?

Ans: major Characteristics of Phylogenetic Trees are:

- a) **Structure:** They are made up of branches (lineages) and nodes (branching points that reflect ancestors).

- b) **Explanation:** The species are more closely related if they have a common ancestor.
- c) **Elements:** The most recent common ancestor of every taxon in the tree is represented by the root.
- d) **Nodes:** Show the points at which two or more descendant groups split off from a common ancestor.
- e) **Tips/Leaves:** Represent the taxa (species, organisms, or genes)
- f) **Sources of data:** Based on genetic, molecular (DNA, protein sequences), or physical traits, similarities and contrasts were constructed.
- g) **Types:** include rooted (which indicates a common ancestor) and unrooted (which indicates ties without ancestry).

Types:

- a) **Rooted Trees:** Determine which creatures on the tree have a common ancestor.
- b) **Unrooted Trees:** Display connections but not the shared ancestry.
- c) **Bifurcating Trees:** Every node divides into precisely two branches.

Techniques for building phylogenetic trees:

- a) **Maximum Parsimony:** A technique that chooses the tree that best explains the data by having the fewest evolutionary changes (such as character characteristics or mutations).
- b) **Maximum Likelihood (ML):** A statistical technique that determines the most likely evolutionary route for a tree by calculating its probability given a certain evolutionary model.
- c) **Distance-Matrix Methods (Neighbor-Joining, UPGMA):** These cluster organisms according to similarity by calculating the genetic distance or dissimilarity between sequences using algorithms like Neighbor-Joining.
- d) **Bayesian Inference:** This method, which frequently offers greater resolution analysis, uses an evolutionary model to ascertain the probability distribution of trees.
- e) **Diagram Data Sources:**
 - **Morphological Data:** Anatomy, fossils, and physical traits.
 - **Molecular Data:** Sequence comparisons of proteins, RNA, and DNA.
 - **Biochemical and behavioral data:** common metabolic processes or behaviors. With tighter branches suggesting more recent common ancestry, these techniques aid in establishing evolutionary links, or phylogeny.

Applications of Phylogenetic trees:

- a) **Epidemiology and virus tracking:** They help track HIV, influenza, and SARS-CoV-2's transmission, origin, and evolution.

- b) **Evolutionary Biology and Systematics:** Classify organisms, explain species diversification, and find shared ancestry.
- c) **Drug Discovery and Biomedical Research:** Researchers utilize these trees to identify species closely related to known venom-producing or medicinal animals to find novel medications like ACE inhibitors.
- d) **Conservation Biology:** They assess genetic diversity and select species for endangered species and ecosystem protection.
- e) **Forensics and Illegal Wildlife Trade:** Legal forensics and illicit wildlife trade: Used to track biological samples and identify poached or trafficked species.
- f) **Agriculture & Crop Improvement:** Finding wild cousins of domesticated crops with disease-resistant genes for breeding.
- g) **Functional Genomics:** Predicting unknown gene or protein functions based on evolutionary closeness to recognized ones in other species.

Summary of the applications of Phylogenetic trees:

- to find out the evolutionary history
- to measure phylogenetic diversity
- to search for natural products
- to guide our search for new species
- to find out how our species spread geographically in their evolution
- to tell us when taxa originated and where

Differentiate between Cladograms & Phylograms.

<i>Features</i>	<i>Cladograms</i>	<i>Phylograms</i>
<i>Definition</i>	A tree diagram shows how species are related to each other based on traits they share (clades).	A branching tree where the length of each branch is related to the amount of change in a trait, like DNA mutations.
<i>Features</i>	Branch lengths are usually all the same and don't show time or genetic difference.	Different branch lengths show different levels of genetic change. Longer branches show more change, while shorter branches show less.
<i>Goal</i>	To illustrate how recent common ancestry is.	This graph shows how species are related to each other and how much they have evolved separately over time.
<i>Key Aspect</i>	It shows an idea about how natural connections work.	Seen as a cladogram with branch lengths, or a "scaled" tree.

What do you mean by Cladistics?

Ans: Cladistics (Gr. Kládos = 'branch') classifies organisms into "clades" based on assumptions of the latest shared ancestry. Shared derived features (synapomorphies) that are absent in distant groups and ancestors support theorized links. However, empirically, common ancestors are predictions based on cladistic hypotheses of taxa whose character states can be detected. A last common ancestor and its progeny form a (minimal) clade. Most significantly, all descendants stay in their ancestral clade. In a rigorous cladistic framework, worms and fishes would include humans. Often employed paraphyletically outside of cladistics, like a 'grade', these concepts are difficult to define, particularly for extinct species. Radiation creates new subclades via bifurcation, although sexual hybridization can muddle closely related groups.

Clades can only be dismissed as hypotheses if some groups were removed. The excluded group may have descended from the group's last ancestor in common and so joined the group. ("Evolved from" is deceptive since cladistics keeps all descendants in the ancestral unit). If the group is paraphyletic, it should be dissolved or awarded excluded groups to maintain just authentic clades.

Branches down to the divergence to the next major (e.g. extant) sister are clade stem-groupings, although each level should have its own name. In a completely bifurcated tree, introducing a group adds a clade and level to that branch. Extinct groups are always placed on a side branch, regardless of whether their progenitor was discovered.

Non-biological fields use cladistics methods and nomenclature. Rank and (genus-) naming of recognized groups may be discordant due to cladistics discoveries. Cladistics is the most popular classification approach.

Who founded cladistics?

Ans: It was founded by German biologist and zoologist Emil Hans Willi Hennig (20 April 1913 – 5 November 1976) (known as father of cladistics).

Write a brief history about Cladistics

Ans: Cladistics, or phylogenetic systematics, organizes species by common derived features (synapomorphies) to show branching evolutionary routes. In the 1950s, German entomologist Willi Hennig developed "phylogenetic systematics," which changed biology by stressing ancestor-descendant ties above resemblance. Historical milestones of cladistics are as follows:

- a) *Foundations (1950s-1960s):* In the 1950s and 1960s, Willi Hennig challenged Taxonomy by arguing that only shared developed features, not basic ones, show close evolutionary relatives. His approach was later called "clade" and "cladistics" by scholars.

- b) Rise and Competition (1970s-1980s): Despite initial resistance, cladistics gained popularity against "phenetics" (numerical Taxonomy based on overall similarity) and "evolutionary Taxonomy".
- c) Computer Revolution (1990s): Computational analysis and DNA sequencing enabled large-scale cladistic analysis, making it the dominant approach for phylogenetic trees.
- d) Modern Use: Cladistics is the main method for inferring evolutionary connections, concentrating on parsimonious trees with little evolutionary changes.
- e) Thus, it changed Taxonomy from a subjective "ladder" concept of life to a branching, objective ancestry-based approach.

What are the basic laws of cladistics?

Ans: Cladistics is a scientific categorization technique that divides organisms into clades according to their derived evolutionary traits. It focuses on branching patterns of evolution (phylogeny), creating links based on common ancestry, as in contrast to classifying organisms by general similarities.

Willi Hennig, a German entomologist, created an approach known as phylogenetic systematics, which is not a "law" in the sense of a single, unchangeable norm.

Important ideas and presumptions: Three fundamental presumptions underlie cladistics:

- a) Common Ancestry: All creatures share a common ancestor and are therefore linked.
- b) Bifurcating Patterns: Cladogenesis, or lineage-splitting, is a process that involves splitting, or branching, usually into precisely two groups at a time.
- c) Linear Change: Lineage characteristics evolve throughout time, making it possible to distinguish between several groups.

Fundamental Ideas in Cladistics

- a) Clade (Monophyletic Group): A group made up of all the descendants of a common ancestor is called a clade.
- b) Synapomorphy (Shared Derived Trait): A trait that a group has that was inherited from a common ancestor but is absent from more distant predecessors is known as synapomorphy (shared derived trait). The most important kind of evidence for classifying creatures is this one.
- c) Plesiomorphy (Ancestral Trait): An ancestral trait known as plesiomorphy is a condition of character acquired from a more distant ancestor that is typically not helpful in figuring out relationships within a particular group.
- d) Cladogram: A cladogram is a branching diagram that illustrates a theory about the connections between species based on traits they have in common.

The Parsimony Principle

The concept of parsimony, which states that the simplest explanation—the cladogram having the fewest evolutionary changes or "steps"—is the most likely to be accurate, is frequently applied in cladistic investigations. Conflicts in data when various characters imply disparate relationships are resolved in this way.

What are the methodologies used in Cladistics?

Ans: Cladistics groups biological organisms into monophyletic clades according to common derived traits (synapomorphies) to determine evolutionary connections. Taxa are selected, character states are identified, character polarity is determined utilizing outgroups, and a cladogram is created applying parsimony to minimize evolutionary alterations.

Major Methods in Cladistics:

- a) Taxa Selection: Selected organisms (ingroup) should form a monophyletic group for analysis.
- b) Identifying and comparing particular, observable, and inheritable traits (morphological, genetic, or behavioral) between taxa.
- c) Character Coding/State Determination: Definition of ancestral (plesiomorphy) and derived (apomorphy) states for each character.
- d) Polarity Determination: Assessing evolution toward primitive or derived traits using an outgroup, a closely related but distinct taxon.
- e) Grouping by Synapomorphies: Organizing organisms by common derived features, not ancestral qualities or general resemblance.
- f) Cladogram Construction & Parsimony: Construction of phylogenetic tree. Parsimony is used to choose the tree with the fewest, most likely evolutionary changes.

Basic Cladistics Assumptions:

- a) All creatures share a common ancestry.
- b) Lineages split into many branches.

Compare Apomorphy and Synapomorphy.

<i>Feature</i>	<i>Apomorphy</i>	<i>Synapomorphy</i>
<i>Definition</i>	A derived/novel character state	A shared derived character state
<i>Scope</i>	Can be unique to one taxon (Autapomorphy) or shared	Shared by two or more taxa
<i>Common Ancestry</i>	Does not necessarily indicate recent common ancestry	Indicates recent common ancestry

Phylogenetic Use	Defines a specific, single terminal taxon	Defines monophyletic groups (clades)
Example	Feathers in birds (as a whole)	Hair in mammals (shared by all mammals)
Relationship	The broad category of new traits	A specific type of apomorphy

Important difference:

Not all apomorphies are synapomorphies, but all synapomorphies are apomorphies. An autapomorphy is a special, non-shared apomorphy.

Phylogenetic Use: Because they show a common ancestor, synapomorphies are essential for identifying monophyletic groupings (clades). A distinct branch is identified by apomorphies, particularly autapomorphies. For instance, Apomorphy: When certain populations of stickleback fish lack a pelvic girdle. Hair is a synapomorphy for the entire class Mammalia, but it is an apomorphy for mammals.

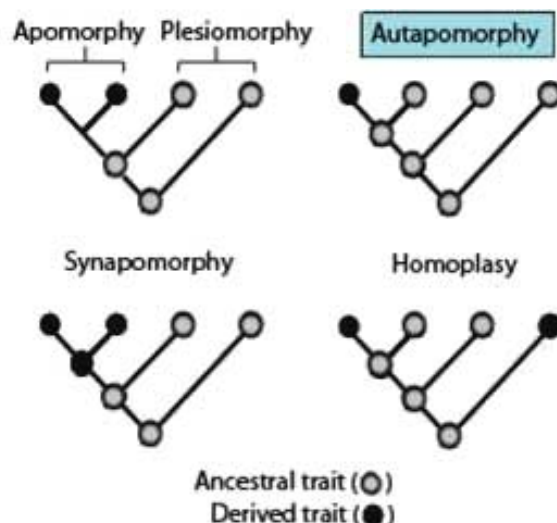


Figure: Phylogenies show the terms used for discussion about various types of ancestors' and derived traits or character states, like evolution of a flatfish.

Give examples of Apomorphy & Synapomorphy in Plants.

Examples of Apomorphy in Plants:

- Flowers (Angiosperms):** What sets flowering plants apart from gymnosperms is their particular Flowers, specialized reproductive system.

- b) ***Velamen (Orchidaceae)***: An apomorphy of *Orchidaceae* family, the specialized, multilayered epidermis (velamen) of orchid roots is used to absorb nutrients and water.
- c) ***Silicles (Brassicaceae)***: A characteristic that sets some mustard families apart is their unusual, short, wide silicle fruit form.

Summary Table for the Examples of Apomorphy, Synapomorphy & plesiomorphy, Symplelesiomorphy

Feature	Type	Group Defined
<i>Flowers</i>	Apomorphy	Angiosperms
<i>Presence of carpel (derived feature from ancestral feature of sporophyll)</i>	Apomorphy	Angiosperms
<i>Multicellular Sporophyte</i>	Synapomorphy	Land Plants (Embryophytes)
<i>Vascular Tissue</i>	Synapomorphy	Tracheophytes (Ferns + Seed Plants)
<i>Seeds</i>	Synapomorphy	Spermatophytes (Gymnosperms & Angiosperms)
<i>Simple Leaves</i>	Plesiomorphy	Contemporary flowering plant groups
<i>Presence of Chlorophyll-b</i>	Plesiomorphy	all green algae and land plants
<i>Flagellated Sperm</i>	Plesiomorphy	ferns, and bryophytes
<i>Thallus Structure (ancestral simple)</i>	Plesiomorphy	Liverworts
<i>Alternation of Generations (with dominant gametophyte)</i>	Plesiomorphy	Bryophytes
<i>Basipetal Leaf Growth</i>	Symplelesiomorphy	seed plants (spermatophytes)
<i>Absence of Vessels</i>	Symplelesiomorphy	certain angiosperms (like <i>Amborella</i>)
<i>Pappus</i>	Autapomorphy	Asteraceae family
<i>Venus flytrap Traps</i>	Autapomorphy	<i>Dionaea</i>

Examples of Synapomorphy in Plants:

- a) ***Vascular Tissue (Tracheophytes)***: The presence of xylem and phloem is a shared derived trait that unites ferns, gymnosperms, and angiosperms.
- b) ***Seeds (Spermatophytes)***: Gymnosperms and angiosperms are linked by the synapomorphy of seed production, which distinguishes them from plants without seeds.
- c) ***Multicellular Sporophyte (Land Plants)***: Liverworts and mosses, for example, undergo a synapomorphy to a dominant multicellular sporophyte phase, which sets them apart from green algae.

Important instances plesiomorphies in plants:

- a) ***Simple Leaves in Flowering Plants:*** Some contemporary flowering plant groups have simple leaves, which are regarded as a plesiomorphy. These species received their basic structure from distant ancestors, whilst other groups developed compound leaves.
- b) ***Presence of Chlorophyll b:*** Although all oxygenic photosynthetic organisms include chlorophyll a, all green algae and land plants (Viridiplantae) share a plesiomorphic characteristic that is inherited from their common ancestor: the presence of chlorophyll b.
- c) ***Early Land Plants with Flagellated Sperm:*** Some vascular plants, such as ferns, and bryophytes, such as mosses and liverworts, have flagellated sperm that need water to travel to the egg. The progenitors of green algae shared this plesiomorphic characteristic (ancestral condition). On the other hand, in seed plants, the lack of flagellated sperm is a derived characteristic (apomorphy).
- d) ***Thallus Structure in Liverworts:*** Early land plants such as liverworts have the plesiomorphic, ancestral simple thalloid form, which is a plant body devoid of genuine roots, stalks, or leaves.
- e) ***Alternation of Generations (with dominant gametophyte):*** In bryophytes, the haploid gametophyte is the dominant, photosynthetic, and persistent generation. While the sporophyte is prevalent in vascular plants (tracheophytes), this is a plesiomorphic, ancestral feature of land plants.

Important instances symplesiomorphies in plants:

- a) ***Basipetal Leaf Growth:*** When comparing various gymnosperms and angiosperms, the base of seed plants (spermatophytes) exhibits unique developmental patterns, such as basipetal leaf growth, which serves as a symplesiomorphy.
- b) ***Absence of Vessels:*** In contrast to the majority of other flowering plants, certain angiosperms (like *Amborella*) have a symplesiomorphy, or primordial characteristic, in their xylem that lacks vessel parts.

Important instances autapomorphies in plants:

- a) ***Venus flytrap Traps:*** *Dionaea* is the only autapomorphy with a snapping, toothed jaw mechanism, but many other plants are carnivorous.
- b) ***Sunflower Pappus:*** In certain species of the Asteraceae family, the distinctive, greatly altered pappus structure (hair-like, scaly, or bristly) might serve as an autapomorphy to identify that particular lineage.

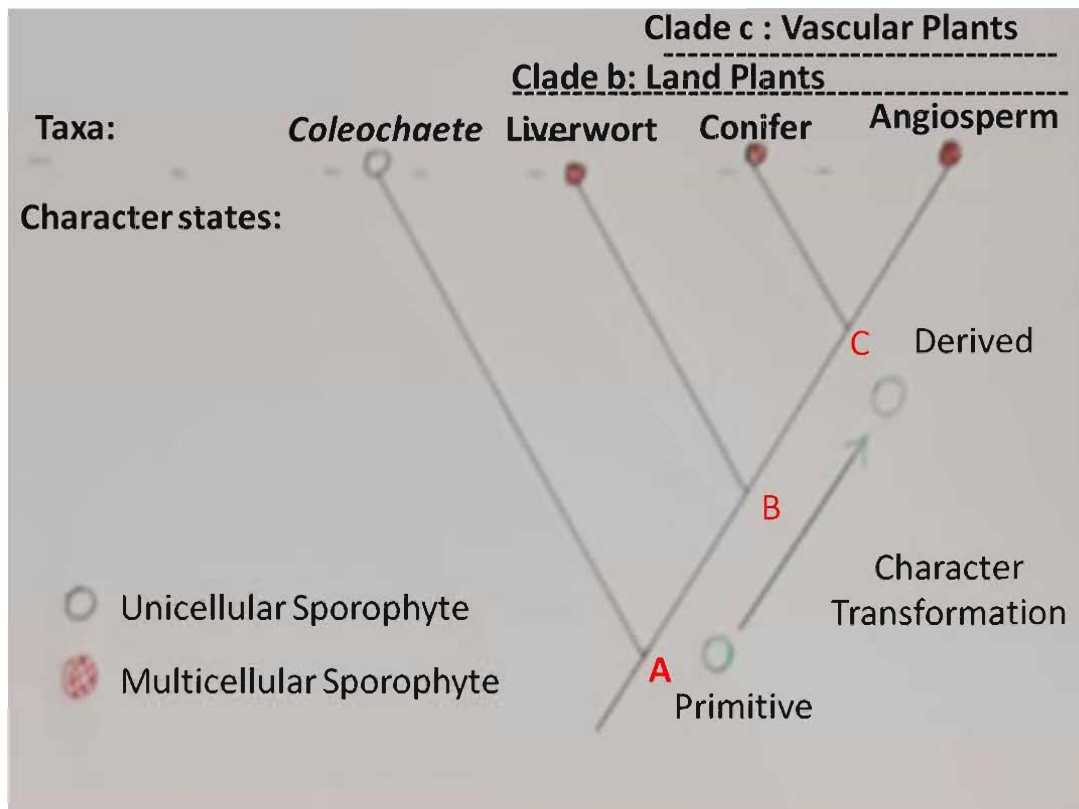


Figure: Phylogeny of Coleochaete, liverworts, conifers and angiosperms;

Synapomorphies involving "multicellular sporophyte" occur at node B (liverworts) and clade c (vascular plants). Sympleisiomorphy between conifers and angiosperms occurs at node B. *Automorphy of clade b (land plants) to "multicellular sporophyte" occurs at node A.* Thus, The multicellular sporophyte is a sympleisiomorphy of conifers and angiosperms, a synapomorphy of liverworts and all other land plants, and an autapomorphy of land plants.

Points to Note:

- Both concepts (Apomorphy and Synapomorphy) are relative; an apomorphy for a larger clade may be a synapomorphy for a smaller clade.
- Since plesiomorphies (or sympleisiomorphies when shared) are inherited from a very distant ancestor, they are not useful for determining closer, more recent connections within a group.

Differentiate between Cladograms and Dendrograms.

Both cladograms and dendrograms are branching diagrams used to show relationships, but they serve different purposes. A cladogram shows possible evolutionary relationships (phylogeny) based on shared traits without implying time, while a dendrogram is a more general term for a diagram (often from clustering analysis) that shows how similar or different organisms or data are.

Features	Cladograms	Dendrograms
<i>Focus and Definition:</i>	Cladograms show the links between species over time (phylogeny) by using clades and focusing on shared origins.	A dendrogram is a broad term for any tree-like image that shows how things are grouped or similar in a hierarchical way.
<i>Meaning of Branch Length:</i>	In a cladogram, branch lengths are usually chosen at random and don't show how much time or character change there is.	In phenetics, for example, branch lengths often show how close two species are or how far apart they are numerically.
<i>Application:</i>	Cladograms are only used in biology to show the path of development.	A dendrogram is a way to show grouping in biology, data analysis, and computer science.
<i>Basis of Construction:</i>	Based on shared derived traits (synapomorphies), the hierarchical structure is called a clasp.	From phenetics, a dendrogram shows how alike things are generally.

To sum up, cladograms are all types of dendrograms, but not all dendrograms are cladograms. A cladogram is a genetic tree, and a dendrogram is just a tree map.

Differentiate between Cladogram, Phylogenetic Tree and Dendrogram.

Feature	Cladogram	Phylogenetic Tree	Dendrogram
Branch Length	No meaning (unscaled)	Represents time/change	Represents distance/similarity
Focus	Shared characteristics	Evolutionary distance	Hierarchical Clustering
Representation	Hypothesis	Detailed ancestry	General data grouping
Application	It shows possible connections between things based on things they have in common, like DNA or bone structure.	shows how species have evolved over time and how they have become different	Used in bioinformatics and data science to show similarity (e.g., in cluster analysis) rather than just evolution.

Q. “All Cladograms are dendrograms, but not all dendrograms are cladograms” - Explain Why?

Ans: Cladograms are specialized forms of dendrograms, or tree-like diagrams, that are only used to illustrate hypothetical, hierarchical evolutionary connections. Not all dendrograms are cladograms, even though all cladograms utilize branching to display taxonomic groups. This is because many dendrograms (such as phenograms and phylograms) are used in clustering analysis to display distance, time, or general resemblance rather than shared derived traits.

This difference occurs for the following reasons:

- a) *Cladograms are particular.* They do not convey time scales or the degree of change; rather, they are intended to depict branching patterns based on synapomorphies, or common derived features. They only demonstrate that living things have a common ancestry.
- b) *Dendrograms are general:* Any tree-like diagram that depicts taxonomic, hierarchical, or cluster connections is referred to be a dendrogram.

Other Dendrogram Types:

- a) **Phenograms:** Instead of displaying evolutionary branching, which may not always indicate ancestry, phenograms display general resemblance (phenetics).
- b) **Phylograms:** A kind of phylogenetic tree in which, in contrast to a typical cladogram, the branch lengths are proportionate to the amount of evolutionary change or time.

In conclusion, all cladograms have branching patterns, which makes them dendrograms. However, not all dendrograms are cladograms, as many of them signify true evolutionary distances or similarities rather than merely shared derived ancestral features.

Brief explanations of the phylogeny of the Magnoliids, Eudicots, Core Eudicots, and Basal Angiosperms.

Magnoliids, Monocots, and the huge Eudicot lineage are the first clades in the phylogeny of flowering plants (angiosperms), which follows a significant, early-diverging break that begins with "basal angiosperms" (also known as ANITA grade). Within the wider eudicot clade, the core eudicots are a very diverse, later-branching subgroup.

Basal angiosperms: Amborellales, Nymphaeales, and Austrobaileyales (ANA grade) are the oldest diverging lineages of flowering plants that make up basal angiosperms. These lineages split before magnoliids, monocots, and eudicots emerged. It is well acknowledged that Amborella trichopoda is the sister group of all other extant angiosperms.

Crucial Phylogenetic Framework

- **ANA Grade:** It refers to the oldest branching lineages, which include the Amborellales, Nymphaeales, and Austrobaileyales.
- **Sister to All:** The oldest branch, Amborella (single species, New Caledonia), is the most basal and devoid of vessels.
- **Subsequent Divergence:** Austrobaileyales (which includes star anise) and Nymphaeales (water lilies) underwent subsequent divergence.
- **Mesangiospermae:** Magnoliids, Chloranthales, Ceratophyllales, Monocots, and Eudicots are among the big, monophyletic group that emerges following the basal angiosperms.
- **Magnoliids:** An important group that was once frequently classified with primitive angiosperms but is now understood to be a separate clade sister to the lineage of monocots and eudicots. Canellales, Laurales, Magnoliales, and Piperales are their four primary orders and has a close kinship with eudicots and monocots.
- **Eudicots (True Dicots):** Tricolpate pollen is a characteristic of the group & represents about 75% of flowering plants. They diverged after the magnoliids.
- **Core Eudicots:** The majority of well-known flowering plants belong to the core eudicots, a large, derived clade of eudicots. Main branches include Gunnerales (frequently basal to the rest), followed by major lineages like Rosids and Asterids.
- **Superrosids:** Consists of the major rosid clade (fabids and malvids), Vitales, and Saxifragales.
- **Superasterids:** These comprise the main asterid clade (Cornales, Ericales, Lamiids, and Campanulids), as well as the Santalales, Berberidopsidales, and Caryophyllales.

Key Features: Laminar stamens, many spirally organized tepals, and monoaperturate pollen are examples of archaic traits frequently seen in basal angiosperms.

Evolutionary Relevance

Origin: Although some, like Nymphaeales, may have earlier fossil records, molecular evidence places these divergencies in the Early Cretaceous.

Flower Evolution: Research on the ANA grade has been essential to comprehending the development of the female gametophyte and the angiosperm flower.

An overview of the relationships

The currently accepted phylogeny is: [Amborellales [Nymphaeales [Austrobaileyales [Magnoliids + Monocots + Eudicots]]]].

"Taxonomy without phylogeny is like bones without flesh" - Armen Takhtajan

CHAPTER 11

Floral: Formula & Diagram

*"Concern for man and his fate must always form the chief interest of all technical endeavors. Never forget this in the midst of your **diagrams** and **equations**". --- Albert Einstein*

What is Floral formula?

A floral formula is a mathematical notation using some symbols, letters and numbers to depict the structure of a flower. They usually present ranges of component numbers and can be used to describe higher taxa or to depict the floral morphology of a specific species.

Early in the 19th century, floral formulas were developed. They were initially used by Cassel (1820), who created lists of integers to represent the number of segments in named whorls (Martius 1828).

Trick to remember the Floral Formulae for families:

Remembering floral formulae is much easier if you understand the symbols as a "language" and use a specific sequence.

1. Key to the Symbols

Before the mnemonics, memorize what each letter/symbol represents in order:

Br: Bracteate (leaf-like structure at base)

$\oplus$: Actinomorphic (Radial symmetry; think of a circle/target)

%: Zygomorphic (Bilateral symmetry; think of a percentage/split)

$\text{♂} \text{♀}$: Bisexual (Male ♂ and Female ♀ combined)

K: Kalyx (Sepals)

C: Corolla (Petals)

P: Perianth (Used when Sepals and Petals look the same, e.g., Lilies)

A: Androecium (Male/Stamens)

G: Gynoecium (Female/Carpels)

G: Superior ovary (Line below G)

$\overline{\text{G}}$: Inferior ovary (Line above G)

(): Parentheses mean parts are fused (united)

2. Numerical Data and Relationships

- a) **Number of Parts:** The number of organs is written as a suffix (e.g., K_5 means 5 sepals).
- b) **Fused Organs (Connation):** Numbers in parentheses indicate fused parts; e.g., $K_{(5)}$ means 5 gamosepalous/fused sepals.
- c) **Free Organs:** Numbers without parentheses mean free parts (e.g., C_5 means 5 polypetalous/free petals).
- d) **Whorls:** The '+' symbol indicates multiple whorls (e.g., $A_{(5+5)}$ means 5 stamens in two whorls).
- e) **Number of Locules:** Shown in the gynoecium description (e.g., $G_{(2)}$ indicates a bicarpellary, syncarpous ovary).
- f) **Adhesion (Fusion of different whorls):** A line drawn over the symbols connects attached parts (e.g., $C^{\frown}A$ for epipetalous stamens).
- g) **Inferior/Superior Ovary:**
 - Superior ovary (line below G)
 - Inferior ovary (line above G)
 - Half-inferior ovary (line in the middle)

What Is Not Shown by a Floral Formula?

- a) **Aestivation:** The particular physical configuration of the bud's petals and sepals.
- b) **Placentation:** The process by which the ovules remain connected to the ovarian wall.
- c) **Inflorescence Type:** The type of flower cluster (such as raceme or cyme) is not indicated.
- d) **Accurate Structural Details:** Although it shows position and fusion, it does not display the precise form or relative orientation of components (e.g., stamens relative to petals).
- e) **Pedicle Information:** There is no indication of whether a flower stalk, or pedicel, is present or not.
- f) **Locule Number:** The ovary's precise chamber count is typically not disclosed.

Note: A floral formula usually depicts floral symmetry, sexuality, ovary position (superior/inferior), and the number/fusion of floral parts (calyx, corolla, androecium, and gynoecium).

The "Bracket & Line" Rule

- **Fusion (Syncarpous/Gamosepalous):** If parts are fused, put the number in **brackets** e.g., $K_{(5)}$ means 5 fused sepals.
- **Free (Apocarpous/Polypetalous):** Write the number **alone** (e.g., C_5).
- **Adnation (Attachment):** Draw an **arc** (over-line) between symbols to show they are joined (e.g., $C^{\frown}A$ (with arc above for epipetalous stamens)).
- **Ovary Position:**

- $\underline{G}$ (G underline): = Superior ovary (Hypogynous).
- $\overline{G}$ (G bar) G^- = Inferior ovary (Epigynous).

Ovary locations in flowers may be recalled using simple mnemonics:

- Hypogynous (Superior Ovary-):** The ovary is at the top, with the other components below.
- Trick:** He Must Cook (Hypogynous: Mustard, China Rose, Citrus).
- Perigynous (Half-Inferior Ovary):** The ovary is seen from outside & placed in the center, with components on the periphery.
- Trick:** People Pluck Pink Roses (Perigynous: Plum, Peach, Rose).
- Epigynous:** The ovary is at the bottom, while the other elements are on top.
- Trick:** Epic Sunny Goes Camping (Epigynous: sunflower, guava, cucumber).

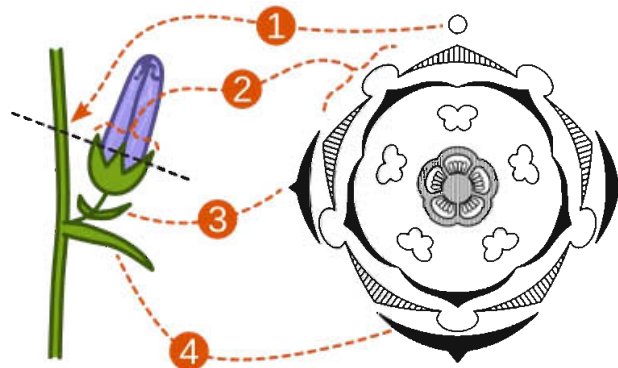
What is Floral diagram?

It is a stylized, two-dimensional visual depiction of the cross-sectional anatomy of a flower. Compared to lengthy textual descriptions, it offers a "ground plan" that successfully conveys complicated morphological information.

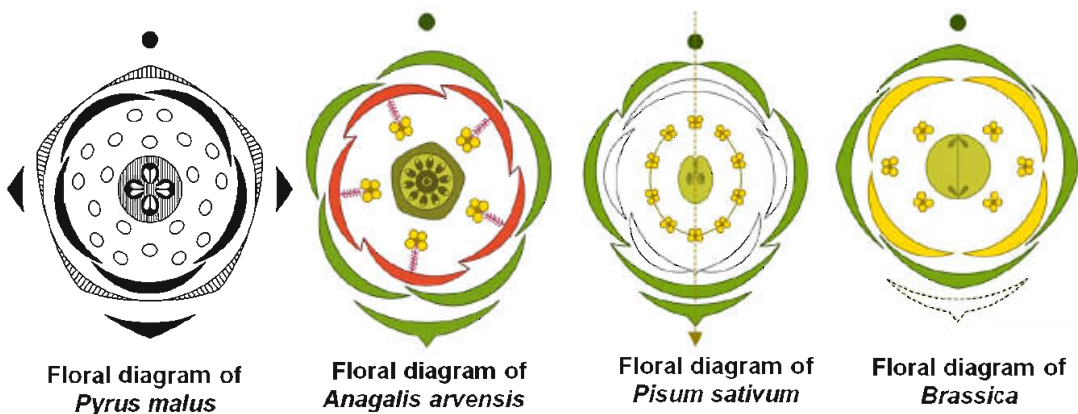
What are the Important Data presented with a floral diagram?

- Number of Floral Organs:** It displays the precise number of stamens, carpels, petals, and sepals in each whorl.
- Arrangement and Whorls:** From the outermost Calyx to the innermost Gynoecium, the organs are depicted in concentric rings.
- Aestivation:** A visual representation of the particular way that sepals and petals are arranged in a floral bud, whether they overlap or do not.
- Adhesion and Cohesion:**
 - **Cohesion:** Connecting lines between comparable portions suggest fusion (e.g., fused petals or gamopetalous state).
 - **Adhesion:** The fusion of various whorls is further shown (e.g., stamens connected to petals or epipetalous condition).
- Symmetry:** The diagram shows whether a flower has zygomorphic (bilateral symmetry, frequently indicated with a prominent arrow) or actinomorphic (radial symmetry).
- Mother Axis:** The posterior side is marked by a little dot or circle at the top that indicates the main stem's position in relation to the flower.

- g) **Placentation and Ovarian Structure:** A cross-section of the ovary is displayed in the center of the diagram, showing the number of locules (chambers) and the ovule layout.
- h) **Accessory Structures:** Bracts (at the base), bracteoles (on the sides), and nectary glands are shown.



Relationship between the floral diagram and a plant specimen for example, *Campanula medium*. The cross-section is shown by the black dashed line; 1 – The main axis's location; 2 – the lateral flower's cross-section; 3 – bracteole; 4 – enclosing bract.



Important Elements of the Floral Diagram for *Pisum sativum* (Papilionaceae):

Mother axis: A little circle or dot at the top of the figure represents the mother axis, which shows where the flower is in relation to the stem.

Symmetry: Zygomorphic (symbol: %), which means that just one plane (bilateral symmetry) may split the flower in half.

Bract: Often seen in the Fabaceae family, a single bract may be visible at the base.

Calyx (K): Five sepals with valvate or imbricate aestivation, typically gamosepalous (fused) at the base.

Corolla (C): Polypetalous (free) and papilionaceous (butterfly-like). It consists of:

- a) **Posterior (Standard/Vexillum):** One enormous outermost petal
- b) **Lateral (Wings/Alae):** Two middle petals.
- c) **Anterior (Keel/Carina):** The stamens and pistil are enclosed by a boat-shaped structure made up of the two innermost, joined petals.
- d) **Aestivation:** Vexillary, meaning that the lateral petals overlap the anterior petals, and the posterior petal overlaps them.

Androecium (A): Ten stamens, (9) +1, diadelphous, which means that nine are united into a tube and one is free.

Gynoecium: Unilocular with marginal placentation, superior ovary, and monocarpellary (one carpel).

Breakdown: Fabaceae (The "1+2+(2)" Pea Family)

This family is characterized by zygomorphic (bilateral) symmetry.

- **Floral Formula:** Br. % $\overrightarrow{\gamma}$ K₍₅₎ C₁₊₂₊₍₂₎ A₍₉₎₊₁ G₁

The Codes:

- **% (Zygomorphic):** Can only be divided into two equal halves in one plane.
- **C₁₊₂₊₍₂₎:** Represents the **Vexillary aestivation** (1 Standard + 2 Wings + 2 fused Keels).
- **(9)+1(Diadelphous):** 10 stamens in two bundles—9 are fused together, and 1 is free.
- **G₁:** Monocarpellary (1 carpel) with a superior ovary.

Important Elements of the Floral Diagram for *Brassica* (Brassicaceae):

- **Mother axis:** A little circle or dot at the top of the figure represents the mother axis, which shows where the flower is in relation to the stem.
- **Symmetry & Sex:** Actinomorphic (radial) symmetry and bisexual, hermaphrodite flowers are depicted in the diagram.
- **Calyx (K):** Four free sepals are grouped in two outer lateral whorls on the calyx (K). The inner pair frequently exhibits imbricate aestivation, whereas the outer pair is typically in the lateral position and the median position.
- **Corolla (C):** a single whorl of four free (polypetalous) petals that form a cruciform (cross-shaped) design.

- **Androecium (A):** two whorls of six polyandrous stamens. There are four long inner middle stamens and two small outer lateral stamens. We call this configuration tetradynamous.

Gynoecium (G): two united carpels (bicarpellary) (syncarpous). Initially unilocular, the superior ovary develops a fake septum known as a replum, which causes it to become bilocular.

What Is Not Shown by a Floral Diagram (FD)?

- Ovary Position:** the exact position of the ovary (whether the flower is hypogynous, perigynous, or epigynous) is not clearly shown.
- Vertical Relationship:** It shows the horizontal arrangement (whorls) rather than the vertical, longitudinal position of organs.
- Specific Details:** Often fails to represent precise details like color, shape, or specific types of veneration.

Note: Though the location of the ovary is not shown in the floral diagram, but it is represented by particular notations in the floral formula.

Differentiation FD Vs Floral Formula

Although they both explain floral structure, a floral formula finds it difficult to convey spatial elements such as aestivation and placentation, which are provided by the floral diagram. On the other hand, the formula clearly indicates whether an ovary is superior or inferior with a line, while the diagram frequently does not do so openly unless particular symbols (such as triangles) are added.

When viewed from above, a floral diagram resembles the "floor plan" of a flower. The following layer-by-layer mental structure can be used to visualize the **Solanaceae** (potato family):

- The Top Dot, or Mother Axis:** There is a little dot at the very top of your diagram. This indicates the orientation of the bloom and is the mother axis, or main stem.
- The Calyx (Outer Ring) Structure:** Draw 5 arcs (sepals).
Connection: Since the formula is $\backslash(K_{\{5\}}\backslash)$, connect the edges of these arcs with lines to show they are fused (gamosepalous).
Pattern: In Solanaceae, these show valvate aestivation (edges touch but do not overlap).
- The Corolla (Second Ring) Structure:** Draw another 5 arcs inside the sepals for petals.
Connection: Since it is $\backslash(C_{\{5\}}\backslash)$, these petals are also fused (gamopetalous).
Position: They are usually alternate with the sepals
- The Androecium (Third Ring) Structure:** Draw 5 kidney-shaped spots for the stamens.

The "Epipetalous" Bridge: In the diagram, draw a line connecting each stamen directly to a petal. This matches the $\overbrace{CA}$ symbol in the formula.

5. The Gynoecium (The Center)

Structure: At the very center, draw a cross-section of the ovary.

Chambers: Since it is $G_{(2)}$, divide the ovary into two chambers (bilocular).

The "Solanaceae Tilt": A unique feature of this family is that the partition (septum) is oblique (tilted at an angle).

Placentation: Draw a swollen center with many tiny dots (ovules) for axile placentation.

Summary Table for Fast Recall

Features	Symbol	Visual trick
Symmetry	$\oplus$	Actinomorphic/Radial
	$\%$	Zygomorphic/Bilateral
Sexuality	σ	Male
	ρ	Female
	$\sigma\rho$	Bisexual
Calyx/Sepals	$K_{(5)}$	5 outer shaded brackets joined together
Corolla/Petals	$C_{(5)}$	5 inner brackets joined together
Androecium/Stamens	A_5	5 stamens holding hands with petals
Gynoecium/Carpels	$\underline{G}_{(2)}$	Superior ovary (Hypogynous); 2 central rooms with a tilted wall; Visualization: Picture a cup (the fused thalamus) with the ovary within, and all other floral components on the cup's rim, gazing down at the ovary.
	$\overline{G}_{(2)}$	Inferior ovary (Epigynous);

Points to remember:

- Examples of epigynous (inferior ovary) flowers include the **mnemonic "Sun-Guava"** (Sunflower ray florets and Guava).
- The Fabaceae (Pea family) diagram is unique because it is "lopsided" (zygomorphic) and looks like a butterfly (Papilionaceae).
- Floral formula of Papilionaceae is: Br. $\% \overline{\sigma} K_{(5)} C_{1+2+(2)} A_{(9)+1} \underline{G}_1$

Floral Diagram Quick-Draw Tricks

Mother Axis: Always start with a small dot at the top; this represents the "back" of the flower relative to the stem.

Whorl Order: From outside to inside: Calyx → Corolla → Androecium → Gynoecium (center).

Aestivation: Pay attention to how the "arcs" overlap. If they don't touch, it's Valvate. If they overlap one-way, it's Twisted.

Placentation: The center (ovary) must show the arrangement of seeds (ovules) to match the formula's "G".

Guidelines for Sketching Aestivation Patterns

Valvate: Draw arcs that do not overlap, just touching at the edges. Typical in *Calotropis*.

Twisted (Contorted): Draw arcs where one margin overlaps the next one consistently in one direction (clockwise or counter-clockwise). Common in Hibiscus (China Rose).

Imbricate: Draw one arc that is entirely internal (covering both margins), one that is entirely external, and the remaining arcs that overlap erratically. Common in: Gulmohar (*Delonix*) and *Cassia*.

Papilionaceous (vexillary): Draw two lateral wing petals overlapping one large standard petal at the top, followed by two fused smaller keel petals. Characteristic to the pea family (Papilionaceae).

Breakdown: Solanaceae (The "5-5-5" Potato Family)

This family is a favourite for exams because of its symmetrical "5s".

- **Floral Formula:** $\oplus K_{(5)} C_{(5)} \overset{\frown}{A}_5 \underline{G}_{(2)}$.
- **The Codes:**
 - $\oplus$ circled plus (Actinomorphic): Perfectly radial symmetry.
 - (5) and $\overset{\frown}{(5)}$: 5 fused sepals and 5 fused petals (Gamosepalous/Gamopetalous).
 - $\overset{\frown}{A}$ (Epipetalous): The arc indicates stamens are fused with petals.
 - $\underline{G}_{(2)}$ (G underline): Bicarpellary, syncarpous (fused) with a superior ovary.
- **Drawing Trick:** Draw 5 petals in *Valvate aestivation* and place the 5 stamens directly alternating with the petal lobes, connecting them with short radial lines.

Visual Mnemonics for Fast Recall

- **Aestivation:** Valvate = Vanishing overlap; Twisted = Twirl; Imbricate = In-and-out.
- **Ovary Position:** A line below G (G underline) means the ovary is high up (superior); a line above G (G bar) means the ovary is buried (inferior).

- **Family Logic:**

- **Solanaceae** = Everything is 5 and fused.
- **Liliaceae** = Everything is 3 (Tepals 3+3), (Stamens 3+3)

Breakdown: Liliaceae (The "3-3-3" Lily Family)

This family is defined by symmetry and the number three (trimerous).

- **Floral Formula:** $Br \oplus P_{(3+3)} A_{(3+3)} \hat{G}_{(3)}$

- **The Codes:**

- **Br (Bracteate):** Usually possesses small leaf-like bracts at the base.
- **(3+3) (Perianth):** No distinct sepals or petals; instead, it has 6 tepals arranged in two whorls (3+3), often fused.
- **$\hat{P}A$ (P - A with arc above) (Epiphyllous):** The stamens are attached to the tepals.
- **A_{3+3} :** 6 stamens arranged in two whorls.
- **(3):** Tricarpellary, syncarpous (fused) with a superior ovary and axile placentation.

2. The "Hierarchy" Trick for the 3 Major Families

A simple way to remember the formulas for Fabaceae, Solanaceae, and Liliaceae is to look at their numerical patterns:

Think: "Solo-5". Liliaceae (The "3" Family): Everything is in multiples of 3 (P 3+3, A 3+3, G 3). Think: "Lily has 3 letters (L-i-l)".

Specific Connection Mnemonics Fabaceae Stamens (9+1): "9 friends are together, 1 is alone." (Diadelphous condition where 9 stamens are fused and 1 is free).

In Solanaceae *Epipetalous Stamens*: Use a bridge symbol over C & A to show stamens are attached to petals.

Mnemonic: "The Sun (Solanaceae) shines on the Bridge between C and A".

<i>Dicot Families</i>	<i>General Floral formulae</i>
1. Acanthaceae	Br. Brl. % $\overline{\sigma} K_{(4-5)} C_{(5)} \hat{A}_4 \text{ or } 2+2 \text{ or } 2 \underline{G}_{(2)}$
2. Annonaceae	Br. $\oplus \overline{\sigma} P_{2+3+3} A_{\infty} \underline{G}_{\infty}$
3. Apiaceae	<i>Centella</i> : Central Flower: Br. $\oplus \overline{\sigma} K_{(5)} C_5 A_5 \overline{G}_{(2)}$ Peripheral Flower: Br. % $\overline{\sigma} K_{(5)} C_5 A_5 \overline{G}_{(2)}$
4. Apocynaceae	Br $\oplus \overline{\sigma} K_{(5)} C_{(5)} A_5 \underline{G}_{(2)}$

<i>Dicot Families</i>	<i>General Floral formulae</i>
5. Asclepiadaceae	$\text{Br} \oplus \overrightarrow{\gamma} K_{(5)} C_{(5)} A_5 \wedge \underline{G}_{(2)}$
6. Asteraceae	<i>Tridax</i>: Ray Floret: Br. % $\overrightarrow{\gamma} K_{\text{pappus}} C_{(5)} A_0 \overline{G}_{(2)}$ Disc Floret: Br. $\oplus \overrightarrow{\gamma} K_{\text{pappus}} C_{(5)} A_{(5)} \overline{G}_{(2)}$ <i>Eclipta</i>: Ray Floret: Br. % $\overrightarrow{\gamma} K_{\text{pappus}} C_{(5-4)} A_0 \overline{G}_{(2)}$ Disc Floret: Br. $\oplus \overrightarrow{\gamma} K_{\text{pappus}} C_{(5-4)} A_{(5-4)} \overline{G}_{(2)}$ <i>Ageratum</i>: Br. $\oplus \overrightarrow{\gamma} K_{\text{pappus}} C_{(5)} A_{(5)} \overline{G}_{(2)}$
7. Brassicaceae	$(\text{Brassica}): \text{Ebr} \oplus \overrightarrow{\gamma} K_{2+2} C_4 A_{2+4} \underline{G}_{(2)}$
	$(\text{Iberis}): \text{Ebr} \% \overrightarrow{\gamma} K_{2+2} C_{2+2} A_{2+4} \underline{G}_{(2)}$
8. Cucurbitaceae	Male Flower: Br $\oplus \overrightarrow{\sigma} K_{(5)} C_{(5)} A_5 \text{ or } (2) + (2) + 1 \underline{G}_0$; Female Flower: Br $\oplus \overrightarrow{\sigma} K_{(5)} C_{(5)} A_5 \text{ or } (2) + (2) + 1 \overline{G}_{(3)}$
9. Dipterocarpaceae	$\text{Br.} \oplus \overrightarrow{\gamma} K_{(5) \text{ or } 5} C_{(5) \text{ or } 5} A_{\infty \text{ or } 5-15} \underline{G}_{(3-5)}$
10. Ericaceae	$\text{Br.} \oplus \text{ or } \% \overrightarrow{\gamma} K_{(4-5)} C_{(4-5)} A_{8-10} \underline{G}_{(2-10)}$
11. Euphorbiaceae	<i>Euphorbia</i>: Male Flower: Br $\oplus \overrightarrow{\sigma} K_0 C_0 A_1 \underline{G}_0$; Female Flower: Br $\oplus \overrightarrow{\gamma} K_0 C_0 A_0 \underline{G}_{(2)}$
	<i>Croton</i>: Male Flower: Br brl $\oplus \overrightarrow{\sigma} K_5 C_5 A_{(5+5)} \underline{G}_0$; Female Flower: Br $\oplus \overrightarrow{\gamma} K_5 C_5 A_0 \underline{G}_{(3)}$
	<i>Ricinus</i>: Male Flower: Br $\oplus \overrightarrow{\sigma} P_5 A_5 \underline{G}_0$; Female Flower: Br $\oplus \overrightarrow{\gamma} P_5 A_0 \underline{G}_{(3)}$
12. Mimosaceae:	$\text{Br.} \oplus \overrightarrow{\gamma} K_{(4) \text{ or } (5)} C_{4 \text{ or } 5} A_{\infty} \underline{G}_1$
13. Caesalpinaceae	$\text{Br.} \% \overrightarrow{\gamma} K_{(5)} C_5 A_{5+5} \underline{G}_1$
14. Papilionaceae	<i>Crotalaria</i>: Br. % $\overrightarrow{\gamma} K_{(5)} C_{1+2+(2)} A_{(10)} \underline{G}_1$ <i>Clitoria</i>: Br. % $\overrightarrow{\gamma} \text{Epik. } K_{(5)} C_{1+2+(2)} A_{(9)+1} \underline{G}_1$
15. Lamiaceae	<i>Leucas</i>: Br. % $\overrightarrow{\gamma} K_{(5)} C_{(2+3)} \wedge A_{2+2} \underline{G}_{(2)}$ <i>Ocimum</i>: Br. % $\overrightarrow{\gamma} K_{(5) \text{ or } (1/4)} C_{(4/1)} \wedge A_{2+2} \underline{G}_{(2)}$
16. Magnoliaceae	$\text{Michelia: Br.} \oplus \overrightarrow{\gamma} K_3 C_{3+3} A_{\infty} \underline{G}_{\infty} \text{ OR,}$

<i>Dicot Families</i>	<i>General Floral formulae</i>
	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{3+3+3} \text{A}_{\infty} \underline{\text{G}_{\infty}}$
17. Malvaceae	<i>Hibiscus</i> : $\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{Epik}_{\infty} \text{K}_{(5)} \text{C}_5 \wedge \text{A}_{(\infty)} \underline{\text{G}_{(5)}}}$
18. Myrtaceae	$\text{Br. Br.l.} \oplus \text{ } \overline{\text{P}}_{\text{K}_{(4+5)} \text{C}_{4-5} \text{A}_{\infty} \overline{\text{G}}_{(2-\infty)}}$
19. Ranunculaceae	<i>Ranunculus</i> : $\text{Br. Br.l.} \oplus \text{ } \overline{\text{P}}_{\text{K}_5 \text{C}_5 \text{A}_{\infty} \underline{\text{G}_1}}$
20. Rosaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{K}_{(5)} \text{ or } 5 \text{C}_5 \text{A}_{\infty} \underline{\text{G}_{1-\infty}}}$
21. Rubiaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{K}_{(5)} \text{ or } 5 \text{C}_{(4-5)} \text{A}_4 \text{ or } 2 \overline{\text{G}}_{(2)}}$
22. Rutaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{K}_{4-(5)} \text{C}_4 \text{ or } 5 \text{A}_8 \text{ or } 10 \underline{\text{G}_{(4) \text{ or } (5)}}}$
23. Scrophulariaceae	$\text{Br.} \oplus \text{ or } \% \text{ } \overline{\text{P}}_{\text{K}_{4-(5)} \text{C}_4 \text{ or } 5 \underline{\text{G}_{(2)}}}$
24. Solanaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{K}_{(5)} \text{C}_{(5)} \wedge \text{A}_5 \underline{\text{G}_{(2)}}}$
25. Sterculiaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{K}_5 \text{C}_5 \text{A}_{(\infty)} \text{ or } \infty \underline{\text{G}_{(5)}}}$
26. Tiliaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{\text{K}_5 \text{C}_5 \text{A}_{5-\infty} \underline{\text{G}_{(5-10)}}}$
27. Verbenaceae	<i>Lantana</i> : $\text{Br. Br.l.} \% \text{ } \overline{\text{P}}_{\text{K}_{(5)} \text{C}_{(5)} \wedge \text{A}_{2+2} \underline{\text{G}_{(2)}}}$

<i>Monocot Families</i>	<i>General Floral formulae</i>
1. Alismataceae	$\text{Br or Ebr} \oplus \text{ } \overline{\text{P}}_{3+3} \text{A}_{6-\infty} \underline{\text{G}_{3-\infty}}$
2. Amaryllidaceae	$\text{Br \% or } \oplus \text{ } \overline{\text{P}}_{6(3+3)} \text{A}_{6(3+3)} \overline{\text{G}}_{(3)}$
3. Araceae	$\text{Br } \overline{\text{P}}_{(4-6) \text{ or } 6} \text{A}_{(2-8) \text{ or } 1} \underline{\text{G}_{(1-3)}}$
4. Arecaceae	Male: $\text{Br} \oplus \text{ } \overline{\text{P}}_{6(3+3)} \text{A}_{6(3+3)} \text{G}_0$; Female: $\text{Br} \oplus \text{ } \overline{\text{P}}_{6(3+3)} \text{A}_0 \overline{\text{G}}_{(3)}$
5. Commelinaceae	$\text{Br \% } \overline{\text{P}}_{6(3+3)} \text{A}_{6(3+3)} \underline{\text{G}_{(3)}}$
6. Cyperaceae	$\text{Br} \oplus \text{ } \overline{\text{P}}_0 \text{A}_3 \underline{\text{G}_{(2) \text{ or } (3)}}$
7. Liliaceae	$\text{Br.} \oplus \text{ } \overline{\text{P}}_{3+3} \text{A}_{1-2} \overline{\text{G}}_{(3)}$
8. Musaceae	$\text{Br \% } \overline{\text{P}}_{3+3} \text{A}_{6-\infty} \underline{\text{G}_{(3)}}$

Monocot Families	General Floral formulae
9. Orchidaceae	Br. % ♂ P ₃₊₃ A ₁₋₂ $\overline{G}_{(3)}$
10. Poaceae	Br % ♂ P ₂ A ₃ $\underline{G}_{(1)}$
11. Zingiberaceae	Br % ♂ P ₃₊₃ A ₆ $\overline{G}_{(3)}$

Do yourself:

Q. A flower is described as: Actinomorphic, Bisexual, Sepals 5 (united), Petals 5 (free), Stamens 5 (epipetalous), Ovary superior, bicarpellary, syncarpous with axile placentation. What is its floral formula and family?

Q. If a floral diagram shows 6 tepals arranged in two whorls of 3+3 (united at base), 6 stamens (3+3), and a superior, tricarpeal, syncarpous gynoecium. What is the formula?

Q. Based on the formula Ebr $\oplus$ ♂ K₂₊₂ C₄ A₂₊₄ $\underline{G}_{(2)}$, analyze the androecium and ovary.

Q. Which family is represented by the formula Br % ♂ P₂ A₃ $\underline{G}_{(1)}$?

Q. Identify the family: Br. $\oplus$ ♂ P₃₊₃ A₁₋₂ $\overline{G}_{(3)}$

Q. A papilionaceous flower features a large posterior petal known as the _____, which covers the lateral _____ petals, which in turn cover the _____.

Q. What does the symbol $\underline{G}_{(5-10)}$ indicate in a floral formula?

*“The greatest value of a picture is when it forces us to notice what we never expected to see”. -
John Tukey*

CHAPTER 12

Glossary of Taxonomic Terminologies

A-: a prefix meaning without, as in asepalous (without sepals)

AB-: Prefix meaning "position away from"

Abaxial / Dorsal: side of an organ away from the axis or center of axis, lower surface

Abaxial: The surface facing away from the axis (e.g., underside of a leaf).

Abortive: defective, imperfectly developed

Acarpous: no carpels or carpellate whorl; no pistil

Acaulescent: plant apparently stem-less; with extremely condensed stem as in some monocots; e.g., some species of *Oxalis*, *Nolina*, *Yucca*. Antonym: caulescent (possessing stem).

Acaulescent: Having no apparent stem, (or none visible above ground).

Accessory / Pseudocarp / False fruit: fruit derived from simple or compound ovary surrounded by some closely adpressed non-ovarian tissues such as calyx, hypanthium, and bracts

Accessory floral organs / semaphylls: the sepals and petals or the tepals. Androecium: a collective term for all the stamens in a flower

Accrescent: Increasing in size with age, such as a calyx continuing to grow after the flower withers

Acerose: needle-shaped; sharp

Achene / Akene: a one-seeded, one-loculed fruit with seed coat free from the thin pericarp, derived from a simple, superior ovary

Achlamydeous: without perianth

Acicular Leaf: long, narrow, needle-shaped and cylindrical; needle-shaped, typically adapted for dry or cold environments; e.g., leaves of onion, Pine, Spruce (*Picea*), Firs (*Abies*), and *Larix*

Acropetal: arising or developing upward in a longitudinal plane from a lower to a more apical position; the opposite of basipetal

Actinomorphic / Regular: perianth with radial symmetry

Aculeate (Spiny leaf margin): Prickly; covered with prickles, often acting as a defense mechanism against herbivores; e.g., *Solanum viarum*, *Aloe ferox*, *Agave americana*, *Opuntia*, *lex* spp., *Carduus*, *Sonchus* spp., *Eryngium* spp., *Berberis thunbergii*

Acumen: A long, tapering point, particularly apex of an acuminate leaf

Acuminate leaf: A leaf with a long, thin, pointed tip that gradually tapers; e.g., leaves of Peepal (*Ficus religiosa*), *Salvia*, *Alocasia* etc.

Acute leaf: leaf with a sharp, pointed apex (tip) forming an angle of less than 90° (45-90°) e.g., leaves of Mango, China Rose

Acyclic/Haplomorphic: arranged spirally, not whorled, floral parts arising spirally on the thalamus at a simple level in a semispheric or hemispheric form

Adaxial / Ventral: side towards the axis, or adjacent to axis, upper surface

Adaxial: The surface facing toward the axis.

Adherent: Slightly united to a dissimilar organ e.g., a sepal connected to a petal

Adnate anther: with elongated anther lobes attached length-wise to the filament, either extrorse, introrse, or latrorse

Adnate stipule: attached to the petiole or petiolule

Adnate: fusion, with histological continuity, of dissimilar organs Aerial or Epigeal: above ground or water, in air

Adpressed/appressed: premised closely to axis upwards

Adventitious bud: bud arising from more or less mature tissues of organs other than the node

Adventitious root: arising from organ other than embryonic root or radicle Annulated: root with a series of ring-like swellings

Aerial stem: above ground stem

Aerophyllus: with leaves in air, above ground or water

Aestival: flowering in summer

Aestivation/Vernation: arrangement of leaves/ perianth parts with respect to each other in bud

Agglomerate /Conglomerate / Crowded / Aggregate: dense structures with varied angles of divergence

Aggregate: a collection of simple fruits developed from separate carpels of a single flower

Agochoric: Plants that are spread through accidental transport

Agrophic: Comb-like series of veins forking from a single side of a primary or secondary vein.

Aianthous / Semperflorous: flowering throughout the year

Alate: Having a wing or wings

Albumen: An older name for the endosperm of flowering plants; nutritive material accompanying the embryo (e.g., endosperm in seed)

Albuminous: (of seeds) Containing endosperm.

-ales: Suffix added to the name of a taxonomic order

Alien: Any plant introduced to an area outside its natural range. Often used interchangeably or in combination with foreign, exotic, non-native, and non-indigenous.

Allelopathy: The secretion by a plant of biochemicals which control the growth and reproduction of nearby plants.

Allopatric: Having geographically separate, non-overlapping ranges of distribution.

Alternate: (adj.) (of leaves or flowers) Borne singly at different levels along a stem, including spiralled parts. (Contrast opposite). (prep.) Occurring between something else, e.g., stamens alternating with petals.

Alternipetalous: a floral structure where the stamens are arranged alternately with the petals; often found when the stamens and petals are in equal numbers; e.g., found in Solanaceae, Primulaceae, Rhamnaceae, Crassulaceae etc. [opposite of antipetalous (or obdiplostemonous), where stamens are located directly opposite the petals].

Amphibious plant: with roots and stem embedded in water or water saturated soil and foliage of plant raised above water surface, e.g., in *Typha*

Amphicarpous: with fruits in two environments, viz., aerial and subterranean from chasmo- and cleistogamous flowers, respectively

Amphimixis: The normal sexual life cycle involving meiosis and syngamy Amplexicaul leaf base: basal lobes completely clasp the stem

Androgynophore/Gynandrophore: the elongated internode above the perianth, bearing the stamens and pistil

Androphore: the elongated internode above the perianth, bearing the stamens; can be seen in *Passiflora* and *Gynandropsis* sp.

Angular stem: many-angled in cross-section

Angular: many angled

Annual: with life cycle of one season duration or living for one year or less

Annular: ring-like

Anterior: part of the flower away from the mother axis; towards the subtending bract; abaxial

Anther: part of the stamen bearing the microsporangium (pl. microsporangia) and pollen

Anthophore: elongated internode between calyx and corolla

Anthotaxis: arrangement of sporophylls

Antipetalous stamens: stamens opposite petals

Antiphiyous stamens: stamens opposite tepals

Antisepalous stamens: stamens opposite sepals.

Antliesis: flowering; opening of flower for pollination

Apex (pl. apices): the tip or distal end

Apex: tip or extreme distal part of lamina

Aphyllous: leafless

Apical / Terminal style: at the apex of ovary

Apical / Terminal: at the top, tip, or distal end of a structure

Apical meristem: meristematic tissue that gives rise to other bud parts

Apical: Pertaining to the tip.

Apocarpous: with free carpels

Apomixis: Reproduction without fertilization (syngamy) or meiosis, leading to embryos that are clones of the mother plant.

Apostemonous / Free: stamens separate, not united

Appendage: an attached, subsidiary or additional part

Appendicular / Appendiculate stamen: typical stamen with variously-shaped or modified, protruding connective, as in *Viola*

Arborescent: tree-like in appearance and in size

Arborescent stem: tree-like in appearance and size

Aril: an outgrowth of the funiculus or ovular stalk outside the seed coat generally covers the seed more or less completely

Arillate seed: a seed covered with aril

Arillode: an aril-like outgrowth of integument at the micropylar region

Aristate leaf: with a much elongated, narrow protrusion, usually a straight and stiff awn or bristle; a leaf that terminates in a stiff, bristle-like tip, known as an arista or awn. It shows an extension of the leaf's midrib or tip, often found in grasses

Article: one of the segments of a jointed fruit such as a lomentum

Articulate: jointed; with nodes or joints

Ascending: directed upward

Ascending imbricate aestivation: with five members, of which the posterior one is the innermost, three with one margin inside or overlapped and the other outside and one member outermost without any overlapped margins, as in the Caesalpiniaceae

Asperulous: having a rough surface (Feels like fine sandpaper, rough-textured) due to small, rigid, or stiff hairs (trichomes) or epidermal projections, e.g., leaf surfaces of *Petrea volubilis*

Assimilatory root: green roots of some plants which help in photosynthesis

Asymmetric / Amorphic / Paleomorphic / Irregular: having a perianth without symmetry; An asymmetric flower, or irregular floral symmetry, is exemplified by *Canna*, which has an asymmetric perianth, an indefinite number of stamens and carpels, and bracts or discolored upper leaves.

Attenuate: tapering gradually to a slender tip; a leaf blade (lamina) that usually extends down the petiole (leaf stalk) rather than ending abruptly, tapering or narrowing very slowly toward the base. It describes the shape of the leaf base and frequently suggests that the leaf tissue tapers either straight or concavely towards the stem, leaving a thin strip of leaf material on either side of the petiole, even if the leaf looks nearly stalkless; e.g., leaf base is attenuate in *Eucalyptus*, many ferns, *Polygonum spp.*

Auriculate: having 2 ear-shaped lobes or appendages (called auricles); obovate with two small basal lobes; the term originated from the Latin "auricular", meaning "ear-lobe" (resembling a human ear) e.g., leaf bases of *Quercus robur*, *Capsella bursa-pastoris*, *Magnolia macrophylla*

Authority: The name of the person who first validly published a scientific name, often abbreviated & cited after the taxon (e.g., "L." for Linnaeus).

Autumnal: flowering in autumn

Awn / Arista: a bristle-like appendage; In Poaceae, an appendage terminating or on the back of glumes or lemmas of some grass spikelets. In Geraniaceae, the part of the style that remains

attached to the carpel that separates from the carpophore (column); In *Strophanthus*, the awn is the beak of the seed, stipe of the coma hairs.

Axil: The upper angle between one part of a plant and another, e.g. the stem and a leaf.

Axile placentation: with ovules borne along the central axis in a compound ovary with septa

Axillary: pertaining to or situated in the axil axillary bud, leaf or leaflet

Axillary bud: in the axil of leaf or leaf scars, generally gives rise to branches

Axillary inflorescence: in the axil of a leaf

Axillary: Situated in the axil (the angle between a leaf and the stem).

Baccate / Succulent: fleshy/ juicy fruit resistant to drying; e.g., Pomegranate, tomatoes, grapes, blueberries; originated from the Latin word "baccatus" (means "provided with a berry").

Baccate seeds: Seeds with a pulpy, fleshy outer layer (e.g., *Semen baccatum*), often designed for animal consumption to aid in seed dispersal.

Baculiform: Rod-like; longer than wide. Compare cylindrical.

Barbed: trichome with short, reflexed projections

Barb: A rear-facing point, as in a fish hook.

Barbed: with short, rigid, reflexed (pointing backward or down) bristles or processes

Barbellate: Having barbed hairs (barbellae)

Bark: tissues of plant outside xylem; protective external layer of tissue on the stems and roots of woody trees and shrubs; includes all of the living and non-living tissue external to cambium.

Basal placentation: with ovules arising from placenta at the base of a compound ovary

Basal: at the bottom or base of a structure

Base: lower or proximal part of lamina

Basicaulus: near the base of stem

Basifixed anther: anther attached at its base to the apex of the filament.

Basipetal: developing downward in a longitudinal plane from an apical or distal point towards the base; e.g. of flowers in an inflorescence.

Bathyphyll: A specialized leaf produced at the base of a plant, usually when the plant is immature, and which serves to anchor the plant to a substrate; especially notable in the fern *Teratophyllum*. (Opposite acrophyll).

Berry / Bacca: with thin, coloured epicarp, fleshy mesocarp and membranous endocarp, derived from a superior or inferior ovary, as in *Lycopersicon esculentum*, *Psidium*

Bi-: a prefix meaning two or twice, as in bilobed or two-lobed

Bicarpellary: with two carpels

Bicrenate / Doubly-crenate leaf margin: with smaller roundedteeth on larger rounded teeth

Biennial: with life cycle of two years duration, usually flowering in the second year

Bifid: two-clefted or divided apically into two parts

Bifid style: divided into two

Bi-foliate / Geminate/ Jugate/ Unijugate leaves: with two leaflets from a common point, palmate or pinnately compound

Bifurcate: divided into two forks or branches

Bifusiform: Fusiform with a pinch in the middle.

Bigeminate/ Bijugate / Di- or bi-foliate leaves: with two orders of leaflets, each bifoliate; doubly paired, palmate or pinnately compound

Bilabiate: two-lipped

Bilobed anther: with two lobes

Bilocular ovary: with two locules

Binomial Nomenclature: The formal system of naming species using two Latin parts: the genus and the species.

Binomial Nomenclature: The formal system of naming species with two parts: Genus (capitalized) and species epithet (lowercase), both italicized (e.g., *Cynodon dactylon*).

Bipalmately compound leaves: with two orders of leaflets, each palmately compound

Biparous / Dichasial branching: with only two lateral branches at each stage, below terminal bud

Bipinnate leaves: with two orders of leaflets, each pinnately compound

Bipinnatisect: A pinnatisect leaf with deeply dissected segments.

Biseriate / Doubly serrate leaf margin: with smaller sharply cut teeth on larger sharply cut

Biseriate: consisting of both calyx and corolla

Biseriate: in two rows, Series or whorls

Bisexual / Perfect / Hermaphrodite: with both stamens and carpels or distils functional

Bitegmic: (of an ovule) Covered by two integuments. (Opp. Unitegmic)

Biternate leaves: with two orders of leaflets, each ternately compound

Bithecaous / Dithecaous anther: with two thecae or pollen sacs

Bladder-like Leaf: like a bladder, as in *Utricularia*

Bladdery: thin-walled and inflated

Bloom: whitish easily rubbed off powdery covering on a surface

Bole: The trunk of a tree, usually the portion below the lowest branch

Bostrychoid: Arranged on a conical surface (like a snail shell); used to describe inflorescences in which the buds are arranged in an almost helical manner on a long, tapering, conical rachis.

Botuliform: sausage-shaped

Bract: modified, usually reduced, leaf at the base of flower or inflorescence

Bracteate: with bract **Bracteolate:** with bracteoles

Bracteolate: having bracteoles (bractlets).

Bracteole / Bractlet / Prophyll / Prophyllum: a secondary or smaller bract like appendage on the pedicel or below the perianth

Bracteose: Having many or showy bracts

Branch: lateral shoot of main stem, generally arises from an axillary bud

Branchlet: A small lateral branch

Branched / ramose: possessing branches or lateral shoots

Bristle: short, stiff trichome or hair

Bristly: covered with bristles

Bud primordium: A tiny cluster of undifferentiated meristematic cells that precedes a new lateral bud, stem, or shoot. In a leaf's axil, these primordial cells evolve into branches or flowers.

Bulb: a short, erect, condensed, underground stem surrounded by fleshy leaves

Bulbel: a small bulb produced from the base of larger bulb

Bud: immature vegetative or floral shoot or both, often covered by scales

Bulbil: a small bulb or bulb-like body produced on above-ground parts; a

Bulblet: a small bulb, irrespective of origin

Burr: A prickly fruit.

Buttress root: root with board-like or plank-like growth on upper side, a supporting structure; e.g. *Ceiba pentandra*, *Ficus macrophylla*.

Caducous: fall off early

Caducous: falling off early or prematurely

Caespitose: Tufted or turf-like, e.g. the growth forms of some grasses and sedges.

Calcarate /Spurred: with spur

Calcarate: having a spur.

Calceolate: Shaped like a slipper

Calciform/calyculate: calyx-like

Calcifuge: a plant that is not suited to calcareous soil (dislikes lime), e.g., *Rhododendron*

Calyciflorous: when petals and stamens fused to the calyx

Calyptrate: sepals fused forming a cap-like structure, the calyptra, which falls off at anthesis, as in some member of Papaveraceae

Calyx (pl. calyces): the outer whorl of floral envelopes or perianth, composed of sepals, a collective term for sepals

Campanulate: bell-shaped; with flaring tube and limb

Camptodromous: Pinnate venation in which secondary veins bend toward the edges, sometimes becoming nearly parallel, and do not form loops.

Campylotropous: When the ovule is oriented transversely (i.e. with its axis at right angles to its stalk) and with a curved embryo sac.

Canaliculate: with a longitudinal channel or groove

Candelabra: candelabrum-like

Canopy: Tree branches and foliage; crown. Refers to a forest's protective top layer.

Capitate stigma: head-like

Capitate: head-like Clavate: club-shaped

Capitulum/Head: a crowded group of sessile or subsessile flowers in racemose or cymose arrangement on a compound receptacle or torus

Capsule: derived from a compound ovary of two or more carpels dehiscing in various ways

Capsule: derived from a two- or more-loculed ovary, as in *Peplis*

Carcerulus: dry fruit derived from a compound, generally superior, ovary which at maturity separates into one- to many-seeded locules or mericarps, as in *Althaea*

Carduoid: having a style with a ring of sweeping hairs borne on the shaft of the style below the style branches, as in Asteraceae

Carinate: keeled

Carnose, carnos: Fleshy or pulpy in texture, particularly applied to some tissues or organs. (Contrast coriaceous and corneous).

Carpel: female sporophyll within a flower; a floral organ that bears ovules in angiosperms; a unit of gynoecium; a simple pistil or part of a compound pistil

Carpel: Angiosperm carpels carry ovules and are gynoecium units.

Carpopliore: extended floral axis between adjacent carpels, as in Apiaceae

Carpopliore: prolonged floral axis between carpels of a compound ovary

Cartilaginous: hard and tough but flexible

Caruncle: a fleshy tissue at the micropylar end of the seed, derived from the tip of the outer integument

Carunculate seed: a seed with a caruncle

Caryophyllaceous: with 5 free petals with long claws & petals at right angles to the claws.

Caryopsis: a one-seeded fruit with a seed coat adnate to the pericarp, derived from a one-loculed superior ovary

Cassideous: Hood-, helmet- or bonnet-shaped; generally referring to floral anatomy, e.g., in the flowers of Aconitum, Satyrium, etc.

Catkin / Ament: a spike or spike-like inflorescence of cymules with unisexual flowers

Caudate Leaf: with a long, tail-like protrusion

Caudex: a slow growing, upright, woody underground or subterranean base of a herbaceous perennial that each year gives rise to leaves and flowering stems

Caudicle / Retinaculum: thread-like or strap-shaped stalk that forms the lower sterile portion of a pollen mass (pollinium) in the Orchidaceae and Asclepiadaceae

Caulescent: plants with distinct stem

Cauliflory / Cladanthy: inflorescence arising directly from the surface of old stems

Cauline: belonging to main conspicuous stem

Caulocarpic: with stem living for many years, bearing flowers and fruits directly on the main stem

Cell / Lobe: the protruding region of the anther containing the microsporangia, a typical anther has two lobes, with two sporangia in each lobe

Cell: locule or cavity in an organ (this does not refer to the cell — the unit of life)

Central placentation: with ovules borne along the central axis in a compound ovary without

Centrifugal: developing or progressing from center to periphery

Centripetal: developing or progressing from periphery to center

Cernuous: drooping

Cespitose / Caespitose: a short, much-branched stem growing in a clump forming a cushion

Chaff / Pale: scale or bract at base of tubular flower in members of Asteraceae

Chasmogamous: flowers that open or expose their reproductive organs for pollination and fertilization

Chalaza: The region of the ovule where the nucellus and integuments meet, opposite the micropyle
Chlamydeous: with perianth

Ciliate leaf margin: with protruding trichomes

Ciliate: with conspicuous marginal trichomes

Cincinnus inflorescence: a dichasial cyme in which each branch is a tight, modified monochasial cyme with flowers having short pedicels

Circinate: coiled from apex downwards

Circumscissile / Pyxis / Pyxidium: dehisces transversely, along the horizontal axis of the fruit

Circumscription: specific definition/boundary of a taxon as determined by a particular author.

Cirrhose / Cirrhous Leaf: with a slender, coiled and flexuous protrusion; tendrillar

Clade: A group consisting of a common ancestor and all its descendants.

Clade: A group consisting of an ancestor and all its descendants.

Cladode: green cylindrical main stem of xerophyte bearing flattened branches of limited growth, usually with single internode, resembling leaf in form and function

Clavate: club-shaped

Clavunculate stigma: dumb-bell shaped, with a receptive apical and a thickened, glandular basal part, as in Apocynaceae

Claw of perianth: the long, narrow petiole-like base of a sepal, petal, or tepal

Cleft leaf margin: with deep indentations or incisions

Clefted: sepals fused to the middle

Cleistogamous: flowers that do not open for pollination; remain closed throughout

Climber: a weak-stemmed, mostly herbaceous, annual/perennial plant which climbs up a support

Climbing: growing upward by means of tendrils, petioles, or adventitious

Climbing root: above-ground, fibrous, adventitious root arising from node, sometimes from internode, frequently with an adhesive disk; a crampon

Clinging root: aerial root of epiphyte which enters the crevices of support.

Coalesced: with like or unlike parts or organs incompletely separated;

Coccus (pl. Cocci): one-seeded part of a lobed and leathery or dry fruit.

Coherent: two similar organs in close proximity without fusion or histological continuity

Coleoptile: protective sheath around epicotyl in grasses

Coleorhiza: protective sheath around radicle in grasses

Colpus: an elongated groove

Column / Gynostemium / Gynandrium: rod-like structure formed by fusion of stamens, stigma, and style, as in Orchidaceae

Columnar stem: a tall, woody, unbranched stem, usually with a crown of leaves

Coma: leafy crown or head (of palms), a tuft of hair

Comeous: horny

Comose / Plumed seed: with a tuft of apical hairs/ trichomes

Complete: leaf with lamina, petiole, and stipule

Complete: with all the floral organs, i.e., with sepals, petals, stamens, and carpels

Composite: compound, apparently simple/ homogeneous organ made up of several distinct parts

Compound cyme inflorescence: a branched cyme

Compound leaves: with leaf divided into 2 or more leaflets

Compound ovary: ovary of a syncarpous gynoecium; fused ovaries of many carpels

Compound Pistil: consisting of more than one carpel

Compound Umbel: a branched umbel; an umbel with primary rays arising at a common point with secondary umbel arising from the tip of the primary rays

Compound: of two or more similar parts in one organ

Compound: with branched inflorescence axis

Compressed / Complanate / Flattened: compressed on two sides, flat

Conduplicate: folded together lengthwise, upward or downward along the central axis

Conglomerate / Agglomerate / Aggregated: densely clustered, irregularly overlapping each other

Conical root: a tap root with a broad upper part gradually tapering below like a cone, as in carrot

Conical: cone-like conditions, as of seed, pollen grain or spore; the process ends with the

Connate / Connate-perfoliate leaf base: bases of opposite leaves fused around the stem

Connate: union or fusion of similar structures with histological continuity

Connective: central tissue connecting the microsporangia, to which is attached the filament

Connivent: convergent apically without fusion Contorted: twisted around a central axis

Contorted / Twisted / Rotate aestivation: with one margin of a member overlapping that of adjacent member

Contractile or Pull root: root capable of shortening, usually drawing the plant or plant part deeper into the soil, generally has a wrinkled surface

Cordate leaf base: deeply invaginated; with rounded lobes

Cordiform / Cordate Leaf: heart-shaped

Coriaceous: thick and leathery

Corm: underground, upright, enlarged, fleshy stem with scale leaves; a storage

Cormel stem: small corm produced at the base of parent corm

Corniculate: terminates in a small horn-like protuberance

Corolla: the inner whorl of floral envelopes (above calyx), composed of petals; a collective term for petals

Corona: a crown; an outgrowth of a petal between stamens and corolla; can also be of staminal origin

Corona: a crown; an outgrowth of stamen between the filaments and the corolla; can be of petaline origin

Coronate: with tubular or flaring outgrowth; petaloid appendage.

Corpusculum: a two-parted gland forming part of the translator apparatus in (the Asclepiadaceae)

Corymb: a flat-topped raceme where extra elongation of the lower flower stalks raise the flowers of whole inflorescence to a common level at the top

Cotyledon: embryonic leaf

Cotyledon: embryonic leaf

Creeper: a herbaceous plant which creeps horizontally on the support, giving rise to roots and shoots intermittently

Cremocarp: derived from a two-loculed, inferior ovary, the locules separating at maturity into two single-seeded, dry, indehiscent mericarps, as in the Apiaceae

Crenate leaf margin: with shallow, round or obtuse teeth

Cruciate/Cruciform: four separate petals in cross-form

Cruciform / Cruciate: cross-shaped

Crustaceous: hard, thin, and brittle

Cucullate: Hooded

Culm: jointed stems (flowering and fruiting) of grasses and sedges with swollen and solid **nodes** and hollow **internodes**

Cuneate leaf base: wedge-shaped; a thin, wedge-shaped leaf base with uniform tapering of the leaf blade's borders (edges) toward the petiole or stem, where it attaches. The angle created by the leaf edges is typically less than 90 °, and the term is derived from the Latin *cuneatus* ("wedge-shaped"). e.g., leaf bases of Apple Serviceberry (*Amelanchier*), Poison Ivy (*Toxicodendron radicans*), *Veronica montana* (Wood Speedwell), Star Magnolia (*Magnolia stellata*), White Oak (*Quercus alba*) & Gray Dogwood (*Cornus racemosa*)

Cuspidate Leaf: with an abruptly elongated, sharp, stiff and coriaceous protrusion

Cyathium: a special type of cymose inflorescence with several highly reduced unisexual flowers clustered within a cup-shaped involucre, often with petaloid glands. Male flowers

reduced to single stamens are generally present in cymose clusters opposite each bract, and a single female flower reduced to a pistil present in the center of the cup

Cyclic: whorled

Cyclic: with floral parts arising in whorls or circles on the thalamus

Cylindrical / Terete: long-tubular with circular cross-section

Cymbiform / Navicular: boat-shaped

Cylindrical: circular in cross-section

Cymba: a woody, durable, boat-like, persistent spathe

Cymose / Determinate inflorescence: sympodial branching; inflorescence axis ends in a flower, with younger, lateral axis or axes developing below the flower; flowers develop in basipetal succession

Cymule inflorescence: a diminutive of cyme, usually few flowered

Cypsela: an achene derived from a compound one-loculed inferior

Deciduous: falling at the end of growth season

Deciduous: falls at maturity

Decumbent: reclining or lying on the ground with the tips ascending

Decomound: a general term for leaflets in two or more orders — bi-, tri- etc; pinnately, palmately, or ternately compound; simple leaf with many times parted or dissected lamina

Decurrent leaf base: a leaf attachment where the lamina or leaf-base extends downward along the stem or petiole, forming a winged, rib-like structure. Instead of stopping at the node leaf tissue "runs down" the stem, making the stem look thickened or winged below the leaf.

Decurrent stigma: elongate, extending downward

Decussate: opposite leaves at right angles to preceding pair, tetrastichous or four rowed with fifth leaf developing over the first one after two cycles of leaves

Definite: a number small enough to make easy an exact count, as opposed to indefinite

Deflexed: bent abruptly downward

Depressed: pressed close to axis downward

Descending: directed downward

Dehiscence: process of opening or splitting, particularly of a fruit or anther

Deliquescent: to quickly become soft and semi-liquid

Deltoid Leaf: triangular; delta-like

Dendroid / Dendritic: branched and tree-like

Dentate leaf margin: with round or sharp, coarse teeth that point outwards

Dissected: cut into more or less fine divisions

Descending/Vexillate aestivation: with five members, of which the posterior one is the outermost, and anterior two keeled, as in the Papilionaceae

Determinate: growth of plant parts limited by cessation of meristematic activity during the year

Dextrorse: rising helically from right to left, a characteristic of twining stems

Divergent: spreading away

Di-: a prefix meaning two, as in dicyclic or two-whorled

Diadelphous: stamens connate by their filaments to form two bundles.

Dichasium/Biparous: a cymose inflorescence with two lateral flowers developing below the central flower at each stage of branching

Dichlamydeous: with a perianth composed of two envelopes

Dichogamy: maturation of stamens or anthers and carpels or stigma at different times

Dichotomous: forked or divided into two equal parts

Dichotomous venation: with veins branching in pairs equally

Dichotomous branching: two branches formed at the tip by the division of apical meristem; commonly found among lower plants, as in *Riccia*

Diclinous: plant with imperfect flowers; stamens and carpels in separate

Dicotyledonous: with two cotyledons

Didymous stamens: having four stamens in two equal pairs

Didynamous: with four stamens in two pairs of different lengths.

Diplostemonous: with stamens in two alternating whorls, outer alternating

Diffuse: spread over a large surface

Diffuse stigma: spread over a wide surface

Digitate / Multifoliate leaves: palmately compound leaf with more than four leaflets

Digitate: hand-like

Dimorphic: occurring in two different form'. (sizes or shapes)

Dioecious: male (staminate) and female (carpellate) flowers borne on different plants

Diplostemonous: a flower with stamens arranged in two distinct whorls, where the total number of stamens is twice the number of petals. The outer stamens alternate with petals (opposite sepals), and the inner stamens are opposite petals; e.g., *Cassia*, *Geranium* and *Tribulus terrestris* (showing 5+5 stamens).

Disc / Disk: a discoid structure developed from the receptacle or stamens below oval

Discoid stigma: disc-like

Discoid: orbicular with convex faces

Dissected: irregularly divided into many slender segments

Distal: away from point of origin or attachment

Distal: Situated away from the point of attachment or origin.

Distichous: 2-ranked, 2-leaves in a spiral so the third grows above the first.

Distinct / free: separate, not fused or closely appressed

Distractile anther: with a transversely elongated connective separating the two anther lobes

Diurnal: flowers opening during the day

Diurnal: opening only during light hours or day

Divergent: anther lobes divaricate or separated from one another at an acute angle to the connective or filament; connective may be bifurcated

Divided / Parted leaf margin: with very deep indentations or incisions

Divided: separated to very near the base

Dorsal: back or abaxial side, pertaining to the surface most distant from the axis

Dorsifixed: anther attached dorsally to the apex of the filament.

Dorsiventral: flattened surface having distinct dorsal and ventral surfaces

Dorsiventral leaves: with structurally different dorsal and ventral surfaces

Dorsiventral: Flattened with distinct upper (dorsal) and lower (ventral) surfaces.

Drupe: with fleshy mesocarp and stony endocarp, derived from a superior ovary, single-seeded, as in *Mangifera*, or many-seeded, as in *Alex*

Dry dehiscent fruits: non-succulent fruits that open along definite sutures and seams, have indistinct layers of pericarp

Dry indehiscent: non-succulent fruits that do not open at maturity and have indistinct pericarp layers

E- or Ex-: a prefix denoting without, as ebracteate meaning without bract

Ebracteate: without bract **Ebracteolate:** without bracteole

Eccentric style: off-center

Eccentric: one-sided; off-center

Echinate / Spiny: covered with spines

Echinoid: spiny, multicellular

Elaminate: without lamina or blade

Elliptical Leaf: oval-shaped

Emarginate Leaf: shallow notch in the middle of a broad apex

Embryo: a mass of cells derived from the zygote; the young sporophyte

Embryonic axis: The embryo's axis has the shoot and root apices.

Emergent: with part (s) of plant aerial and part/s submerged; rising out of the

Emergent: with parts extending above water

Enation: an epidermal outgrowth

Endocarp: innermost layer

Endosperm: nutritive tissue derived from the fertilized central cell

Endospermous / Albuminous seed: with food reserves in the endosperm

Endothelium (Integumentary Tapetum): A specialized nutritive layer of the inner integument surrounding the embryo sac in some ovules.

Ensiform Leaf: sword-shaped

Entire leaf margin: smooth; without indentations or incisions

Entire: sepals fused completely

Ephemeral: persisting for a short period

Epi-: prefix denoting on or upon, as in epiphytic on another plant)

Epicalyx / Calycle / Calyculus: a calyx-like whorl of bracteoles below it

Epicarp / Ectocarp / Exocarp: outermost layer

Epicotyl: part of embryonic axis or stem above the point of insertion of cotyledon(s), gives rise to shoot system

Epigeal: germination where cotyledons are pushed upward by the elongation of the hypocotyl

Epigynous: with perianth and androecial parts inserted above the ovary, ovary is inferior

Epipetalous / Petalostemonous: with stamens attached to or inserted upon the petals; filaments partly or wholly fused to the corolla, anthers free.

Epiphyllous / Foliar bud: buds arising from leaves

Epiphyllous inflorescence: on a phylloclad or bract

Epiphyllous: stamens attached to tepals, anthers free

Epiphyte: plant growing on another plant

Epiphytic root: root of epiphyte, with a special spongy velamen layer, for moisture absorption

Episepalous stamens: with stamens attached to, or inserted upon, sepals.

Exserted / Phaneranthorous: with stamens protruding out of the flower

Equitant: 2-ranked with overlapping bases, usually sharply folded along

Erect: upright

Essential organs: the androecium and gynoecium

Etaerio of achenes / Achenecetum: an aggregation of achenes

Etaerio of berries / Baccacetum: an aggregation of berries

Etaerio of drupes / Drupecetum: an aggregation of drupelets

Etaerio of follicles / Follicetum: an aggregation of follicles

Etaerio of Samaras / Samaracetum: an aggregation of samaras

Eurypalynous / Multipalynous: a taxonomic group with more than one pollen type

Eusporangiate: type of sporangium which forms from more than one cell

Eustele: cylindrical arrangement of vascular bundles separated by parenchyma

Evergreen: bears leaves throughout the year

Evident: clearly visible macroscopically

Excrecence: outgrowth on surface

Excurrent: extend beyond the margin or tip;

Exfoliate: to peel off

Exserted: stick out, project beyond

Exstipellate: without stipels

Exstipulate: without stipules

Extra-axillary inflorescence: emerges from the internode above the axil of a leaf (*Solanum*)

Extra-floral: present in organs of plant other than the flower, as in leaf, - bract

Extrorse anther: anther lobes facing and dehiscing outward, away from the center of the flower

Eye: center of a flower or a bud on tuber

Falcate / Falciform Leaf: sickle-shaped

Falcate / Seculate: sickle-shaped

Falcate: sickle-shaped

Farinaceous / Farinose / Mealy: covered by white or bluish mealy powder or bloom

Fasciated: showing abnormal fusion of parts or organs, resulting in a flattened ribbon-like structure. e. g., inflorescence of *Celosia* (cocks comb)

Fascicled / Fasciculated root: fleshy or tuberous roots in a cluster, a modification of adventitious roots

Female / carpellate / pistillate: bearing flowers without functional stamens

Fertile: with functionally viable gametes

Fertilization: fusion of male, and female gametes to give rise to a zygote

Fibonacci phyllotaxis: a fundamental type of leaf arrangement expressed as a fraction in which each succeeding fraction is the sum of the two previous numerators and the sum of the two previous denominators, i.e., 1/2, 1/3, 2/5, 3/8, 5/13, 8/21, etc. The numerator represents the number of turns or spirals around a stem before one leaf is directly above another and the denominator represents the number of leaves between the first leaf and the next leaf that is directly above the first. The 2/5 phyllotaxy would mean between the one leaf directly above it, there are two twists and five leaves before one leaf is directly above the other.

Fibrous root: fine, thread-like or slender, generally adventitious root

Fibrous: fiber-like; having loose, woody fibers

Filament: stalk of a stamen

Filiform: slender thread-like

Fimbriate leaf margin: fringed

Fistulose: hollow, as a culm without a pith

Flabellate style: fan-shaped

Flaccid: lax and weak; limp

Fleshy fruits: having succulent or fibrous pericarp with well-differentiated epicarp, mesocarp and endocarp

Fleshy seed: covered by a fleshy outer coat

Floating plant: foliage of plant floating on the surface of water, plant may

Floccose: covered with dense, appressed, woody trichomes in patches or tufts

Floral: present in the flower

Floral envelope: envelop of accessory organs present around the sporophyll, usually these are the calyx or corolla

Floret: a small flower, usually one of a dense cluster

Floriferous: flower bearing

Flower / Floral bud: bud which will give rise to one or more flowers

Flower primordium: meristematic tissue that gives rise to a flower

Flower: modified (reproductive) shoot of flowering plants

Foetid: having disagreeable smell

Foliaceous: leaf-like

Foliaceous stipule: flattened, green and leaf-like, as in *Lathyrus*

Foliaceous: leaf-like

Foliar: pertaining to leaves or leaf-like parts; (term originated from Latin *folium* = leaf)

Follicle: A dry fruit formed from one carpel splitting along a single suture to which the seeds are attached, e.g. from the pod of a legume.

Forked: bifurcated

Free-central placentation: as in central placentation except that the central axis is not attached to ovary wall at its apical or distal end

Free-lateral stipule: small, green and free, borne on two sides of leaf base, as in

Frond: large leaf, as in palms and ferns

Fruit: mature fertilized ovary of flowering plants, with or without the

Fruticose: shrubby, woody throughout, commonly with several main stems but no main trunk

Fugacious: falling or withering away shortly after development

Furcate: forked

Furrowed: with longitudinal channels or grooves

Fusiform: spindle-shaped; broadest in middle and tapering to each end

Fusiform root: a tap root where the middle part of root is swollen and it tapers towards both ends gradually; spindle-shaped

Gametophyte: generation or body that produces gametes

Gamo-: a prefix meaning united,

Gamopetalous / Sympetalous / Synpetalous / Monopetalous: with fused or united petals of various forms

Gamophyllous: with fused or united tepals (exhibits gamopetalous or gamosepalous forms)

Gamosepalous/Synisepalous/Synsepalous/Monosepalous: with fused or united sepals of various forms

Gelatinous: jelly-like; soft and semi-solid

Geniculate style: Abruptly bent like a knee

Germination: a process of activation of dormant structure under favorable

Gibbous: Inflated on one side near the base, as in snapdragon

Glabrous: smooth; devoid of outgrowths

Gland: a secreting body or appendage

Glandular: covered with glands or trichomes with enlarged tips

Glandular trichomes: unicellular or multicellular trichomes involved in secretion of various substances! Such as, Digestive enzymes, mucilage, nectar, poisons or tissue irritants (stinging

nairs), salts, terpenes or essential oils, aqueous solution of organic and inorganic substances (stigmatic papillae, trichome, hydathodes), and sticky substances (colleters)

Glaucous: covered with a bloom or smooth, waxy coating that rubs off Glochidiate : with barbed trichomes, glochids, usually in tufts

Globose: nearly spherical

Glomerate: in dense or compact clusters

Glume: bract, usually occurring in pairs, at the base of the spikelet of grass

Gregarious: growing in company

Gynandrial / Gynosteminal / Gynostegial: with stamens and carpels (style and stigma) fused, as in Orchidaceae and Asclepiadaceae

Gynobasic style: attached at the base of the ovary in a central depression.

Gynoecium: a collective term for carpels or female sporophylls in the flower; comprises a single carpel of a simple pistil, a group of separate carpels, or fused carpels forming a compound pistil

Gynophore: the elongated internode between the androecium and gynoecium

Gynostegium: disc-like structure formed by fusion of stamens, stigma and

Habit: general appearance of plant,

Hairy / Woolly seed: covered with hair or trichomes; generally used when type of hair not specified

Halophyte: tolerant of excess amounts of salts (usually sodium chloride) in the soil solution

Haplostemonous: with stamens in one whorl, alternating with petals; Examples of Families with Haplostemonous Flowers: Liliaceae, Proteaceae (*Grevillea*), Geraniaceae (*Geranium*)

Hastate / Hastiform Leaf: triangular with two flaring basal lobes

Hastate leaf base: with two basal lobes oriented outward or divergently in relation to

Haustorial root: absorbing root within host of some parasitic species

Helicoid branching: a type of uniparous sympodium branching where successive lateral branches arise only on the same side of stem

Helicoid cyme inflorescence: a monochasium with all flowers developing only on one side of axis, forming a helix

Heliophyte: can grow only in well-lighted places

Hemicyclic / Spirocyclic: with some floral parts arising spirally and others in circles

Herb: a usually short and soft plant with annual, above-ground stems lacking definite woody structures

Herbaceous: a non-woody perennial with the aerial shoot system dying after each growing season, persists with the help of a perennate underground shoot system

Herbaceous: soft and succulent, not woody

Hermaphroditic / Monoclinous: plant with all perfect flowers

Hesperidium: a berry with leathery epicarp, fibrous mesocarp, and membranous endocarp bearing fleshy glandular hairs, as in *Citrus*

Hetero-: prefix signifying various, as in heterostyly meaning occurrence of styles of different sizes, lengths, and shapes in different populations within a species

Heterocarpic: Plants producing different fruit types (e.g., in Asteraceae/Brassicaceae families)

Heterochlamydeous: with the two envelopes distinguishable into calyx and corolla

Heterogamous: inflorescence with flowers of different sexes

Heterogamous Head: with flowers of different sexes

Heteromerous / Anisomerous: different floral envelopes with different number of members

Heteromorphic: inflorescence with flowers of different morphological forms and functions, as in capitula of some Asteraceae

Heterophyllous: bearing more than one type of leaves

Heterotroph: cannot produce food on its own and is dependent on other sources of nutrition

Hibernal / Hiemal: flowering in winter

Hilum: scar left behind on the seed coat after detachment of the funiculus

Hip/Cynarrhodium: an aggregation of achenes surrounded by an urceolate receptacle or hypanthium, as in Rosaceae

Hirsute: covered with long, rather stiff trichomes

Hispid: covered with very long, bristly, stiff trichomes

Hoary (Canescent): covered with very short dense trichomes giving a whitish appearance

Holdfast / Haptera: root which helps in attaching the plant to surface on which it is growing

Hollow / Fistulas: without pith, generally in the internode

Holoparasite (Complete parasite): Cannot photosynthesize and relies entirely on the host for all nutrients; e.g., *Orobanche*

Homo-: prefix signifying alike or similar

Homochlamydeous: with the two envelopes of similar parts, not distinguishable into calyx and corolla, each part called a tepal

Homogamous: with maturation of stamens or anther and carpels or stigma at the same time; in some Asteraceae, inflorescence with flowers of same morphological form and function

Homogamous Head: with flowers of same morphological form and function

Homomorphic: inflorescence with flowers of same morphological form

Homonym: A name that is spelled exactly like another, but applies to a different taxon.

Homonym: Identical names given to different taxa.

Hood: a cover-like perianth part, usually with a turned-down margin

Hook: a sharp, curved structure; may be modification of leaf or leaflet or inflorescence axis,

Hooked: unicellular with tip bent like a hook

Husk: outer covering derived from the perianth or involucre

Hyaline: thin and translucent or transparent

Hydrophyte: plant growing in water or in very wet place

Hygrophyte: plant which grows in constantly moist places

Hygroscopic: capable of expanding or contracting with changes in humidity

Hypanthodium: a unique inflorescence with unisexual blooms on the inside of a hollow, fleshy, pear-shaped receptacle with a thin, scale-guarded apex.

Hypanthium: fused or coalesced basal portion of floral parts (sepals, petals, and stamens); extension of floral axis around ovary bearing the perianth and androecium at its margin; may be cup-shaped, saucer-shaped, tubular, or rod-shaped

Hypocotyl: part of embryonic axis between the point of insertion of cotyledon(s) & the radicle

Hypogeal: germination where cotyledons remain in soil, and the plumule is pushed up by elongation of epicotyl

Hypogynous: with perianth and androecial parts attached below the ovary, ovary superior

Imbricate aestivation: members with overlapping margins within one whorl

Imparipinnate leaves: with odd number of leaflets, odd leaflet terminal

Incised: cut sharply, irregularly and rather deeply

Included / Cryptanthous stamens: with stamens present inside the flower, not protruding out

Included: present within, not protruding or exerted

Incomplete: leaf without one or more parts — lamina, petiole, stipules

Incomplete: with one or both accessory organs absent, but possessing two essential organs

Incurved: curved inward or upward

Indefinite: a number large enough to make an exact count difficult

Indehiscent: not regularly opening as a pod or anther

Indeterminate: continual growth of plant parts, not limited by cessation of meristematic activity

Indument: having hairy or pubescent covering

Indurated: hardened, usually Sntogenetically

Inferior ovary: an ovary positioned completely below other floral organs

Inflated: blown up

Inflated petiole: swollen or thickened, as in *Eichhornia*

Inflexed: bent abruptly upward

Inflorescence: mode of arrangement of flowers on the stem/floral axis

Inflorescence axis / Peduncle: main stalk for entire inflorescence

Inflorescence: The arrangement of flowers on a plant axis.

Infundibular: Funnel-shaped

Infundibuliform stigma: funnel-shaped, as in *Crocus sativus*

Innovations: sterile shoots of grasses and sedges

Insectivorous: which derives nutrition partially from insects; trap and digest insects

Inserted: attached to, the point of origin

Inter-: a prefix meaning between, as in interfoliar between leaves)

Intercalary: near the base of an internode or base of a blade

Intercalary inflorescence: between leafy or vegetative regions of an axis

Internode: a section or region of stem between successive nodes

Interpetiolar stipule: present between the petioles of opposite leaves, as in Rubiaceae

Interstitial: all over; no localized region

Intra-: prefix signifying below, as in infrafoliar (below leaves)

Introrse anther: anther lobes facing and dehiscing inward or towards the center of the flower

Involucel: small or secondary involucre

Involucre: a group or cluster of bracts subtending an inflorescence

Involute: margins or outer portion of sides rolled inward over upper or ventral surface

Involute leaf margin: rolled inward

Isobilateral: with structurally indistinct dorsal and ventral surfaces

Jaculator / Echma / Retinaculum: a persistent, indurated, hook-like funiculus on which the seed rests, as in Acanthaceae; helps in dispersal of seed

Jointed: with nodes; with points of real or apparent articulation

Jugum: a pair, as of leaflets

Keel / Carina: a projecting central longitudinal line or ridge, as in the bottom of a boat, the two united petals of a Papilionaceous flower

Keeled: ridged like the bottom of a boat

Labellum / Lip: one of the two parts of a divided corolla or calyx

Lacerate: irregularly cut, appearing torn

Lacerate: torn; irregularly cleft or cut

Laciniate: slashed into narrow pointed and parallel ribbon-like or strap-like

Lactiferous: producing or bearing latex

Lacuna: a cavity, hole, or gap

Lamellate: provided with many fin-like blades or cross-partitions

Lamellate Laminar Superficial placentation: modification of parietal placentation wherein the ovules are borne on the inner surface of plate-like lamellae or septae formed by the invagination of placentae

Lamina / Blade: flat, expanded portion of leaf

Lanceolate Leaf: lance-like

Lateral: on or at the side

Lateral branching: branches are produced laterally from the sides of the main stem

Lateral stipule: adnate to petiole, with free part located along the petiole

Lateral style: at the side of ovary

Latex: milky sap

Latrorse anther: anther lobes facing and dehiscing laterally, neither inward nor outward

Lax: loose, not congested

Leaf primordium: meristematic tissue that gives rise to a leaf

Leaf Scar: the mark left on stem or axis after detachment of leaf

Leaf: a photosynthetic organ developed from leaf primordium in the bud and borne on the stem of a plant

Leaflet: a distinct and separate segment of a compound leaf

Leaf-opposed inflorescence: on the stem opposite the base of the leaf, as in *Corchorus*

Legume / Pod: derived from a simple ovary that splits along two sutures

Lemma: outer scale or the fertile bract subtending the grass floret

Lenticel: lens-shaped or wart-like patches of parenchymatous tissue or a 'breathing' pore on the surface of stem and branches, sometimes on fruit

Lenticular: biconvex, usually elongate and flat; lens-shaped

Leptosporangiate: type of sporangium development where the sporangium

Ligneous / Woody / Sclerous: hard and lignified

Ligulate: strap-shaped

Ligulate/Ray: Strap-shaped

Ligule: a strap-shaped flap of tissue outgrowth or projection from the surface of leaf

Limb: expanded portion of corolla or calyx above the tube, throat, or claw
Lobe: any, usually rounded, segment or part of the perianth

Linear Leaf: long, narrow and flat, as in grasses

Lineate / Linear stigma stigma: in lines, stigmatic surface linear Lobed stigma: divided into lobes

Lineate: lined, bearing thin parallel lines

Lobe: any part or segment of an organ

Locule/Locus (pl. locules/loculi): central region of a microsporangium containing reproductive or germ cells

Locule / Locus (pl. Locules / Loculi): a compartment or cavity

Locule / Locus (pl. locules /loculi): cavity of the ovary containing ovules

Locule / Locus (pl. locules /loculi): cavity or chamber within fruit

Loculicidal Capsule: dehisces longitudinally opposite the locule exposing the cavity

Lodicule: liyaline, scale-like, abortive perianth part at the base of ovary in Family Poaceae, functions to push apart the lemma and palea

Lomentum: a legume which is constricted or partitioned between the seeds and splits into several one-seeded compartments or articles at maturity, as in Acacia

Longitudinal dehiscence: dehiscing along the long-axis of an anther lobe

Lorate Leaf: strap-shaped, often flexuous or limp

Lyrate Leaf: lyre-shaped, with large terminal lobe and smaller lower lobes

Male / staminate: plant with staminate flowers only

Marcrescent: withering but the remains persisting

Marginal / Ventral placentation: with ovules borne along the ventral suture or margin of a simple ovary

Marginal: pertaining to the border or edge

Medial: upon or along the longitudinal axis

Megaspore: A haploid spore that develops into the female gametophyte

Megasporangium (Ovule): Structure within the ovary that produces megaspores and contains the female gametophyte

Megasporophyll: a sporophyll that bears megasporangia, often produced in the

Membranous / Membranaceous: membrane-like; thin and semi-translucent

Mericarp: an indehiscent 1-seeded fruit part that divides and may develop separately

Meristem: undifferentiated tissue whose cells are capable of developing into

-merous: a suffix indicating the number of parts in a whorl of stems, leaves or floral organs, as a tri-merous flower having perianth parts in sets of three

Mesocarp: middle layer

Mesophyte: plant growing in normal environment, i.e., in average conditions of temperature, light, soil and water

Micropyle: pore through the seed coat

Microsporangium: sporangium containing only microspores

Microsporangium: male sporangium consisting of wall layers (epidermis, endothecium, and tapetum, with or without middle layers) and sporogenous cells which differentiate into pollen grains

Microspore: the spore which on germination gives rise to male gametophyte

Microspore: male spore with a single haploid nucleus

Micropyle: A small opening in the ovule integuments through which the pollen tube usually enters

Midrib: the central conducting and supporting structure of blade of a simple leaf; a continuation of petiole

Midvein: the central conducting and supporting structure of the blade of a leaflet

Monadelphous stamens: with stamens in one group connate by their filaments

Moniliform / Beaded root: elongated roots with regularly arranged swollen areas

Moniliform: like stringed beads

Mono-: a prefix meaning one or once, as in monocyclic (one whorled)

Monocarpellary / Unicarpellary: with single carpel

Monocarpic / Hapaxanthic: fruiting once; perennial, biennial or annual, flowering and fruiting once, then dying; usually applied to perennials that grow for several years before flowering and dying

Monochasium / Uniparous inflorescence: a cymose inflorescence with only one lateral flower developing at each stage of branching

Monochlamydeous / Haplochlamydeous: with only one perianth envelope.

Monocotyledonous: with one cotyledon

Monoecious: male and female flowers borne on same plant

Monophyletic: A group/clade that includes all offspring of the most recent shared ancestor

Monopodial / Racemose branching: main stem continues to grow indefinitely, branches develop in acropetal succession, the lower branches are older and larger than the upper ones

Monothealous anther: with one theca or pollen sac more than two lateral flowers developing at each stage of branching'

Mother axis: axis on which the flower is borne.

Mucilage: sticky and slimy substance produced by glandular cells in plant

Mucilaginous: gummy or gelatinous

Mucronate Leaf: a leaf with an apex (tip) that ends abruptly in a short, sharp, or stiff point; The leaf blade terminates suddenly, rather than tapering gradually, into a sharp, sometimes spiny tip. It is characterized by a "mucro," a small, sharp, abrupt point. This feature is often described as a small bristle or thorn at the very end of the leaf. Examples: Common in plants like the Cotoneaster (e.g., *Cotoneaster horizontalis*), Japanese Barberry (*Berberis thunbergii*), and various other plant species. The term is derived from the Latin *mucronatus* (pointed), which comes from *mucro* (a sharp point or edge).

Multi-: a prefix meaning several or many, as in multicellular (many-celled)

Multicarpellary / Polycarpellary: with many carpels

Multicostate: with more than one primary vein arising from a common point at base

Multilocular ovary: with many locules

Multiparous / Polychasial branching: with more than two laterals at each stage of branching

Multiple / Composite: derived from coalesced ovaries of flowers on inflorescence axis

Multithecous: with many thecae or pollen sacs formed due to septation of thecae, as in *Acacia nilotica*

Napiform: turnip-shaped

Napiform root: a modification of tap root, upper part considerably swollen and tapers suddenly downward

Nectary: a secretory gland producing sugary liquid that attracts pollinators

Nerve: one of the principal veins of parallel-veined leaf

Neuter / Agamous / Sterile: without stamens and carpels; sex organs abortive

Node: region of stem from which leaf, leaves, or branch(es) arise

Nodiform / Nodulose: knotty or knobby, as the roots of most of the Fabaceae

Nodose: knobby; knotty

Nodulated root: root with nodular outgrowths, as roots of legumes with nitrogen fixing nodules

Nodulose root: slender root with swollen tip

Non-endospermous / Exalbuminous seed: without endosperm

Non-glandular trichomes: unicellular or multicellular trichomes not involved in secretion

Nut: a one-loculed, one-seeded fruit with a hard pericarp, generally derived from a compound, two or more loculed, superior or inferior ovary by abortion of all but one ovule

Nutlet / Nuculi: a small one-seeded part of a fruit that splits off and resembles a nut with a hard pericarp

Ob-: a prefix usually signifying inversion, as in obovate (inverted ovate)

Obcordate Leaf: notched with rounded lobes on both sides; Its shape is inversely heart-shaped (heart-shaped but upside down); Its apex is broad, notched, or rounded lobes & its base is pointed, tapering toward the stem; e.g., yellow wood sorrel (*Oxalis* spp.) and some *Zieria* species. [Etymology: Derived from "ob-" (inverted) + "cordate" (heart-shaped)].

Obcordiform / Obcordate Leaf: inversely heart-shaped

Obdiplostemonous: A flower with two whorls of stamens, with the outer whorl opposite the petals (antipetalous) and the inner whorl opposite the sepals. This condition features twice as many stamens as petals i.e., total no. of stamens is double the number of petals (e.g., 5 petals = 10 stamens, arranged in two sets of 5); commonly found in *Citrus* (Rutaceae), *Oxalis* (Oxalidaceae), *Tribulus terrestris* (Zygophyllaceae), *Silene* and *Stellaria* (Caryophyllaceae).

Oblique: two halves of leaf unequal

Oblique anther: the anther lobes are lower on one side of the connective than the other

Oblong Leaf: longer than broad, with margins parallel most of their length, as in

Obovate Leaf: inversely ovate, terminal half broader than the basal half

Orbicular / Rotund Leaf: circular or disc-shaped, as in lotus

Obtuse leaf base: blunt and rounded

Obtuse Leaf: blunt or rounded with a terminal angle of more than 90°

Ochreate stipule: hollow, tube-like, encircling the stem from the node up to a certain height of internode, as in *Polygonum*

Octostichous: eight rowed or ranked; 3/8 arrangement with eight leaves in three spirals so that ninth leaf arises over the first leaf, as in *Carica papaya*

Offset: a short, stout, horizontal branch which grows to a limited extent and produces at the apex a tuft of leaves above and a cluster of small roots below

Oligci-: a prefix signifying few, as in oligospermous (few seeded)

Olutinous / viscid: sticky

Open aestivation: without overlapping margins within one whorl

Operculate: fused petals forming a cap-like structure or operculuni, adnate to calyptra, which falls off at anthesis, as in *Eucalyptus*

Operculum: a lid or cover produced by circumscissile dehiscence

Opposite: two leaves borne on opposite sides of a stem

Ortho-: a prefix indicating straight ovary

Ovary wall: wall forming the ovary

Ovary: ovule-bearing part of the pistil.

Ovate Leaf: egg-shaped; broader at base than at apex

Ovule: megasporangium with integument(s) containing the megagamete or egg cell; embryonic seed

Ovuliferous: bearing ovules

Palate: raised area or rounded prominence in the throat of a sympetalous, especially personate, corolla

Palea: inner scale or bracteole subtending the grass floret.

Paleaceous: with small membranous scales; chaffy

Palmately compound leaves: with leaflets arising from one point at end of petiole

Palmate-parallel-convergent venation: parallel veins diverge from the base but converge at apex, as in grasses

Palmate-parallel-divergent venation: parallel veins diverge from the base and remain divergent, as in *Borassus*

Palmate-pinnate leaves: First-order leaflets palmate, second-order pinnate.

Palmate-reticulate-convergent venation: multicostate with main veins converging at tip, secondary veins forming a network, as in *Zizyphus*

Palmate-reticulate-divergent venation: multicostate with main veins diverging toward margins, secondary veins forming a network, as in cotton, grapes

Palmatifid leaf margin: cut palmately

Palmatifid: cut palmately

Palmatisect: sectioned or divided palmately into distinct segments

Panduriform / Pandurate Leaf: fiddle-shaped; obovate with indentation on each side near base and with two small basallobes

Panicle: a branched raceme

Pannose / Felted: with matted, felt-like layer of trichomes

Papilionaceous: with large posterior petal (standard), two lateral petals (wings) and usually two connate lower petals (keel); as in Papilionaceae Papilionaceous corolla

Papilionate: Butterfly-like; having a corolla as in pea

Papillate: short and blunt

Papillose / Papillate: covered with minute tubercles

Pubescent: with straight, slender trichomes

Pappus: bristly, hairy or scaly calyx, common in the Asteraceae

Parallel anther: anther lobes, longitudinal to each other and along the sides of the connective

Parallel venation: with veins extending from base to apex, unbranched and essentially parallel

Paraphyletic: A group that includes a common ancestor but not all of its descendants.

Parasite: dependent on another living plant (host) for nutrition partially or totally

Parietal placentation: with ovules borne on the wall of a unilocular compound ovary

Paripinnate leaves: with even number of leaflets, without a terminal leaflet

Partial root parasite: obtains partial nutritional requirement from the roots of host, e.g., *Santalum album*

Partial root parasite: plant that makes its own food via photosynthesis but uses specialized roots (haustoria) to tap into other plants' roots (like *Dalbergia* or *Eucalyptus*) for water and

essential minerals, hence deriving only part of its nourishment from a host. e.g., Sandalwood, *Striga* sp

Partial stem parasite: obtains partial nutritional requirement from the stem of host; such plants photosynthesize their own food but use specialized roots (haustoria) to tap into a host tree's xylem for water and minerals; e.g., *Viscum album*, *Loranthus*

Partite: sepals fused only at the base and free above

Pauciflor: Having few flowers per inflorescence

Pauline: more or less evenly distributed on stem

Pectinate leaf margin: pinnatifid with closely set segment; comb-like

Pectinate: Pinnately divided with closely parallel tooth-like projections (comb-like)

Pedate Leaf: foot-shaped; bird's claw-shaped with lobes spreading outwards, as in

Pedate: Having a terminal lobe or leaflet, and on either side of it an axis curving outward and backward, bearing lobes or leaflets on the outer side of the curve

Pedicel: stalk of a flower

Pedicellate / Pedicillate: with pedicel

Peltate leaf base: base near center of lamina; petiole attached on the underside of

Peltiform / Peltate Leaf: shield-shaped, with petiole attached to center of lamina Pitcher-like: like a pitcher, as in *Nepenthes*

Pendulous: hanging loosely or freely

Penta-: a prefix meaning five, as in pentacyclic (five-whorled)

Pentamerous: with each perianth envelope composed of five members

Pentastichous: In five rows; 2/5 arrangement with five leaves in two spirals so that the sixth leaf develops over the first one

Pepo: a berry fruit with leathery epicarp, derived from an inferior ovary, as in Cucurbita

Perennate: lasting the whole year through, self-renewing by lateral shoots from the base

Perennial: plant that persists for more than two years

Perfoliate leaf base: When a sessile leaf's base totally encircles or clamps the stem, making it seem to go right through the leaf blade. This occurs when the leaf's basal edges entirely attach to the stem. Leaf appears to "pierce" stem. It is a kind of amplexicaul, clasping, or sessile leaf. *Connate-perfoliate*, a characteristic frequently observed in honeysuckles (*Lonicera* spp.), is the

fusion of two opposing leaf bases to encircle the stem. Examples include *Bupleurum rotundifolium* (thorough-wax), *Uvularia perfoliata* (perfoliate bellwort), *Claytonia perfoliata* (miner's lettuce), and *Eupatorium perfoliatum* (common boneset). *Function:* These leaves, often beneath the inflorescence, decrease herbivory and protect developing flowers.

Perianth / Perigone: collective term for the floral envelopes, corolla, and calyx; generally used when the envelopes are not distinct; an aggregation of tepals

Pericarp: matured ovary wall; fruit wall; generally composed of three differentiated layers

Pericladial petiole: with a sheathing base, as in Apiaceae

Pericladium: a sub-floral stalk of compound nature, formed by fusion of the gynophore and the bases of other floral parts, found in many members of Liliaceae

Perigynous: with perianth and androecial parts inserted on hypanthium around the ovary, the hypanthium and ovary may not be united (ovary superior) or may be partially united (ovary semi-inferior)

Perisperm: nutritive tissue derived from the nucellus or integuments

Perispermous seed: with food reserves in perisperm

Persistent: remain attached and not falling off till fruit formation

Personate: two-lipped with the upper one arched, and with a projection; the palate, from the lower lip, protrudes into and almost closes the corolla throat

Perulate: scale-bearing, as most buds

Petal: a corolla member or segment; a unit of corolla

Petalantherous: with a terminal anther and distinctly petaloid filament, as in Saxifraga

Petaloid stamen: petal-like stamen without a distinct anther and filament, but with marginal microsporangia as in *Magnolia nitida*

Petaloid style: petal-like

Petaloid: coloured and petal-like

Petaloid: petal-like sepals or tepals

Petiolate: leaf with a petiole

Petiole: leaf stalk

Petiolulate: leaflet with a petiolule

Petiolule: leaflet stalk

Phyllary: individual bract of an involucre

Phylloclade / Cladophyll: green, flattened or cylindrical stem and branches of many internodes of certain xerophytic plants resembling a leaf in form and function

Phyllode / Phyllodium: The lamina is shortened, yet the petiole or midrib is flattened.

Phyllodial petiole: flattened and lamina-like; leaf-like

Phyllotaxis / Phyllotaxy: arrangement of leaves

Phylogeny: The evolutionary history and relationships among organisms.

Pinna (pl. pinnae): primary division of a compound leaf bearing leaflets

Pinnately compound leaves: with leaflets arranged oppositely or alternately along the rachis

Pinnate-parallel / Penni-parallel / Penni-nerved venation: unicostate with veins extending from midrib to margins, essentially parallel, as in banana

Pinnate-reticulate venation: Unicostate venation with midrib, secondary veins forming a network.

Pinnatifid leaf margin: cut pinnately

Pinnatisect: sectioned or divided pinnately into distinct segments

Pinnule: secondary division of a compound leaf bearing leaflets

Pistil: A unit of gynoecium, comprised of ovary, style (when present), and stigma

Pistillate / Carpellate: with only pistils or carpels

Pistillode: a rudimentary or vestigial pistil without ovules, present in some staminate flowers

Placenta (pl. placentae): tissue in the ovary from which ovules develop

Placentation: the arrangement of ovules within the ovary

Plicate: with series of longitudinal folds; plaited

Plumose stigma: feather-like

Plumule: embryonic leaves and shoot apex derived from epicotyl; first bud of embryo

Pluriflor: Having many flowers per inflorescence

Pneumatophorous: aerating, apogeotropic or negatively geotropic root with lenticels/pores/pneumatodes which help in gaseous exchange, usually found in marsh plants

Pollen grain: male gametophyte

Poly-: a prefix meaning many, as in polycyclic (many-whorled)

Polyadelphous stamens: with several groups of stamens connate by their filaments

Polyandrous: with many stamens

Polychasium / Pleiochasium / Multiparous inflorescence: a cymose inflorescence with

Polygamous: plant with perfect and imperfect flowers

Polymerous: with each perianth envelope composed of many members

PseudomonoiTlerous: with each perianth envelope seemingly composed of one member which is a fusion product of two or more parts

Polypetalous / Apopetalous / Choripetalous: with separate petals

Polyphyllous / Apophyllous / Choriphyllous: with separate tepals Polysepalous / Aposepalous / Chorisepalous: with separate sepals

Polystemonous: stamens in more than two whorls

Polystichous: in many rows

Pome: fruit with cartilaginous pericarp surrounded by fleshy receptacle, as in *Malus*

Poricidal / Poral dehiscence: dehiscing through a pore at the apex of anther lobe

Poricidal Capsule: dehisces via pores, may be coated with an operculate (*Papaver*)

Posterior: flower close to mother axis, distant from subtending bract; adaxial.

Prefoliation: form and arrangement of young leaves and perianth parts in bud condition; comprises of ptyxis and aestivation/vernation

Prickle / Emergence: a sharp-pointed outgrowth of epidermal, or epidermal and sub-epidermal origin of any organ lacks vascular supply

Primary / seminal: which develops from the radicle of embryo

Procumbent / Prostrate / Reclining / Humistrate: trailing or lying flat, not rooting at the nodes

Proembryo: The early, undifferentiated structure formed from the division of the zygote before it develops into a mature embryo

Prop root: adventitious, supporting root, usually arises from the horizontal lower branches of trees and grows vertically down, gets anchored in soil, becomes thick, strong, and pillar-like

Protandry: stamens or anthers maturing before carpels or stigma

Protected / Covered / Scaly bud: shoot and/or flower primordia surrounded by scales

Protogyny: carpels or stigma maturing before stamens or anthers

Proximal: Situated near the point of attachment or origin.

Pseud- / Pseudo-: A prefix meaning false, not genuine, not the true or the typical

Pseudanthium: cluster of several flowers appearing as a single flower, as capitulum of Asteraceae

Pseudocarp: an aggregation of achenes embedded in a fleshy receptacle, as in strawberry

Ptyxis: form of an individual part in a bud; the way a part is folded and rolled in the bud

Pubescent: Covered with short, soft hairs.

Pulvinal / Pulvinus (petiole): with swollen base, as in Fabaceae

Pulvinate: cushion shaped

Pyrene: pit or stone of fleshy fruits containing a stony or bony endocarp with seed(s)

Pyriform: pear-shaped

Quadrifid: cut or divided into four lobes or parts

Quadrifoliate leaves: a palmately compound leaf with four leaflets, as in

Quincuncial aestivation: with five members, two of which are exterior, two interior, and a fifth with one margin outside and other inside

Raceme: an unbranched racemose inflorescence with pedicelled flowers

Racemose / Indeterminate: monopodial branching; main inflorescence axis grows indefinitely and gives off flowers laterally in acropetal succession, i.e., lower and outer flowers are older than the upper and inner flowers

Rachilla / Rhachilla: diminutive, secondary Axis of compound leaf

Rachilla: central axis of a grass or sedge spikelet

Rachis (pl. rachidesV rachises): the main axis of a pinnately compound leaf, Radiate: spreading outwards from a common center

Radical / basal / rosulate leaves: near ground, arising from top of rootstock

Radical / basal / rosulate: near ground, arising from top of rootstock

Radical: buds arising on roots

Radicle: embryonic root with the root apex that gives rise to root system.

Ramal / Ramous: more or less evenly distributed on branch

Ramiform: branched

Rank: Two-ranked leaves are in two vertical rows, alternating or opposing. Also, the hierarchical position of a taxon (e.g., Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species).

Raphe: ridge on the seed coat created by funiculus-seed fusion when bent.

Ray: secondary axis in a compound inflorescence, as branch of a compound umbel

Recurved / retrorse: curved or bent outward or downward

Region of elongation in Root: Part of root where cells rapidly elongate and expand

Region of maturation in Root: part of root where cells undergo differentiation into various kinds of primary tissues, and where root hairs are present

Regma: derived from a compound, multi-locular ovary which separates at maturity into dry, one-chambered, one- or two-seeded cocci which open along the ventral suture to expel, as in *Ricinus communis*

Reniform: kidney-shaped

Repent / trailing: creeping or lying flat and rooting at the nodes

Replum: false septum (of placental origin) between the two locules of cruciferous fruits

Replum: false septum formed by extension of placental tissue, as in Brassicaceae

Reproductive: with foliar buds present on the leaf, aid in vegetative

Reproductive root: contain buds that readily develop into new individuals, aid in

Respiratory / Floating root: adventitious, soft, light, spongy, colorless, above-water roots of aquatic plants that store air and float.

Resupination: the complete inversion of flower by the torsion of its support such that the anterior part of flower becomes apparently posterior, and vice-versa, seen in orchids

Reticulate: with veins branching and anastomosing to form a network

Retuse Leaf: obtuse or truncated apex with a shallow notch in the middle

Revolute leaf margin: rolled under

Revolute: edges or outer sides roll outward or downward across lower or dorsal surface

Rhizome: a horizontal underground stem with scale leaves, generally has

Rhombate / Rhomboidal / Rhombiform Leaf: shaped like a rhomboid

Root apex: extreme tip of radicle containing the root meristem and the

Root cap: parenchymatous, protective, cap-like tissue at the apex of the root

Root hair: lateral, single-celled, absorbing outgrowth of the epidermal cell

Root pocket: a type of root cap which does not regenerate, found in water

Root: an absorbing and anchoring organ, usually positively geotropic and initially developed from the radicle

Rootstock: a term applied to miscellaneous types of underground stems or parts

Rosaceous: free petals with very short claws, and limbs spread outward.

Rosette: an arrangement of leaves radiating from a crown or center and usually at or close to the ground

Rostellurn / Beak: persistent styler base on fruit

Rostrate: having a beak or beak-like projection

Rotate: wheel-shaped, with a short tube and a wide limb at right angles to the tube

Rounded Leaf: apex forms a smooth arc

Rudimentary: imperfectly developed and non-functional

Ruminate Endosperm: Endosperm with an irregular surface, often becoming deeply furrowed, found in species like *Myristica*

Runner: a slender, prostrate branch with nodes and long internodes, which produces roots and shoots at tip, and forms a new plant

Saccate: pouch-like

Sae: a pouch or baggy cavity

Sagittate leaf base: an arrowhead shape, where the base of the leaf blade has two distinct, acute lobes that point downwards or backwards towards the petiole. This morphological feature is common in aquatic plants and specific foliage plants, designed to facilitate water shedding or attachment. Examples: *Sagittaria latifolia* (Common Arrowhead), *Ipomoea aquatica* (Water Spinach), and various *Syngonium* species.

Sagittiform / Sagittate Leaf: arrowhead-shaped; triangular-ovate with two straight or slightly incurved basal lobes

Salverform / Hypocrateriform: Trumpet-shaped, with long slender tube and limb nearly at right angles to tube

Samara: an achene with wings that are derived from pericarp

Sapling: a young tree

Saprophyte: a plant (usually lacking chlorophyll) that draws its nutrition from dead and decaying organic matter of vegetable or animal origin

Sarcocaulous: fleshy

Scabrous / Scabrid: having a harsh surface, often due to very stiff hairs or projections

Scabrous: rough

Scale leaves: small, non-green leaf on bud or modified stem

Scale: a small, dry, scarious to coriaceous, flattened, protective leaf surrounding the bud structure

Scaly stipule: small, dry, and scale-like

Scaly: scale-like

Scandent: climbing without aid of tendrils

Scape: leafless inflorescence axis

Scapose: with a solitary flower or inflorescence on a scape

Scar: a mark indicating former place of attachment, may be of bud scale/leaf

Scarious: thin and dry, appearing shrivelled

Schizocarpic achenes: separating achenes, as in *Sida*

Schizocarpic berries: separating berries, as in *Phytolacca*

Schizocarpic follicles: separating follicles, as in Apocynaceae

Schizocarpic fruits: derived from a two- or more-loculed compound ovary in which the locules separate at maturity, appearing as fruits derived from simple pistils

Schizocarpic nutlets / Cenobium: separating nutlets enclosed in a calyx tube, as in Lamiaceae

Schizocarpic samaras: separating samaras, as in *Acer*

Sciophyte: plant which grows only in shady places; shade-loving plants

Sclerocaulous / Woody: hard, dry; not herbaceous

Scorpioid branching: a type of uniparous sympodium branching where successive lateral branches arise on either side of the stem

Scorpioid cyme inflorescence: a monochasium with successive lateral flowers developing alternately on opposite sides below the central flower

Seasonal: flowering during a particular season or during each season

Seasonal: occurring during a seasonal cycle, or each season

Secondary root / Lateral root: root branch with root cap and hairs, derived endogenously from the pericycle of main root

Secund / Unilateral: on one side of the stem

Secund: inflorescence with flowers appearing to be borne from only one side Solitary: one-flowered; not a cluster of flowers

Secund: with flowers arranged on one side of axis

Seed coat: outer protective covering of the seed derived from integument(s)

Seed: a mature ovule

Seed: mature, fertilized ovule of seed-plants

Seedling: a young plant developed from a seed

Semataxis: arrangement of semaphylls (sepals, petals, tepals)

Semi-inferior / Half-inferior ovary: other floral organs inserted on a hypanthium, which is adnate to lower half of the ovary; the basal part of the ovary is below the point of attachment of other floral organs

Sensitive stigma: sensitive to touch, as in *Mimulus*, *Martynia*

Sepal: a calyx member or segment; a part of the calyx; usually green and foliaceous

Sepaloid: sepal-like petals or tepals

Sebate leaf margin: saw-toothed; small, sharp, ascending teeth septe

Septe: divided by internal partitions into locules or cells

Septicidal Capsule: dehisces longitudinally along the septe

Septifragal Capsule: dehisces irregularly loculicidally or septicidally with valves falling away, leaving the seeds attached to the central axis

Septe (p1. septe): partition or cross-wall in the ovarian cavity

Septum / Dissepiment: partition separating adjacent locules of a multi-locular fruit

Septum: tissue separating adjacent sporangia or locules in a lobe

Seriate: in series, usually in whorls or apparent whorls

Serrated: cut into saw-like teeth

Sessile leaves: leaf without a petiole or epetiolate, (leaflet without a petiolule or epetiolule)

Sessile leaves: leaf without a petiole or epetiolate, (leaflet without a petiolule or epetiolule)

Sessile stigma: without style

Setose: stiff and bristle-like

Shaggy: multicellular and rough

Sheath: portion of leaf surrounding the stem

Sheathing / Protective stipule: enclosing a leaf

Sheathing leaf base: tube-like, enclosing the stem above insertion of lamina or petiole

Sheathing petiole: flattened and encloses stem

Shining / Nitid / Laevigate: lustrous, polished

Shoot apex: extreme tip of embryonic axis containing shoot meristem and the underlying undifferentiated cells derived from them

Shoot: part of plant developed from the shoot apical meristem and it generally consists of parts of plant other than roots

Shrub: a much-branched woody perennial plant usually without a single trunk

Sigmoid: said of a structure that is curved sidewise in opposing directions; S-shaped

Silicula / Silicle: short and broad fruit derived from a compound ovary. With 2 valves and a persistent partition after dehiscence

Siliqua: long and narrow fruit derived from a compound ovary, with two valves and a persistent partition after dehiscence

Simple cyme inflorescence: a cyme with only one stage of branching; It shows determinate growth (The central axis stops growing after forming a terminal flower) & basipetal flowering (Older flowers are at the center/top, while younger ones open at the base/sides); Examples: Jasmine (*Jasminum*) and *Hibiscus* (axillary flowers), *Trillium grandiflorum* etc.

Simple leaves: leaf not divided into leaflets

Simple leaves: leaf not divided into leaflets

Simple ovary: ovary of a single carpel

Simple Pistil: consisting of one carpel

Simple Umbel: unbranched with one cluster of flowers

Simple: derived from the ovary of a solitary pistil in a single flower

Simple: with single, unbranched inflorescence axis

Sinistrorse: rising helically from left to right, a characteristic of twining stems

Solid: not hollow

Sorosis: multiple fruit derived from an aggregation of fruits of individual flowers along with the fleshy perianth and fleshy or woody peduncle, as in pineapple, jack-fruit, and mulberry

Spadix: a spike with elongated and sometimes fleshy inflorescence axis, subtended by a spathe

Spathe: a large sheathing bract enclosing an inflorescence

Spathulate Leaf: spoon-shaped; oblong or obovate apically with a long attenuated base

Sperm: a male gamete or reproductive cell

Spiculate: with crystals in or on the surface

Spike: a racemose inflorescence of sessile flowers

Spikelet / Locusta: a small, few flowered, spike

Spine: a small, stiff and pointed outgrowth lacking vascular supply, may be a modified stipule or leaf

Spinose leaves: spine-like modification of whole leaf, or leaflet

Spinose/Pungent Leaf: spine-tipped; coriaceous and stiff acuminate apex

Spinose: spine-like modification of whole leaf, or leaflet

Spinous stipule: small, sharp, and pointed; spine-like

Spinous: spine-like sepals, as in *Trapa bispinosa*

Spiral: twisted like a corkscrew

Spongy: soft / sponge-like

Sporophyll: a spore bearing leaf

Sporophyte: the organ or plant which can bear sporogenous tissue

Spur: a hollow, slender, tubular, or sac-like projection from a flower part (calyx or corolla), often containing nectar to attract pollinators e.g., in flowers like columbines (*Aquilegia*) or larkspurs; may be Stem Spur/Spur Shoot (a stunted, perennial branchlet with very short internodes that produces leaves, flowers, and fruit, such as those found on apple, pear, and plum trees); Conifer Spur: Specialized shoots in certain conifers that bear leaves. Squamiform: flattened and multicellular

Staininode / Staminodium: sterile stamen, may be in a reduced form or modified as a nectary or petaloid structure

Stamen: male sporophyll within the flower; organ that bears pollen in angiosperms; a unit of androecium

Stamen: the male sporophyll within the flower, bearing pollen; a unit of the androecium

Staminal disc: a fleshy, elevated cushion formed from coalesced staminodes or nectarines

Staminate: with only stamens

Staminode: a rudimentary or vestigial stamen

Standard / Banner / Vexillum: the upper, usually wide petal in a

Stellate / Radiate stigma: star-shaped

Stem: a supporting and conduction organ developed initially from the epicotyl, and is negatively geotropic

Stenopalynous: a taxonomic group with only one pollen type

Stereomorphic: flowers 3-dimensional with basically radial symmetry; parts are many or reduced, and usually regular as in *Narcissus*

Sterile: lacking functional sex organs or gametes

Stigma: pollen-receptive surface of the carpel, present generally at the tip of the style

Stilt root: supporting root which arises from the lower portions of stem, grows obliquely down, gets anchored in soil and provides additional support to main stem

Stipe: pistillate or carpellary stalk formed by the sterile basal part of the gynoecium or the ovary

Stipel: one of a pair of appendages at the base of a petiolule

Stipule: one of a pair of appendages at the base of a petiole

Stolon: a prostrate, horizontally growing lateral branch with nodes and short

Stoma / Stomate (pl. stomata / stomates): an aperture or pore in epidermis bounded by two guard cells which provide regulated gas exchange between the tissue and atmosphere

Stomatal apparatus / Stomatal complex: stoma together with the subsidiary cells if present

Storage leaf: succulent, fleshy leaf

Storage root: swollen, fleshy root which functions as storage and may be perennating organ

Straggler: plant with a weak stem which climbs other supports with the help of

Strigose: sharp, coarse, bent with a bulbous base

Strigose: covered with sharp, coarse, bent hairs usually with a bulbous base

Style: non-ovule bearing portion of the pistil between the stigma and the ovary

Stylopodiac style: with a stylopodium or swollen base

Sub-: a prefix signifying somewhat, slightly or rather as in sub-basal or near the base

Suberous: corky

Submerged plant: plant completely under water, may or may not be anchored to substratum

Subshrub / Shrublet: a suffrutescent perennial (the stem basally woody) or a

Subtend: to stand below and close to, as a bract underneath a flower

Subterranean / Hypogeous: below the surface of the ground

Sucker / Siirculose: an underground branch growing upwards to form an aerial shoot, roots arise from nodes below ground

Suffrutescent: semi-shrubby, lower parts of stem woody and upper herbaceous

Superior ovary: ovary above the point of attachment of other floral organs and hypanthium, if present

Superposed: opposite leaves directly above the preceding pair in the same plane, distichous with two leaves in one cycle so that the third leaf develops over the first one

Suppressed: vestigial to the degree of not being evident superficially or macroscopically, but whose presence in ancestral forms may be indicated by other features, such as anatomical

Surficial / Epigeous: upon or spread over the surface of ground

Suture: demarcation on the ovary wall indicating the marginal fusion of carpel(s); a line along which the fruit opens

Suspensor: A chain of cells produced from the proembryo that pushes the developing embryo into the endosperm for nutrition

Syconus / Syconium: multiple fruits surrounded by a hollow, fleshy, pear- shaped receptacle, as in *Ficus*

Symmetrical: with symmetrically arranged perianth parts

Sympodial / Cymose / definite branching: growth of the main stem is limited or definite, lateral branches, at each stage of branching, develop at the tip below the inactive terminal bud

Synandrous: with stamens connate by their filaments as well as by their anthers.

Syncarpous / Coenocarpous: with ovaries of adjacent carpels completely fused, styles and stigmas may or may not be fused

Synergids: Two cells associated with the egg cell in the female gametophyte, crucial for pollen tube guidance.

Syngenesious stamens/ Synantherous: with stamens coherent by their anthers.

Synonym: Different scientific names applied to the same taxon

Tap root: persistent well-developed primary root

Tapering: gradually becoming smaller or diminishing in diameter or width toward one end

Taxon (pl. Taxa): A formally recognized group of organisms at any level in a hierarchy (e.g., species, genus, family).

Taxon (pl. Taxa): Any named group of organisms at any level of the hierarchy.

Taxonomy: The science of naming, describing, and classifying organisms.

Tegmen: inner seed coat derived from inner integument and, rarely, outer layers of nucellus

Tendrill: slender twisting appendage, an organ for support

Tendrillar: tendrill-like modification of branch, adapted for climbing

Tendrillar leaves: a slender, coiled tendrill-like modification of a leaf, or leaflet

-Tendrillar petiole: tendrill-like, as in *Clematis*

Tendrillar Phyllode / Phyllodium: leaf with much reduced lamina, but with flattened lamina-like petiole or midrib

Tendrillar stipule: tendrill-like

Teniate leaves: with leaflets in three's

Tepal: a perianth member or segment; generally used for perianth parts undifferentiated into distinct sepals and petals

Terete petiole: cylindrical, e.g., Papaya (*Carica papaya*) has long, hollow, cylindrical (terete) petioles; Common Fig (*Ficus carica*) has a petiole that is described as filiform (thread-like) and terete; edible stalks (petiole) in Rhubarb (*Rheum rhabarbarum*) are roughly terete, although they may have a slight, shallow channel (subterete); some species of *Populus* and *Prunus* have stout, terete petioles.

Terete stigma: cylindrical and elongate

Terete style: cylindrical and elongate

Terminal: situated at apex or end of stem

Terminal inflorescence: at or near the tip of the branch

Terminal: At the tip or apex

Teniate: with leaflets in three's

Terrestrial: of the ground

Testa: outer hard and leathery seed coat derived from one or both integuments

Tetra-: a suffix signifying number four or 4 times, as in tetracyclic (4-whorled)

Tetradynamous stamens: with 6 stamens, 4 inner longer than the outer 2 (two)

Tetramerous: with each perianth whorl composed of four members

Thalamus / Receptacle / Torus: the end of the stem or flower axis on which some or all of the flower parts are borne

Thallus: a flat leaf-like organ without differentiation into stem and foliage

Theca (pl. thecae) / Pollen sac: sac-like cavity containing all the pollen grains of one anther lobe, formed after breakdown of the septum between locules of adjacent microspordtigia of a mature anther

Thorny: a sharp, pointed modification of branch, usually with vascular supply Tiller: a branch produced from the base of the stem, especially in grasses

Thyrse (pl. Thyrsus): a mixed inflorescence with an indeterminate central axis and many lateral cymes

Tomentose: covered with dense, woolly, matted, interwoven trichomes

Toothed: sepals are almost completely fused, only the tips are free

Torose: cylindrical with contractions at intervals

Tortuous: irregularly twisted

Total root parasite: obtains entire nutritional requirement from roots of host, e.g., *Rafflesia*

Total stem parasite: obtains entire nutritional requirement from stem of host, e.g., *Cuscuta*

Transverse / Explanate anther: anther lobes with maximum divergence of about 90° from the connective or filament

Transverse dehiscence: dehiscing at right angles to the long-axis of anther lobe

Tree: a tall woody perennial plant usually with a single trunk

Tri-: a suffix signifying number three or 3-times

Trichome: a hair or bristle; surface appendage of diverse form, structure and function represented by hair, scale, and papilla, of epidermal or

Tridynamous stamens: with six stamens in two equal groups of three

Trifoliate leaves: with three leaflets, pinnately compound with terminal petiolule longer than lateral, or palmately compound with petiolules equal in length

Trifoliate leaves: with three leaflets, pinnately compound with terminal petiolule longer than lateral, or palmately compound with petiolules equal in length

Trilocular ovary: with three locules

Trimerous: with each perianth whorl composed of three members

Trioecious: plants with staminate, pistillate or perfect flowers

Tripalmate leaves: with three orders of leaflets, each palmately compound

Tripinnate leaves: with three orders of leaflets, each pinnately compound

Triple Fusion: The fusion of one male gamete with two polar nuclei to form the primary endosperm nucleus

Tristichous: in three rows, 1/3 arrangement with three leaves in one spiral so that fourth leaf arises over the first one

Truncate Leaf: straight across, at right angles to midrib or mid-vein; the leaf end is not tapered or pointed, but rather straight-edged, as if it was cut off. It can refer to either the leaf apex (tip) or the leaf base (where it connects to the stem). Examples: Found in certain plants like the *Liriodendron tulipifera* (tulip tree), where the leaf tip is often truncate. (Term originated from the Latin *truncare* = "to maim or to cut off"); It may be applied to Truncate Apex (A blunt or squared-off tip) or Truncate base (A straight, horizontal base)

Trunk: wide lower part of stem bearing the branches, especially of a tree

Truss: A compact cluster of flowers or fruits arising from one center; evident in many *Rhododendron* spp.

Tube of perianth: the cylindrical part of the perianth

Tuber: a thick, swollen, underground, storage stem, usually not upright

Tuberculate / Yemicose: with a warty surface

Tuberoid: An alternative name for underground storage organ formed by the swelling of a root; occurs in many orchids

Tuberous root: fleshy root resembling a tuber, generally modification of adventitious root

Tubular Leaf: long and tube-like, as in onion

Tubular: cylindrical; tube-like

Tunic: a loose membranous outer skin other than epidermis; the loose membrane about a corm or bulb

Tunic: The outer covering of some bulbs and corms.

Tunicate leaf base: The dry, membranous, or papery sheath that covers bulbs or corms derived from the bases of old, dead leaves. These structures act as protective layers (tunics) for the plant, with variations ranging from delicate membranes in onions to thick, fibrous, or woody layers in gladiolus. They are essential in horticultural and taxonomic descriptions to identify bulb types. [Origin: Derived from leaf bases or specialized leaves (cataphylls) that die and remain attached, often protecting the inner bulb]

Tunicated: arranged in circles when viewed in cross-section, as in onion

Turbinate: top-shaped; obconic

Turgid / Tumid: swollen or inflated

Tussock: A dense tuft of vegetation, usually well separated from neighbouring tussocks, e.g., some grasses

Twig: a young woody stem; more precisely, the shoot of a woody plant

Type genus: In nomenclature, a single genus on which a taxonomic family is based

Type Specimen (Holotype): The single physical specimen on which the description and name of a new species are based.

Type: The specific specimen(s) to which a name is permanently attached.

Typical/Filantheros: stamen with distinct anther and filament with or without thecal appendages

Umbel: a racemose or cymose inflorescence with flowers arising from a common point forming a flat or rounded cluster

Umbellet: the secondary umbel in a compound umbel

Unarmed: without prickles/spines

Unbranched / Eramous: without branches or lateral shoots

Unciform: Hook-shaped

Uncinate: covered with trichomes having hooked tips

Uncinate: Having a hook at the apex

Underlying undifferentiated cells derived from them

Undershrub: a perennial plant having stems that are woody only in the basal parts, the upper part dying back

Undershrub: A low shrub, often with flowering branches that die off in winter.

Understory: Plant life growing beneath the forest canopy

Undulate leaf margin: wavy in a vertical plane

Undulate: Wavy and not flat

Undulate: with a series of vertical curves at right angles to central axis

Unguiculate: perianth members with limb and claws, claws well-developed

Uniseriate: consisting of one floral envelope, calyx or corolla

Uni-: a prefix meaning one or single, as in uniseriate (one-rowed)

Unicostate venation: with only one primary vein or midrib

Uniflor: Having a single flower (uniflory).

Unifoliate leaves: with a single leaflet, petiolule distinct from the petiole of the whole leaf, as in *Cercis*: a slender, coiled tendril-like modification of a leaf, or leaflet

Unifoliate leaves: with a single leaflet, petiolule distinct from the petiole of the whole leaf, as in *Cercis*

Unilobed anther: with a single lobe

Unilocular ovary: with 1-locule

Uniparous / Monochasium: with only one branch at each stage of branching

Unipinnate leaves: with one order of leaflets, pinnately compound; leaflets borne directly on the midrib

Unisexual / Imperfect: flowers with only stamens or carpels

Unitegmic: (of an ovule) Covered by a single integument

Urceolate: corolla tube urn-shaped

Urceolate: Shaped like an urn or pitcher, with a swollen middle and narrowing top; e.g., pitchers of *Sarracenia* and *Nepenthes*.

Validly Published: A name published according to ICN code rules.

Valvate aestivation: with margins of adjacent structures touching at edges only

Valve: a segment of a capsule

Valvular dehiscence: dehiscing through a pore covered by a flap or valve

Variiegated: Irregularly marked with blotches or patches of another color

Varietas: Often variety in common usage and abbreviated as var.; a taxonomic rank below that of species and between the ranks of subspecies and form various organs or tissues

Vasiform: elongated funnel-shaped

Vegetative / Leaf: an immature shoot consisting of a short stem, apical meristem and young leaves covering meristem; gives rise to a branch with leaves

Vein: a secondary conducting structure in the leaf blade, arising from midrib or petiole

Veinlet: a tertiary conducting structure in the leaf blade, arising from a vein

Velutinous: velvet-like

Venation: disposition or arrangement of veins

Ventral: adaxial; top or upper side of a surface, adjacent to axis

Verticil: a whorl

Vermiform: worm-shaped

Vernal: flowering in spring

Vernation: The arrangement of leaves in a bud

Versatile anther: dorsifixed, but attachment to the filament is limited to a single point on the connective, so that the anther swings freely on the filament

Verticillaster: a mixed inflorescence with paired and sessile dichasia at each node of an indeterminate, elongated main axis

Vesicle: a small bladdery sac or cavity filled with air or fluid

Vesicular: (of hairs) Bladder-like; vesiculous, bearing such hairs

Vestigial: Reduced in form and function from the normal or ancestral condition

Vesture /Vestiture: anything on or arising from a surface causing it to be other than glabrous

Villosulous: Minutely villous

Villous/Villose: Covered with long, soft, straight hairs; shaggy with soft hairs

Vine/Liana: an elongate, weak-stemmed, often climbing annual or perennial plant, with herbaceous or woody texture

Viscid: Sticky; coated with a thick, syrupy secretion

Vivipary: development of seedling on the parent plant; seed germinates inside fruit while still on the parent plant

Voluble: twining

Warty: A surface covered with small round protuberances, especially in fruit, leaves, twigs and bark

Watershoot: An erect, strong-growing, or epicormic shoot developing from near the base of a shrub or tree, but distinct from a sucker

Waxy / Ceraceous: covered with wax or wax-like coating

Whorled / Radiate /Verticillate: three or more leaves per node

Wing / Alate: lateral petal in a Papilionaceous corolla; appendage or projection from a perianth part

Winged petiole: with margins flattened and lamina-like; e.g., *Citrus* (Oranges, lemons), and grapefruits have a distinct, narrow, or wide green wing on the petiole connecting the leaf blade to the stem; In *Dionaea muscipula* (Venus flytrap) leaf blade is attached to a flattened, winged petiole; In *Lathyrus latifolius* (Everlasting Pea) petiole is winged, similar to the stem

Winged seed: with wing(s) or flat membranous expansion(s) of seed coat

Wood: central part of stem consisting of xylem

Woody: a tree or shrub, the shoot system remains above ground

Xerophyte: a plant of dry, arid habitat, such as the desert

Xylem: the wood elements of a vascular cylinder; water conducting complex tissue of tracheary elements, parenchyma and fibers

Zonate: Having light and dark circular bands or rings, typically on leaves or flowers

Zygomorphic: Bilaterally symmetrical; symmetrical about one vertical plane only; applies to flowers in which the perianth segments within each whorl vary in size and shape

Zygomorphic: perianth with bilateral symmetry, i.e., can be cut into equal halves in only one, vertical, oblique, or transverse plane

Zygote: A fertilized cell, the product of fusion of two gametes

Zygote: the first cell of new sporophytic generation that gives rise to the embryo

“Flowers always make people better, happier, and more helpful; they are sunshine, food, and medicine for the soul.” – Luther Burbank

APPENDIX-A

LIST OF SOME NOTABLE ENDEMIC, CRITICALLY ENDANGERED AND EXTINCT PLANTS OF INDIA

1. *Andrographis beddomei*: An herb endemic to Andhra Pradesh.
2. *Carvia callosa*: Found in the Western Ghats, known for its rare mass flowering.
3. *Diospyros sylvatica*: Found in evergreen forests from Maharashtra to Kanyakumari.
4. *Elaeocarpus blascoi*: Endemic to the Western Ghats.
5. *Hopea ponga*: Known as 'pongu', endemic to Goa and Karnataka.
6. *Kalanchoe bhidei*: Endemic to Southwest India.
7. *Mangifera andamanica*: A mango relative from the Andaman Islands.
8. *Nepenthes khasiana* (Indian Pitcher Plant): Carnivorous plant, endemic to Meghalaya.
9. *Paphiopedilum druryi*: A rare slipper orchid from the Western Ghats.
10. *Pterocarpus santalinus* (Red Sandalwood): Endemic to Andhra Pradesh.
11. *Sapria himalayana*: A root parasite found in Northeastern India.
12. *Shorea tumbergaia*: A rare tree species from the Eastern Ghats.
13. *Strobilanthes kunthiana* (Neelakurinji): Blue flowers, every 12 years, Nilgiri Hills.

According to the IUCN following are Some Extinct plants of India:

1. *Ilex gardneriana* (Aquifoliaceae)
2. *Vachellia bolei* (Fabaceae)
3. *Hopea shingkeng* (Dipterocarpaceae)
4. *Wendlandia angustifolia* (Rubiaceae)
5. *Sterculia khasiana* (Malvaceae)
6. *Corypha taliera* (Arecaceae- extinct in the wild)
7. *Euphorbia mayurnathanii* (Euphorbiaceae - extinct in the wild)

According to the IUCN following are some critically endangered plants of India:

1. *Acer oblongum* var. *membranaceum* (Aceraceae)
2. *Buchanania barberi* (Anacardiaceae)
3. *Nothopegia aureo-fulva* (Anacardiaceae)
4. *Semecarpus kathalekanensis* (Anacardiaceae)
5. *Bombax insigne* var. *polystemon* (Bombacaceae)

6. *Mesua manii* (Calophyllaceae)
7. *Garcinia cadelliana* (Clusiaceae)
8. *Ceropegia odorata* (Apocynaceae)
9. *Utleria salicifolia* (Apocynaceae)
10. *Berberis nilghiriensis* (Berberidaceae)
11. *Dipterocarpus bourdillonii* (Dipterocarpaceae)
12. *Hopea erosa* (Dipterocarpaceae)
13. *Hopea jacobi* (Dipterocarpaceae)
14. *Vateria macrocarpa* (Dipterocarpaceae)
15. *Elaeocarpus gaussonii* (Elaeocarpaceae)
16. *Pseudoglochidion anamalayanum* (Phyllanthaceae)
17. *Dialium travancoricum* (Fabaceae)
18. *Actinodaphne lanata* (Lauraceae)
19. *Cinnamomum travancoricum* (Lauraceae)
20. *Magnolia gustavii* (Magnoliaceae)
21. *Eugenia singampattiana* (Myrtaceae)
22. *Meteoromyrtus wynaadensis* (Myrtaceae)
23. *Syzygium andamanicum* (Myrtaceae)
24. *Syzygium courtallense* (Myrtaceae)
25. *Hygrophila madurensis* (Acanthaceae)
26. *Pyrenaria cherrapunjeana* (Theaceae)
27. *Rotala malabarica* (Lythraceae)
28. *Sonneratia griffithii* (Lythraceae)
29. *Ixora johnsonii* (Rubiaceae)
30. *Hildegardia populifolia* (Malvaceae)
31. *Cayratia pedata* var. *glabra* (Vitaceae)
32. *Crinum malabaricum* (Amaryllidaceae)
33. *Chlorophytum borivillianum* (Asparagaceae)
34. *Curcuma bhatii* (Zingiberaceae)
35. *Curcuma vama* (Zingiberaceae)
36. *Eriocaulon ratnagiricum* (Eriocaulaceae)
37. *Eriocaulon rouxianum* (Eriocaulaceae)
38. *Eriocaulon santapaui* (Eriocaulaceae)
39. *Eriocaulon sharmae* (Eriocaulaceae)

"Let us permit nature to have her way. She understands her business better than we do." —
Michel de Montaigne

APPENDIX-B

INDIA'S NATIONAL SYMBOLS

India, a nation rich in diversity and cultural legacy, has a number of national symbols that stand for its distinct identity. The following are some of India's most well-known national symbols.

<i>National items (symbols)</i>	<i>Particulars/Common names/Scientific names</i>	<i>Remarks</i>
<i>National Fruit</i>	Mango (Mangifera indica L.)	Known as the “king of fruits” and enjoyed across the country. It’s loved by everyone and it is one of the most popular fruits in India.
<i>National tree</i>	The banyan tree Ficus benghalensis	It is the core heritage of India. The Banyan tree is sacred in Hindu philosophy. Symbolizes longevity and immortality.
<i>National Vegetable</i>	Pumpkin Cucurbita pepo, Family: Cucurbitaceae (a trailing vine)	Pumpkins are pepo fruits. High in beta-carotene, potassium, and fiber. The nutrients enhance immunity and are low-calorie. Pumpkin skin, leaves, seeds, and the flowers are edible. Soups, roasts, and desserts employ them. Mexican cultivation dates back 7,000–9,000 years. Over 45 pumpkin varieties exist in varying colors, shapes, and sizes. They endure months in cold, dry places. They supply critical nutrients for pies, soups, and roasting, and are famous Halloween decorations.
<i>National Flower</i>	Lotus - Nelumbo nucifera Family: Nelumbonaceae (an aquatic perennial)	Revered for its Buddhist and Hindu symbolism. It possesses hydrophobic, self-cleaning leaves, thermo regulating flowers, and millennium-surviving seeds. Every single part is edible. Seeds are used in moon cakes, but rhizomes and roots are used in soups and stir-fries. Lotuses are more closely related to plane trees (Platanus) than to water lilies (Nymphaea), which often get confused with N. nucifera. Vietnam and India's national flower. In Asian cultures, it symbolizes fertility, divinity, and purity.
<i>National Aquatic Animal</i>	Ganges River Dolphin ('Susu') - Platanista	An endangered freshwater mammal. Nearly blind, it uses echolocation to travel Ganges-Brahmaputra-

<i>National items (symbols)</i>	<i>Particulars/Common names/Scientific names</i>	<i>Remarks</i>
	gangetica Family: Platanistidae	Meghna. Environmental degradation, pollution, and dam development endanger this side-swimming mammal. Symbolizes the health of the river ecosystems in India.
<i>National Bird</i>	Peacock (Indian Peafowl) - Pavo cristatus, Family: Phasianidae	Symbolizes beauty, grace, and elegance. Linnaeus described the species in 1758. The female is known as a peahen, while the male is distinguished by its huge, colorful tail covering used to perform courtship.
<i>National Game</i>	Field Hockey	Although cricket is more popular, field hockey is considered the national sport due to its historical significance.
<i>National Flag</i>	The Tiranga (Tricolor)	The flag consists of three horizontal stripes of saffron (top), white (middle), and green (bottom) with a 24-spoke navy blue Ashoka Chakra (wheel) in the center.
<i>National Emblem</i>	The State Emblem of India	Adapted from the Lion Capital of Ashoka at Sarnath, featuring four Asiatic lions standing back to back, symbolizing power, courage, pride, and confidence.
<i>National Anthem</i>	“Jana Gana Mana”	Composed by Rabindranath Tagore, it was adopted as the national anthem in 1950.
<i>National Animal</i>	Bengal Tiger (Panthera tigris tigris) Family: Felidae	Represents strength, power, and grace. A subspecies of tiger under the family Felidae. It is a top predator under the subfamily Pantherinae and genus Panthera. Found across Asia & listed as endangered (EN).
<i>National Song</i>	“Vande Mataram”	Written by Bankim Chandra Chatterjee, it was first sung in 1896 during the Indian National Congress session.
<i>National Currency</i>	Indian Rupee (₹)	The symbol (₹) distinctly represents India, merging the Devanagari 'Ra' (र) and the Roman 'R', with two parallel lines representing the national flag and equality, officially accepted in 2010.
<i>National River</i>	Ganges (Ganga)	Considered the holiest river in India and a lifeline for millions.
<i>National Calendar</i>	Saka Calendar	Adopted as the official civil calendar alongside the Gregorian calendar.

APPENDIX – C

A-Z AUTHOR ABBREVIATIONS AND FULL NAMES

A

- **"Adans."** (Michel Adanson)
- **"Arn."** ("Carl Anton von Arnott") The abbreviation "Arn." refers to George Arnott Walker-Arnott, who often collaborated with Robert Wight (Wight & Arn.) on Indian botany. He was a 19th-century botanist known for his work on flowering plants, particularly in South America.
- **"Rchb."** (Friedrich Reichenbach)- He was a German botanist and plant collector who lived from 1798 to 1879. He is known for his contributions to the Flora of Germany and Switzerland.
- **"Takht."** (Armen Takhtajan)
- **B. Lau** - Alfred B. Lau (wrote 1940-1980)
- **Berger** - Alwin Berger (1871-1931)
- **Cast.** - Alberto Castellanos (1896-1968)
- **DC.** for Alphonse de Candolle
- **Dietr.** - Albert Gottfried Dietrich (1795-1856)
- **E. Hoffmann** - Adriana E. Hoffmann
- **Gray** - Asa Gray (1810-1888)
- **Juss** Andrien de Jussieu
- **W. Hill** - Arthur William Hill (1875-1941)
- **Abraham** - Wolf-Rainer Abraham
- **Akers** - John F. Akers
- **Alexander** - Edward Johnston Alexander (1901-1985)
- **Allan D. Zimmerman** - (wrote 1991)
- **Arechavaleta (Arechav)** - José Arechavaleta (1838- 1912)
- **Arn.** (George Arnott Walker)
- **Arp** - Gerald Kench Arp
- **Audot** - N. Audot (wrote 1845)

B

- **B. J. Br.** - B. J. Brown (wrote 1985)
- **B. W. Benson** - Bernhard W. Benson (wrote 1957)
- **Backeberg (Backeb.)** - Curt Backeberg (1894- 1966)
- **Baird** - Ralph O. Baird (wrote 1931)
- **Barthlott** - Wilhelm A. Barthlott (*1946)
- **Benth.** (George Bentham)
- **Bernger** - Siegfried Bernger
- **Bertero** - Carlo Luigi Guiseppe Bertero (1789-1831)
- **Bewer.** - W. Bewerunge (wrote 1948)
- **Bigelow** - Jacob Bigelow (1787-1879)
- **Böd.** - Friedrich Bödecker (1867-1937)
- **Boissev.** - Charles Hercules Boissevain (1893-1946)
- **Borg** - John Borg (1873-1945)
- **Br. et R.** - Britton, Nathaniel L. (1859-1934) and Rose, Joseph N. (1862-1928)
- **Brandeggee** - Townshend Stith Brandeggee (1843-1925)
- **Bravo** - Helia Bravo Hollis
- **Brederoo** - A. J. Brederoo (wrote 1971)
- **Bregmann** - R. Bregmann (wrote 1986)
- **Buchheim** - Arno Fritz Günther Buchheim
- **Buining** - Albert F. H. Buining, (1902-1976)
- **Buining** - Albert Frederik Henrik Buining (1901-1980)
- **Büneker** - Rudi Werner Büneker
- **Buxbaum (Buxb.)** - Franz Buxbaum (1900-1979)
- **Burm f.** (Burman filius)
- **Byles** - Ronald Stewart Byles (wrote 1957)

C

- **C. Ehrenb.** - Carl August Ehrenberg (1801-1849)
- **C. F. Först.** - Carl Friedrich Förster (wrote 1846)
- **Cárdenas** - Hermosa Martín Cárdenas (1899-1973)
- **C. Presl** (Carl Borivoj Presl)- (Czech: Karel Bořivoj Presl; 17 February 1794 – 2 October 1852) was a Czech botanist.
- **Castañeda** - M. Castañeda (wrote 1941)
- **Castetter** - Edward Franklin Castetter (1896-1978)

- **Cav.** - Antonio José Cavanilles (1745-1804)
- **Cels** - August Louis Cels (1743-1806)
- **Cels** - Cels (family of French gardeners in the 19th century)
- **Clover** - Elzada Urseba Clover (1896-1980)
- **Colla** - Luigi Aloysius Colla (1766-1848)
- **Console** - Michelangelo Console (1812-1897)
- **Croizat** - Léon Camille Marius Croizat (1894-1982)
- **Cullm.** - Willy Cullmann (1905-1992)
- **Cullman** - Willy Cullman
- **Cutak** - Ladislaus Cutak (1908-1973)

D

- **Herzog** - D. Herzog
- **D. M. Porter** - Duncan McNair Porter (*1937)
- **D. R. Hunt** - David Richard Hunt
- **Dams** - Erich Dams (wrote 1905)
- **Däniker** - Albert Ulrich Däniker (1894-1957)
- **Daston** - J. S. Daston
- **Davidson** - Anstruther Davidson (1860-1932)
- **DC.** - Augustin Pyramus de Candolle (1778-1841)
- **De Haas** - De Haas (wrote 1940)
- **Distefano** - Concetto Distefano (wrote 1956)
- **Dodds** - Lionel G. Dodds (wrote 1937)
- **Dölz** - Bruno Dölz
- **Donald** - John Donald Donald (1923-1996)
- **Dörfl.** - Ignaz Dörfler (1866-1950)
- **Dusén** - Per Karl Hjalmar Dusén (1855-1926)

E

- **F. Anderson** - Edward Frederik Anderson
- **Morren** - Charles Jacques Édouard Morren (1833-1886)
- **E. Y. Dawson** - Elmer Yale Dawson (1918-1966)
- **Engelm.** - Georg Engelmann (1809-1884)

F

- **A. C. Weber** - Frédéric Albert Constantin Weber (1830-1903)
- **G. Buchenau** - F. G. Buchenau
- **H. Brandt** - Fred H. Brandt
- **F. M. Knuth** - Frederik Markus Knuth von Knuthenborg (1904-1970)
- **F. Rchb.** - F. Reichenbach (wrote 1896)
- **F. Ritter** - Friedrich Ritter (1898-1989)
- **F. Schmoll** - Ferdinand Schmoll (†1950)
- **Farwig** - S. Farwig (wrote 1987)
- **Fechser** - H. Fechner
- **Ferryman** - R. M. Ferryman (wrote 1991)
- **Fittkau** - Hans W. Fittkau (wrote 1971)
- **Fitz Maurice** - W. A. Fitz Maurice (wrote 1992)
- **Fleischer** - Z. Fleischer (1905-1978)
- **Fobe** - Friedrich Fobe (1941)
- **Foster** - Robert A. Foster
- **Fric** - Alberto Vojtech Fric (1882-1944)

G

- **G. D. Rowley** - Gordon Douglas Rowley
- **G. E. Linds.** - Georg Edmund Lindsay
- **G. Frank** - Gerhard R. W. Frank (wrote 1963-1978)
- **G. Lawr.** - Georg Lawrence (wrote 1841)
- **G. Lodd.** - George Loddiges (1784-1846)
- **G. Unger** - Gottfried Unger (wrote 1984)
- **Gaertn.** - Joseph Gaertner (1732-1791)
- **Galeotti** - Henri Guillaume Galeotti (1814-1858)
- **Gay** - Claude Gay (1800-1873)
- **Gerloff** - Norbert Gerloff
- **Gillies** - John Gillies (1792-1834)
- **Glaetzle** - W. Glaetzle (wrote 1983)
- **Glass** - Charles Glass
- **Gosselin** - R. Roland Gosselin (1854-1925)
- **Greene** - Edward Lee Greene (1843-1915)
- **Griseb.** - August Heinrich Rudolf Grisebach (1814-1879)

- **Gürke** - Robert Louis August Maximilian Gürke (1854-1911)

H

- **H. B. K.** - Friedrich Wilhelm Heinrich Humboldt (1769-1859)
- **H. E. Gates** - Howard Elliott Gates (1895-1957)
- **H. E. Moore** - Harold Emery Moore (1917-1980)
- **H. F. Wendl.** - Heinrich Ludolf Wendland (1792-1869)
- **H. Friedrich** - Heimo Friedrich
- **H. J. Thompson** - Henry Joseph Thompson
- **H. Jacobsen** - Hermann Johannes Heinrich Jacobsen (1898-1978)
- **H. Johnson** - H. Johnson
- **H. Karst.** - Gustav Karl Wilhelm Hermann Karsten (1817-1908)
- **Haage Jr.** - Ferdinand Haage (1859-1930)
- **Haage Sen.** - Ferdinand Haage (1830-1921)
- **Haage or F. Haage** - Frederick Adolph Haage (1796-1866)
- **Haage or W. Haage** - Walther Haage (1899-1992)
- **Havlicek** - Radim Havlicek
- **Haworth (Haw.)** - Adrian Hardy Haworth (1767-1833)
- **Heese** - Emil Heese (1862-1914)
- **Heinrich** - W. Heinrich
- **Herm** - Konrad Herm
- **Herter** - Wilhelm Guillermo Herter (1844-1958)
- **Herter** - Wilhelm Gustav Franz Herter (1884-1958)
- **Hester** - J. Pinckney Hester (wrote 1943)
- **Hewitt** - Florence Ellen Hewitt (1910-1979)
- **Heyder** - Edward Heyder (1808-1884)
- **Hildm.** - H. Hildmann
- **Hofacker** - Andreas Hofacker
- **Hook.** (William Hooker)
- **Hook.f.** (Joseph Dalton Hooker)
- **Hooker (Hook.)** - Jackson Hooker (1785-1865)
- **Hopffer** - Carl Hopffer
- **Hosseus** - Carl Kurt Hosseus (1878-1950)
- **Houghton** - Arthur Duvernoix Houghton (1870-1938)
- **Houtt.** - Maarten Houttuyn, Examples: *Dracaena umbraculifera* Houtt. It refers to a species of dragon tree, where Houttuyn first published the name in his 18th-century work,

Natuurlijke Historie. Other examples: *Ginkgo biloba* L. (Houtt.) - Houttuyn was the first to place the maidenhair tree into the genus *Ginkgo*. *Trachycarpus fortunei* (Hook.) H.Wendl. (Sometimes associated with early descriptions by Houttuyn in specific literature contexts).

- **Hutch.** - abbreviation for John Hutchinson, (1884–1972), e.g., *Kigelia talbotii* Hutch. & Dalziel

J

- **J. A. Purpus** - Joseph Anton Purpus (1860-1932)
- **J. F. Macbr.** - James Francis Macbride (1892-1976)
- **J. Forbes** - James Forbes (1773-1861)
- **J. G. Ortega** - Jesús Gonzales Ortega (1876-1936)
- **J. M. Coulter** - John Merle Coulter (1851-1928)
- **J. Meyrán** - Jorge Meyrán
- **Jacobi** - Georg Albano von Jacobi (1805-1874)
- **Jahn** - E. Jahn
- **Jajó** - Bedrich Jajó (wrote 1947)
- **Juss.** - A.L. de Jussieu; e.g., Caryophyllaceae Juss. means that the family name Caryophyllaceae was published by Antoine Laurent de Jussieu in 1789 in his work *Genera Plantarum*.

K

- **K. Brandege** - Mary Katherine Brandege (1844-1920)
- **K. Friedrich** - Karl Friedrich (wrote 1965, 1974)
- **K. Kayser** - Konrad Kayser (wrote 1932)
- **K. Wagner** - Klaus Wagner (1935-1987)
- **Karw.** - Wilhelm Friedrich von Karwinsky von Karwin (1780-1855)
- **Kattermann** - Fred Kattermann (wrote 1994)
- **Kesselr.** - F. W. Kesselring (1876-1966)
- **Kimnach** - Myron William Kimnach
- **Kladiwa** - Leo Kladiwa (1920-1988)
- **Klein** - Klein (wrote 1859)
- **Knize** - Karel Knize
- **Kolarik** - Jiri Kolarik
- **Königs** - Günter Königs
- **Krähenbühl** - Felix Krähenbühl

- **Krahn** - Wolfgang Krahn
- **Krainz** - Hans Krainz (1906-1980)
- **Kreuzinger (Kreuz.)** - Kurt G. Kreuzinger (1905-1989)
- **Kunth** - Karl Sigismund Kunth (1788-1850)
- **Kuntze** - Carl Ernst Eduard Otto Kuntze (1843-1907)
- **Kupper** - Walter Kupper (1874-1953)

L

- **L.** - Carl von Linné or Carolus Linnaeus (1707-1778); Example: *Mangifera indica* L.; *Areca catechu* L.; *Triticum aestivum* L.; *Panicum virgatum* L.; *Quercus alba* L.
- **L. Bremer** - L. Bremer (wrote 1977)
- **L. D. Benson** - Layman David Benson
- **L. Diers** - L. Diers (wrote 1977 and 1980)
- **L.f.** Carl Linnaeus the Younger (1741–1783) described several plant species. L.f. stands for "Linnaeus the son". His legitimate writings differ from his father, Carl Linnaeus (commonly listed as "L."). Example: *Guaiacum afrum* L.f.; *Cucumis africanus* L.f.; *Strychnos potatorum* L.f.; *Tectona grandis* L.f.; *Dalbergia lanceolaria* L.f.; *Ficus hispida* L.f.
- **Labouret (Labour.)** - J. Labouret (wrote 1853-1858)
- **Lag.** - Mariano Lagasca y Segura (1776-1839)
- **Lagerh.** - Nils Gustav Lagerheim (1860-1926)
- **Lahman** - Berta Marion Lahman
- **Lam.-** Jean-Baptiste Lamarck (1744–1829), a French naturalist and botanist who published several works on French flora, including the *Encyclopédie méthodique. Botanique*. Example: *Polycarpaea corymbosa* (L.) Lam.
- **Lam.** - Jean Baptiste Antoine Pierre de Monnet de Lamarck (1744-1829)
- **Lehmann (Lehm.)** - Johann Georg Christian Lehmann (1792-1860)
- **Lemaire (Lem.)** - Antoine Charles Lemaire (1801-1871)
- **Lembcke** - Hans Lembcke
- **Liebner** - C. Liebner (wrote 1895)
- **Lindl.** - John Lindley (1799-1865), Examples: *Zephyranthes rosea* Lindl.; *Pycnocycla glauca* Lindl.; *Eriocycla* Lindl. (A genus of plants in the family Apiaceae)
- **Link** - Johann Heinrich Friedrich Link (1767-1851)
- **Lisal** - Kamil Lisal
- **Loefgr.** - Johan Alberto Constantin Loefgren (1854-1918)
- **Looser** - Gualtiero Looser (1898-1982)

- **Luetzelb.** - Philipp von Luetzelburg (1880-1948), Examples: *Melocactus bahiensis* (Britton & Rose) Luetzelb.; *Cereus albicaulis* (Britton & Rose) Luetzelb.; *Isoetes luetzelburgii* U.Weber in Luetzelb.

M

- **Marchesi** - Eduardo Marchesi
- **Marn.-Lap.** - Julien Marnier-Lapostolle (1902-1976)
- **Mart.** - Carl Friedrich Philipp von Martius (1794-1868), widely known for his work on Brazilian flora. Examples: *Eichhornia crassipes* (Mart.) Solms; *Xylopia aromatica* (Lam.) Mart.; *Schubertia multiflora* Mart.; *Ilex diuretica* Mart. ex Reissek; *Gomphrena celosioides* Mart.
- **Merr.** - American botanist Elmer Drew Merrill (1876–1956), who specialized in the flora of the Asia-Pacific region. Example: *Lanea coromandelica* (Houtt.) Merr.; *Glycine max* (L.) Merr. (Soybean), *Fissistigma oldhamii* (Hemsl.) Merr.; *Acanthopanax trifoliatum* (L.) Merr.; *Clerodendrum quadriloculare* (Blanco) Merr.; *Brucea javanica* (L.) Merr.
- **Meyen** - Franz Julius Ferdinand Meyen (1804-1840)
- **Miq.** - Friedrich Anton Wilhelm Miquel (1811-1871), e.g., *Ficus arnottiana* (Miq.) Miq.; *Tetrastigma rafflesiae* (Miq.) Planch.; *Mimusops coriacea* (A. DC.) Miq.; *Gonostegia hirta* (Blume) Miq.; *Canarium patentinervium* Miq.
- **Monville (Monv.)** - M. Chevalier de Monville
- **Moran** - Reid Venable Moran (*1916)
- **Muehlenpf.** - Fr. Muehlenpfordt (wrote 1849-1891)
- **Müll.** - Johannes Müller Argoviensis, a 19th-century botanist specializing in Euphorbiaceae.
Example: *Trigonostemon semperflorens* (Roxb.) Müll. Arg.
Explanation: This indicates that the species was validly published or modified by Johannes Müller Argoviensis.
Note: *Phyllanthus* L. emend. Müll.Arg. (Indicates Müller modified the description of the genus)
- **Mill.**, Philip Miller (1691–1771), a renowned Scottish botanist and author of *The Gardeners Dictionary* published in 1754. Examples: *Pinus rigida* Mill.; *Foeniculum vulgare* Mill. (Common Fennel), *Datura innoxia* Mill. (Sacred Datura); *Opuntia ficus-indica* (L.) Mill. (Barbary Fig), *Helianthemum nummularium* (L.) Mill. (Common Rock-rose), *Senna alexandrina* Mill. (Alexandrian Senna), *Abies balsamea* (L.) Mill.;
Parenthesis (): If a name appears as (L.) Mill., it means Linnaeus (L.) first described the species, but later Miller (Mill.) transferred it to a different genus or changed its rank.

N

- **N. E. Br.** - Nicholas Edward Brown (1849-1934)
- **N. P. Taylor** - Nigel Paul Taylor, a British botanist known for his work on cacti (Cactaceae). Examples: *Cereus kroenleinii* N. P. Taylor; *Cipocereus laniflorus* N. P. Taylor & Zappi; *Skimmia anquetilia* N.P. Taylor & Airy Shaw
- **Nicolai** - Ernst August Nicolai (1800-1874)
- **Nutt.** - Thomas Nuttall (1786-1859); "Nutt." is used extensively for North American plants described in the 19th century. Example: *Calyptridium monandrum* Nutt.; *Achras zapotilla* (Jacq.) Nutt.; *Actaea arguta* Nutt.; *Euploca convolvulacea* Nutt.

O

- **Oehme** - Hanns Oehme
- **Oosten** - M. W. B. van Oosten (wrote 1840)
- **Orcutt** - Charles Russel Orcutt (1864-1929)
- **Osten** - Cornelius Osten
- **Otto** - Christoph Friedrich Otto (1783-1856)

P

- **P. J. Braun** - German botanist Pierre Josef Braun, specialist in Cactaceae. Examples: *Melocactus lanssensianus* P. J. Braun; *Pilosocereus goianus* P.J.Braun & Esteves; *Pilosocereus flexibilispinus* P.J.Braun & Esteves; *Melocactus uebelmannii* P.J.Braun; *Mammillaria duwei* Rogozinski & P.J.Braun
- **P. Thiele** - Peter Thiele (wrote 1963)
- **Palmer** - Edward Palmer (1831-1911)
- **Papousek** - K. Papousek
- **Parm.** - Antoine-Auguste Parmentier (1737-1813)
- **Parry** - Charles Christopher Parry (1823-1890)
- **Patoni** - Charles Patoni (wrote 1910)
- **Pazout** - Frantisek Pazout
- **Pers.** C. H. Persoon; Example: *Cynodon dactylon* (L.) Pers. (Bermuda grass)
- **Pfeiff.** - Louis Ludwig Karl Georg Pfeiffer (1805-1877)
- **Pfeiffer** - Louis Pfeiffer (1805-1878)
- **Phil.** - Rudolf Amandus Philippi (1808-1904)
- **Pilbeam** - John Pilbeam
- **Porto** - Paulo Campos Porto

- **Poselg.** - Heinrich Poselger (1818-1883)
- **Prestlé** -Karl Heinz Prestlé

Q

- **Quehl** - Leopold Quehl (1849 - 1922), Example: *Gymnocalycium quehlianum* (F.Haage ex H.Quehl) Vaupel ex Hosseus; *Explanation*: Leopold Quehl is referred to in this reference as H. Quehl, Ferdinand Friedrich Haage as F. Haage, Friedrich Karl Johann Vaupel as Vaupel, and Carl Curt Hosseus as Hosseus. The "ex" means that while F. Hage suggested the name, it wasn't officially published until H. Quehl did.

R

- **R. Br.** Robert Brown, early 19th-century Australian flora researcher. Example: *Alstonia scholaris* (L.) R. Br.; Here, the "(L.)" indicates it was originally described by Linnaeus, and R. Br. indicates Robert Brown reclassified it. Other Examples: *Ipomoea pes-caprae* (L.) R. Br.; *Brachychiton populneus* (Schott & Endl.) R. Br.; *Leucas biflora* (Vahl) R. Br.
- **R. E. Fries** - Klas Robert Elias Fries (1876-1966)
- **R. Kiesling** - Roberto Kiesling
- **R. T. Craig** - Robert T. Craig (wrote 1945)
- **Raf.** - Constantine Samuel Rafinesque (1783-1840)
- **Rauh** - Werner Rauh
- **Rausch** - Walter Rausch
- **Rauschert** - Stephan Rauschert (1931-1986)
- **Rebut** - P. Rebut (May 14th, 1827-1898)
- **Redecker** - G. Redecker (1902-1975)
- **Regel** - Eduard August von Regel (1815-1892)
- **Rémy** - Esprit Alexandre Rémy (1826-1893)
- **Repp.** - Werner Reppenhagen
- **Riccob.** - Vincenzo Riccobono (1861-1943)
- **Ríha** - Jan Ríha
- **Rodr.** - João Barbosa Rodrigues, a renowned Brazilian botanist specializing in palms (Arecaceae) in the late 19th century. Examples: *Geonoma baculifera* (Poit.) Kunth var. *espíritu-santensis* Rodr.; *Explanation*: *Geonoma baculifera* was first described by Poiteau (as *Gynestum*), then placed in *Geonoma* by Kunth, and finally, the variety *espíritu-santensis* was identified by Brazilian botanist Barbosa Rodrigues.
- **Rogoz.** - H. Rogozinski (wrote 1985)
- **Rose** - Joseph Nelson Rose (1862-1928)

- **Roxb.** (William Roxburgh), Examples: *Boswellia serrata* Roxb.; *Indigofera coerulea* Roxb.; *Cenchrus biflorus* Roxb.; *Ailanthus excelsa* Roxb. ; *Callicarpa arborea* Roxb.
- **Royle.** (John Royle) He was a Scottish botanist and medical practitioner who made significant contributions to the field of botany, particularly in the Himalayas. Examples: *Gentiana kurroo* Royle, *Cerasus cornuta* Wall. ex Royle, *Polygonatum cirrhifolium* (Wall.) Royle
- **Rümppler** - Karl Theodor Rümpler (1817-1891)
- **Runge** - C. Runge (wrote 1889)

S

- **S. Watson** - Sereno Watson (1826-1892), e.g., *Juglans californica* S.Watson, *Drymaria anomala* S.Watson, *Abutilon malacum* S.Watson, *Amaranthus powellii* S.Watson, *Acacia palmeri* S.Watson
- **Saff.** - William Edwin Safford (1859-1926)
- **Salisb.** - Richard Anthony Salisbury (1761-1829)
- **Salm-Dyck** - Joseph Franz Maria Anton Hubert Ignatz Fürst zu Salm-Reifferscheid-Dyck (1773-1861)
- **Sanchez-Mej.** - Hernando Sanchez-Mejorado (1926-1988)
- **Sand.** - Henry Frederick Conrad Sander (1847-1920)
- **Schäfer** - Gerhardt Schäfer
- **Scheer** - Friedrich Scheer (1792-1868)
- **Scheidw.** - Michael Joseph François Scheidweiler (1799-1861)
- **Scheinvar** - Leia Scheinvar (wrote 1974)
- **Schelle** - Ernst Schelle (1864-1945)
- **Schlosser** - Hugo Selmar Schlosser
- **Schott** - Heinrich Wilhelm Schott (1794-1865)
- **Schumann (K. Schum.)** - Karl Moritz Schumann (1851-1904)
- **Schütz** - Bohumil Schütz (1903-1993)
- **Scop.** (G. A. Scopoli)
- **Sencke** - Ferdinand Sencke (wrote 1830-1866)
- **Shurly** - Ernest William Shurly (1888-1963)
- **Slaba** - Rudolf Slaba (wrote 1985)
- **Söhrens** - Johannes Söhrens
- **Solms** - Hermann Maximilian Carl Ludwig Friedrich zu Solms-Laubach (1842-1915)
- **Spegazzini (Speg.)** - Carlos Luigi Spegazzini (1858-1926)
- **Sprengel (Spreng.)** - Curt Polycarp Joachim Sprengel (1766-1833)

- **Stearn** - William Thomas Stearn
- **Steeg** - M. G. van der Steeg (wrote 1960)
- **Stein** - Friedrich Stein (1818–1885), a German botanist/microbiologist who, among other works, described various microorganisms and algae in his publication *Organismus der Infusionsthier.*, e.g., *Scrippsiella trochoidea* (F. Stein) A.R. Loeb. Explanation: This is a dinoflagellate (treated as algae), originally described by Stein as *Glenodinium trochoideum* and later reclassified. Other Example: *Volvox carteri* F. Stein;
- **Steud.** - Ernst Gottlieb von Steudel (1783-1856), a German physician and botanist who published many plant names, mainly in his work *Synopsis Plantarum Glumacearum*. Examples: *Abildgaardia brevifolia* Steud.; *Acacia brownii* Steud.; *Geranium arnottianum* Steud.; *Chenopodium loureiroi* Steud.;
- **Swales** - G. J. Swales (wrote 1978)
- **Sweet** - Robert Sweet (1783-1835); a British horticulturist/botanist who transferred the species to the genus *Camellia* in his work *Hortus britannicus* (1827). Example: *Camellia sinensis* (L.) Sweet (Tea plant)

T

- **T. Macdoug.** - Thomas Baillie MacDougall (1895-1973)
- **T. Moore** - Thomas Moore (1821-1887)
- **Terschek** - Terschek (wrote 1840)
- **Theunissen** - Sjef Theunissen
- **Thomson.** (Thomas Thomson) - known for his contributions to plant Taxonomy. For instance, if a plant species is named *Species thomsonii*, "Thomson" following the scientific name indicates that Thomas Thomson described or first published the name for that species. Example: *Tinospora crispa* (L.) Hook. f. & Thomson; this citation indicates that the species was originally described by Linnaeus (L.) and later reclassified in the genus *Tinospora* by Hook. f. and Thomson. Other examples: *Impatiens glauca* Hook. f. & Thomson; *Magnolia cathcartii* (Hook.f. & Thomson) Noot.
- **Tiegel** - E. Tiegel
- **Tjaden** - William Louis Tjaden
- **Torr.** - John Torrey (1796-1873)
- **Toumey** - James William Toumey (1865-1932)
- **Tourne.** Joseph Pitton de Tournefort Examples: *Lupinus Tourn. ex L.* (Lupines/Lupins); *Heliotropium Tourn. ex L.* (Heliotrope); Note: In *Lupinus* [Tourn.] L., square brackets indicate that the name was published before 1753.
- **Turpin** - Pierre Jean François Turpin (1775-1840)

U

- **U. Köhler** - Udo Köhler (1911-1983), Published between 1883 and 1914, Köhler's therapeutic Plants (German: Köhler's Medizinal-Pflanzen in naturgetreuen Abbildungen mit kurz erläuterndem Texte) is a well-known three-volume German herbal that includes thorough descriptions and drawings of medicinal plants.

V

- **V. John** - Volker John
- **Van Vliet** - Dirk Jan van Vliet (wrote 1699)
- **Vaupel** - Friedrich Karl Johann Vaupel (1876-1927)
- **Vell.** - José Mariano da Conceição Vellozo (1742-1811)
- **Voll** - Otto Voll (1884-1958)

W

- **W. H. Earle** - W. Humbert Earle (1906-1984)
- **W. O. Moore** - Winifred Olivia Moore
- **W. T. Marshall** - William Taylor Marshall (1886-1957)
- **Wall.** - Nathaniel Wallich, e.g., *Cerasus cornuta* Wall. ex Royle, Explanation: In this example, Wall. is the abbreviated author citation for Nathaniel Wallich, a botanist who proposed the name, while the name was validly published by J.F. Royle (often written as *Cerasus cornuta* Wall. ex Royle).
- **Walp.** - Wilhelm Gerhard Walpers (1816-1853), e.g., *Vigna unguiculata* (L.) Walp., *Clerodendrum colebrookianum* Walp. (An edible, medicinal plant), *Pavonia procumbens* (Wight & Arn.) Walp., *Ochna serrulata* (Hochst.) Walp., *Lepidium meyenii* Walp. (Maca)
- **Walton** - Frederick Arthur Walton (1853-1922), e.g., *Isoetes tuckermanii* (a plant species used in studies by Walton A. Green).
- **Weidlich** - E. Weidlich (wrote 1928)
- **Weing.** - Wilhelm Weingart (1856-1936)
- **Werdermann (Werderm.)** - Erich Werdermann (1892-1959)
- **Wessner** - Wilhelm Wessner (1904-1983)
- **Wiggins** - Ira Loren Wiggins (1899-1987)
- **Willd.** - Carl Ludwig von Willdenow (1765-1812), Examples: *Euphorbia pulcherrima* Willd. ex Klotzsch.; *Juncus balticus* Willd.; *Salix pentandra* L. var. *herbacea* Willd.

Y

- **Y. Itô (Ito)** - Yoshi Itô , chiefly associated with Cactus Taxonomy, e.g., *Sericocactus* Y.Itô; *Neotanahashia* Y.Itô

Z

- **Zappi** - Daniela Zappi (wrote 1991), e.g., *Genipa infundibuliformis* Zappi & Semir , *Pilosocereus novaromanus* P.J.Braun & Esteves ex F.O.Pereira & Zappi; Several species of *Tacinga*, including *Tacinga braunii* and *Tacinga saxatilis* subsp. *estesvesii*, were covered in Taylor & Zappi's book Cacti of Eastern Brazil.
- **Zucc.** - Joseph Gerhard Zuccarini (1797-1848), Examples: *Taxus wallichiana* Zucc. (Himalayan Yew); *Hechtia glomerata* Zucc.; *Mitracarpus scaber* Zucc.; *Leucaena trichandra* (Zucc.) Urb.; *Lindera glauca* (Siebold & Zucc.) Blume; *Phyllostachys* Sieb. & Zucc. (Genus)

Meaning of "Del." in a scientific name: In "*Acacia nilotica* (L.) Del. ssp. *nilotica*" "Del." means an abbreviation that stands for "delimited by" or "delimited". It indicates that the author of the plant name is the person or group that first defined or described the taxon, usually in a published text or document.

"The environment is where we all meet; where we all have a mutual interest; it is the one thing all of us share." – Lady Bird Johnson

APPENDIX - D

SOME OBJECTIVE QUESTIONS WITH ANSWERS

Q. What governs the nomenclature of cultivated plants?

Ans- ICNCP [International Code of nomenclature for Cultivated Plants.]

Q. What ICNCP stands for?

Ans-International Code of nomenclature for Cultivated Plants.

Q. What CITES stands for?

Ans-The Convention on International Trade in Endangered species. It regulates the shipment of several plant groups viz, Orchidaceae, Cactaceae, Cycadaceae, Cyatheaceae, Nepenthaceae, Sarraceniaceae & Zamiaceae. The plants listed in CITES need proper authorization before its collection.

Q. What IAPT stands for? Ans: International Association of Plant Taxonomy.

Q. What is SEPASAL?

Ans: It is one of the several database operated by the royal botanical garden, Kew & represent "The survey of economic Plants for arid & Semoarid lands".

Q. Can you mention an example where the family name has been retained in spite of the name of the type genus being changed?

Ans: The Ebenaceae bears name Ebenus Kuntze (1891) not Linnaeus 1753 as its stem. Kuntze's genus is now called Malba but its parent family retains the name Ebenaceae even though Ebenus L. is the name used for a genus of the pea family.

Q. When did the last international botanical congress held?

Ans: The last international botanical congress i.e., The 20th International Botanical Congress (XX IBC) took place from July 21–27, 2024, in Madrid, Spain.

Q. When will be the next international botanical congress held?

Ans: Cape Town will host the 21st International Botanical Congress (IBC) in 2029.

Q: Where is the headquarters of the ICN? Ans: Geneva, Switzerland.

Q: What is the primary purpose of the ICN?

Ans: To represent nursing worldwide, advance the profession, and influence health policy.

Q. What is Palynology, and how is it used in Taxonomy?

Ans: Palynology is the study of pollen grains. Palynological data (pollen shape, size, aperture, ornamentation) are used to determine relationships and create pollen keys.

Q. When did the modqueern system of botanical nomenclature begin?

Ans: The starting point for most plant nomenclature is May 1, 1753, which is the date of publication of Linnaeus's Species Plantarum.

Q. What is meant by "Valid Publication" of a name?

Ans: A name is validly published when it meets all criteria set by the ICN:

It is effectively published (distributed in printed or electronic material).

It is accompanied by a description or diagnosis of the taxon.

It includes a designation of a nomenclatural type (e.g., holotype).

It complies with naming rules (e.g., valid form, rank indication).

Q. What is the Principle of Priority in plant Taxonomy?

Ans: The principle of priority dictates that the earliest legitimately published name for a taxon is the correct one. If a species has multiple names, the oldest validly published name takes precedence.

Q. What is a "nom. nud." (nomen nudum)?

Ans: Nom. nud. stands for nomen nudum (naked name) which refers to a name published without a proper description/diagnosis, making it invalidly published.

Q. What are the authorized languages for validating a new plant name?

Ans: Since January 1, 2012, new plant names can be described or diagnosed in Latin or English.

Q. What is the difference between a Lectotype and a Neotype?

<i>Feature</i>	<i>Lectotype</i>	<i>Neotype</i>
Origin	Selected from original material (syntypes)	Selected from new/different material
When to designate	When no holotype was named or it's lost	When all original materials are lost/destroyed
Original author	Relates to the original study	Used as a last resort
Priority	Higher	Lower

Q. What does the citation "*Mangifera indica* L." mean?

Ans: It implies Carl Linnaeus first validly described *Mangifera indica*.

Q. What is the difference between a synonym and a homonym?

<i>Feature</i>	<i>Synonym</i>	<i>Homonym</i>
Definition	Multiple different names that refer to the same taxonomic group (taxon)	Identical names for two or more different taxonomic groups (taxa)
Spelling	Different spelling	Identical spelling
Taxon(s)	One taxon, multiple names	Multiple taxa, one name
Usage in ICN	One name is accepted (valid), others are synonyms (excluded)	The senior homonym is valid; junior homonyms are rejected
Types	Homotypic (same type) or Heterotypic (different types)	Primary (different combinations) or Secondary (same genus)
Example	<i>Rhus laurina</i> is a synonym of <i>Malosma laurina</i>	<i>Generic Homonym (Genus level): Tapeinanthus Boiss. ex Benth. (1848) is a later homonym of Tapeinanthus Herb. (1837); Specific Homonyms (Species level) : Zingiber truncatum S. Q. Tong (1987) is a later homonym of Z. truncatum Stokes (1812).</i>

Q. What is a "basionym"?

Ans: A basionym is the original, validly published name upon which a new combination (a new name for an existing species in a new genus) is based.

Q. Why can't DNA be a 'type' specimen?

Ans: According to the ICN, a type must be a physical, preserved specimen (usually a herbarium sheet).

Q. What are the standard suffixes for plant family and order names?

Ans: Family & order names usually end in -aceae (e.g., Rosaceae), and -ales (e.g., Rosales) respectively.

Q. What is the fundamental purpose of author citation?

Ans: It ensures the accuracy of scientific names, helps trace the historical origin of a plant description, and clarifies taxonomic changes such as transfers or revisions.

Q. How is a single author citation written?

Ans: The name of the author follows the scientific name, usually in abbreviated form (*Solanum nigrum* L. - "L." stands for Carl Linnaeus).

Q. What do the abbreviations "et" and "&" mean?

Ans: They are used to link two or more authors who jointly published a new species or name.

Example: *Delphinium viscosum* Hook. f. et Thomson (or Hook. f. & Thomson).

Q. What does "(L.)" mean in *Cynodon dactylon* (L.) Pers.?

Ans: The parenthesis indicates that the species was originally described by Linnaeus ("L."), but was later transferred to another genus (in this case, *Cynodon*) by Persoon. The original author is placed inside brackets, and the re-arranging author outside.

Q. When is "ex" used in an author citation?

Ans: "ex" is used when an earlier author proposed a name but did not validly publish it, and a later author subsequently validated it. e.g., *Cerasus cornuta* Wall. ex Royle. Wallich proposed the name, but Royle validly published it.

Q. What does "in" mean in *Carex kashmirensis* Clarke in Hook. f.?

Ans: "in" is used when one author publishes a new species within the work of another author. Clarke described the species, but it was published in a book authored by Hooker.

Q. What is a "basionym" and how is it cited?

Ans: A basionym is the original name of a taxon that is retained when the taxon is transferred to a different genus or its rank is changed. The author of the basionym is placed in parentheses. e.g., *Panicum dactylon* L. is the basionym for *Cynodon dactylon* (L.) Pers..

Q. What is the meaning of "emend."?

Ans: "emend." (emendavit) indicates that a second author has amended (corrected/modified) the circumscription of a taxon, but the original author remains valid. e.g., *Phyllanthus* L. emend. Müll. Arg..

Q. What does it mean when a name is in square brackets, e.g., *Lupinus* [Tourn.] L.?

Ans: Square brackets indicate a pre-starting point author. Since botanical nomenclature officially begins with Linnaeus' *Species Plantarum* in 1753, earlier authors (like Tournefort) are placed in brackets.

Q. How are multiple authors (more than two) cited?

Ans: The citation is restricted to the first author followed by "& al." (or "et al."). e.g., *Lapeirousia erythrantha* var. *welwitschii* (Baker) Geerinck & al..

Q. What is an autonym and how is it cited?

Ans: An autonym is an automatically created name for the typical subspecies or variety (e.g., *Acacia nilotica* ssp. *nilotica*). It does not bear an author's name.

Q. Are author names always written in full?

Ans: No, it is standard practice to abbreviate author names based on recognized lists, such as Brummitt & Powell's Authors of Plant Names (1992).

Q. What is the foundation for the classification proposed by Bentham & Hooker?

Ans: In contrast to superficial or artificial, single-character attributes, this Natural System of Classification is founded on a thorough, meticulous, and extensive examination of natural, morphological, and structural characteristics (such as habit, leaves, flowers, fruit, and seed structure).

Q. How were the Dicotyledons divided in Bentham & Hooker's System?

Ans: Three subclasses were created from the class Dicotyledonae: Polypetalae (Petals are free), Gamopetalae (Fused petals) & Monochlamydeae (Perianth absent or simple, not differentiation into calyx and corolla).

Q. Why is gymnosperm placement a major problem in Bentham & Hooker's System?

Ans: Gymnosperms are comparatively primitive plants with naked seeds that ought to have existed before the Dicotyledons. Rather, Bentham and Hooker placed them in the middle of the two main Angiosperm classes (Monocots and Dicots).

Q. Does Bentham & Hooker's System take evolution into account?

Ans: No, the Bentham and Hooker's System was put forward prior to Darwin's theory of evolution becoming widely accepted in 1859. Instead of descent, it is founded on morphological similarities and natural affinities.

Q. What is Bentham & Hooker's System's current status?

Ans: The Bentham and Hooker method is still widely used, particularly in India, since it is useful for identifying plants in the field and in the lab, even though it has been supplanted by phylogenetic systems (e.g., Engler & Prantl and contemporary APG) that take molecular and evolutionary data into account.

Q. Which family is considered to be the most archaic by Bentham & Hooker?

Ans: The Ranunculaceae family, which is ranked first in the Dicotyledonae (Series: Thalamiflorae, Order: Ranales), is thought to be the most archaic.

Q. What forms the foundation of Engler & Prantl's System?

Ans: It is a phylogenetic system that ranks species from simple to advanced and is founded on the idea of evolutionary development. They viewed insect-pollinated, bisexual, dichlamydeous flowers as advanced, and wind-pollinated, unisexual, achemydeous (without perianth) flowers as primitive.

Q. In which group are gymnosperms classified in Engler & Prantl's System?

Ans: As a result of their evolution from naked seeds to angiosperms, gymnosperms are ranked before angiosperms.

Q. What role does the Amentiferae group play in Engler & Prantl's system?

Ans: They considered Amentiferae (catkin bearers/wind-pollinated plants) the most primitive dicots. Modern study shows they are reduced forms, not primitive.

Q. Where does Ranales fit within Engler & Prantl's System?

Ans: Engler positioned Ranales (like *Magnolia*) later in the Archichlamydeae after the amentiferous, simpler-flowered groupings, in contrast to other systems that place them at the beginning as primitive.

Q. Why is Engler & Prantl's System "not strictly phylogenetic" by modern standards?

Ans: Although they were meant to be evolutionary, they mistakenly thought that bare, simple flowers (like those in the Amentiferae) were primitive, even though they were really reduced forms. They also thought that unisexual flowers gave rise to bisexual ones, a theory that is frequently refuted by contemporary data.

Q. Write the full form of APG. Ans: Angiosperm Phylogeny Group.

Q. What is the primary objective of the APG system?

Ans: To create a consensus classification of flowering plants (angiosperms) that reflect evolutionary relationships (phylogeny) based on molecular data.

Q. How many different APG system versions are there now?

Ans: Four versions: APG I (1998), APG II (2003), APG III (2009), & APG IV (2016).

Q. How does a cladistic classification of Angiosperms subclass Magnoliidae make sense?

Ans: Based on molecular phylogenetics (DNA sequencing), the cladistic classification of angiosperms that treats the Magnoliidae (or magnoliids) as a separate group—often positioned as a major basal lineage—shows that these plants are a sister group to them rather than true monocots or eudicots. This classification's fundamental reasoning centers on common derived traits (synapomorphies), evolutionary branching order, and molecular data that challenge traditional assumptions regarding primitive angiosperms.

Q. APG uses which genes for molecular research? Ans: rbcL, atpB, & 18S rDNA.

Q. According to APG IV, which group of angiosperms first diverged from the common ancestor?

Ans: Amborellales (part of the ANA grade: Amborellales, Nymphaeales, Austrobaileyales).

Q. Why Dicots became Eudicots?

Ans: Since molecular research proved that traditional "dicots" did not have a single common ancestor, the Angiosperm Phylogeny Group (APG) classified them as Eudicots (or "true dicots"). Most plants comprise a separate, evolved clade, however many "dicots" (like magnolias) are more primitive than monocots, which form a single, cohesive evolutionary branch.

Q. Why have the conventional "dicots" been abandoned as a taxonomic group?

Answer: Molecular studies showed that traditional dicots are not a monophyletic group (do not share a single common ancestor), whereas monocots are.

Q. What does APG utilize to define higher-level groups than order or family?

Ans: Clades (e.g., Eudicots, Rosids, Asterids).

Q. In the APG system, what is a "bracketed family"?

Ans: A family that can be treated as a separate entity or merged into another, larger family (a practice mostly discontinued after APG II).

Q. Is it true that monocots are recognized as a monophyletic group by APG IV? Ans: True.

Q. In APG III, which family was combined to form the asparagus family (Asparagaceae)?

Ans: The Agavaceae and Hyacinthaceae families.

Q. What is the current state of the Boraginales order in APG IV?

Ans: It was recognized as a new/separated order, contributing to the 64 total orders in APG IV.

Q. What is the main drawback with the APG classification?

Ans: The dependence on, and changing of, family placements based on new data, and the use of informal, non-ICBN compliant names above the ordinal level.

Q. Does APG use molecular information or morphology to categorize plants?

Ans: Principally molecular, but it aims to harmonize these findings with morphology.

Q. Which classification scheme does not use the conventional dicot/monocot divisions to categorize angiosperms? Ans: The APG system.

Q. What is the primary distinction between APG and Bentham-Hooker?

Ans: Bentham-Hooker is a natural system based on morphology, whereas APG is a phylogenetic system based on molecular data.

Q. What is a "Vasculum" and its use?

Ans: It is a conventional, usually cylindrical, lidded metal box that botanists and plant collectors use to carry and store newly collected plant specimens in the field. It ensures that plants remain fresh for a few hours by keeping them cold, damp, and safe from crushing without excessive evaporation.

Q. What makes herbarium sheets a "quick referral system" in taxonomic studies?

Ans: They give a permanent, accessible record of a plant species' morphology, allowing fast Identification, Taxonomic comparison, and geographical distribution without visiting the plant's native environment.

Q: What are the four essential components of a good herbarium specimen?

Ans: (a) Properly preserved (dried/pressed) specimen, (b) Accurate & detailed label information, (c) Systematic organization, (d) Secure mounting on the sheet.

Q: How do digital or "virtual" herbaria improve upon traditional physical herbarium sheets?

Ans: Virtual herbaria provide high-resolution, accessible digital images and searchable, transcribed data (metadata) that can be accessed globally, reducing the need to handle fragile physical specimens and facilitating AI-based research.

Q: Herbarium sheet labels normally contain what information and where?

A: The label is placed on the lower right-hand corner and includes the scientific name, family, local name, locality of collection, date of collection, habitat description, and the name of the collector.

Q: What information is generally NOT included on a standard herbarium label?

Ans: The height of the plant, its lifespan (annual/perennial), or the specific soil types are often not recorded, although they can be inferred from the habit.

Q: A student calls a herbarium sheet a "living library." Examine this claim.

Ans: Metaphorically right. The "library" contains botanical data. A "dry garden" of dead, dried, and preserved samples serves as a repository for historical and contemporary study.

Q. Why could two herbarium sheets of the same plant species look different?

Ans: Phenotypic plasticity occurs when plants change appearance due to ecological circumstances, age, and collecting season.

Q. What happens if a specimen is gathered but not pressed and dried?

Ans: The specimen may mold, lose shape (e.g., petals curling), or decay fast, making it unsuitable for morphological research and a permanent record.

Q. Why do herbarium sheets need "poisoning"?

Ans: To keep drying specimens away from insects (e.g., silverfish), fungus, and vermin (in metal cabinets). Preserving the sheet using Mercuric Chloride or fumigation is common.

Q. What distinguishes a "voucher specimen" from a casual herbarium specimen?

Ans: A voucher specimen is a carefully recorded, conserved sample used as a reference for a scientific study (such as ecological, genetic, or phytochemical research) that guarantees the study's findings may be confirmed at a later time.

Q. What is DNA Barcoding in Taxonomy?

Ans: DNA Barcoding uses short, standardized genetic markers (like *rbcL* or *matK* in plants) to identify a specimen as belonging to a particular species.

Q. What is Exsiccatum?

Ans: The technical term for a dried, pressed plant specimen mounted on a sheet.

Q. Define Chemotaxonomy.

Ans: Chemotaxonomy is the study of classification based on the chemical constituents (secondary metabolites) of plants, such as proteins, amino acids, alkaloids, and flavonoids.

Q. What is a couplet?

Ans: A pair of contrasting statements (leads) that provide a two-choice selection to help identify an organism is called couplet.

Q. What is a lead? Ans: Each individual statement within a couplet is called lead.

Q. Why is the Solanaceae family called "specialized" and why is the ovary "oblique"?

Ans: Solanaceae is considered advanced/specialized due to the fusion of parts (gamosepalous, gamopetalous, epipetalous stamens), persistent calyx, and specialized bicarpellary gynoecium. The ovary is placed obliquely (at about 45° to the median plane) rather than straight. This is a crucial diagnostic feature that distinguishes it from other similar families like Scrophulariaceae.

Q. Identify the plant from this family that is used for pupil dilation in eye exams, and state its key alkaloids.

Ans: *Atropa belladonna* (Deadly Nightshade). It produces tropane alkaloids, specifically atropine and scopolamine, which act as anticholinergics to dilate the pupil.

Q. What type of placentation is found in Solanaceae? Ans: Axile, with a swollen placenta.

Q. What is "gynobasic style" and why is it a key diagnostic feature of Lamiaceae?

Ans: The style arises from the base of the ovary, rather than the top, due to the rapid growth of the ovary wall and the deep lobing of the carpels. This is a definitive, almost universal characteristic of Lamiaceae, differentiating it from the closely related Verbenaceae (which has a terminal style).

Q. Explain the pollination mechanism in the genus *Salvia* (Lamiaceae).

Ans: *Salvia* exhibits a "lever mechanism." The stamens are reduced to two, and their connectives are long, holding a fertile anther lobe under the upper lip and a sterile, flat lobe lower down. When a bee pushes the lower sterile lobe, the upper fertile anther pivots down and hits the bee's back with pollen.

Q. What is the typical fruit type in this family?

Ans: A schizocarpic fruit that splits into four one-seeded nutlets (carcerulus).

Q. What makes the Asteraceae inflorescence a "pseudanthium" (false flower) and what is its evolutionary advantage?

Ans: What looks like one flower is actually a "capitulum" or head containing dozens or thousands of tiny, separate flowers called florets. This maximizes pollination efficiency: a single insect visit can pollinate multiple flowers, and the bright outer ray florets act as petals to attract insects to the inner fertile disc florets.

Q. What is the function of the "pappus" in Asteraceae, and what does it represent structurally?

Ans: The pappus is a modified calyx, existing as hairs, scales, or bristles. It acts as a parachute-like structure for wind dispersal (anemochory) of the fruit (cypsela).

Q. Describe the stamens of the Asteraceae family.

Ans: They are syngenesious (anthers united into a tube, filaments free).

Q. How can Verbenaceae be distinguished from Lamiaceae, given their similar bilateral (zygomorphic) flowers?

Ans: While both have opposite leaves and bilabiate corollas, Verbenaceae usually has a terminal style (not gynobasic), and the ovary is not deeply 4-lobed. Additionally, Verbenaceae fruits are usually fleshy drupes or berries, whereas Lamiaceae fruits are dry nutlets.

Q. What is the economic significance of *Tectona grandis*?

Ans: *Tectona grandis* (Teak) is a member of the Verbenaceae family and is one of the most valuable timber trees in the world for furniture and construction.

Q. What is the inflorescence type commonly found in Verbenaceae?

Ans: Racemose, specifically spike or cyme.

Q. Write Important Differences between Solanaceae, Lamiaceae, Asteraceae

<i>Feature</i>	<i>Solanaceae</i>	<i>Lamiaceae</i>	<i>Asteraceae</i>
<i>Stem</i>	<i>Cylindrical</i>	<i>Quadrangular</i>	<i>Cylindrical/Hairy</i>
<i>Inflorescence</i>	<i>Cymose</i>	<i>Verticillaster</i>	<i>Capitulum</i>
<i>Flower</i>	<i>Actinomorphic</i>	<i>Zygomorphic (Bilabiate)</i>	<i>Zygomorphic/Actinomorphic</i>
<i>Gynoecium</i>	<i>Bicarpellary, Oblique</i>	<i>Bicarpellary, Gynobasic</i>	<i>Bicarpellary, Inferior</i>
<i>Fruit</i>	<i>Berry/Capsule</i>	<i>4 Nutlets (carcerule)</i>	<i>Cypsela</i>

Q. What is the defining floral characteristic of the Orchidaceae family?

Ans: The flowers are highly zygomorphic (bilaterally symmetrical), often resupinate (twisted 180°), with a labellum (modified, showy lip), and a "column" or gynostemium (fusion of stamens and style).

Q: How are pollen grains typically arranged in Orchidaceae?

Ans: Pollen is united into waxy masses called pollinia.

Q: Why do orchid seeds require a symbiotic relationship with fungi (mycorrhizae)?

Ans: Orchid seeds are microscopic, lack endosperm, and cannot produce their own nutrients during early germination, making them entirely dependent on fungi.

Q: Which famous spice is derived from an orchid?

Ans: Vanilla, obtained from the dried pods of *Vanilla planifolia*.

Q: What is the unique, characteristic fruit type of the Poaceae family?

Ans: Caryopsis, where the seed coat is completely fused with the pericarp (fruit wall).

Q: Describe the inflorescence of the Poaceae family.

Ans: It is a compound inflorescence consisting of spikelets, often arranged in spikes or panicles, protected by bracts called glumes, lemmas, and paleas.

Q: What are lodicules in Poaceae?

Ans: Lodicules are 2 or 3 small, membranous, or fleshy scales representing the perianth, which swell to open the spikelet for pollination.

Q: Name some major food crops belonging to Poaceae.

Ans: Rice (*Oryza*), Wheat (*Triticum*), Maize (*Zea*), Barley (*Hordeum*), and Sorghum.

Q: What is the typical floral formula for the Liliaceae family?

Ans: This represents an actinomorphic, trimerous flower with 6 perianth parts, 6 stamens, and a superior ovary.

Q: Describe the perianth of the Liliaceae family.

Ans: The perianth consists of 6 tepals arranged in two whorls of 3 (3+3), which are often similar in appearance and sometimes united.

Q: What is the nature of the stem in many Liliaceae plants?

Ans: They are often perennial herbs with underground storage organs like bulbs, corms, or rhizomes.

Q: What is an example of a medicinally important plant in Liliaceae?

Ans: *Aloe vera* (used in skin care, Wound and Burn Healing, Anti-inflammatory and Anti-arthritis, Gastrointestinal Health, Antiseptic and Anti-tumor) and *Colchicum autumnale* (used for treating rheumatism/gout, Musculoskeletal and Rheumatic Disorders, Familial Mediterranean Fever (FMF), Anti-fibrotic Properties, Cancer Research, & source of colchicine, an alkaloid used to treat inflammatory diseases).

Q: What is a distinguishing ecological feature of the Alismataceae family?

Ans: They are primarily aquatic or semi-aquatic plants, often known as "water plantains".

Q: What is the characteristic habit of the Arecaceae (Palm) family?

Ans: They are woody, tree-like, or shrub-like plants, rarely herbs, with large compound leaves (fronds) and a spadix inflorescence, commonly known as palms.

Q: What are the key features of the Commelinaceae (Spiderwort) family?

Ans: They are usually succulent herbs with leaves having sheathing bases, and the flowers often have distinct sepals and petals, typically lasting only one day.

Q: What is the main characteristic of the Zingiberaceae (Ginger) family?

Ans: They are aromatic, rhizomatous herbs with specialized, showy flowers.

Q: What is the difference between the root systems of Poaceae and Liliaceae?

Ans: Both are monocots, but Poaceae typically have fibrous, branching adventitious roots, while many Liliaceae are bulbous/corm-forming.

Q: Compare the pollination mechanism in Orchidaceae vs. Poaceae.

Ans: Orchidaceae mostly rely on specialized entomophilous (insect) pollination, while Poaceae are predominantly anemophilous (wind-pollinated) with feathery stigmas.

Q. Why is the Fabaceae family considered economically significant?

Ans: It is a major source of protein-rich pulses (e.g., peas, groundnut, and soybean) and oil. Many species act as green manure or forage for livestock, and they fix nitrogen, enhancing soil fertility.

Q: Which plant in this family is used for producing natural dye?

Ans: *Indigofera* (specifically *I. tinctoria* and *I. suffruticosa*) is used for producing indigo dye.

Q: Which family is the most important for human nutrition?

Ans: The Poaceae family (Gramineae) is paramount because it includes staple cereals like rice, wheat, maize, barley, and sugarcane.

Q: What are the economic uses of Bambusoideae (bamboo) within this family?

Ans: They are used in construction, as a source of paper pulp, for making furniture, and as food (bamboo shoots).

Q: What is the economic importance of the Solanaceae family?

Ans: It is a major source of food (potato, tomato, brinjal) and spices (chillies). It is also significant for medicinal plants, such as Ashwagandha.

Q: Which fumigatory product is extracted from Solanaceae family?

Ans: Nicotine is extracted from tobacco, a member of the Solanaceae family.

Q: Which, economically important, fiber-yielding plant belongs to Malvaceae family?

Ans: Cotton (*Gossypium* species).

Q: Name an ornamental plant belonging to the Malvaceae family?

Ans: *Hibiscus* and Hollyhock.

Q: What is the primary economic use of the Apiaceae family?

Ans: It is a major source of spices and condiments, including coriander, cumin, fennel, and asafoetida.

Q: Which family is known for providing spices like cloves and medicines?

Ans: The Myrtaceae family, particularly *Syzygium aromaticum* (cloves).

Q: Name a medicinal plant belonging to the Rubiaceae family?

Ans: Coffee (*Coffea arabica*) is a major economic product of this family.

Q: Which family is a source of essential oils and ornamental plants like Aloe? Ans: Liliaceae.

Q. "All synapomorphies are apomorphies, but all apomorphies are not synapomorphies." explain?

Ans: This expression emphasizes the hierarchical link between derived qualities in evolutionary perspectives. Any "derived" or "new" character state that has developed from an ancestor form is referred to as apomorphy.

Q. Why every apomorphy is a synapomorphy

A common derived character is called a synapomorphy. It must, by definition, be an apomorphy (a novel characteristic) before it may be shared by several populations. For instance, the mammalian lineage inherited the feature of mammary glands. This characteristic is an apomorphy as it represents a "evolutionary novelty" in comparison to ancestral vertebrates. It is also a synapomorphy for mammals as all of them share it (primates, rodents, etc.).

Q. Why apomorphies are not always synapomorphies

Only when an apomorphy is shared by two or more taxa does it become a "synapomorphy". A developed property is referred to as an autapomorphy if it is exclusive to a single group or species. For instance, human speech is an evolutionary innovation (apomorphy), but it is an autapomorphy rather than a synapomorphy as it is exclusive to humans and not shared by other primates.

Apomorphy is the wide category of all derived traits in the hierarchy.

Synapomorphy: A subset of apomorphies, or a derived characteristic shared by many taxa. Another subgroup of apomorphies is autapomorphy, which is a derived characteristic exclusive to a single taxon.

In summary, since they are derived, all synapomorphies are apomorphies. However, apomorphies can also be unique (autapomorphies), which excludes them the status of "syn-" (shared).

Q. Who is credited with calling the origins of angiosperms a "abominable mystery"?

Ans: In 1879, Charles Darwin referred to the abrupt and swift emergence of modern-looking angiosperms during the Cretaceous epoch as a "abominable mystery" since there were no obvious intermediate fossil forebears.

Q. When did the fossil record initially include the first undeniable angiosperms?

Ans: Although there are some contentious Jurassic fossils, there are undeniable angiosperm fossils from the early Cretaceous era, which occurred between 130 and 140 million years ago.

Q. What are the main characteristics that set angiosperms apart from gymnosperms?

Ans: The following characteristics set angiosperms apart:

- a) Enclosed Ovules: The ovarian wall, or carpel, encloses ovules.
- b) Flowers: Unlike cones, flowers have specialized reproductive systems.

- c) Double fertilization produces a triploid endosperm and a diploid zygote.
- d) Vessel Elements: The xylem's more effective water-conducting tissue.

Q. Regarding the origins of flowers, what is the "Euanthial Theory"?

Ans: According to the Euanthial theory, which was put out by Arber and Parkin in 1907, the angiosperm flower—more especially, the Magnoliales—evolved from a bisexual, Magnolia-like strobilus (cone), which was probably descended from the extinct Bennettitales (Cycadeoidales).

Q. What is the "Pseudanthial Theory"?

Ans: According to this concept, angiosperm flowers are formed by the condensation of unisexual inflorescences (like Gnetales), where aments (catkins) are regarded as primordial. This shows that angiosperm flowers are not analogous to gymnosperm cones.

Q. What is the idea for "ANITA" grade?

Ans: It suggests that Amborella, Nymphaeales (water lilies), and Austrobaileyales are the oldest divergent lineages of extant angiosperms. This grade offers hints about the ancestry of flowering plants, such as Amborella's absence of real vessels.

Q. Which gymnosperm families are most likely to be the ancestors of angiosperms?

Ans: A number of extinct gymnosperm groups have been proposed, such as: Bennettitales: For their reproductive structures that resemble flowers and are bisexual. Caytoniales: For their ovules that carry cupules, which may be the carpel's predecessor. Glossopterids: Because of their cupulate shape, they are also recommended.

Q. Describe the "Durian Theory" of the origin of angiosperms.

Ans: According to Corner's view, the first angiosperm was a woody plant with huge, succulent, meaty fruits (like durian fruit) and large leaves; small-fruited versions evolved later.

Q. Where is the "cradle of the angiosperms" that is thought to exist?

Ans: Takhtajan is one of several botanists who have proposed that South-East Asia was the ancient home (cradle) of angiosperms. This is especially true given the region's high concentration of primitive families, such as the Magnoliaceae and Winteraceae.

Q. Are angiosperms considered monophyletic or polyphyletic?

Answer: According to the current botanical agreement, which is backed by molecular evidence (the APG system), angiosperms are a monophyletic group, which means that all flowering plants had a single common ancestor.

Q. What role does the fossil *Archaeofructus* play?

Ans: Originally believed to be the earliest angiosperm (early Cretaceous) without a proper perianth (petals or sepals), *Archaeofructus* was found in China and had a very basic, herbaceous watery habit.

Q. Describe "Double Fertilization" and explain its importance.

Ans: One male gamete fertilizes the egg, creating a diploid embryo, while another male gamete unites with two polar nuclei, creating a triploid endosperm. This is a unique mechanism. It is important because it waits until fertilization is assured before investing energy in nutritive tissue.

Q. What distinguishes an unrooted phylogenetic tree from a rooted one?

Ans: In response, a rooted tree displays the direction of time as well as the ancestor of every taxon. Without revealing the common ancestor or the course of evolution, an unrooted tree illustrates the connections between species.

Q. In a phylogenetic tree, what does a "node" mean?

Ans: A node, which typically denotes a speciation event, is the most recent common ancestor of all branches that branch off of it.

Q. What is meant by a monophyletic group (clade)?

Ans: A monophyletic group consists of all of the descendants of a common ancestor. It is regarded in evolutionary biology as a natural grouping.

Q. Which chemical is most frequently employed to analyze distant connections using phylogenetic Analysis, and why?

Ans: The reason ribosomal RNA (rRNA) genes are utilized is because they are extremely conserved, present in all living organisms, and seldom undergo long-term changes.

Q. In creating trees, what is the Principle of Maximum Parsimony?

Ans: It says that the phylogenetic tree that needs the fewest evolutionary changes (mutations or changes in character states) to explain the observable data is the best and most reasonable.

Q. How do homologous and analogous characteristics in a cladogram vary from one another?

Ans: In response, homologous characters—such as a bat wing or a human arm—are descended from a common ancestor. When comparable traits—like the wings of birds and flies—emerge separately in different species due to similar circumstances rather than common ancestry, this is known as convergent evolution.

Q. In a phylogram, what does "branch length" mean?

Ans: In a cladogram, branch length is typically random, but in a phylogram, it indicates the amount of genetic change or time that has transpired.

Q. How can we deduce that Species A and B share a more recent node than Species A and C?

Ans: The relationship between Species A and B is closer than that between either and Species C.

Q. Describe the meaning of "outgroup" and its application.

Ans: A taxon that is closely related to but distinct from the group under study (the ingroup) is called an outgroup. It serves to identify the ancestral vs derived features and to root the tree.

Q. Why is ribosomal RNA (rRNA) frequently chosen over DNA sequences when building phylogenetic trees for organisms that are extremely distant from one another?

Ans: Because ribosomal RNA sequences are essential for protein synthesis, they are remarkably conserved throughout all domains of life. In contrast to fast-evolving DNA sequences, which would lose their phylogenetic signal and become saturated with mutations (homoplasy), slowly evolving DNA sequences enable alignment and precise comparison of evolutionary history spanning billions of years.

Q. How may "Long-Branch Attraction" (LBA) alter a phylogenetic tree, and what does it mean?

Ans: In phylogenetic inference, LBA is the phenomena wherein quickly evolving lineages (long branches) are mistakenly clustered together, irrespective of their true evolutionary connection. Due to the random accumulation of convergent mutations (homoplasy), distant taxa look more alike than they actually are.

Q. Can a single-gene phylogenetic tree accurately depict species evolution?

Ans: Not always. A gene tree may display a different topology than the species tree due to factors like insufficient lineage sorting or gene transfer. Concatenation, or the use of numerous genes, is typically necessary to improve the species tree's accuracy.

Q. Why should species trees use orthologous genes instead of paralogous ones?

Ans: Orthologous genes are those found in several species that diverged from a common ancestor gene through speciation; they nevertheless serve the same purpose and are indicative of the phylogenetic tree of the species. Since paralogous genes reflect the history of gene duplication rather than species divergence, they might result in inaccurate tree structures. Paralogous genes are generated from gene duplication events.

Q. How is the most likely (parsimonious) cladogram chosen out of several possibilities?

Ans: A tree with the fewest evolutionary changes (few character state transitions) is considered the "best" tree. This method, known as maximal parsimony, makes the assumption that the most likely evolutionary path is the simplest one.

Q. How is cladistic analysis complicated by homoplasy (convergent evolution)?

Ans: When homologous traits arise in species as a result of environmental forces rather than inheritance from a common ancestor, this is known as homoplasy (e.g., wings on bats vs. birds).

It can result in the grouping of unrelated organisms together if it is confused with homology.

Q. Do all the characters have the same weight?

Ans: Not always. More complex studies may weight characters according to their pace of development, and characters with high homoplasy are less trustworthy.

Q. Why are DNA sequences often selected above morphology in cladograms?

Ans: Molecular data, such as DNA or protein sequences, offer a lot of independent features and are less prone to the morphology-related convergence problems. Furthermore, although DNA immediately reflects hereditary alterations, amino acids are more stable.

Q. What is the conclusion if the differences in the protein cytochrome c oxidase between species A and B are less than those between species A and C?

Ans: As they share a more recent divergence, species A and B are more closely related (closer to a common ancestor) than species A is to C.

Q. What are the primary drawbacks of cladistics?

Ans: The assumption of straightforward, bifurcating evolution, which might not take into consideration intricate processes like horizontal gene transfer; the dependence on available data; the potential for poor character selections; and difficulties in assessing homology.

APPENDIX - E

A FEW CHOSEN QUESTIONS FOR COMPETITIVE EXAMINATION INTERVIEWS IN FORESTRY, BOTANY, AND AS AN ASSISTANT PROFESSOR

1. Who coined the word "Taxonomy"? Could you give the title of the book he wrote?
2. Define: Taximetrics, Genus, Species, Cohort, Holotype, Isotype, Lectotype, Neotype, taxonomic key, Effective/Valid Publication, Resupination, Monotypic family/genus.
3. Name the monocotyledonous plant in which reticulate venation is seen?
4. What is $\frac{1}{2}$ phyllotaxy & what will be its Angular Divergence?
5. Bentham & Hooker's system – most primitive & advanced families?
6. Which is known as walking fern?
7. What is the world's smallest/largest flower?
8. What is the world's smallest plant?
9. Which is the tallest tree in the world?
10. State International size of Herbarium sheet?
11. What is the English name of *Dillenia indica*?
12. What kind of fruit is a jack fruit or fig?
13. What is the botanical name of spinach?
14. What is the function of the vascular bundle?
15. Name 4 plants that live in the ocean?
16. What is the difference between Taxonomy and systematics?
17. Define a herbarium and mention its importance.
18. What is binomial nomenclature? Who introduced it?
19. What do "endemic" species mean? Cite an example.
20. What does "endangered" species mean? Cite an example.
21. What is the distinction between Taxonomy, Systematics, and Classification?
22. When is a Neotype chosen?
23. What is a "Nomen Nudum" and why is it invalid?
24. Mention one merit and one demerit of Bentham & Hooker's system of classification?
25. Why the Engler & Prantl system is considered phylogenetic?
26. Define herbarium and mention essential steps of making a herbarium.

❖ Differentiate between:-

Monograph & Revision, Alpha & omega Taxonomy, Herbarium & Arboretum, Legume (pod), lomentum and follicle, Thorn, spine & prickle, Phylloclade, cladode, & phyllode, Raceme & spike, Applied botany & Pure botany, Basionym & Synonym, Artificial, Natural, & Phylogenetic systems of classification, Monophyletic, Paraphyletic, & Polyphyletic groups, Indented (Yoked) & Bracketed keys, Poaceae and Cyperaceae, Papilionoideae, Caesalpinioideae, Mimosoideae.

Points to Remember:

- a) *Preparing for competitive interviews* in Forestry, Botany, and Assistant Professor Positions needs pedagogical competence, research expertise, and technological mastery. The interviewers will evaluate your skills in teaching, research, and topic clarity. Study fundamentals and be ready to explain complex topics simply.
- b) *Give examples:* Always use scientific names to back up your definitions.
- c) *Floral Formulae:* For the major families (*Solanaceae, Lamiaceae, Fabaceae, Asteraceae, Orchidaceae & Poaceae*), Be ready to write the floral formula and floral diagram.
- d) Use Botanical terminology when referring to plants (for example, "*epiphyllous stamens*").
- e) Jobs in forestry need knowledge of native & invasive species, local ecological issues, and pests.
- f) Keep updated on recent advances or trends in the field of plant science.
- g) *Lecture Demo:* Get ready to present a 10- to 15-minute lecture on a fundamental topic.
- h) Prepare to discuss the impact of your published articles and the journals you want to publish in.
- i) *Professionalism:* Remain cool, speak clearly, and make eye contact. If you don't know, politely admit it.
- j) *Prepare your answers in advance to a few common interview questions, like,*
How do you deal with a challenging student? Why do you want to work at this institution? How do you follow current trends in your field? What professional development have you done recently? How do you manage stress or balance teaching, research, and service? Share a lesson that went wrong and what you learnt. Your greatest educational strengths and weaknesses? etc.

"Success is where preparation and opportunity meet."

— Bobby Unser

APPENDIX-F

CHARACTERS OF SPECIAL INTEREST (*Family-wise*)

FAMILIES	CHARACTERS OF SPECIAL INTEREST
RANUNCULACEAE	Exstipulate, sheathing base, hypogynous, bisexual, bracteate, actinomorphic, stamens free & spiral, carpels many, apocarpous, ovules anatropous, 1 - to many, parietal placentation, style one, stigma one, anther extrose, nectaries present, spurred & store honey
BRASSICACEAE	Exstipulate, hypogynous, bisexual, bracteate, actinomorphic, corolla cruciform, stamens tetradynamous, syncarpous, parietal placentation, style one
MYRTACEAE	Exstipulate, epigynous, bisexual, actinomorphic, corolla free, stamens many, syncarpous, axile placentation, style 1, simple, long, stigma 1, capitate
APIACEAE	Exstipulate, epigynous, bisexual, actinomorphic, calyx persistent, corolla margin incurved, stamens alternating with petals, carpels (2), ribbed, crowned by disc, syncarpous, ovule 1-pendulous, axile placentation, style 2, free, swollen at base, stigma 2, capitate, 2-mericarps, schizogenous oil ducts (vittae)
ASTERACEAE	Exstipulate, epigynous, unisexual, actinomorphic, calyx modified into pappus, corolla tubular or ligulate, stamens epipetalous, 5, syngenesious, protandrous, syncarpous, ovule 1, ascending anatropous, basal placentation, style one, long, stigma bifid, central disc & outer ray florets surrounded by involucre of bracts. Homogamous head (<i>ageratum</i> , <i>vernonia</i> , <i>eupatorium</i>) heterogamous head (<i>eclipta</i> , <i>helianthus</i>)
SOLANACEAE	Exstipulate, hypogynous, bisexual, involucre of bracts, actinomorphic, calyx persistent, corolla rotate or funnel shaped, stamens 5, epipetalous, alternate with petals, carpels (2), obliquely placed, syncarpous, ovules anatropous, axile placentation, style one, stigma bilobed, embryo curved or semi-straight
LAMIACEAE	Stem square, hairy exstipulate, hypogynous, bisexual, zygomorphic, calyx persistent, corolla (5), bilabiate, stamens epipetalous, carpels (2), syncarpous, ovules 1, anatropous, axile placentation, style one, gynobasic, stigma bifid
EUPHORBIACEAE	Stipulate, hypogynous, unisexual, bracteate, actinomorphic, syncarpous, ovules 1 or 2 pendulous, axile placentation, styles 3 free or united at base, stigma 3 or 6, milky or watery latex, micropyle carunculate, fruit splitting into 3-one seeded cocci
COMMELINACEAE	Exstipulate, sheathing leaf base, hypogynous, bisexual, bracteate, actinomorphic, stamens 6, carpels 3, syncarpous, ovules 1 or few orthotropous, axile placentation, style one, terminal, stigma capitate or

FAMILIES	CHARACTERS OF SPECIAL INTEREST
	trifid, anther basifixed, angled seed, embryo small
POACEAE	Exstipulate, sheathing leaf base, hypogynous, bisexual, boat shaped bract, zygomorphic, stamens 6, carpel 1, ovules 1, anatropous, basal placentation, styles 2, stigma feathery, stem fistular, chasmogamous, lodicules, empty glumes, lemma, anther versatile

<i>Families</i>	<i>Stipule</i>	<i>Leaf</i>	<i>Inflorescence</i>	<i>Ovary</i>	<i>Fruit</i>	<i>Endosperm</i>
<i>Ranunculaceae</i>	Exstipulate	Incised leaf blades	Cymose/ racemose	Unilocular	Aggregate of follicles or achenes	Oily
<i>Brassicaceae</i>	Exstipulate	Lyrate	Raceme	Unilocular	Siliqua	Non- endospermic
<i>Myrtaceae</i>	Exstipulate	Coriaceous, entire, gland dotted with submarginal veins	Cymose/ racemose	3-5 locular	Various- berry, drupe, capsule etc	Non- endospermic
<i>Apiaceae</i>	Exstipulate	Alternate, decompound, incised	Umbel	2-locular	Schizocarp (cremocarp)	Endospermic
<i>Asteraceae</i>	Exstipulate	Simple	Capitulum	Unilocular	Cypsella, crowned by pappus	Non- endospermic
<i>Solanaceae</i>	Exstipulate	Simple, alternate	Extra-axillary cymose	2-celled, falsely 3-5 celled	Berry (many seeded)	Albuminous
<i>Lamiaceae</i>	Exstipulate	Simple, hairy, opp-decussate	Verticillaster	4-celled, anatropous,	Carcerule (1-seeded 4 nutlets) surrounded by persistent calyx	Absent or scanty
<i>Euphorbiaceae</i>	Stipulate	Simple, alternate,	Cyathium	3-celled	Schizocarpic capsule (regma)	Fleshy
<i>Commelinaceae</i>	Exstipulate	Simple, alternate,	Monochasial cyme, or solitary	3-celled	Capsule	Albuminous
<i>Poaceae</i>	Exstipulate	Simple, alternate, distichous, ligulate	Spikelet	1-celled	Caryopsis (1-seeded)	Albuminous

“The ultimate test of man’s conscience may be his willingness to sacrifice something today for future generations whose words of thanks will not be heard.” – Gaylord Nelson