E-RESOURCE

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Topic:Artificial, Natural and Phylogenetic, Bentham and Hooker (upto series) System of classification.

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In general, weare much dependent on plants to fulfil our primary needs. For the proper knowledge, exploitation of plant resources and conservation of plant biodiversity, the systematic knowledge of plants is very much essential .

It is highly impossible for any one to study each and every plant individually, therefore it is must to place them into small/large groups and divisions on the basis of their variations and identification, which is known as classification.

CLASSIFICATION is the process of placing or groping taxa into groups or categories, on the basis of observed similarities and/or differences or according to a particular plan.

The conformity with the rules of Nomenclature are essential in the process of classification.

TYPES OF BOTANICAL CLASSIFICATION

1. **Empirical Classification:** Plants are arranged in alphabetical (ABC....Z) order. No character was in consideration.
2. **Reasonal Classification :** Plants were grouped together on the basis of some natural characters which may connect them.

SYSTEMS OF CLASSIFICATION

Based on the number of characters used for classification and their evolutionary relationship different systems of classification which have been proposed over time can be grouped into three categories:

A. Artificial System of Classification;
B. Natural/Phenetic System of Classification;
C. Phylogenetic System of Classification

A. Artificial System of Classification

The earliest system of classification were artificial systems and the system of this nature remained dominant from 300 B. C. up to about 1830.

300 B.C. → **1830**

Since very little information was available about the plants, this system is more or less arbitrary as the plants are classified merely **on the basis of one or a few characters** without taking into consideration the relationships or affinities with one another.
The artificial systems propounded by early herbalists.
In fact plants are classified for the sake of convenience using one or at most a few easily observable characters.
The aim of this system is to aid the process of identification and arrange the taxa in a manageable form.
These are utilitarian systems based on habit, color, form or characters of similar nature.
This system has limited applications mainly in finding out the name of a plant.
Since this system contains only a very limited amount of information about its members, therefore, identification may be difficult.
The idea followed was that of a MONOTHETIC grouping ('mono' means single and 'thetos' means arrangement), i.e., using a unique set of features for classification.
The drawback of the system is that the plants closely resembling each other are often placed in same group.
Some well known Artificial System of classifications are as follows :

A.1. Theophrastus: (370-287 B.C.) A Greek naturalist, who is known as **'Father of Botany'**, was thepupil of the great philosopher Pluto and Aristotle. He is accredited with more than 200 publications. ***'Inquiry into plants'*** and ***'Causes of plants'*** were his two important botanical contributions.

History of Taxonomy starts with the work of Theophrastus, which appeared in a monumental work entitled ***'Historia Plantarum'*** having description of approximately five hundred plants. This is the **oldest botanical work** in existence. Because of wide use, his names received general recognition and some of them still appear as generic names in modern classification, e.g., daukan (*Daucas*) and aspharagos (*Asparagus*). He pointed out fundamental differences between Dicotyledons and Monocotyledons and also recognised different types of insertion of floral appendages thus laying foundation fir the study of floral morphology.

Theophrastus, was the first to describe plants on the basis of size/habit and life span.

- **Trees, -Shrubs,-Undershrubs and Herbs.**
- **Annual,-Biennial and,-Perennial.**

A.2. Parasara (250-120 B. C.) : He was an Indianscholar who compiled ***Vrikshayurveda*** **(Science of Plant Life),** one of earliest work dealing with plant life from a scientific stand point. Plants were classified into numerous families (ganas) on the basis of morphological features not known to theEuropeans until 18th century.

A.3.Caius Plinus Secundus (23-79 A.D.) : Romannaturalist, compiled a 37 volume work 'Historia Naturalis' (77 A. D.) in whichhe described about 1000 plants, especially timber trees and plants of medicinal importance.

A.4. Dioscorides (64 A. D.) : He published a book entitled ***'De Materia Medica'*** with description of 600 plants. He proposed many latinised generic names viz. ***Aristolochia, Aloe, Anemone*** and ***Phaseolus*** which are still retained as valid name.

A.5. Clausius (1526-1609 A.D.) : Made first attempt to classify plants on the basis of the similarities of characters in his publication entitled, '***Rariorum Plantarum Historia***'in 1576.

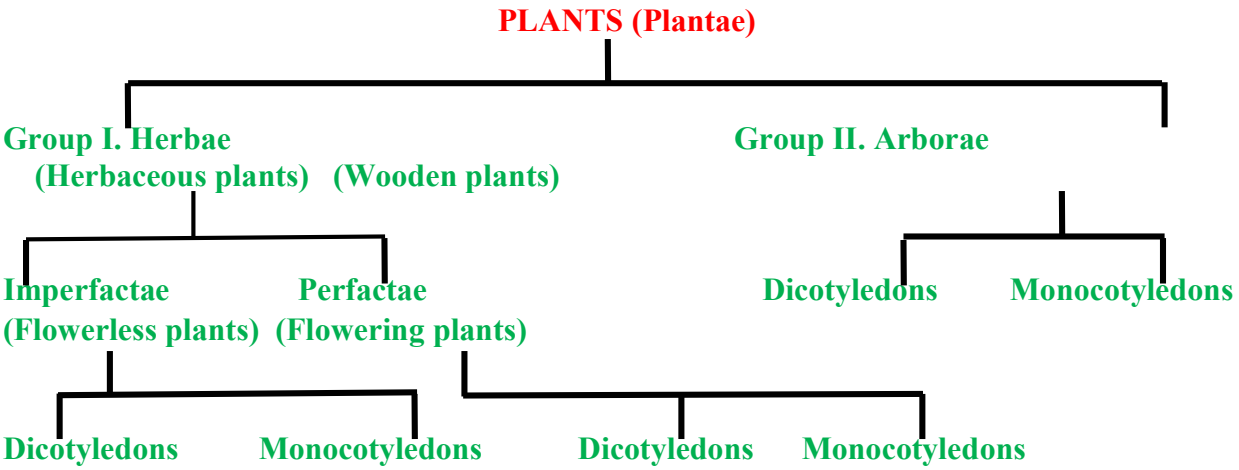
A.6. Andrea Caesalpino (1519-1603) : He was a Italian Taxonomist and published a book entitled, **"De Plantis Libri"** and sketched out in outline about the plants known at that time.

A.7. Gasperd Bauhin (1560-1603) : He classified plants on the basis of **texture and form,** and published two books entitled, ***"Prodromus Theatri Botaniici"*** (1620) and ***"Ponax Theatri Botanici",***(1623), where he tried to distinguish between species and genus on the basis of nomenclature.
The binomial nomenclature which is usually attributed to Linnaeus in his *SpeciesPlantarum* was founded by Bauhin more than century before Linnaeus used it.

A.8. J. P. de Tournefort (1656- 1708 A.D.) :Father of the modern genus concept.

He treated genus as the smallest practical unit of classification and considered species as the variant of the genus.
He divided plants into two categories: herbs and trees. His important publication was, **"Institution Rei Herbariae"** (1700). The herbs, shrubs and trees are distinguished by the form of their flowers, especial importance being being attached to the presence of calyx and corolla, to the regularity or irregularity of the flower and to the petals whether they are free or united with one another.

A.9. John Ray (1627-1725) : He classified plants into two groups:
Herbae (Herbaceous plants) and**Arborae** (Woody plants). He was a well reputed Bristish Taxonomist and published' **"Methodus Plantarum Nova"**, in 1703 with classification of 18000 plants of totality of morphological similarities.
He was the first to divide plants into MONOCOTYLEDONS and DICOTYLEDONS.



A.10. Carolus Linnaeus (Carl von Linne) [1707-1778] :
(FATHER OF TAXONOMY)
A great Swedish naturalist is rightly known as the **"Father of Modern Botany"**. His important publications are :

1. **"Hortus Uplandicus"** (1730),
2. **"Hortus Ciffortianus"** (1737),
3. **"Genera Plantarum"** (1737),
4. **"Classes Plantarum"** (1738),
5. **"Philosphia Botanica"** (1751)

The most important contribution of Linnaeus is the publication of ***"Species Plantarum"*** (1753), which is selected by modern botanists as the **starting point** of present day nomenclature. A work where some 935 genera and 7,300 species are described and arranged according to his sexual system of Classification. In this book he introduced the consistent use of the **binomial system** plant names.
Taxonomic Hierarchy was introduced by Carolus Linnaeus. It is the arrangement of various taxonomic levels.

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

Linnaeus system of classification was **Artificial** in nature an did not show any natural relationship between plants. But due to its simplicity and easy way of use, the system persisted for more than hundred years after Linnaeus.

Species Plantarum was very important contribution of Linnaeus, as the modern nomenclature, binomial system and art of description of plants could come into existence after it.

Linnaeus system was sexual system, after this the floral characters were more widely used in taxonomy.

In recognition of his work Linnaeus was honoured as **Knight of the Polar Star**, 1753. He was the first Swedish scientist to receive this honour. In 1761, Linnaeus was granted the **Patent of Nobility** and then he became famous as **Carl von Linne.**

Linnaeus recognized 24 classes in his sexual system of classification for all flowering plants on the basis of number, arrangement and fusion of the sex organs {He used only one attribute, *i.e.*, the number of stamens, for categorizing plants into classes. [Sexuality in flowering plants was first of all established by **Camerariusin** (1694). He concluded that stamens are the male sex organs while the style and ovary form female sex organs of a flower. His concept of sexuality in plants was amply exploited by Linnaeus for classifying flowering plants.]}.

S. No.	Class	S. No.	Class
1.	Monandria (Single stamen)	13.	Polyandria (Stamens 20 or more)
2.	Diandria (Stamens two)	14.	Didynamia (stamens didynamous)
3.	Triandria (Stamens three)	15.	Teytradynamia (Stamens tetradynamous)
4.	Tetrandria (Stamens four)	16.	Monadelphia (Stamens monoadelphous)
5.	Pentandria (Stamens five)	17.	Diadelphia (Stamens diadelphous)
6.	Hexandria (Stamens six)	18.	Polyadelphous (Stamens polyadelphous)
7.	Heptandria (Stamens seven)	19.	Syngenesia (Stamens syngenesious)
8.	Octandria (Stamens eight)	20.	Gynandria (Stamens united with gynoecium)
9.	Enneandria (Stamens nine)	21.	Monoecia (Plant monoecious)
10.	Decandria (Stamens ten)	22.	Dioecia (Plant dioecious)
11.	Dodecandria (Stamens 11-19)	23.	Polygamia (Plant polygamous)
12.	Icosandria (Stamens 20 or more)	24.	Cryptogamia (Flowers concealed)

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➢ Types of Species

There are different types of species :

1. Process of evolution – Biological Species;
2. Product of evolution – Morphological Species and Phylogenetic Species

(a). Morphological Species (Taxonomic Species) : When the individuals are similar to one another in one or more features and different from other such groups, they are called **Morphological Spceies.** These species are defined and categorized with no knowledge of phylogenetic history, gene flow or detailed reproductive mechanism.

(b). Biological Species (Isolation Species) : These are groups of populations that interbreed and are reproductively isolated from other such groups in nature (Ernest Mayr, 1963).

(c). Phylogenetic Species: An evolutionary species is a single lineage of ancestor descendent populations which maintains its identity from other such lineages which has its own evolutionary tendencies and historical fate (Meglitsch, 1854; Simpson, 1961 and Wiley, 1978)

B. Natural System of Classification

A natural system of classification is based on a large number of characters.

It reflects the situation as it exists under natural conditions. It helps us to ascertain the relationship and affinities with other plants. This system increases the amount of information available from the groupings.Naturalsystem is based not only on the characters of reproductive organs and structural relationship but all the important characters are being considered and the plants are classified according to their related characters, mostly in gross morphology

Michel Adason (1727-1806) :A French Botanist, who first rejected all artificial classifications and emphasized the importance of **equal weightage of characters.** He proposed a "natural system" of taxonomy distinct from the Linnaeus. Linnaeus' system was the last among the artificial system of classification.

Because this system of classification not only ascertains the name of a plant but also its relationship and affinities with other plants, they are also known as **Horizontal System of Classification.**

Most of the later Pre-Darwinian systems are natural. For example, classification by **Antoine Laurent de Jussieu** (1748-1836), **Augustin Pyramus de Candolle** (1778-1841) and **Bentham & Hooker**(1862-1883).

De Jussieu : The de Jussieu family had four members **(Antonie, 1686-1758; Bernard, 1699-1776; Joseph, 1704-1779; and Antonie Laurent, 1748-1836)** who made noteworthy contributions to botany.

Bernardnever published his systemduring his lifetime due to personal dissatisfaction over perfection of his system. However, he rearranged the plants in a garden at La Trianon, Versilles according to his own system.

Antonie Laurent de Jussieu published his uncle's system with some improvements in **'Genera Plantarum'** (1789). This is the first major work which was natural in its approach. In this system the plants that looked alike were grouped together. **De Jussieu**abandoned the aristotalian concept of habit and gave

emphasis to features such as the number of cotyledons, the presence and absence of petals and position of petals and stamens with respect to the overy. He divided the plants into **15 classes**. The classes were further divided into **100 natural orders** (families).

de Candolle : Three generations of de Candolles have contributed much to the science of systematic botany. The first of this Swiss-French family is **Augustin Pyramus de Candolle** (1778-1841).

In 1813 **A. P. de Candolle** published a book entitled ***'Theorie Elementaire de la Botanique'*** in which he set forth the principles of a natural system of classification and further developed morphological approach to classification.

The system of de Candolle was similar to de Jussiu in many respects but it was certainly an improvement over that of the latter particularly in the treatment of the Dicotyledons. He divided the the Dicotyledons into two groups on the basis of presence or absence of petals. The one with petals was subdivided on the basis of free or fused petals and the former was further divided on the basis of the position of ovary.

One of the serious drawback of the de Candolle's system was the inclusion of vascular cryptogams among Monocotyledons.

de Candolle's system superceded all other systems because of its easiness and simplicity.

Bentham & Hooker System of Classification

- **GEORGE BENTHAM** (1800-1883) AND **JOSEPH DALTON HOOKER** (1817-1911)-Two British Botanists, associated with Royal Botanic Garden, Kew, England, London.
- Their Natural System of Classification, based on De Candolle's and Lindley's view, published in **three volumes**(Ist Volume in 1862 & IIIrd Volume in 1883).
- Their detailed classification system of Seed Plants published in the form of book entitled ***GENERA PLANTARUM*****(1862-1883).**In this publication they presented their outstanding system of classification. This was the greatest taxonomic work ever produced in the United Kingdom. This monumental work which required quarter of a century, comprised description of all of seed plants known to science at that time and they were classified according to the system proposed by them. They have provided first rate descriptions of the families and genera of seed plants then known. The geographical distribution of esch geus was given.
- **The Order Ranales placed (A group with well developed petals) in the beginning and Grasses at the end. Their treatment is in consistent with our present day understanding of these groups.**

RANALES → POALES [Grasses)

SEED PLANTS (PHANEROGAMIA)

(202 Families, 7569 Genera & 97205 Species)

(Cohorts=Orders, Natural Orders=Families)

Seed Plants divided into three**CLASSES:**

A. Dicotyledonae :(Two cotyledons in seeds, Venation reticulate, Flowers penta or tetramerous)

B.Gymnospermae :(Seeds are nor enclosed in the fruit)

C.Monocotyledonae :(One cotyledon in the seed, Venation parallel, Flowers trimerous)

- **Class A.Dicotyledonae** divided into three **Sub Classes**:
  - **-Polypetalae** (Petals free)
  - **-Gamopetalae** (Petals fused)
  - **-Monochlamydeae**(Flowers usually with one whorl of perianth, commonly sepaloid or none)
  - **I: Sub Class- Polypetalae**with **three Series:**
    - i. **Thalamiflorae**(Thalamus convex, Flowers hypogynous, ovary superior)
    - ii. **Disciflorae**(A disc is usually present below the superior ovary, flower hypogynous)
    - iii. **Calyciflorae**(Thalamus cup shaped, ovary inferior).
  - **II: Sub Class-Gamopetalae** with **three Series:**
    - i. **Inferae** (Ovary inferior)
    - ii. **Heteromerae** (Ovary superior, carpels more than two)
    - iii. **Bicarpellatae**(Ovary usually superior, carpels two)
  - **III: Sub Class-Monochlamydeae** (**Incompletae**/**Apetalae**) divided into **8 series.**
    - **i.**Curvembryeae; **ii.** Multiovulateaquaticae; **iii.** Multiovulate terrestris; **iv.** Microembryae; **v.**Daphnales; **vi.**Achlamydosporae; **vii.**Unisexuales; **viii.**Ordines Anomali
- **Class B. Gymnospermae**- Divided into **three Natural Orders or families:**

i. Gnetaceae; **ii.** Coniferae;**iii.**Cycadaceae.

- **ClassC.Monocotyledonae-**Divided into **seven series:**
  - **i.** Microspermae;**ii.**Epigynae; **iii.**Coronarieae; **iv.**Calycinae; **v.**Nudiflorae; **vi.**Apocarpae; **vii.**Glumaceae

ANALYSIS

	Orders	Genera	Species
DICOTYLEDONAE			
Polypetalae (3 Series)	84	2610	31874
Gamopetalae (3 Series)	45	2619	34556
Monochlamydeae (8 Series)	36	801	11784
GYMNOSPERMAE (3 families)	3 Families	44	415
MONOCOTYLEDONAE (7 Series)	34	1495	18576
TOTAL	202	7569	97205

C. Phylogenetic/Evolutionary System of Classification

The Natural System remained dominant before the idea of evolution was accepted.

This system classifies organisms according to their **evolutionary (phylogenetic)** and**genetic relationships****and in addition to several constant characters.**It enables us to find out the ancestors or derivatives of any taxon. Phylogenetic classificationis not only based on the data available at any one time but it also relies on the presumed ancestry. So, they are also termed as **VERTICAL CLASSIFICATION**.

Our present day knowledge is insufficient to construct a perfect phylogenetic classification and all present phylogenetic systems are formed by the combination of natural and phylogenetic evidences.

In such a system organisms belonging to the same group are believed to have a common ancestry and may be represented in the form of a family tree, the **cladogram.**

The outlook of taxonomy changed with the publication of "**Origin of Species**" by **Darwin** (24.11.1859). Phylogenetic System of Classification came into existence with this great publication.

The systems of this period are based on the course of evolutionary descent and they tried to reflect the genetic and phylogenetical relationships. Phylogenetic systems, however, were as a matter of fact not based on, "actual phylogeny but on what their authors have believed to be phylogeny". The authors of most of these systems have emphasized on certain pre-selected characters which they considered of phylogenetic importance.

Post Darwinian systems can be broadly categorized into two groups :

1. **The Englerian School/Thought**
2. **The Ranalian School**

1. The Englerian School : This school considered simplicity as the primitive and complexity as advanced and is based on the concept of progressive evolution. He considered apetalous and catkin bearing dicots primitive to the dicots bearing petals and simple unisexual flower. Placed monocot before dicot.

MONOCOT → **DICOT**

Apetalous & Catkin bearing dicots

↓

Dicots bearing petals & simple unisexual flower

The Englerian view has been supported by some taxonomists, viz. A. W. Eichler (1839-1887), A. B. Rendle (1865-1938) etc.

2. The Ranaian School : This view was just reverseof Englerian School. According to Arber Parkin (1907) the extinct Gymnosperms group **Bennettitales** has given rise **Magnolia** like Angiosperms.

BENNETTITALES [Bisexual strobilus]

MAGNOLIA {Bisexual flower}

Here the naked flower is more advance flower, so it is called as RETROGRESSIVE EVOLUTION THEORY. Here Dicot (Primitive) placed before Monocot (Advance).

DICOT  **MONOCOT**

[Primitive] [Advance]

This view has been supported by **Bessey** (1915), **Hutchinson** (1959-1969), **Cronquist** (1968, 1981), **Takhtajan** (1967, 1980) and others.

Engler & Prantl System of Classification

- **Heinrich Gustav Adolf Engler** (1844-1930) and **Karl Anton Eugen Prantl** (1849-1893) were two German Plant Taxonomists.
- Important publication: ***Die Naturlichen Pflanzenfamilian*** (1887-1899)**,** in 23 volumes, covering the entire plant kingdom starting from Algae to Angiosperm. The plant kingdom was divided into **14 major divisions**. The first division was **Schizophyta** and last division was **Embryophyta Siphonogamia** (Spermatophytes/Seed Plants).
- This was first recognised true phylogenetic system of classification.
- This system has replaced Bentham & Hooker's system in European and American continents.
- Seed Plants into two subdivisions:
  - **A.** Sub. Division: Gymnospermae (7 classes, Cycadofilicales to Gnetales)
  - **B.** Sub. Division: **Angiospermae** (Ovules enclosed in the ovary and true vessels are present)
    - **a. Class: Monocotyledonae**(Includes **11 orders** and **45 families**; [Pandanales to Microspermae]; cotyledons one, leaves with parallel venation, stem with closed vascular bundles, flowers trimerous)
    - **b. Class: Dicotyledonae** (Includes 44 orders and 258 families; cotyledons two, leaves with reticulatevenation, stem with open vascular bundles, flowers tetra or pentamerous)
      - i. **Sub class: Archichlamydeae**{**33 Orders**&**201 families**; **petals free**; Verticillateae to Umbelliflorae}
      - ii. **Sub class: Metachlamydeae/Sympetalae** {**11 Orders** [Diapensiales to Campanulatae] & 57 families, **petals fused**}

Since this system was proposed subsequent to the acceptance of the theory of descent. It throws light on the phylogeny of the various groups and traces the increasing complexicity of the flowers, particularly their essential whorls. The system is based on the following principles :

1. A naked flower is primitive than the one having a perianth.
2. Anemophily is more primitive than entomophily.
3. A flower with one perianth (Monochlamydeous) whorl is primitive than one with two whorls in perianth (Dichlamydeous).
4. Polypetale is primitive than sympetaly.
5. A sepaloid perianth is more primitive than a petaloid perianth.
6. Unisexual flower is primitive than a bisexual flower.

Specific Features of Engler and Prantl System

(i).In this phylogenetic system, families were arranged according to the Increasingcomplexity of the flower, fruit and seed development.
(ii). In this system, entire plant kingdom (algae to angiosperm) is classified.
(iii). It is the first angiosperm system to take anatomical data into account.
(iv). They have placed monocots before dicots and treated them as primitive.
(v). Exhaustive keys to the orders and families are given in this system.
(vi). This system has also embryological, anatomical and morphological data of the families.

The significant feature of this system is that monocotyledons placed before Dicotyledons, considered the Orchids to be more highly evolved than the Grasses, the apetalous and catkin bearing Dicotyledons (Amentiferae) as primitive to the ones with flowers which bear petals. These views are, however, not acceptable to most of the recent phylogenetists. The amalgamation of the Polypetalae and Apetalae (of Bentham and Hooker) was certainly a forward step.

[All these three kinds of classification are not mutually exclusive but often overlap in practice. Even though the phylogenetic system of the classification is recent one and most advanced; from point of view of the practical utility, natural system of classification serves the greatest number of purposes.]

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Angiosperm Phylogeny Group (APG IV CLASSIFICATION)

With the advancements of molecular techniques and generation of large amount of data, it was clear that the earlier classifications suggested conflicting relationships and did not discuss about the evolution of plants.

The Angiosperm Phylogeny Group (APG) is an informal international group of systematic botanists who collaborate to establish a consensus on the taxonomy of flowering plants (angiosperms) that reflects new knowledge about plant relationship discovered through phylogenetic studies.

The Angiosperm Phylogeny Group (APG) system is an updated classification that is established by taking information from recent molecular studies. **It is not a complete formal classification but provides a stable grouping of flowering plants in families and orders.**
The principle of priority is taken into consideration while establishing the correct name of the families. It was also kept in mind that the principle of priority does not work above the level of family.
The APG system follows the rules of ICNafp [International Code Of Nomenclature for algae, fungi and plants] for naming the taxa and does not adopt any phylogenetic naming.
In addition to phylogenetic relationships, the **phylogenetic synapomorphies** {i.e., the characters shared by a group of organisms due to common ancestry} were also taken into consideration during the process of grouping.

[After the 1980s, detailed genetic evidences analysed by phylogenetic methods and while confirming some relationships in existing classification systems, it radically changed others. The new genetic evidences found applicable vary much from systematic point of view and created a rapid increase in knowledge leading to many proposed changes. The stability of Natural System was contradicted in a big way.
{Bremer and Wanntrap (1978, 1981) were the first to make such an attempt.. they proposed that angiosperms should be treated as subclass Magnoliidae of the **class PINATAE** (Seed plants). They opined that instead of dividing Magnoliidae into monocotyledonae and dicotyledonae (as in traditional systems of classification), it should be divided directly into various monophyletic groups (super orders). However, the proposal was not well received at that time since all major systems of classification recognized monocots and dicots as two separate groups.
Almost about a decade later, a team of botanists viz., K. bremer, MW chase, A Backlund, B. briggs, MHG Gustafsson, FA Kellogg, PF Stevens and their co-workers, collected some very useful molecular data in connection with the establishment of phylogenetic relationships amongst plant groups. This eventually led to the development of Angiosperm Phylogeny Group (APG) classification.}
This posed problems for all users of Natural System. The major impetus came from a molecular study based on **rbcL gene** in 1993 of 5,000 flowering plants. This produced a number of surprising results with respect to affinity between grouping of plants. **For example, the dicotyledons were rejected as a distinct group.**

[The "rbcL" gene stands for ribulose-1,5-biphosphate carboxylase/oxygenase large subunit. It's a critical gene in photosynthetic organisms, like plants and some bacteria. This gene codes for a protein that plays a key role in the process of photosynthesis by capturing carbon dioxide from the atmosphere and converting it into organic compounds. **The rbcL gene is located in the large single copy region of chloroplast genome.**The rbcL gene is often used in molecular biology and evolutionary studies to trace the relationships between different species due to its relatively CONSERVED NATURE.]

Large number of systemetists get involved and an unprecedented collaboration developed based on their findings on single gene rbcL. As a result, rather than naming all the individual contributors a decision was made to adopt the name **Angiosperm Phylogeny Group** classification (APG). The first publication under this name was in 1998 and got tremendous recognition among systematists. The main object was to develop a well accepted and more stable classification of angiosperms.

As of 2016, four incremental versions of a classification systems have resulted from collaboration, published in 1998 **(APG I)**, 2003 (**APG II**), 2009 (**APG III**) and 2016 (**APG IV**), each superseding the previous system. Thirteen researchers have been listed as authors to the three research papers and a further 43 as contributors.

The APG IV system of classification is the fourth revised version of a modern system of plant taxonomy based on molecular characteristics incorporating many genes/whole plastid genomes. Before the availability of genetic evidence, the classification of angiosperms was based on their morphology; particularly of their flower and biochemistry.

Although APG System gives a more reliable representation of the relationships, **it has practical limitations.**

The findings of 1998, explained the authors' view that **there is a need for a classification system for angiosperms at the level of families, orders and above, but that existing classifications were outdated.**

The main reason **why existing systems were rejected was because they were not phylogenetic, i.e. not based on strictly monophyletic groups** (groups which consist of all descendants of a common ancestor).

APG IV uses the linear approach (**LAPG** – Linear Angiosperm Phylogeny Group) as advocated by Haston *et al.* (2009).

The APG systems are increasingly regarded as an authoritative point of reference. Following are some examples of the influence of the APG system :

- A significant number of major herbaria, including Kew, are changing the order of their collections according to APG.
- The influential World Checklist of Selected Plant Families including Kew is being updated as per the APG III system.
- In USA and Canada in 2006, a photographic survey of the plants is organized according to the APG III system.
- In the UK, the 2010 edition of the standard flora of the British Isles is based on the APG III system.

PRINCIPLES OF APG SYSTEM

The brief of principles of the APG System Classification (1998) are as follows :

- The Linnean system of orders and families should be retained. "The family is central in flowering plant systematic". An ordinal classification of families is proposed as a "reference tool of broad utility". Orders are considered to be of particular value in teaching and in studying family relationships.
- Groups should be monophyletic (*i.e.*,each group consists of all descendants of a common ancestor). **The main reason why existing systems are rejected is because do not have this property, they are not monophyletic.**

- A broad approach is adopted in defining the limits of groups such as orders and families. Thus, of orders, it is said that a limited number of larger orders will be more useful.
- Families containing only a single genus and orders containing only a single family are avoided wherever possible, without violating the over-riding requirement of monophyly.
- Above or parallel to the level of orders and families, the term clades is used more freely.

The findings of 1998, explained the authors' view that there is a need for a classification system for angiosperms at the level of families, orders and above, but that existing classification were "outdated". The main reason why existing systems were rejected was because they were not phylogenetic, *i.e.*, not based on strictly monophyletic groups (groups which consist of all descendents of a common ancestor). An ordinal classification of flowering plant families was proposed as a "reference tool of broad utility". The broad approach adopted to defining the limits of orders resulted in the recognition of 40 orders, compared to, for example, 232 in Takhtajan's 1997 classification.

In the development of a fourth version (APG IV) there was some controversies over the methodology and the development of a consensus proved more difficult than in previous iterations. The validity of discussions regarding family delimitation in the absence of changes of phylogenetic relationships was questioned by Peter Stevens.
Further progress was made by the use of large banks of genes, including those of plastid, mitochondrial and nuclear ribosomal origin (Douglas *et al.,* 2011). The fourth version was finally published in 2016, after an International Conference at Royal Botanical Gardens (2015) and also an online survey of botanists and other users.
The broad outline of the system remains unchanged but several new orders are included [Boraginales, Dilleniales, Icacinales, Metteniusales, and Vahliales], some new families are recognised [Kewaceae, Macarthuriaceae, Maundiaceae, Mazaceae, Micrteaceae, Nyssaceae, Peraceae, Petenaeaceae and Petiveriaceae] and some previously recognised families are lumped {Aristolochiaceae now includes Lactoridacea and Hydnoraceae; Restionaceae now includes Anarthriaceae and Centrolepidaceae; and Buxaceae now includes Haptanthaceae]. Due to nomenclatural issues, the family name Asphodelaceae is used instead of Xanthorrhoeaceae and Francoaceae is used instead of Melianthaceae (and now also includes Vivianiaceae). This brings the total number of orders and families recognized in the APG system to **64** and **416**, respectively. 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 asteroids are also included in the larger clades dominated by the rosids and asterids are also included. APG IV also uses the linear approach (LAPG – Linear Angiosperm Phylogeny Group) as advocated by Haston *et al*. (2009).

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- **The cladistic classification of angiosperms (i.e., APG System), treats the flowering plants as a CLADE (Group), called angiosperms, without a formal botanical name.**
- **According to APG system, monocots are monophyletic group (clade) whereas dicots are paraphyletic [**Term applied to a group of organisms which includes the most recent common ancestor but not all of the descendants of that most recent common ancestor.**]**
- **Nevertheless, the majority of dicot species form a monophyletic group, called EUDICOTS or TRICOLPATES, whereas a few belong to a third major clade known as the MAGNOLIIDAE. The rest include paraphyletic grouping of primitive species**

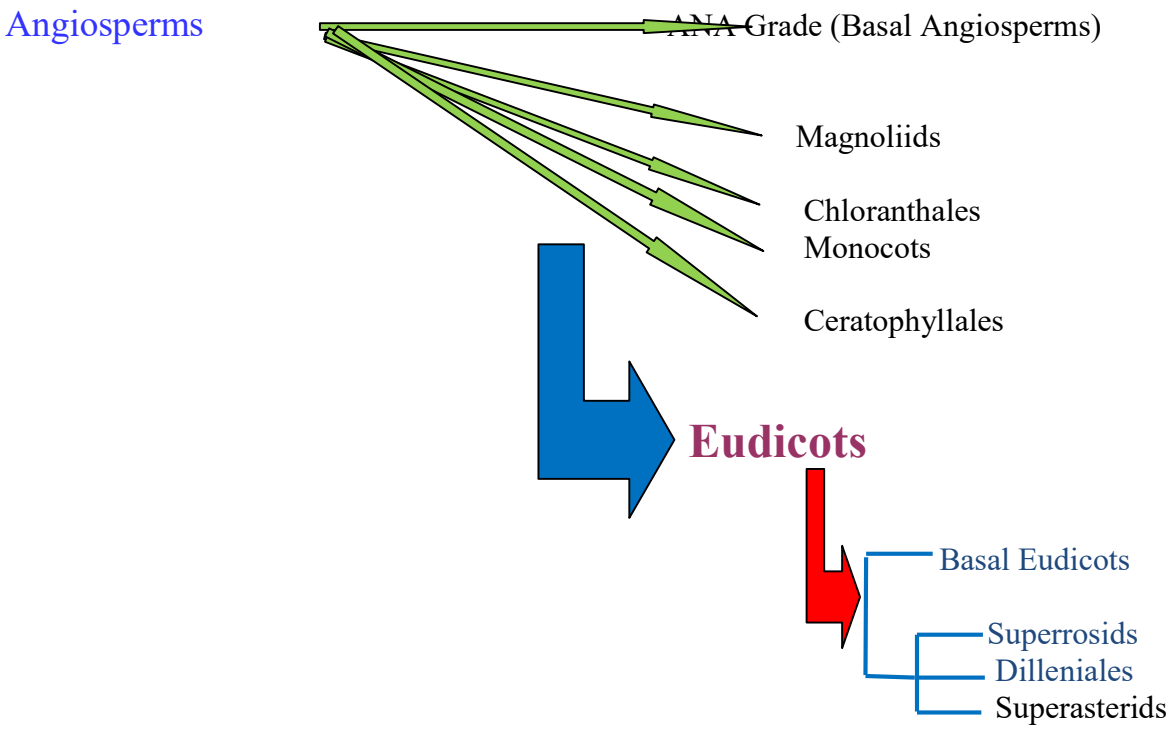
collectively known as BASAL ANGIOSPERMSplus the families **Ceratophyllaceae** and **Chloranthaceae**

According to the APG classification, the basal angiosperms are represented as the **ANA grade** (Amborellales, Nymphaeales and Austrobaileyales) that leads to the major radiation of angiosperms and all the remaining angiosperms are together known as the **MESANGIOSPERMS.** The Mesangiosperms comprises of five clades:

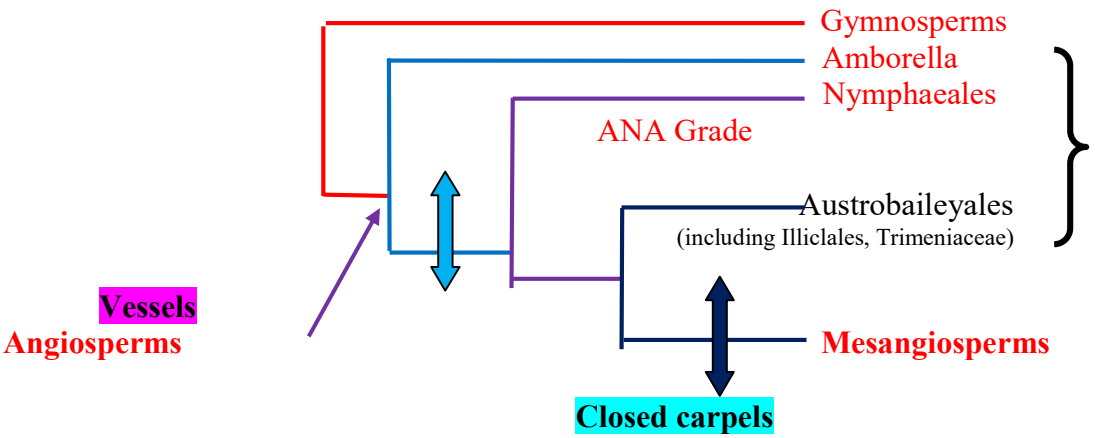
Clade-I: Chloranthales;
Clade-II: Magnoliides;
Clade-III: Monocots;
Clade-IV: Ceratophyllales;
Clade-V: Eudicots

The general scheme of arrangement followed in APG IV (2016) is as follows:

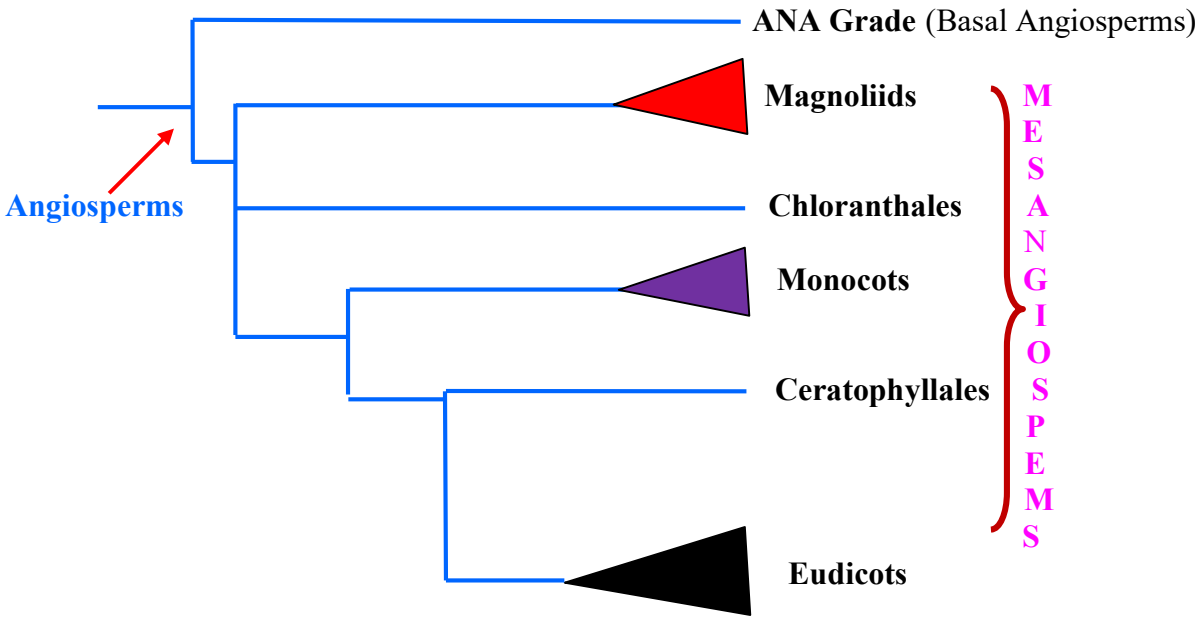
- the **ANA grade**;
- a clade of **Magnoliid** families;
- a clade having all **Monocots**;
- a large **Eudicot** (tricolpate) clade subdivided into two major groups:
  - Superrosids
  - Superasterids



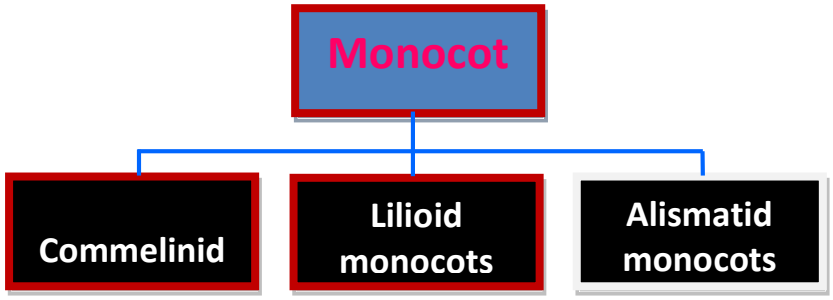
Simplified version of APG IV Classification (2016)



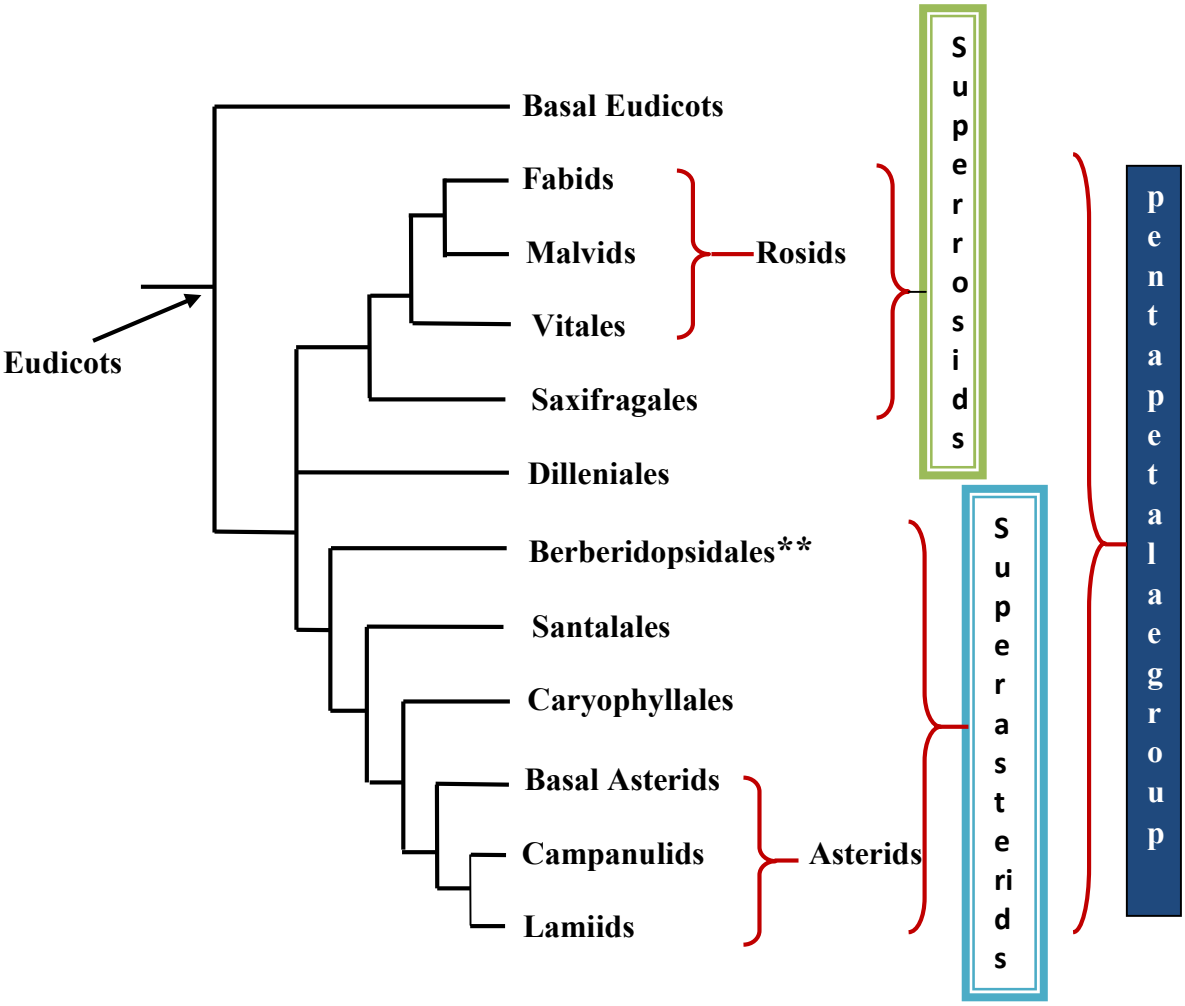
Basal Angiosperms according to the APG IV Classification (2016)



Arrangement of Mesangiosperms in APG IV as sister to basal angiosperms

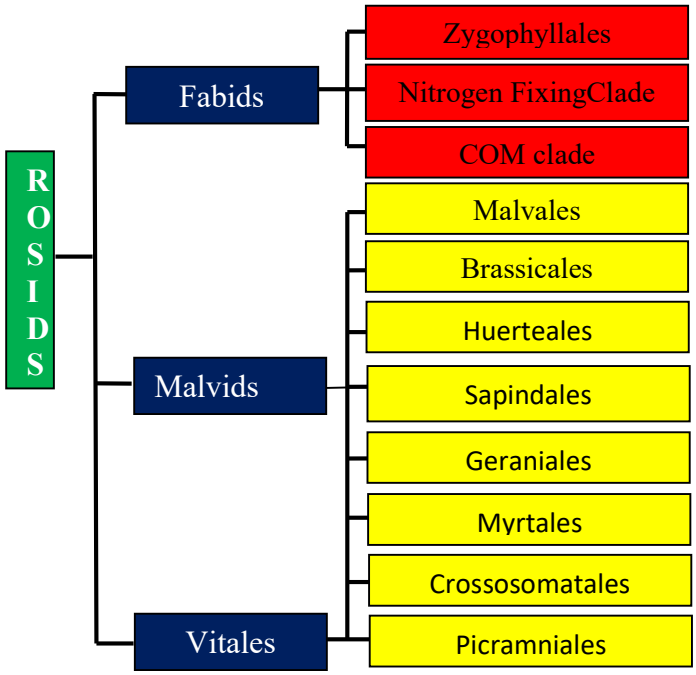


Three major clades within Monocots in APG IV classification

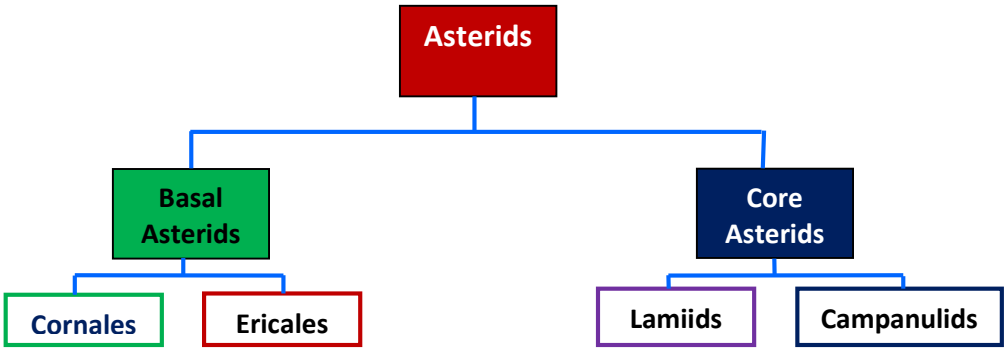


The pentapetalae group of Eudicots in APG IV classification

Nitrogen Fixing Clade



The major groups within Rosids in APG IV classification



The major groups within Asterids in APG IV classification

It is important to remember that APG IV (2016) recognized 64 orders and 416 families.

Out of 416 families 259 are represented in India.

There has been certain changes from APG (1998) to APG IV (2016) and more recent with continuous upgradation on **Angiosperm Phylogeny website (APweb)** by**Peter F. Stevens (2017)**where he added four orders of gymnosperms Cycadales, Ginkgogoales, Pinales and Gnetales in APweb.

Since, the stability is an important aspect in any classification system and the APG system has remained remarkably consistent since its inception.

The advent of routine whole-plastid genome sequencing and nuclear gene sequencing has played significant role in new phylogenetic understanding and this appears to be the most likely source of new data that will require future alteration of the APG system .

Merits of APG IV System :

1. The system is strongly based on molecular studies.
2. Traditional division of angiosperms has not been followed.
3. Families with primitive characters were placed in the beginning.
4. APG IV adopts phylogenetic principle of monophyly.

Demerits of APG IV System :

1. Classification below the rank of family not attempted. Classification.
2. Not very popular, difficult in application particularly in herbaria.

[Recent advent of genetic, biochemical and molecular tools provided a rapid increase in knowledge of classification systems. The research studies involved collaboration between a very large number of molecular systematists. Therefore rather than naming all the individual contributors a decision was made to adopt the name **Angiosperm Phylogeny Group (APG)**system of classification. This system established the basic phylogenetic framework (**a DNA phylogeny based**) of angiosperm classification system at the order and familial levels. Swedish Botanists **Kare Bremer** and **Birgitta Bremer** first proposed a cladistic classification of angiosperms and have played a leading role in the development of APG classification along with **Peter F. Stevens, A. Backlund, B. Briggs, M. W. Chase,M. H. G. Gustafsson, S. B. Judd, F. A. Kellogg** and **M. Thulin**.

APG is an informal international group of systematic botanists who work together and try to establish a common view (consensus) of their relationships based upon phylogeny.

In 1998, APG-I was proposed, followed by APG-II (2003), APG-III (2009) and APG-IV (2016).

THE BASAL ANGIOSPERMS

The flowering plants which diverged from a fundamental lineage leading to evolution of mostflowering plants. In particular, the most basal angiosperms were called the **ANITA grade.**

ANITA stands for *Amborella, Nymphaeales, Illiciales, Trimeniaceae-Austrobaileya*.

Amborella – A single species of shrub from New Caledonia.

Nymphaeales – water lilies, together with some other aquatic plants.

Austrobaileyales – Woody aromatic plants including Star anise.

Some authors have shortened this to **ANA** – grade for the three orders, *Amborellales,Nymphaeales* and *Austrobaileya*

SUMMARY

- APG IV system of classification is the collaborative effort of Angiosperm Phylogeny Group (Botanical Journal of Linnean Society, 2016), developed by using information from recent molecular studies.
- It is a phylogenetic system of classification and **not useful for identification purpose but provides a stable grouping.**
- This system follows the rules of ICNafp.
- Basal angiosperms are placed before monocots.
- About 462 families are recognized.
- According to this classification *Amborella trichopoda* is the most basal angiosperm.
- The basal angiosperms are represented as the ANA grade (Amborella, Nymphaeales and Austrobaileya) representing the major radiation of angiosperms.
- The monocots divided into three major clades viz., Commelinids, Lilioid and Alismatid.

- Asterids consists of a large group of angiosperms having iridoid compounds, sympelalous corolla and unitegmic, tenuinucellate ovules.
- Asclepiadaceae merged within the family Apocynaceae, similarly Bombacaceae, Sterculiaceae and Tiliaceae merged within the family Malvaceae.
- Ceratophyllaceae is treated as the most probable relative to monocots.

Declaration:

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THANX