

Systems of Classification

CC VI: Plant Systematics

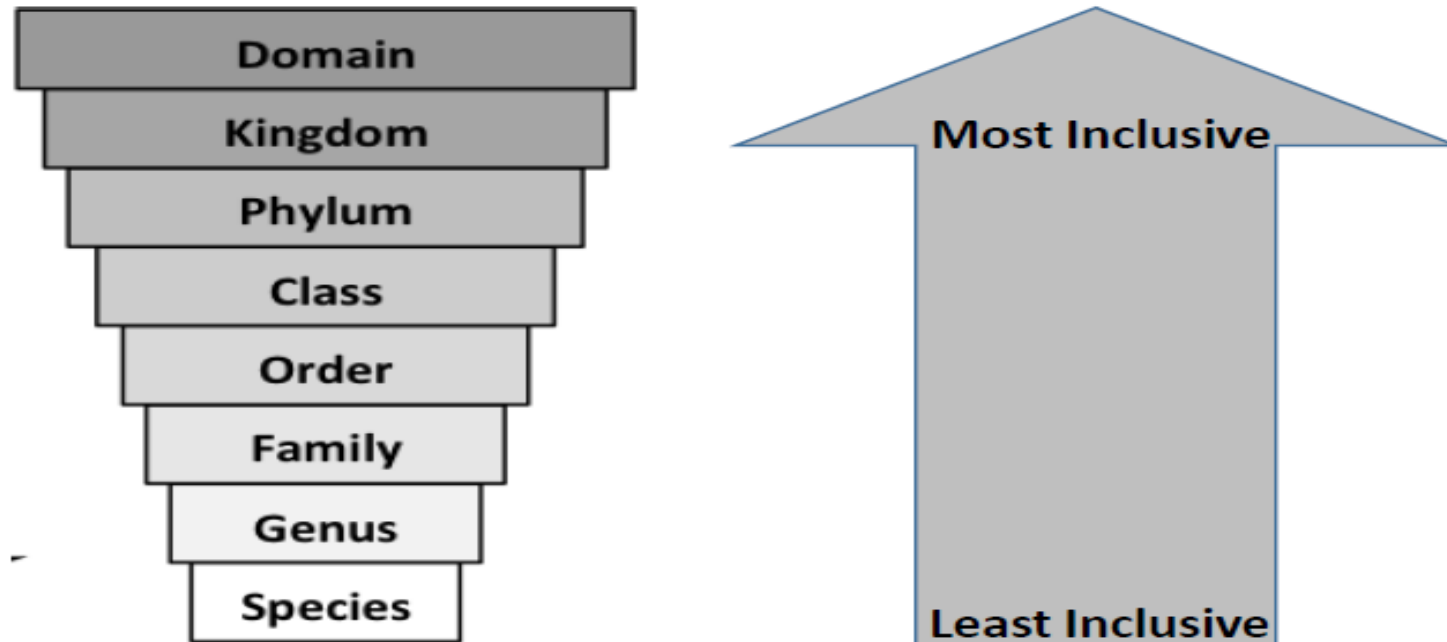
Unit 4

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What is Classification:

“Classification is an arrangement of organisms into groups on the basis of their similarities. The grouping is done from less inclusive to more inclusive group until the organisms are assembled into a final most inclusive group”

The sequence of classification follows a fixed system of hierarchy of categories such as species-genus-family-order and so on. The classification process includes assigning appropriate **position** and **rank** to a new **taxon**.



Need for Classification:

- ❑ Around **400000 plant** species are reported in the world now (Stearn, 1980)
- ❑ The World Conservation Union's (**IUCN**) **Red List** of Plants included some **34,000 threatened species** in 1997.
- ❑ **60,000 to 100,000** plant species are **currently threatened**
- ❑ **75%** of the world's population relies on **traditional medicines**.
- ❑ Globally, **80%** of our plant based calorie intake comes from just **12 domesticated plant species** (8 cereals, 4 tubers) though 30,000 species of plant are edible.

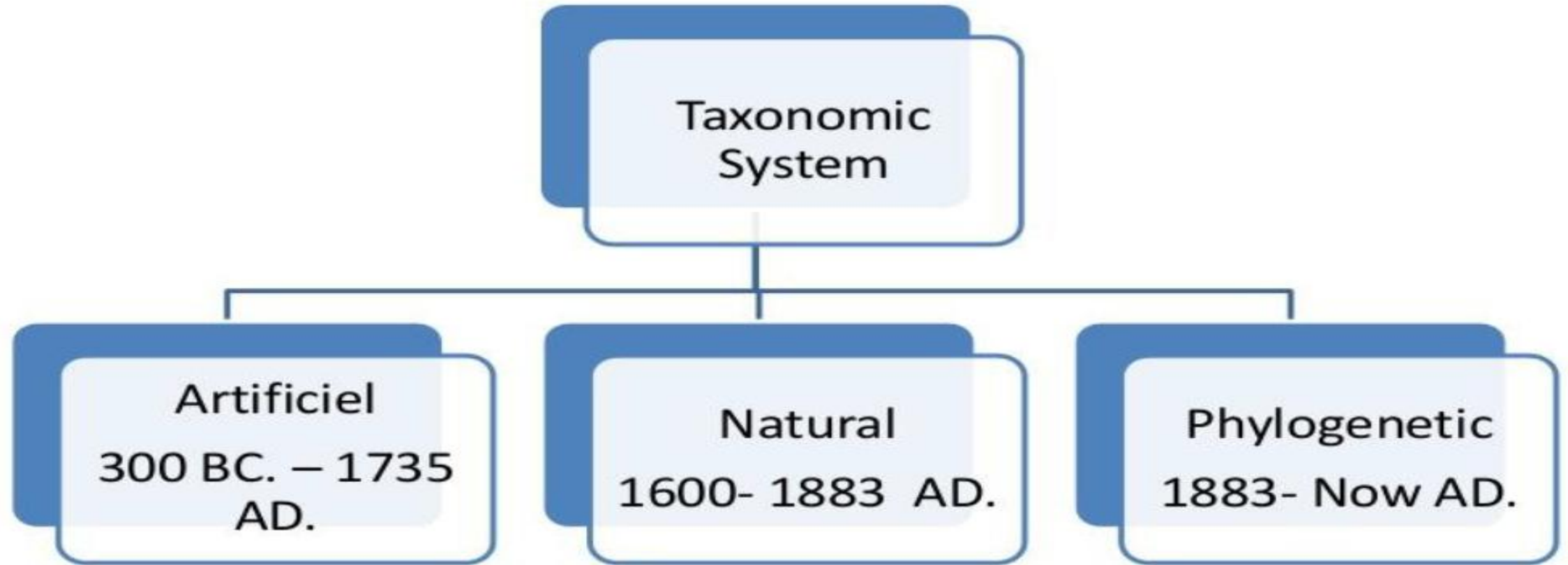
Need to study about all plants and for:

- **Know about the ecosystem**
- **Conserve biodiversity**
- **Proper management**
- **Scientific study**

Classification at Early Stage

- The earliest records for classification dated back 2000 B.C. in Atharva Veda.
- A botanist named Parashara wrote Virak-shayurveda.
- Different methods used by Aztecs, Assyrians, Chinese, and Egyptians have also been discovered.
- Classification is also evident in the early Judeo-Christian record (Genesis 2: 19-20)
- In the western world classification starts with the eminent Greek philosophers of that time

Types of Classification in Taxonomic System:



Artificial System of Classification

- ❑ Oldest and first approach of classification of plants
- ❑ Artificial Classification is utilitarian, based on arbitrary, easily observable few characters such as habit, habitat, phenology, number of plant parts (e.g. cotyledons), or floral characters (particularly the number of stamens and carpels).
- ❑ Although it can not describe and classify all plants correctly since it involves only a few characters

Artificial System of Classification was followed by/in:

- 1. Vedas (ar. 200 BC.)**
- 2. Theophrastus (370-285 BC.)**
- 3. Secundus (23-79 AD.)**
- 4. Dioscorides (62-128 AD.)**
- 5. Magnus (1200-1280 AD.)**
- 6. Brunfels (1464-1553 AD.)**
- 7. Bock (1489-1554 AD.)**
- 8. Fuchs (1501- 1556 AD.)**
- 9. Tournefort (1656-1708 AD.)**
- 10. Linnaeus (1707-1778 AD.)**

Name of the Contributors	Contributions
Theophrastus	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.
Tournefort	1. He published <i>Elements de Botanique</i> in 1694, including 698 genera and 10,46 species. 2. A latin translation of this work with additions was published as <i>Institutions rei herbariae</i> 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.

Name of the Contributors	Contributions
Linnaeus	1. In 1735 he first published <i>Systema Naturae</i> where he introduced his method of classification (sexual system) for plants. 2. He identified and grouped plants according to their reproductive parts (stamen and pistils) and divided groups of plants downward until the lowest set (species) was reached at which point no further division was possible. He started with only three classification levels (class, genus, and species) but in later printings added order as well. Several other levels have been added in the years since. This basic system is still in common use today for biologists to classify organisms. 3. The other major contribution of Linnaeus is the Binomial nomenclature for naming plants. First introduced in his book <i>Species Plantarum (1753)</i>, plants are named by their genus and species using the Latin names. Both words are italicized, and the first word is capitalized. This basic system has been utilized over the years to name all types of biological organisms.



Carl Linnaeus (1707-1778)
Often referred as “Father of
Biological Classification”



The climate controlled vault at the Linnean Society of
London, where Linnaeus’ original specimens were
housed

Artificial system of classification: Advantage and Disadvantages

Advantages:

- ☐ Makes the classification simple and easy
- ☐ Less time consuming and manage to classify with little information of one or two characters only.
- ☐ Poorly known plants can be classified easily
- ☐ Less instruments of classification are needed
- ☐ Very specific to the character of choice

Disadvantages:

- ☐ Not universally applicable
- ☐ Cannot initiate bold prediction
- ☐ Since the choice of characters are arbitrary, the exact correlation cannot be established
- ☐ Various unrelated taxa, which are not at all related but, similar in one respect only, have been placed under the same Class.
- ☐ Cannot establish evolutionary relationships among taxa.

Natural System of Classification

- ❑ This taxonomic system was introduced by **Jean Bauhin in 1623**.
- ❑ These systems are based on natural affinities of plants.
- ❑ It is done based on natural characteristics of plant.
- ❑ It place together organisms that have the greatest number of shared features.
- ❑ No single feature is not important but total features are the tools of classification.

*So, classification of plants which is done based on **maximum natural characteristics** of plants and not a single characteristic but total characteristics act as the key to place a plant into a definite **texa** is termed as natural system of plant classification.*

Natural System of Classification was followed by/in:

- 1. Gaspard Bauhin (1550-1624)**
- 2. Ray (1627-1705 AD.)**
- 3. Adanson (1727-1806)**
- 4. A. L. de Jussieu (1748-1836)**
- 5. Robert Brown (1773-1858)**
- 6. A.P. Candolle (1778-1884)**
- 7. Alphonse (1806-1893)**
- 8. Benthum (1800-1884) and Hooker (1817-1911)**

Name of the Contributors	Contributions
Bauhin	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 <i>Phytopinax</i>(1596), <i>Prodromus theatre botanici</i> (1620), and lastly , <i>Pinax theatre botanici</i> (1623) containing a list of 6000 species of plants giving synonyms.
Adanson	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.
de Candolle	<i>Theorie elementaire de la botanique</i> (1813), wherein he proposed a new classification scheme, outlined the important principles and introduced the term Taxonomy .

Name of the Contributors	Contributions
Benthum & Hooker	1. This system was fundamentally based on that of Augustin Pyramus de Candolle (1778-1841), but disagreed in many respects. 2. They emphasized much on the nature of perianth, especially number of whorls (one or two) and if two, whether the members of inner whorl(petals) are free or fused. 3. In Genera Plantarum, 97, 205 species under 7,569 genera of seed plants known to them, have been described and classified. 4. The spermatophytes are divided into three classes viz. Dicotyledons, Gymnospermae and Monocotyledons, which are further divided into 3 subclasses, 21 series, 25 cohorts(orders) and 202 natural orders (families). 5. Out of 202 families recognized by them, three belong to Gymnospermae and 199 to angiosperms. 6. The dicots are divided into three subclasses viz. Polypetalae, Gamopetalae and Monochlamydeae, depending on the free or fused nature of petal or perianth in one whorl. 7. The Family -Ranunculaceae (Ranales) are considered to be most primitive, therefore placed in the beginning and Family- Gramineae (Poaceae) are considered to be most advanced, therefore placed in the end.

Natural system of classification: Advantage and Disadvantages

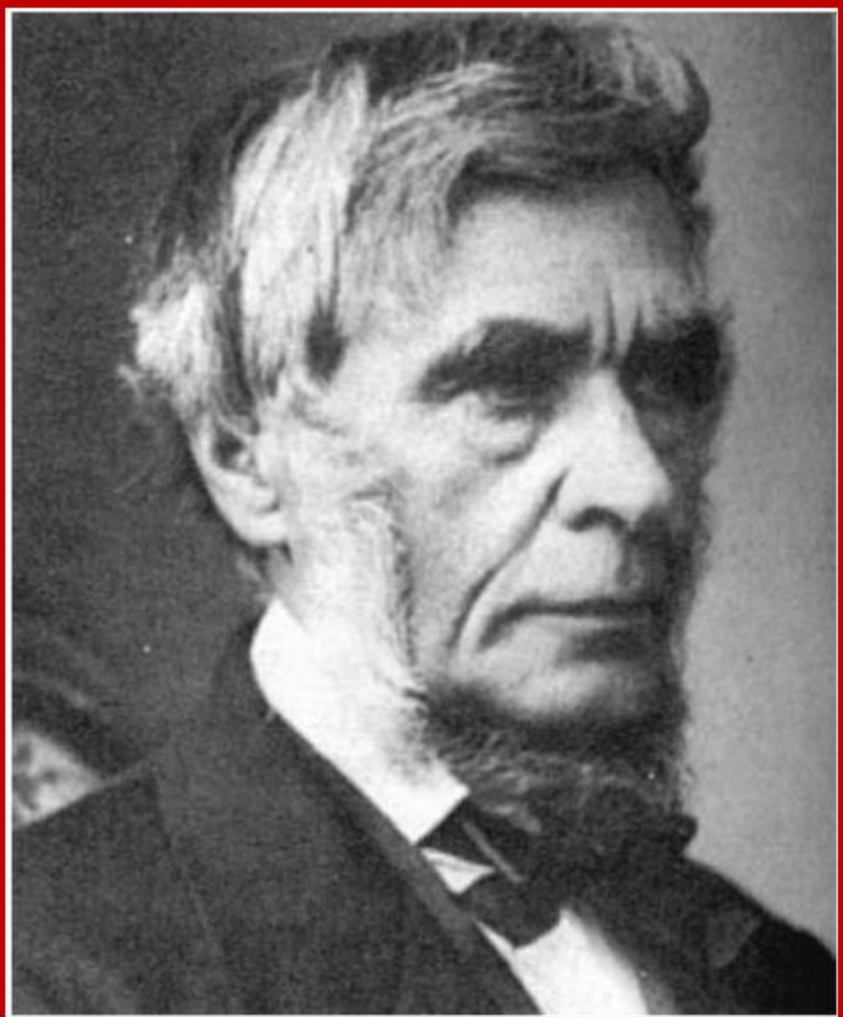
Advantages:

- ☐ Makes the classification more inclusive
- ☐ It can be used for bold prediction of ranks and categories for newly identified plants.
- ☐ Contains more exclusive information about the taxonomic hierarchy.
- ☐ It can help to predict properties of even not-so-closely related species.
- ☐ Members of different groups are mostly similar in hereditary pattern.

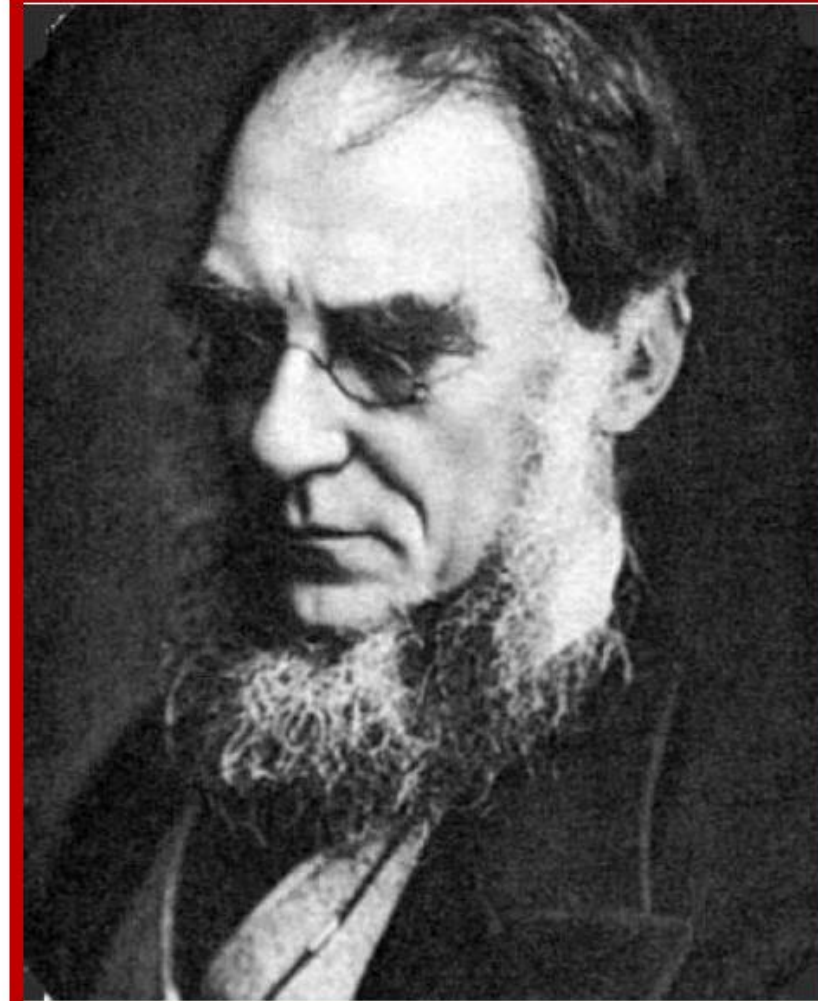
Disadvantages:

- ☐ The complexity level is more than artificial
- ☐ Combursive and time consuming
- ☐ Less known plants cannot be classified through this system since their characteristics are not fully defined.
- ☐ A single property of interest cannot be taken into consideration for classification

<i>Natural classification</i>	<i>Artificial classification</i>
<i>Basis</i> sum total of all the characters of its members	<i>Basis</i> one character or a very few characters of its members, especially chosen
<i>Advantages</i> groups together plants most alike in their hereditary constitutions in general groups together plants most closely related phylogenetically contains a great deal of information about its members can easily incorporate additional information about its members has a high predictive value	<i>Disadvantages</i> may not group together plants most alike in their hereditary constitutions may not group together plants most closely related phylogenetically contains only a very limited amount of information about its members cannot incorporate more information about its members has little or no predictive value
<i>Disadvantages</i> identification may be difficult the placing of poorly-known plants may be uncertain or impossible is liable to change with increase in our knowledge	<i>Advantages</i> identification can be made easy poorly-known plants may be definitely placed is stable and is not changed by increase in our knowledge



George Bentham (1800-1884)



Sir Joseph Dalton Hooker (1817-1911)

Bentham & Hooker's system of classification

- The system of classification of seed plants was proposed by Bentham and Hooker.
- It's the most well developed natural classification system , it was published in 3 volume work *Genera plantarum* (1862-83).
- They described 97,205 species of seed plants belonging to 7,569 genera of 202 families starting from Ranunculaceae up to Gramineae.

An Out-line of Classification systems of Bentham and Hooker

Class **DICOTYLEDONES**

Sub-class **DICOTYLEDONUM POLYPETALE** vol I

Series 1. Thalamiflorae

Series 2. Disciflorae

Series 3. Calyciflorae

Sub-class **DICOTYLEDONES GAMOPETALAE** vol II

Series 1. Inferae

Series 2. Heteromerae

Series 3. Bicarpellatae

Sub-class **DICOTYLEDONES MONOCHLAMIDEAE** vol III

Series 1. Curvembryeæ

Series 2. Multiovulatae Aquaticæ

Series 3. Multiovulatae Terrestres

Series 4. Microembryeæ

Series 5. Daphnales

Series 6. Achlamydosporeæ

Series 7. Unisexuales

Series 8. Ordines nomali (*incertae sedis*)

Class **GYMNOSPERMEAE** vol III (1)

Class **MONOCOTYLEDONES** vol III (2)

Series 1. Microspermæ

Series 2. Epigynæ

Series 3. Coronarieæ

Series 4. Calycineæ

Series 5. Nudifloreæ

Series 6. Apocarpæ

Series 7. Glumaceæ

Class 1: Dicotyledons

- Seed with 2 cotyledons
- Flowers with pentamerosous or tetramerosous
- Reticulate venation

Subclass 1: Polypetalae

- **Polypetalae:** sepals and petals distinct, petals free (14 series, 25 orders and 165 families)
 - **Thalamiflorae:** flowers hypogynous, stamens many, disc absent
 - **6 Orders:** *Ranales, Parietales, Polygalineae, Caryophyllineae, Guttiferales and Malvales*
 - **Disciflorae:** flowers hypogynous, disc present below the ovary
 - **4 Orders:** *Geraniales, Olacales, Celastrales and Sapindales*
 - **Calyciflorae:** flowers perigynous or epigynous
 - **5 Orders:** *Rosales, Myrtales, Passiflorales, Ficoideales and Umbellales*

Subclass 2: Gamopetalae

- **Gamopetalae:** Sepals and petals distinct, petals fused
 - **Inferae:** ovary inferior
 - **3 orders:** Rubiales, Asterales and Campanales
 - **Heteromerae:** Ovary superior, stamens in one or two whorls, carpels more than 2
 - **3 orders:** Ericales, Primulales and Ebenales
 - **Bicarpellatae:** Ovary superior, stamens in one whorls, carpels 2
 - **4 orders:** Gentianales, Polemoniales, Personales and Lamiales

Subclass 3: Monochlamydeae

- **Monochlamydeae:** flowers apetalous, perianth lacking or if present not differentiated into sepals and petals
 - **Curvembryae:** embryo coiled, ovule usually 1
 - **Multiovulate aquaticae:** aquatic plants, ovules many
 - **Multiovulate terrestres:** terrestrial plants, ovules many
 - **Microembryae:** embryo minute
 - **Daphnales :** carpel 1, ovule 1
 - **Achlamydosporae:** ovary inferior, unilocular, ovules 1-3
 - **Unisexuales:** flowers unisexual
 - **Ordines anomali:** relationship uncertain

Class 2: Gymnospermae

- Ovules naked
 - 3 families

Class 3: Monocotyledons

- Flowers trimerous, venation parallel
 - **Microspermae** : ovary inferior, seeds minute
 - **Epigynae**: ovary inferior, seeds large
 - **Coronarieae** : ovary superior, carpels united, perianth colored
 - **Calycinae**: ovary superior, carpels united, perianth green
 - **Nudiflorae**: ovary superior, perianth absent
 - **Apocarpae**: ovary superior, carpels more than 1, free
 - **Glumaceae** : ovary superior, perianth reduced, flowers enclosed in glumes

Merits of Bentham and Hooker's System

- Each plant has been described either from the actual specimen or preserved herbarium sheets so that the descriptions are detailed as well as quite accurate.
- The system is highly practical and is useful to students of systematic botany for easy identification of species.
- The flora describes geographical distribution of species and genera.
- The generic descriptions are complete, accurate and based on direct observations.

Merits of Bentham and Hooker's System

- Larger genera have been divided into sub genera, each with specific number of species.
- Dicots begin with the order Ranales which are now universally considered as to be the most primitive angiosperms.
- Placing of monocots after the dicot is again a natural one and according to evolutionary trends.
- The placing of series disciflorae in between thalami floriae and calyciflorae is quite natural.
- The placing of gamopetalae after polypetalae is justified since union of petals is considered to be an advanced feature over the free condition

Demerits of Bentham and Hooker's System

- Keeping gymnosperms in between dicots and monocots is anomalous.
- Subclass monochlamydeae is quite artificial.
- Placing of monochlamydeae after gamopetalae does not seem to be natural.
- Some of the closely related species are placed distantly while distant species are placed close to each other.
- Certain families of monochlamydeae are closely related to families in polypetalae, e.g. Chenopodiaceae and Caryophyllaceae

Demerits of Bentham and Hooker's System

- Advanced families, such as Orchidaceae have been considered primitive in this system by placing them in the beginning. Placing of Orchidaceae in the beginning of monocotyledons is unnatural as it is one of the most advanced families of monocots.
- Similarly, Compositae (Asteraceae) has been placed near the beginning of gamopetalae which is quite unnatural.
- Liliaceae and Amaryllidaceae were kept apart merely on the basis of characters of ovary though they are very closely related.
- There were no phylogenetic considerations

Phylogenetic System of Classification

- ☐ **Latest** system of classification of life.
- ☐ Done in very micro scale(cells)
- ☐ Basic of the system is the **Darwin's "Origin of Species (1859)"**
- ☐ First introduced by **August Wilhelm Eichler in 1883.**
- ☐ Goal of the system is to establish a system of classification based on the course of evolutionary descent of its members.
- ☐ System where it is believed that every species is come from the evolutionary change.

So it is defined as the classification system based on phylogenetic characteristics of a species.

Phylogenetic System of Classification was followed by/in:

- ☐ Eichler (1839-1889)
- ☐ Engler (1844-1930)★
- ☐ Prantl (1849-1893)★
- ☐ Bessey (1845-1915)
- ☐ Wettstein (1862-1931)
- ☐ Sokal & Sneath (1963,73)
- ☐ Henning (1966)
- ☐ Hallier (1868-1938)
- ☐ Hutchinson (1884-1972)★
- ☐ Takhtajan (1980)★
- ☐ Cronquist (1981)
- ☐ Dahlgren (1981)
- ☐ Thorne (1981)
- ☐ APG (Angiosperm Phylogeny Group system) (1998,03,09)★

Note: The star marked are the most popular

Name of the Contributors	Contributions
Bessey	1. Charles Edwin Bessey, (born May 21, 1845) works include Botany for High Schools and Colleges (1880), The Essentials of Botany (1884), and Essentials of College Botany (1914), all widely popular textbooks that dominated botanical instruction in the United States for more than half a century. 2. He introduced to the United States the systematic study of plant morphology and the experimental laboratory for botanical instruction on the college level. His arrangement of angiosperm (flowering plant) taxa, emphasizing the evolutionary divergence of primitive forms, is considered by many as the system most likely to form the basis of a modern, comprehensive taxonomy of the plant kingdom. 3. Initiated the representation of evolutionary relationships through an evolutionary tree with primitive groups at the base and the most advanced at the tip of the branches –a diagram resembles a cactus plant is better known as Besseyan Cactus.
Hutchinson	1. Associated with the Royal Botanic gardens at Kew, developed a system of classification which appeared in its final form in 3rd edition of his the <i>Families of flowering plants (1973)</i>. 2. Hutchinson's earliest work was on aquatic ecosystems, particularly the systematics and distribution of the aquatic insects Heteroptera. 3. Later he works on various aspects of evolution.

Name of the Contributors	Contributions
Takhtajan	1. Takhtajan, a Russian botanist developed a classification system of flowering plants, which was periodically revised, the last revision being published in 1997. 2. Phylograms (unfortunately missing in the 1997 version) are provided indicating the putative relationship of groups, latter being represented by balloons or bubbles (hence the name ' bubble diagram ') of different sizes indicating the relative number of species in the groups. Because of the elaborate bubble diagram and its unique display, Woodland has aptly named it 'Takhtajans flower garden'.
Cronquest	1. Author of 'An integrated system of classification of flowering plants' (1981). 2. Takhtajan attaches more importance to cladistics. 3. Phylogram in the form of a bubble diagram has been proposed and that depicts only the major groups of angiosperms.

Phylogenetic system of classification: Advantage and Disadvantages

Advantages:

- ☐ It adds a third dimension to the earlier classification methods by involving past history or ancestral history.
- ☐ It has a higher predictive capacity than any other known classification.
- ☐ More detailed and scientific in nature.
- ☐ It can help to trace back the evolutionary history of a plant family.

Disadvantages:

- ☐ The complexity level is maximum than any other known classification.
- ☐ Combursive and time consuming.
- ☐ Phenotypic characters are not given importance.
- ☐ Same looking species can be grouped together if they share common phylogeny even at distant level.

Natural vs Phylogenetic

Natural Classification

1. Based on several constant characters
2. Used for simple identification
3. Evolutionary sequence not considered
4. Example: [Bentham and Hooker's classification](#)

Phylogenetic Classification

1. Along with several constant characters, evolutionary sequence are also considered.
2. Used for studying relationship
3. Evolutionary affinities are taken into account
4. Example: Eicher's, [Engler and Prantl](#), [Hutischson's](#)

ARMEN TAKHTAJAN



Takhtajan's System of Classification

Armen Takhtajan, a Russian taxonomist of Komarov Botanical Institute, Department of Higher Plants, Leningrad presented a phylogenetic system of classification of angiosperms in 1966 under the title "System et Phylogenia Magnoliophytorum".

This system with some modifications appeared in english edition in a book entitled "Flowering Plants :- Origin and Dispersal " (1969).

The Takhtajan system is similar to the classification scheme of Cronquist, but with somewhat greater complexity at the higher levels. Takhtajan favored smaller orders and families, to allow character and evolutionary relationships to be more easily grasped.

In the class Magnoliopsida,

- Most primitive order: Magnoliales

- Most advanced order: Asterales.

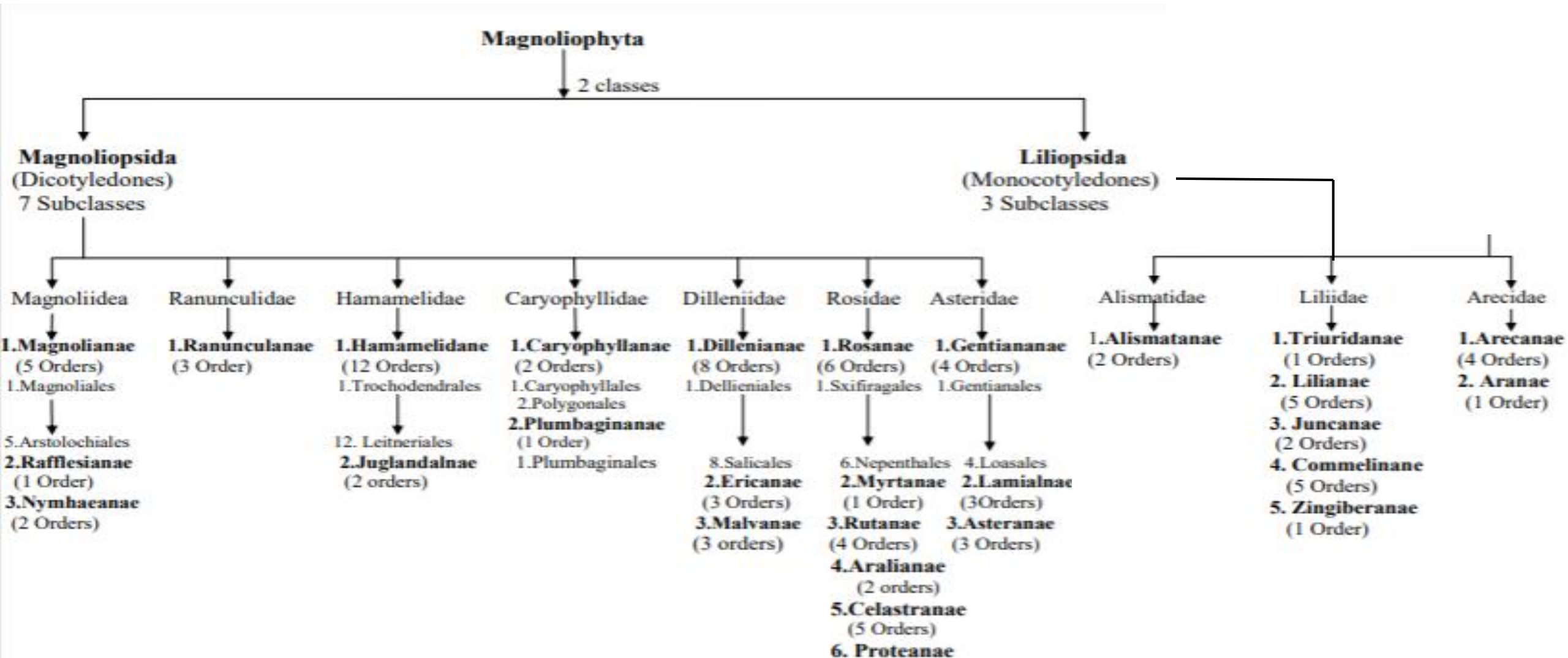
In the class Liliopsida,

- Most primitive order: Alismatales

- Most advanced order: Arales.

The Takhtajan classification system remains influential; it is used, for example, by the Montréal Botanical Garden.

An Out-line of Classification systems of Takhtajan



An Out-line of Classification systems of Takhtajan

Division	Class	Sub-class	Order
Magnoliophyta (Angiosperms)	Magnoliopsida (Dicotyledons)	Magnolidae	7
		Hamamelidae	8
		Ranunculidae	3
		Caryophyllidae	3
		Dilleniidae	12
		Rosidae	16
		Asteridae	7
	Liliopsida (Monocotyledons)	Alismatidae	3
		Lilidae	3
		Arecidae	5
		Commelinidae	6

Salient Features of Takhtajan's Classification System

- For the origin of angiosperms Takhtajan (1959) pleaded the phenomenon of Neoteny, defined as the attainment of reproductive stage at a juvenile stage.
- In his opinion, the transitional groups between gymnosperms and angiosperms existed as small populations where evolution took place at an accelerated rate. These populations provide the combination of genetic drift and selection, which are most effective in promoting rapid evolution.
- The evolution in the immediate ancestors of angiosperms must have been very rapid and facilitated the production of large adaptive modifications. Under such conditions, one of the ancient branches of gymnosperms must have initiated a more progressive group of seed plants that possessed high adaptability and plasticity. This group was unusually plastic, because it developed through neoteny.
- He considered angiosperms to be monophyletic which arose from some very ancient group of gymnosperms (like Bennettitales) and monocots to have originated from primitive dicots with apocarpous flowers presumably something like the present day Nymphaeales.

Evolutionary Consideration/Dicta/Principles of Classification of Takhtajan

Character	Primitive	Advanced
Growth habit	Woody habit	Herbaceous habit
	Small woody angiosperm	Large trees of tropical rain forests
	Sparingly branched trees	Trees with numerous slender branches
	Evergreen plants	Deciduous woody plants
Leaves	Simple leaves	Compound leaves
	Reticulate venation	Parallel venation
	Alternate leaves	Opposite leaves
Stomata	Mesogenous type	Perigenous type
	With subsidiary cells	Lacking subsidiary cells
Nodal structure	Tri to pentalacunar type	Unilacunar type
Inflorescence	Cymose	Racemose
Floral structure	Indefinite and variable number of floral parts arranged spirally on an elongated axis.	Fixed number of floral parts arranged in cyclic pattern on a short axis

Evolutionary Consideration/Dicta/Principles of Classification of Takhtajan

Character	Primitive	Advanced
Pollen grains	Exine devoid of external sculpturing	Sculpturing is of various types
	Monocolpate (dicots)	Ticolpate (dicots)
Gynoecium	Apocarpous	Syncarpous
Ovules	Anatropous ovule	Other types
	Crassinucellate ovules	Tenuinucellate ovules
Pollination	Entomophily	Anemophily
Gametophyte & fertilization	Monosporic Polygonum type	Tetrasporic type
Seeds	Abundant endosperm with a minute and undifferentiated embryo	Endosperm is reduced or wanting and the embryo is large and well differentiated
Fruits	Many seeded follicular fruit develop from multicarpellary apocarpous gynoecia.	Coenocarpous fruits

Merits of Takhtajan's Classification

1. The classification of Takhtajan is more phylogenetic than that of earlier systems.
2. This classification is in a general agreement with the major contemporary systems of Cronquist, Dahlgren, Thorne, and others.
3. Nomenclature adopted in this system is in accordance with the ICBN, even at the level of division.
4. The treatment of Magnolidae as a primitive group and the placement of Dicotyledons before Monocotyledons are in agreement with the other contemporary systems.
5. The concept of primitive flower in the classification is in accordance with modern taxonomists
6. The introduction of the rank of “super order” in the classification has provided an important link between the large ‘subclass’ and the smaller ‘order’.

Demerits of Takhtajan's Classification

1. In this system, more weightage is given to cladistic information in comparison to phenetic information.
2. This system provides classification only upto the family level, thus it is not suitable for identification and adoption in herbaria.
3. Takhtajan recognised angiosperms as division which actually deserve a class rank like that of the systems of Dahlgren (1983) and Thorne (2003).
4. Numerous monotypic families have been created in 1997 due to the further splitting and increase in number of families to 592 (533 in 1987), resulting into a very narrow circumscription.
5. Takhtajan incorrectly suggested that smaller families are more 'natural'.
6. Although the families Winteraceae and Cancellaceae showed 99 to 100% relationship by multigene analyses, Takhtajan placed these two families in two separate orders.

Development of APG System

- With the rapid advances in the field of molecular research with respect to DNA sequencing over the past three decades provided new datasets for classifying angiosperms more precisely.
- With the efforts of two international groups of systematic botanists from **Royal Swedish Academy of Sciences** and **Missouri Botanical Garden**, a new classification has been proposed under the umbrella of **Angiosperm Phylogeny Group** in 1998.
- With the efforts of 29 botanical systematists around the world, APGC was proposed.

Development of APG System

- APG relies on the synthesis of information from the disciplines of **morphology, anatomy, embryology, phytochemistry** and more strongly on **molecular studies** with reference to:

DNA sequences of two chloroplast genes (cpDNA) and one gene coding for ribosomes (nuclear ribosomal DNA).

- ***atpB* (1450bp)**
- ***rbcL* (1428bp)**
- **18S r DNA (1855bp)**
- a total of 4733bp**

Development of APG System

Three further versions of the APG classification were published in 2003, 2009 and 2016, each with multiple compilers and contributors. The most recent version, APG IV published this month, has ten compilers and 15 contributors from six countries and is the result of a workshop hosted by Kew in September 2015. An online survey also provided useful background about the views of botanists and other users of the classification around the world (Christenhusz *et al.*, 2015).

Each version of APG has included a list of families and/or genera of uncertain position – in 1998, 25 families fell in this category, but by 2016 the list had shrunk to seven genera, demonstrating the increase in knowledge as more plants have been sampled and more DNA regions have been investigated.

The number of higher-level groups, formal and informal, has also increased, as a reflection of increasing confidence in the relationships of families to each other. Changes in APG IV on the basis of published studies include placement of *Petenaea* in its own family (Petenaeaceae), recognition of Kewaceae for the genus *Kewa* (previously included in *Hypertelis* in Molluginaceae) and reorganisation of some families that were known to be problematic. For example, several genera had been moved from Icacinaceae into the previously monogeneric Metteniusaceae.

Introduction to APG

- In the late 1990s, an informal group of botanists from major institutions of world that have been carrying out the analysis of plant genetic material came together under the title of the 'Angiosperm Phylogeny Group' or APG.
- Their intention was to provide a widely accepted and more stable point of reference for angiosperm classification.
- Their first attempt at a new system was published in 1998 (the APG system). Three revisions have been published, in 2003 (APG II) , 2009 (APG III) and 2016 (APG IV), each superseding the previous system.
- Eight researchers have been listed as authors to the three papers, and a further 33 as contributors.

Introduction to APG

- The existing systems are rejected because they are not phylogenetic, i.e. are not based on strictly monophyletic groups (i.e. groups which consist of all descendants of a common ancestor).
- APG, show that the monocots form a monophyletic group (clade), but that the dicots do not (-paraphyletic).
- Majority of dicot species do form a monophyletic group, called the **eudicots** or **tricolpates**. Of the remaining dicot species, most belong to a third major clade known as the **Magnoliidae**.
- The rest include a paraphyletic grouping of primitive species known collectively as the **basal angiosperms**, plus the families Ceratophyllaceae and Chloranthaceae.

Introduction to APG

- ***Monophyletic*** refers to a group that consists of a common ancestor plus all descendants of that ancestor. ***Paraphyletic*** refers to a group that includes a common ancestor plus some, but not all, descendants of that common ancestor.
- The diversity of flowering plants is not evenly distributed. Nearly, all species belong to the eudicot (75%), monocot (23%) and magnoliid (2%) clades. The remaining 5 clades contain a little over 250 species in total, i.e., less than 0.1% of flowering plant diversity, divided among 9 families.

Principles of APG

- The principles of the APG's approach to classification were set out in the first paper of 1998, and have remained unchanged in subsequent revisions. These are:
- The Linnean system of orders and families should be retained. "The family is central in flowering plant systematics".
- Groups should be monophyletic (i.e. consist of all descendants of a common ancestor). The main reason why existing systems are rejected is because they do not have this property, they are not phylogenetic.
- Families containing only a single genus and orders containing only a single family are avoided where this is possible without violating the over-riding requirement for monophyly.

Salient Features of APG

- The system is based on the sound phylogenetic principle of constructing taxa on the basis of established monophyly.
- The traditional division of angiosperms has been abandoned and various monocot taxa placed in between primitive angiosperms and eudicots.
- The monocots are placed under two groups, the commelinids and the rest of the monocots. These two groups find their place after primitive angiosperms.

Evolution of APG Classification System

- APG. 1998. An ordinal classification for the families of flowering plants. *Annals of the Missouri Botanical Garden* 85: 531–553



- APG II. 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* 141: 399–436.



- APG III. 2009. "An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III", *Botanical Journal of the Linnean Society* 161 (2): 105–121.



- Angiosperm Phylogeny Group (2016). "An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV" (PDF). *Botanical Journal of the Linnean Society* **181** (1): 1–20. doi:10.1111/boj.12385.

Summary of APG 1998

- Formal, scientific names/ ranks are not used above the level of order, named clades being used instead. Thus eudicots and monocots are not given a formal rank (Linnean rank) on the grounds that "it is not yet clear at which level they should be recognized.
- The number of families in APG (1998) was 462 and recognized 40 orders, compared to, for example, 232 in Takhtajan's 1997 classification.
- A substantial number of taxa whose classification had traditionally been uncertain are given places, although there still remain 25 families of "uncertain position.

Summary of APG 1998

- Alternative 'bracketed' classifications are provided for some groups, in which a number of families can either be regarded as separate or can be merged into a single larger family. For example, the Fumariaceae can either be treated as a separate family or as part of Papaveraceae.
- A major outcome of the classification is the disappearance of the traditional division of the flowering plants into two groups, monocots and dicots. The monocots are recognized as a clade, but the dicots are not, with a number of former dicots being placed in separate groups basal to both monocots and the remaining dicots, the eudicots or 'true dicots'.

angiosperms (Basal groups) 11 families and 4 orders

– **monocots (5 families and 6 orders)**

o **commelinoids**

– **eudicots**

o **core eudicots**

– **rosids**

– **eurosids I**

– **eurosids II**

– **asterids**

– **euasterids I**

– **euasterids II**

Summary of APG II 2003

- **APG II was a revision of the first APG system, published in 1998, APG II was superseded 6½ years later by the APG III system (2009).**

Some of the main changes in APG II are:

- **New orders are proposed, particularly to accommodate the 'basal clades' left as families in the first system.**
- **Many of the previously unplaced families are now located within the system.**
- **Several major families are re-structured.**

Summary of APG II 2003

- The APG II system recognized 45 orders, five more than the APG system.
- The new orders were *Austrobaileyales*, *Canellales*, *Gunnerales*, *Celastrales*, and *Crossosomatales*, all of which were families unplaced as to order, although contained in supraordinal clades, in the APG system.
- APG II recognized 457 families, five fewer than the APG system. Thirty-nine of the APG II families were not placed in any order, but 36 of the 39 were placed in a supra-ordinal clade within the angiosperms.

- **Fifty-five of the families came to be known as "bracketed families".**
- **The use of alternative 'bracketed' taxa allowing the choice of either a large family or a number of smaller ones.**
- **For example, the large Asparagaceae family includes 7 'bracketed' families which can either be considered as part of the Asparagaceae or as separate families.**

Major Clads of APG 2003

angiosperms: (paraphyletic basal angiosperms)

_ magnoliids

_ monocots

o commelinids

_ eudicots

o core eudicots

_ rosids

_ eurosids I

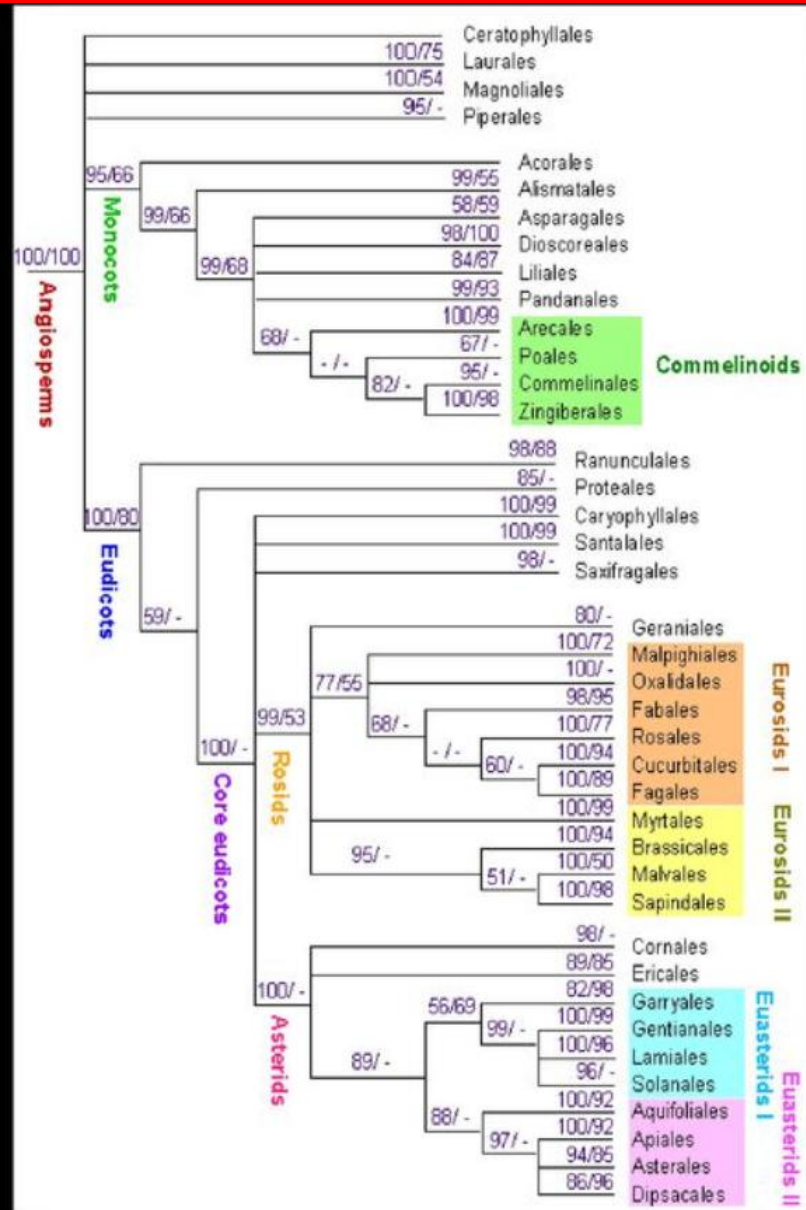
_ eurosids II

_ asterids

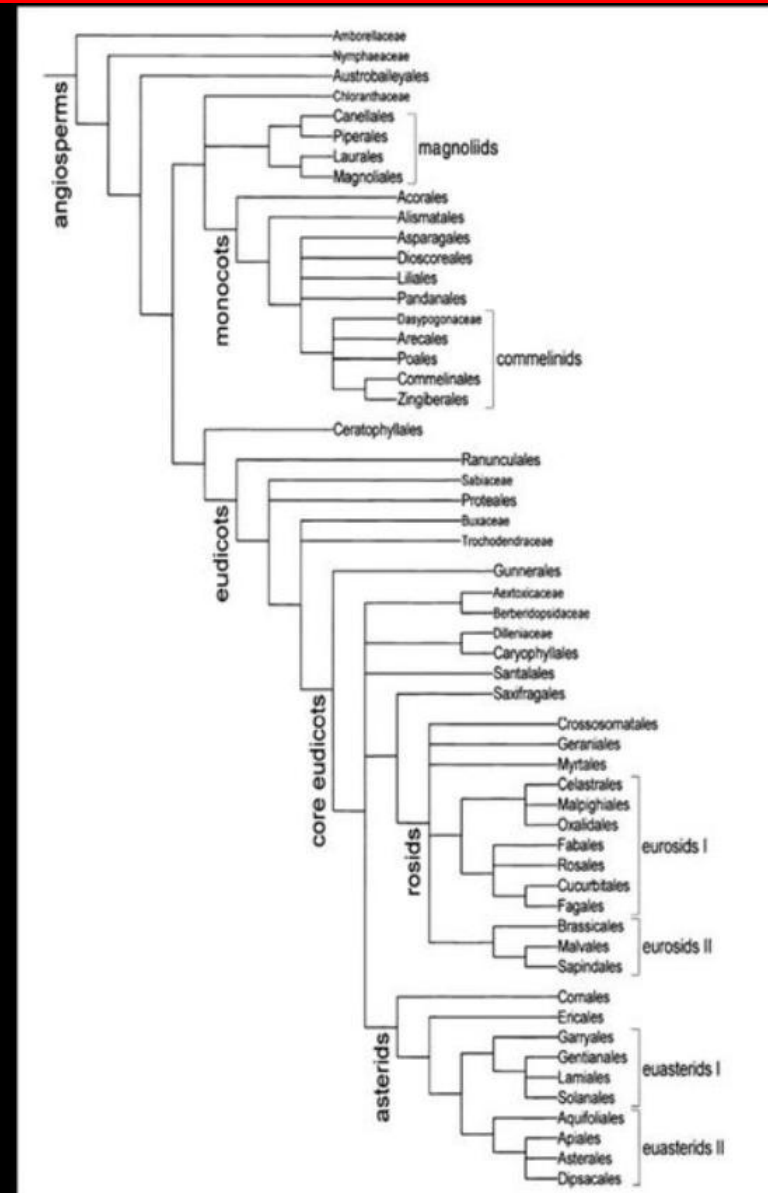
_ euasterids I

_ euasterids II

Outline of APG 2003



APG 1998



APG 2003

Summary of APG III 2009

- **The third paper from the APG updates the system described in the 2003 paper.**
- **The broad outline of the system remains unchanged, but the number of previously unplaced families and genera is significantly reduced. This requires the recognition of both new orders and new families compared to the previous classification.**
- **The APG III system recognized all of the 45 orders of the previous system, as well as 14 new ones (the number of orders goes up from 45 to 59).**
- **Only 10 families are not placed in an order and only two of these (Apodanthaceae and Cynomoriaceae) are left entirely outside the classification.**

Summary of APG III 2009

- The designation of alternative "bracketed families" was abandoned in APG III, because its inclusion in the previous system had been unpopular. APG III recognized 415 families, 42 fewer than in the APG II.
- Forty-four of the 55 "bracketed families" were discontinued, and 18 other families were discontinued as well. For example, the agave family (Agavaceae) and the hyacinth family (Hyacinthaceae) are no longer regarded as distinct from the broader asparagus family (Asparagaceae).
- The classification of the families in APG III which uses formal taxonomic ranks; previously only informal clade names have been tried to use above the ordinal level.

- Published in October, 2009 by a team of 8 scientists in the name of APG III. Prof. P.F. Stevens led the revised edition
- **Total 413 families.**
- Except 10 families like Ceratophyllaceae, Boraginaceae, rest of the 403 families are assigned to 59 orders.

Outline of APG III 2009

- **11 clades**
- **59 orders** (5 unplaced-not in clades)
(4 at beginning/ 1- after monocots-
Ceratophyllaceae)
- **413 families**
- **Unplaced within the orders**-10 families
(e.g. Boraginaceae)
- **Taxa of uncertain position**
2 families: Apodanthaceae/ Cynomoriaceae
3 genera : *Gumillea*, *Petenaea* and
Nicobariodendron

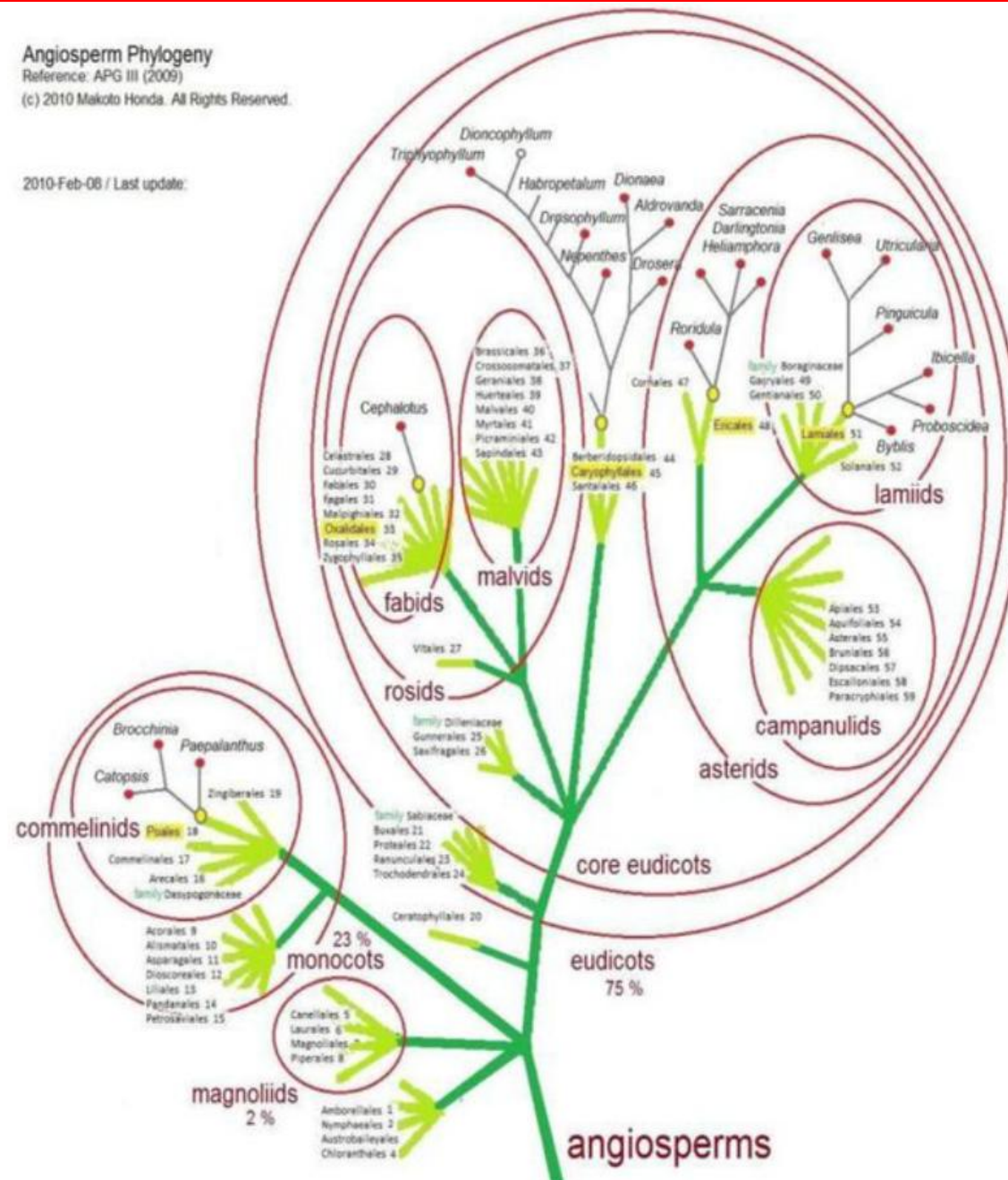
Outline of APG III 2009

Angiosperm Phylogeny

Reference: APG III (2009)

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2010-Feb-08 / Last update:



Summary of APG IV 2016

- An update of the Angiosperm Phylogeny Group (APG) classification of the orders and families of angiosperms is presented.
- Several new orders are recognized: Boraginales, Dilleniales, Icaciniales, Metteniusiales and Vahliales.
- 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 are proposed, that each comprise the additional orders that are included in the larger clades dominated by the rosids and asterids.
- Families that made up potentially monofamilial orders, Dasypogonaceae and Sabiaceae, are instead referred to Arecales and Proteales, respectively
- Two parasitic families formerly of uncertain positions are now placed: Cynomoriaceae in Saxifragales and Apodanthaceae in Cucurbitales

- Published on March 24, 2016
- 64 orders
- 416 families
- Unplaced one limited to 7 genera

Outline of APG IV 2016

BASAL ANGIOSPERMS

ANA GRADE- AMBORELLALES/ NYMPHAEALES/ AUSTROBAILEYALES
INDEPENDENT LINEAGE - CHLORANTHALES

MESANGIOSPERMS

1. **MAGNOLIIDS** - 4 ORDERS

2. **MONOCOTS** (11 ORDERS) - COMMELINIDS (4 ORDERS)- NOW MERGED
PROBABLE SISTER OF EUDICOTS-CERATOPHYLLALES

3. **EUDICOTS** (43 ORDERS)-4 ORDERS

4. **CORE EUDICOTS** (39 ORDERS)

ORDER 1- DILLENIALES

5. **SUPERROSIDS** (18 ORDERS)-

ORDER 1- SAXIFRAGALES

6. **ROSIDS** (17 ORDERS)

ORDER 1-VITALES

7. **FABIDS**-8 ORDERS

8. **MALVIDS** – 8 ORDERS

9. **SUPERASTERIDS** (20 ORDERS)-

ORDERS 3- BERBI/SANTA/CARYOPHY

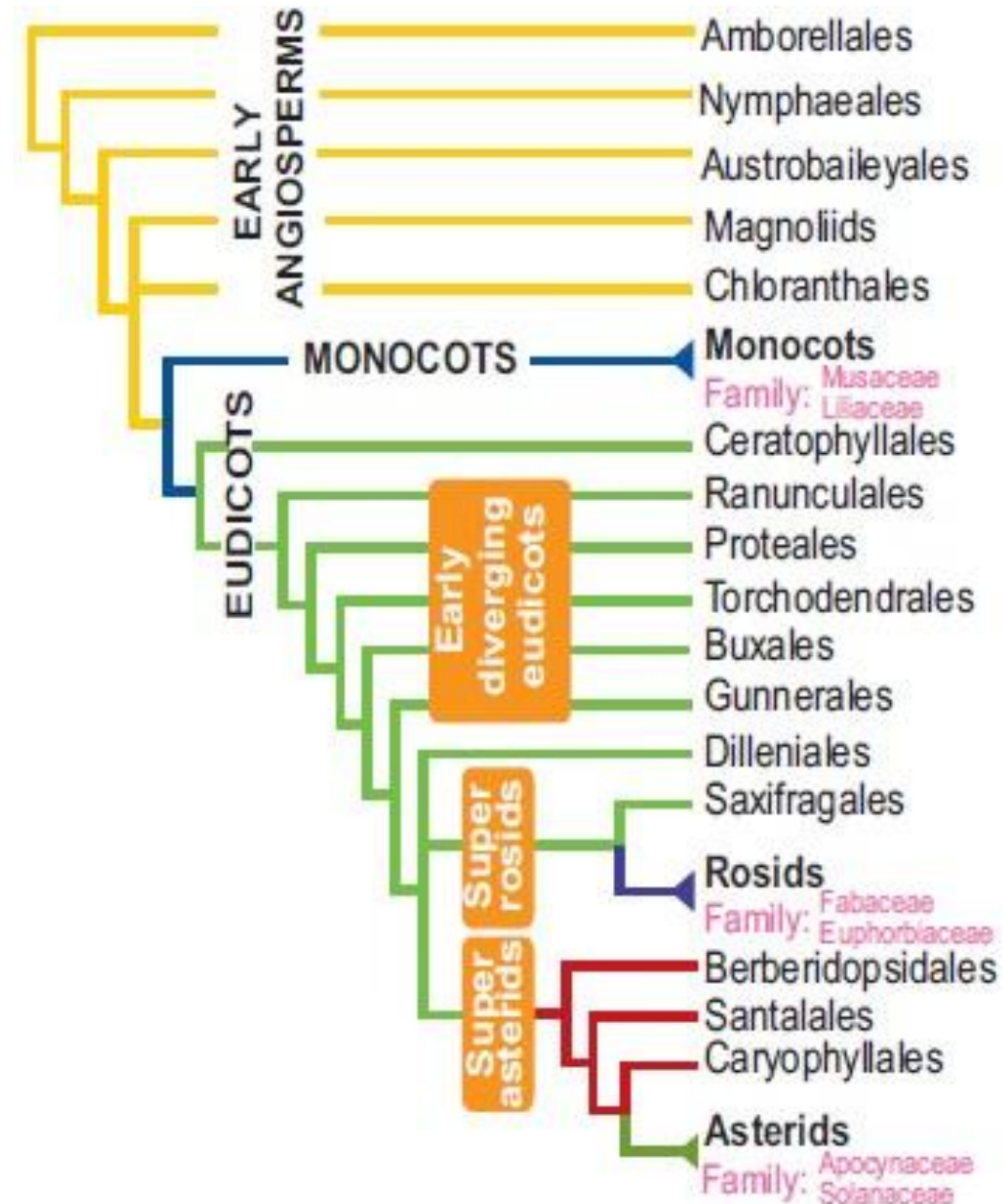
10. **ASTERIDS** (17 ORDERS)-

ORDERS 2- ERICALES/ CORNALES

11. **LAMIIDS**- 8 ORDERS

12. **CAMPANULIDS**- 7 ORDERS

Outline of APG IV 2016



Family Delimitations in APG IV 2016

- Asclepiadaceae merged with Apocynaceae
- **Bombacaceae, Sterculiaceae and Tiliaceae are merged with Malvaceae.**
- Brassicaceae *s.l.* split into 3 families' viz., Brassicaceae *s.s.*, Capparaceae and Cleomaceae.
- **Chenopodiaceae merged with Amaranthaceae**
- **Euphorbiaceae *s.l.* is split into Euphorbiaceae *s.s.*, Phyllanthaceae, Picrodendraceae and Putranjivaceae.**
- Fabaceae comprises three subfamilies: Faboideae, Ceasalpinioideae and Mimosoideae.
- **Liliaceae *s.l.* is split into 14 families and many taxa are transferred to Asparagaceae**
- Molluginaceae and Gisekiaceae are recognized separately from Aizoaceae.

Largest Families in APG IV 2016

- **Orchidaceae (880/ 27,800)**
- **Asteraceae (1620/ 23,600)**
- **Fabaceae (745/ 19,560)**
- **Rubiaceae (611/ 13,150)**
- **Poaceae (707/ 11,337)**

Limitations of APG IV 2016

- A fourth version has now been published, but the methodology has been the subject of criticism, and developing a consensus has proved more difficult than in previous iterations.
- In particular Peter Stevens has questioned the validity of discussions regarding family delimitation in the absence of changes of phylogenetic relationships.



Thank you

