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BOTA 241: TAXONOMY OF HIGHER PLANTS

Course Description

The Significance and relationship of plant taxonomy to other botanical disciplines. Plant hierarchy and intra-specific classification. Nomenclature. Sources of phylogenetic evidence. Biosystematics and modern taxonomy. Taxonomic resources; identification techniques, plant variation and evolution. Survey of selected angiosperm families of East Africa flora.

Introduction To Plant Taxonomy

- Taxonomy is the method by which scientists, conservationists, and naturalists classify and organize the vast diversity of living things on this planet in an effort to understand the evolutionary relationships between them.
- Plant Taxonomy is the science of classifying and identifying plants. Scientific names are necessary because the same common name is used for different plants in different areas of the world.

Objectives of plant taxonomy

(i) To gather knowledge of different kinds of plants on earth, their systematic groups and names of their distinctive affinities, their distribution and habitat characteristics.

- The flora of the earth is so large that it is not possible to gain knowledge on them without arranging them systematically.
- This includes naming of plants, their distinction, identification habitat characteristics and correlation.

(ii) To provide a method of identification which is accomplished by producing descriptions, keys and illustrations

(iii) To prepare phylogenetic system of classification.

- To classify plants, it is desirable to know the basic units of classification, the resemblance of plants in morphological characters to have knowledge about their phylogenetic relationship.
- Demonstration of the tremendous diversity of the plant world and its relation to man's understanding of evolution.
- An organized reconstruction of the plant kingdom as a whole can be made only after the inventory of its components (the plants) has been assembled.
- When this has been done, the charting of the degree and character of variation will demonstrate its diversity and these data can be integrated with other facets of evolutionally knowledge to produce a more accurate phylogenetic scheme.

(iv) The assemblage of knowledge gained.

- Knowledge is sterile unless it's made available to others, only then is it of use and an aid to the progress of civilization. This conversion of taxonomic data from a status of sterility to fertility is accomplished in many ways through documentations e.g

  (a) Floras. - Are published to account for the plants of a given area (flora is a plant).

  (b) Manuals- are prepared that the plants of given area may be more easily identified and named. It as a flora with a basic information plus keys descriptions, glossary, history of botanical exploration of area, documentations for the treatment of the included taxa

  (c) Revision -Are treatments for selected taxa throughout their range or in a major portion thereof. The treatment include studies of nomenclature and classification along with descriptions based on several types of evidence. Geographical and ecological evidence are treated differently.

  (d) Monographs-Detailed investigation of a particular taxon e.g. a genus, sub genus, section or species etc Includes complete descriptions, keys to the taxa and other information such as chromosome numbers, historical or ecological data.

Aims of plant taxonomy and systematic

- -Plant taxonomy is closely allied to plant systematics, and there is no sharp boundary between the two.
- -Plant systematics is involved with relationships between plants and their evolution, especially at the higher levels, whereas plant taxonomy deals with the actual handling of plant specimens

Plant taxonomy terminologies

- **(i) Plant taxonomy**
- -That branch of biological science that deals with identification, nomenclature and classification of plants
- **(ii) Classical taxonomy**
- -Deals with the morphological characteristics of plants
- **(iii) Taxon**
- -Any group or category within a taxonomic hierarchy e.g species, genus, family
- **(iv) Identification**
- -Is the determination of a taxon as being similar or identically equal to a known taxon
- - Involves determination of the identity of an unknown plant by comparison with previously collected specimens or with the aid of books or identification manuals called Identification keys.
- **(v) Nomenclature**
- -The correct determination of the name of an identified plant according to an established system; The International Code of Botanical Nomenclature (ICBN)

Functions of taxonomy

(i) Identification:

- Keying out an unknown plant, by comparing with known specimens and with description of such a plant.
- If it is completely unlike any other known plant, then it must be a new species. This identification or comparison is done by use of books, manuals, floras, herbaria, subject authorities' e.t.c. Morphological features or anatomical characteristics that are shared are usually used in identification.
- A character: is any attribute that can be counted, measured or assessed e.g. Height is a character; 169cm is a character state. We use several characters for identification. If the characteristics shared are more than the unshared then they belong to the same family.

(ii) Nomenclature:

- It is the assignments of names to plants. It is the correct naming of the plant that has been identified. It tells us whether the name is correct or synonymous e.t.c. Botanical nomenclature deals with Latin names only (ICBN).
- Naming follows ICBN (International Code of Botanical Nomenclature). Nomenclature requires that names be in binomial system. This was established by Linnaeus in 1753. Linnaeus is the father of taxonomy. Names should be underlined when handwritten or in italics when typed. The first letter of the first word should be in capitals. But some names are trinomial e.g. Brassiaca oleraceae capitata
- (Brijans, egg plants) Belong to solanum melongena.

- **(vi) Classification**
- - Is the arrangement of a single plant or a group of plants in distinct categories following a system of nomenclature and in accordance with a particular and well established plan.
- **(vii) Artificial classification**
- -Is the classification of plants based up on afew convenient characters for the purpose of sorting or identification.
- -This system is based on the habit and floral characters of the plant thus also called sexual system.
- **(viii) Natural classification**
- -Classification mainly based on form relationships realizing all information available at that time
- -Based mainly on morphological similarities

- **(ix) Phylogenetic classification**
- -Based on genetic relationships of plants and according to their evolutionary sequences
- **(x) Phytography**
- -Phase of taxonomy dealing with descriptive terminology of the plant and its parts with the objective of providing accuracy and completeness for the characterization of taxa.

- **(xi) Biosystematics**
- -The field of study dealing with variation and evolution, primarily experimental and analytical and mostly treating the species and infraspecific taxa. Includes genetics and chemotaxonomic studies.
- **(xii) Phenetic classification**
- -Is where maximum number of generalizations are to be made from general classification.
- -The totality of characters of living plants are considered here and the classification is based on living phenotypes
- -The natural system of classification is considered to be phonetic

The History of Plant taxonomy

- The history of taxonomy dates back to the origin of human language.
- Western scientific taxonomy started in Greek some hundred years BC and are here divided into prelinnaean and postlinnaean.
- The most important works are cited and the progress of taxonomy (with the focus on botanical taxonomy) are described up to the era of the Swedish botanist Carl Linnaeus, who founded modern taxonomy

- The development after Linnaeus is characterized by a taxonomy that increasingly have come to reflect the paradigm of evolution.
- The used characters have extended from morphological to molecular.
- Nomenclatural rules have developed strongly during the 19th and 20th century, and during the last decade traditional nomenclature has been challenged by advocates of the Phylocode.

Classification based on habit

- Ancient greeks, herbalists and botanists mainly grouped plants giving importance to the habit of the plant.
- The first attempt to classify all the plants known was about 300 BC. by Theophrastus, the great student of Aristotle.
- He classified plants by their habit or form--the trees were grouped together, the shrubs, the undershrubs, herbs, and so forth. He also recognized more specific botanical characteristics such as ovary position.

- His work, History of Plants, is the oldest botanical work in existence.
- The system of Theophrastus was refined only a little by other Greek botanists and herbalists.
- Pliny the Elder (23-79 A.D. a Roman naturalist and scholar who made a notable contribution to early botany, describing nearly 1,000 plants in his 37 volume work.

Pre-Linnaean taxonomy

- Earliest taxonomy is as old as the language skill of mankind. It has always been essential to know the names of edible as well as poisonous plants in order to communicate acquired experiences to other members of the family and the tribe.
- A taxonomist should be aware of that apart from scientific taxonomy there is and has always been folk taxonomy, which is of great importance in, for example, ethnobiological studies.

- When we speak about ancient taxonomy we usually mean the history in the Western world, starting with Romans and Greek.
- However, the earliest traces are not from the West, but from the East. Eastern taxonomic works were not known to the Western world until the Middle Ages and could thus not influence the progress of Western sciences.

The Early taxonomists (Historia Naturalis)

- It was not until the end of the 16th century that taxonomic works became original enough to replace the ancient Greek works.
- One of the reasons for this was the development of optic lenses, which made it possible to study details in the different species.
- Collection of specimens became part of the growing sciences, and the emphasis turned from medical aspects to taxonomic aspects.
- One of the earliest authors was Caesalpino (1519–1603) in Italy, who is sometimes called "the first taxonomist".
- In 1583 he wrote De Plantis, a work that contained 1500 species. His classification was based on growth habit together with fruit and seed form, as was that of Theophrastos.
- Some groups that he recognized we still acknowledge, like the plant families Brassicaceae and Asteraceae (Compositae).

- Two Swiss brothers Johann Bauhin (1541- 1613) and Caspar Bauhin and (1560–1624) wrote the work Pinax Theatri Botanici in 1623.
- The word Pinax means register, and the work is a listing of 6000 species.
- The Bauhin brothers included synonyms, which was a great necessity of the time.
- By this time, species were known with many different names in different books, and Pinax Theatri Botanici made a welcome order in the taxonomic world.
- The Bauhin brothers recognized genera and species as major taxonomic levels.
- Dioscorides (first century A.D.) was a military physician under Emperor Nero of Rome.
- The Codex, an herbal prepared in 512 A.D. from his work was still used until the 16th century.
- Little botanical progress was made after the decline of the Roman and Greek civilizations, some of the ancient works being copied and recopied.
- In the early 16th century arose a period of intense herbal activity, stimulated by the reflowering of the arts, especially painting and wood cutting.
- This enabled plates of the herbs to be produced.

- The forerunners of the modern herbal were produced during this time, notably by the "German Fathers of Botany", Brunfels, Bock, Fuchs, and Cordus.
- The "doctrine of signatures" was popular during this time. Handed down by the ancient Greeks, its thesis was mainly relating a shape or color of a plant part to a part of the body that it was said to cure i.e “like cures like”.
- Plants with red juice then, were considered beneficial for disorders of the blood or cardiovascular system. This feeling persists even today, and in many cultures traditional herbs are used on this basis.
- It was not until the 17th century that any taxonomic system of great impact or importance arose.

- A few of the notable contributions include:
- Andrea Cesalpino (1519-1603), an Italian physician, used the ancient grouping into herbs and trees, but recognized the importance of fruit and seed characters.
- His writing influenced later botanists, such as Turnefort and Linnaeus. John Ray (1627-1705), wrote Historia Plantarum, in which appears one of the first indications of a natural system of classification.
- He also used the old groups of herbs and trees, but within these groups he recognized and named the Dicotyledons and Monocotyledons.

- John Ray (1628-1705) was a renowned English naturalist that devised another system at about the same time.
- His system was even more refined in some ways, and he separated the dicots from the monocots.
- Pierre Magnol (1638-1715) was a contemporary of John Ray. He found Ray's system too difficult, and divided plants into families. His name is commemorated by the genus Magnolia in the family Magnoliaceae.
- Joseph Pitton Tournefort (1656-1708), a Professor of Botany in France, followed Theophastus in dividing plant groups into herbs and trees, but greatly refined the system.
- He further divided these large, artificial groups into smaller ones based on the flowers being petal or non-petal bearing, regular or irregular, etc.
- He was the first to group plants by Genera (a distinction usually attributed to Linnaeus) as we know them today.
- Genera are natural groups under family, i.e., the Oaks, Roses, Maples

- Dioscorides (40–90 AD) was a greek physician, who travelled widely in the Roman and Greek world to gather knowledge about medicinal plants.
- Between 50-70 AD he wrote De Materia Medica, which was a pharmacopoeia of medicinal plants and the medicines that can be obtained from them and contained around 600 species.
- De Materia Medica was used in medicine until the 16th century, and was copied several times.
- One famous copy from the 6th century is kept in Vienna. The classification in his work is based on the medicinal properties of the species.
- Plinius (23–79 AD) was involved in the Roman army and later in the Roman state. He wrote many books, but the only one that has survived is his Naturalis Historia, a work of 160 volumes, in which he described several plants and gave them Latin names.
- Many of these names we still recognize, like Populus alba and Populus nigra, and since latin was later kept for botanical science, we may call him the Father of Botanical Latin. Plinius died in Pompeii.

- The English naturalist John Ray (1627–1705) wrote several important works through his life.
- His most important contribution was the establishment of species as the ultimate unit of taxonomy.
- In 1682 he published Methodus Plantarum Nova, which contained around 18 000 plant species, a result of a relatively narrow species concept.
- His complicated classification was based on many combined characters, as opposed to earlier taxonomists.
- Ray aimed at publishing a complete system of nature, which included works on mammals, reptiles, birds, fishes and insects, the latter including pioneering entomological taxonomic work.

- In France Joseph Pitton de Tournefort (1656–1708) constructed a botanical classification that came to rule in botanical taxonomy until the time of Carl Linnaeus.
- In 1700 he published Institutiones Rei Herbariae, in which around 9000 species were listed in 698 genera.
- He put primary emphasis on the classification of genera, and many genera were accepted by Linnaeus and still in use today.
- Tournefort's plant classification was exclusively based on floral characters.
- Tournefort's system was the one used by Linnaeus as a young student, but whereas Tournefort denied the presence of sexuality in plants, Linnaeus on the contrary based his system on that argument.

China and taxonomy

- In the Eastern world, one of the earliest pharmacopoeias was written by Shen Nung, Emperor of China around 3000 BC.
- He was a legendary emperor known as the Father of Chinese medicine and is believed to have introduced acupuncture.
- He wanted to educate his people in agriculture and medicine and is said to have tasted hundreds of herbs to test their medicinal value.
- The pharmacopoeia Divine Husbandman's Materia Medica included 365 medicines derived from minerals, plants, and animals.

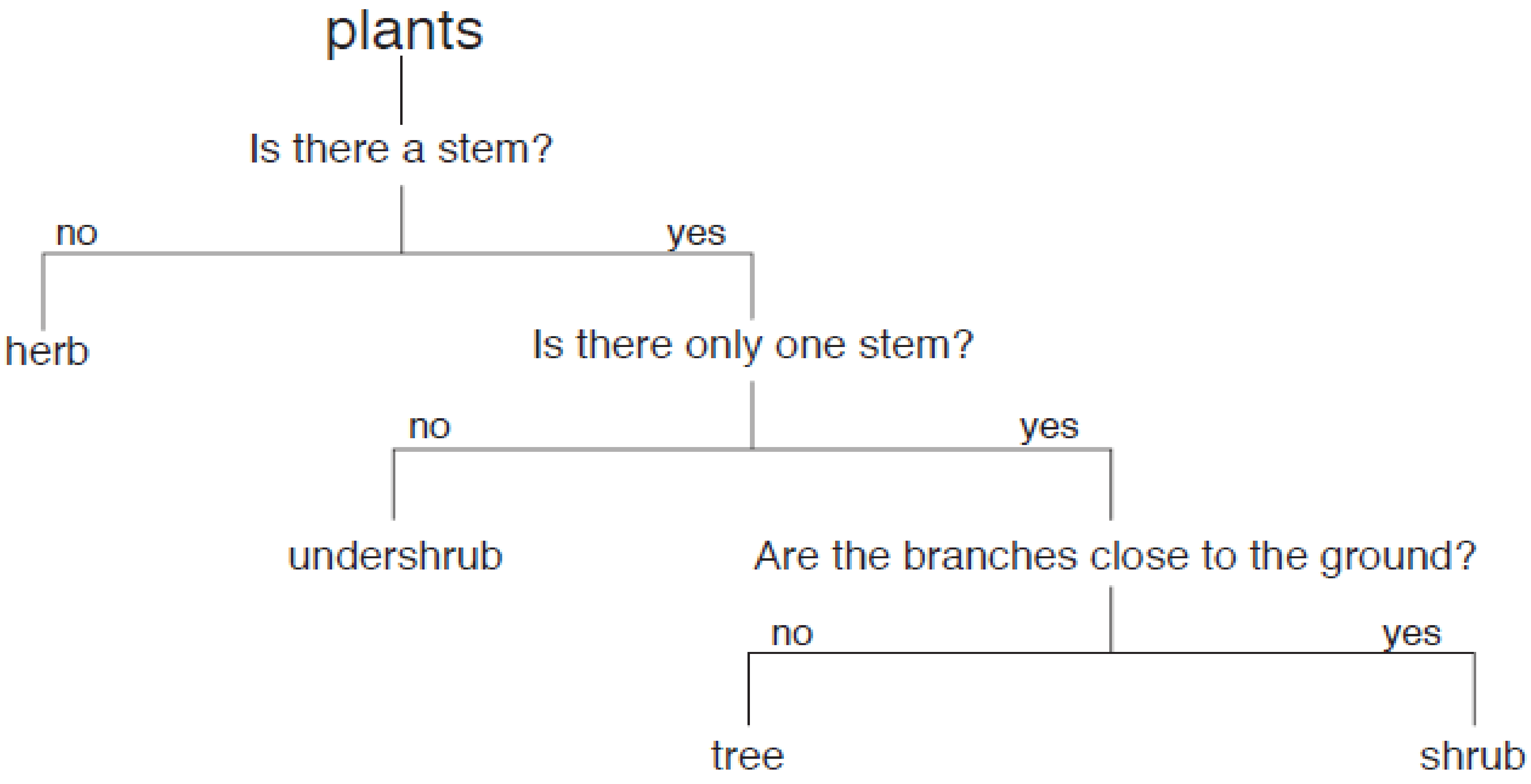
- Around 1500 BC medicinal plants were illustrated on wall paintings in Egypt. The paintings gives us knowledge about medicinal plants in old Egypt and their names.
- In one of the oldest and largest papyrus rolls, Ebers Papyrus, plants are included as medicines for different diseases.
- They have local names such as "celery of the hill country" and "celery of the delta", species of Apiaceae that Egyptian doctors had to be able to distinguish in the field.

The Greeks and Romans

Aristotle (384–322 BC)

- In Western scientific taxonomy the Greek philosopher Aristotle was the first to classify all living things, and some of his groups are still used today, like the vertebrates and invertebrates, which he called animals with blood and without blood. He further divided the animals with blood into live-bearing and egg-bearing, and formed groups within the animals without blood that we recognize today, such as insects, crustacea and testacea (molluscs).
- Theophrastus (370–285 BC) was a student of Aristotle and Plato. He wrote a classification of all known plants, De Historia Plantarum, which contained 480 species. His classification was based on growth form, and we still recognise many of his plant genera, like Narcissus, Crocus and Cornus. This is because Carl Linnaeus accepted many of his generic names. De Historia Plantarum was used for taxonomic purposes until the Middle Ages in Europe.

Theophratus plant classification key



The Herbalists

- With the art of book printing in Europe new books could be made in large numbers. This was the time of the different herbals written by herbalists like Brunfels, Bock, Fuchs, Mattioli, Turner, L’Obel, Gerard, L’Ecluse. We recognize some of these authors in beautiful plants later named by Linnaeus in honour of them: Brunfelsia, Mattiolia, Turnera, Lobelia, Gerardia and Fuchsia. There is usually not much of a classification in the herbals, and the earliest works were merely copying Theophrastos and Dioscorides. With time the herbals became more and more original with more elaborate woodcuts as illustrations.

Linnaean era

Carolus Linnaeus

- Carolus Linnaeus is probably the single most dominant figure in systematic classification. He had a mind that was orderly to the extreme. He has been hailed as the 'Father of modern taxonomy'. People sent him plants from all over the world, and he would devise a way to relate them. At the age of thirty-two he was the author of fourteen botanical works. His two most famous were Genera Plantarum, developing an artificial sexual system, and Species Plantarum, a famous work where he named and classified every plant known to him, and for the first time, he gave each plant a binomial. The binomial consists of a Generic name (Rosa, for the Rose), and a specific epithet (rugosa) for a particular Rose. This binomial system was a vast improvement over same of the old descriptive names for plants used formerly

- With an expanded knowledge of the global fauna and flora through 17th and 18th century scientific expeditions, a large number of new species were found and named, and more terms had to be added to each phrase name. By the time of Linnaeus the situation was really bad. Linnaeus counted 8530 species of flowering plants in 1753. The simplicity of Linnaeus' trivial names revolutionized nomenclature, and soon binary nomenclature came to replace the phrase names. Today, every plant or animal name published before 1753 or 1758, respectively, is called "prelinnaean" and is thus not valid. Also early names published by Linnaeus himself are "prelinnaean"!

- Before Linnaeus, the Catnip plat was known as: "Nepeta floribus interrupte spicatis pedunculatis" which is a brief description of the plant. Linnaeus named it Nepeta cataria--cataria meaning "pertaining to cats". The binomial nomenclature is not only more precise and standardized, it also relates plants together, thus addinq much interest and information in the name. For instance, Solanum relates the potato, the tomato and the Nightshade. Species Plantarum was the starting point for the svstem of binomial priority used in our present-day system of nomenclature. From that point, there were many botanists that contributed to the evolution of taxonomy. Antoine Laurent de Jussieu (1748-1836) created many of the familv groups that we use today, and created a much more natural system than ever before. Sir Joseph Hooker (1817-1911) contributed an outstanding svstem of classification in his Genera Plantarum, which described around 202 orders (now families), qrouped into cohorts (now orders). He was associated with the Royal Gardens at Kew in England. Asa Gray (1810-1888) is the father of American Botany, and wrote several important botany texts and floras, which can still be found in used book stores today, and are useful for their clear explanation of plant morphology.

- August Wilhelm Eichler (1839-1887), Adolf Engler (1844-1930), and Charles Bessey (1845-1915) helped refine previous schemes to make the system we have used until the last few Years. Refined the system using modern research methods and equipment, such as chemotaxonomy and electron microscopy.

Transforming botany and zoology into a science

- Carl Linnaeus started his career by publishing a system of all living things and minerals in 1735 called Systema Naturae. In this he introduced the sexual system of plants, an artificial classification based on the sexual parts of the flower: the stamens and pistils. In a time when people debated whether plants had sexuality or not, this suggestion from an unknown person not belonging to any classical European school of natural sciences more or less shocked the scientific world. However, the practical use of the system and Linnaeus careful observations persuaded the critics and Linnaeus sexual system of plants became the highest fashion also outside the scientific community.

- In an attempt to make order in the world of taxonomy and explain his way of thinking, Linnaeus published several books that would transform botany and zoology into sciences of their own. Until then, these two disciplines had merely been a fringe of practical medicine built on scattered observation of different species, a Historia Naturalis. With the works of Linnaeus, botany and zoology transformed into a Scientia, a science surrounded by philosophy, order and systems, just like the disciplines of theology, philosophy and law.

- In 1735 he published Critica botanica, with rules for the formulation of generic names. In the same year came Genera Plantarum with a list of all known genera. In subsequent books like Fundamenta botanica in 1736 and Philosophia botanica in 1751 he created rules for species descriptions, terminology, and even on how to build a proper herbarium cupboard. instructions
- Linnaeus established many of the rules taxonomists use today. Terms like corolla, stamen, filament and anther were created by him, as well as well-known taxon names like Mammalia. After a long life with a massive publication in the philosophy and practicality of systematics, Linnaeus had laid out the foundation for botany and zoology, and it was now time for subsequent taxonomists to improve this newborn science.

Post-Linnaean taxonomy

Natural system emerging in France.

One of the few countries in which the Linnaean systematics did not make success was France. The French stuck to Tournefourt and continued to work on a development of the natural system. Four French scientists emerged that made an impact on future biological sciences. Georges-Luise Leclerc de Buffon (1707–1788) was a strong critic to Linnaeus work, and he found it wrong to impose an artificial order on the disorderly natural world. His approach was to describe the world rather than to classify it. His theories touched upon development of species, intraspecific variety and in species, which opened up a pathway for an evolutionary theory. acquired inherited characters. Michel Adanson (1727–1806) wrote Familles des Plantes already in 1763. He launched the idea that in classification one should not put greater emphasis on some characters than on others, but use a great range of characters. He critized Linnaeus' works, and considered Tournefort's classification far superior

- Antoine Laurent de Jussieu (1748–1836) changed the system of plants with his Genera Plantarum in 1789, in which he launched a natural system based on many characters that came to be a foundation of modern classification. He divided the plants into acotyledons, monocotyledons and dicotyledons and established the family rank in between the ranks "genus" and "class". Jean-Baptiste de Lamarck (1744–1829) launched an evolutionary theory including inheritance of acquired characters, named the "Lamarckism". This was foreboding the theory of evolution presented by Charles Darwin and Alfred Russel Wallace in 1858 in London. The French scientific work, the development of anatomy and physiology and improved optical instruments made way for a new era of taxonomy, which was trying to cope with an increasing number of species in a rapidly expanding flora and fauna of the world.

Rules for nomenclature

- One of the first attempts to create rules in botanical taxonomy was made by Augustin Pyramus de Candolle (1778–1841) in Théory élémentaire de la botanique in 1813. There he stated that published names should have priority according to the date of publication, starting with Linnaeus (without mentioning a particular year). The English did not follow that rule. On a congress in Paris, 100 botanists adopted the rules in a book by the son Alphons de Candolle (1806–1873), Lois de nomenclature adoptee from 1867. The rules were thereafter discussed and different starting points for botanical taxonomy were suggested. During the years 1891 to 1898 the German botanist Otto Kuntze (1843–1907) published the controversial work Revisio generum Plantarum, in which he applied Candolle's laws from 1867 rigidly. He changed 1000 generic names and 30 000 species names.

- Kuntze's strict application of insufficient nomenclature laws and the nomenclatural mess he made triggered botanists to create a code of botanical nomenclature. In Europe this was decided on a botanical congress in Vienna in 1905. During this meeting the starting point for priority of botanical names was set to 1753, the year of Linnaeus' Species Plantarum. To stabilize nomenclature after Kuntze's rigid work, a list was made of well-established names, ***nomina conservanda***, that should be conserved although they did not have priority, i.e. were not the first names published.
- In 1907 American botanists created a code of their own where they introduced type specimens and allowed tautonyms (identical names in a species name, now only allowed in zoology, e.g. Grus grus).
- Not until 1935 did the European and American codes merged into one international code of botanical nomenclature (IBCN).

- The initiation of a zoological code started somewhat later. In 1842 a British ornithologist Hugh Edwin Strickland (1811–1853) elaborated the first nomenclatural laws for zoology, the "Strickland Code". He was assisted by a committee where Charles Darwin was a member, among others The Strickland Code was accepted among British and American zoologists within three years. However, in 1881 a geological international congress in Bologna modified the code to make it applicable also to fossils. During the next five years a number of different codes were suggested by French zoologists, American ornithologists, German zoologists and English entomologists, creating an impractical condition of taxonomic anarchy. The need of an international code of zoological nomenclature was obvious, and the first was accepted on an international congress in Moscow in 1892. In 1905, a further modified international code was published in French, English and German languages. There are continuous modifications of the codes of botanical nomenclature and zoological nomenclature.

- Changes in the botanical nomenclature is decided by discussions and votes on open meetings at every International Botanical Congress, held every sixth year. The botanical code decided upon in Vienna 2005 opened up for extended possibilities to reject or conserve plant names to promote nomenclatural stability. Changes in the zoological code are decided upon by the International Commission on Zoological Nomenclature, elected by the international society of zoologists. The zoological code differs in many ways from the botanical. Among other things, species do not need to be described in Latin. Since 1953 there is also an international code of nomenclature for cultivated plants, and since 1980 there is a code for bacteria (prokaryotes), excluding the cyanobacteria, which are still included in the botanical code.

Classification

- The placing of a plant or group of plants in categories according to a particular system and in conformity with a nomenclatural system.
- Is the grouping of organism according to laid down rules.
- It is the assignment of like objects to recognizable groups. -It is the production of a logical System of categories each containing any number of plants or organisms with easy reference to its components as its kind of plants.
- It is the placing of plant into groups or categories to a particular plant sequences and in conformity with a nomenclatural system.
- Every species is classified as a number of a particular family, order to class, a class to a particular division, then to kingdom.
- In actual practice, classification deals, more with placing of plant group in its proper place within a selected scheme than the placing of an individual plant in one or several minor categories. For a satisfactory classification, knowledge is drawn from all available sources. We mostly use morphology and anatomy.

- There are two types of Classification; Artificial and natural classification.
- **Systematics:** Is used synonymously with taxonomy but its defined as study and description of variations of organism, the investigation of the causes and consequences of these variations, and the manipulation of the data obtained to produce a system of classification. A plant taxonomist is recognized universally as one who identifies, names and classifies plants.
- **Classification:** Is the process of deciding whether or not two things are in your opinion the same. It is the determination of a taxon being identical with or similar to another and already known element.
- No names are needed or involved in identification. The recognition of a plant as similar to another is its identification. Taxon is any taxonomic group.
- The fundamental concepts of systematic are;
- 1. Classification – artificial, phonetic (based on overall similarities), phylogenetic (evolutionally),
- 2. Identification,
- 3. Description (dealing with characters and character states)
- 4. Nomenclature.
- Traditional methods of identification
- i) Experts determination
- ii) Recognition
- iii) Comparison
- iv) Use of keys

- Plants have certain consistent features by which they could be reliably placed in distinct groups.
- To succeed in identifications;
  - One must make comparisons
  - One must select a character
  - Determine its state (character state) and compare with specimens
- **Sources.-** Any that will enable us to categorise plants where they belong.
- Among these sources, are the basis of science that deals with plant morphology, anatomy, cytology, genetics, phytogeography, biochemistry, and embryology.
- A description of a taxon is a statement of its characteristics. Characteristics contributing to a taxonomic description are known as taxonomic or systematic character.
- **Diagnosis:** Is a shortened description counting only those characters (diagnostic characters) which are necessary to distinguish a taxon from other related taxa.

HIERARCHY OF TAXONOMIC RANKS

What is a taxon?

- A taxon (plural taxa) is a taxonomic unit. It is a population or group of populations of organisms, usually inferred to be phylogenetically related. The individuals in a taxon share characteristics that differentiate them from individuals in other taxa. A taxon can be at any rank in the hierarchy. A taxon encompasses all included taxa of lower rank and the individuals in those taxa. Note that the taxon is the population of individuals. It exists or did exist in nature before humans gave it a name. The name given to the taxon is separate from the taxon even though this distinction is often ignored.

Taxonomic Hierarchy (The Linnaeus Hierarchy)

- Taxonomic hierarchy is the process of arranging various organisms into successive levels of the biological classification either in a decreasing or an increasing order from kingdom to species and vice versa.
- Taxonomic Hierarchy Categories were introduced by Linnaeus. They are also known as Linnaean hierarchy.
- It is defined as sequence of categories in a decreasing or increasing order from kingdom to species and vice versa.
- Kingdom is the highest rank followed by division, class, order, family, genus and species.
- Species is the lowest rank in the Hierarchy.
- The hierarchy has two categories:

Structure of the hierarchy

- Each level in the hierarchy is given a special name. The different levels in a hierarchy are known as ranks. The groups of plants in each rank are referred to as taxonomic unit i.e species. All taxonomic units in one rank belong to same taxonomic category e.g Ranks – species, genus, family e.t.c; taxonomic unit – Acacia abyssinica (one species). So all species of Acacia belong to the taxonomic category species and each of them likewise is a taxonomic unit of the rank.
- The hierarchy employed in the scientific classification of plants is made up of a set of conventional taxonomic categories. These categories are abstract concepts to which groups of plants are assigned. The level at which the category stands in the hierarchy is known as its rank.
- The groups of plants themselves are known as taxa. For a botanist, a hierarchy varies from the larger plant Kingdom Plantae to the lowest individuals member of a given species. All related species are grouped to form a genus and all related genera, family.

Properties of Hierarchial system

- Taxa of lower ranks are always sub-ordinate to and included in those that are of higher rank.
- Successful classification into large and larger groups is a basic feature of a taxonomic era.
- The taxonomic position of a taxon is the place of that taxon in classification indicators by the higher taxa which it is included.
- The ranking is the organization of plants in groups at different levels.
- The higher the rank, the higher the generalization involved while at lower levels, the rank will be more specific to a point where, at the lowest possible rank, there will be one specific individual.
- The higher the rank is, the more numerous are its members and the less they have in common i.e a genus has more members than a species.

Species - It's the fundamental unit of taxonomy. This is a group of very similar individual that have a potential to interbred freely and produce off-springs but cannot interbred successfully with individuals from other species. It's made up of a number of individual plants.

A genus

- This refers to group of species that are fairly closely related, such as the genus Solanum which includes several species *S. tuberosum , S. esculantum* etc. generic name can be used alone to describe a genus whereas specific name is always used with the generic name.
- A genus consist of more than one species each being made up of individuals plants. Therefore, genus would contain a greater number of individual plants than does anyone species it contain.
- The lower the rank of a taxon, the more numerous are its members and the less they are in common. The higher the rank the fewer the character its members have in common.
- Below the rank of a species, there are accepted taxa which are likewise arranged in a hierarchical system.
- Those below the rank of a species are named by means of a combination of a specific name with appropriate infraspecific epithet.
- The two part being linked by a term denoting the level of the taxa e.g. sub-species, varieties, sub-varieties, forms etc.
- Their names consist of a minimum of 3 parts: binomial and epithet e.g.
- *Betula pubescence* sub variety *Odorata*
- *Salex repens* variety *fusca*
- *Brassica oleracea* var. *capitata*
- *B. oleracea* var. *acephala*
- *B. oleracea* var *botrytis*

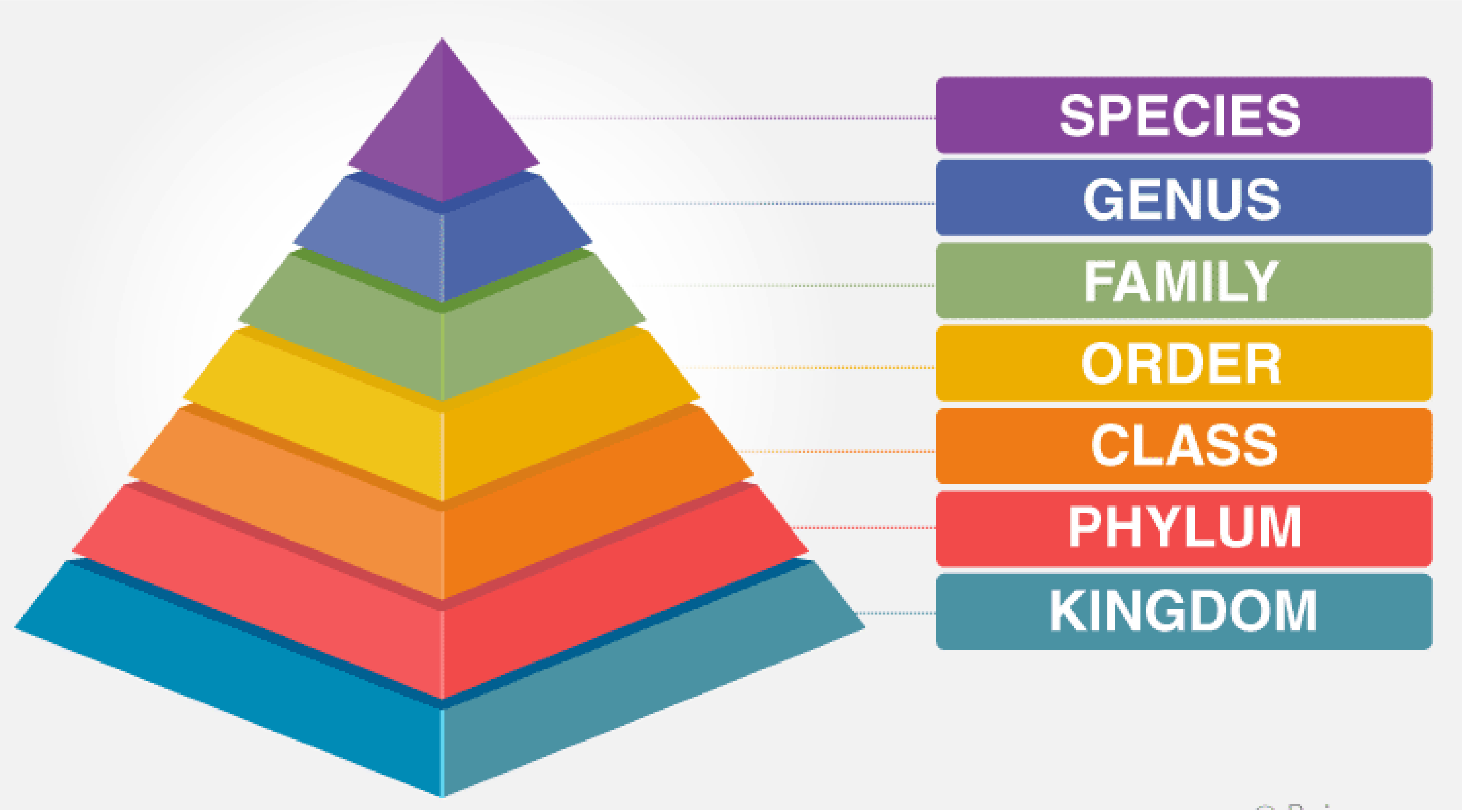
- **(i) Principal ranks:** Every plant belongs to one, and only one, species and that every species belongs in a genus,
- -Every genus in a family, every family, in an order, every order in a class, every class in a division (which may be referred to as a phylum), and every division in a kingdom. These are the principal ranks, the ranks to which every species belongs.

- **(ii) Secondary ranks:** There are also several secondary ranks.
- -These are ranks that may be used, but need not be.
- -The secondary ranks are generally used to subdivide large groups. Thus, a large family may be divided into tribes, a large genus into sections, large sections in series, large species into varieties, and large varieties into forms. "
- - For instance, one could put the two genera of a single family into two tribes, each tribe having one genus, but this is not usually done.

- The variety of life forms on earth is far too complex for the human mind to comprehend without some type of classification. Biologists have adopted and expanded the system initially devised by Linnaeus in the eighteenth century.
- The system is a hierarchy because all organisms are assigned to smaller and smaller groups as you move from higher levels down to lower levels.
- Each group at lower level is placed in one, and only one, group at a higher level.
- For zoologists, the official starting point is the tenth edition of Systema Naturae per Regna tria naturae, published in 1758 (in which Linnaeus described three species of phasmids).
- Before the time of Darwin, the classification was used for convenience without implying any relationship other than degree of similarity.

- As evolution became accepted by most biologists, there has been a major effort to make the classification correspond to the phylogeny (the evolutionary relationships among the groups). All animals are placed in a hierarchy that contains the following ranks:
  - Kingdom
  - Phylum (plural phyla)
  - Class
  - Order
  - Family
  - Genus (plural genera)
  - Species

Taxonomic Hiearachy



Hierarchy used in Species Files

- •The top of the hierarchy is called the apex taxon. The apex taxon can be of any rank with family, tribe, genus, and species as the main ranks at lower levels.
- (The words "rank" and "level" have the same meaning in this context.) Tribe is added as an additional rank between family and genus, but its use is optional.
- It is used in large families where is useful to place certain genera (plural of genus) together in groups at a rank lower than family (or subfamily).
- However, family, tribe, genus, and species do not provide enough levels. "Super" can be added as prefix to indicate a rank higher. "Sub" can be added as a prefix to indicate a rank lower.
- "Infra" can be added as a prefix indicating a rank underneath that shown by "Sub." Even then we sometimes need still more levels, so we insert "group" and "series" when needed. The full hierarchy used in this website is:
- Superorder group
- Superorder
- Order
- Suborder
- Infraorder

- Superfamily group
- Superfamily
- Family
- Subfamily group
- Subfamily
- Tribe
- Subtribe
- Genus
- Genus group
- Subgenus
- Species series
- Species group
- Species subgroup
- Species
- Subspecies

TAXONOMIC RANKS OF LAND PLANTS	ENDING	EXAMPLE TAXON
Kingdom	(various)	**Plantae**
Phylum [Division]	**-phyta**	**Magnoliophyta**
Subphylum [Subdivision]	-phytina	Magnoliophytina
Class	**-opsida**	**Asteropsida**
Subclass	-idae	Asteridae
Order	**-ales**	**Asterales**
Suborder	-ineae	Asterineae
Family	**-aceae**	**Asteraceae**
Subfamily	-oideae	Asteroideae
Tribe	-eae	Heliantheae
Subtribe	-inae	Helianthinae
Genus	(various)	***Helianthus***
Subgenus	(various)	*Helianthus*
Section	(various)	*Helianthus*
Series	(various)	*Helianthus*
Species [abbr. sp. (sing.), spp. (pl.)]	(various)	***Helianthus annuus***
Subspecies [abbr. subsp. or ssp. (sing.), subspp. or sspp. (pl.)]	(various)	*Helianthus annuus* ssp. *annuus*
Variety [abbr. var. (sing.), vars. (pl.)]	(various)	*Helianthus annuus* var. *annuus*
Form [abbr. f.]	(various)	*Helianthus annuus* f. *annuus*

Taxonomic ranks of land plants

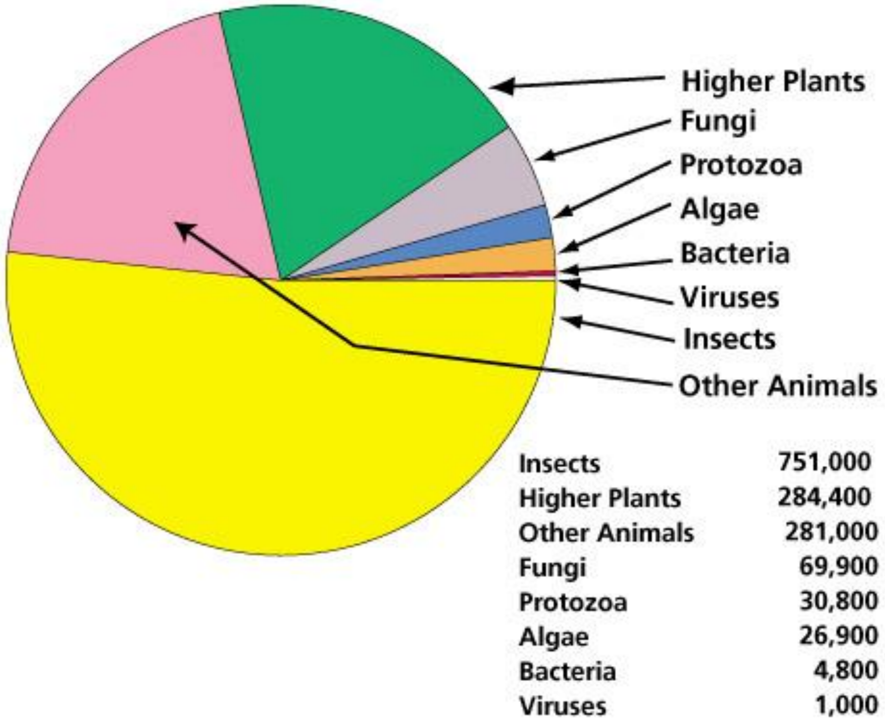
Significance of rank in taxonomy

- The assignment of a particular group of organisms to a specific rank in the hierarchy is arbitrary. Some taxonomists (the splitters) would place the group at a higher level while others (the lumpers) would put it at a lower level. The important information is the relationships to other groups of organisms placed nearby in the hierarchy.
- There is, however, one level that is more objective than any other. That is the rank of species.
- A species includes those individuals that would interbreed if they had the opportunity to interact in a natural setting.
- This simplistic definition ignores a lot of complications such as changeover evolutionary time and parthenogenetic species (females reproduce without males).
- It also ignores a practical problem: How can a taxonomist know what individuals would interbreed if given the opportunity? Nevertheless, it is an ideal concept that most taxonomists apply as best they can.

The need for a taxonomic hierarchy

- There is an incredible diversity of life on planet Earth.
- There are over 280,000 extant species of angiosperms (with the total number of angiosperm species reaching 400,000 by some counts).
- The number of angiosperm families is well over 400. No one person could possibly remember all of these.
- It is necessary to organize this diversity into a classification scheme to communicate with others.
- The classification system that has been traditionally most useful to biologists is one that groups related plants together into a series of hierarchical categories, so that very closely allied plants are placed together.
- Plants somewhat related are grouped near each other, and plants that have very little in common with each other are placed far apart.
- Classification usually done based on characteristics shared by certain plants. Classifying helps us put into order the many varieties of plants that exist

- It also enables us to identify which group of plants can be used for a certain purpose because of their similar characteristics



Proportion of species composition

- Zea mays (corn or maize)
- Phylum or Division – Magnoliophyta – flowering plants
- Class–Liliopsida – [monocotyledons or monocots]
- Order – Cyperales
- Family – Poaceae
- Genus – Zea
- Species – Zea mays

- Alternative Family Names/ Permissible alternatives of acea for families
- There are eight family names that have been used for so long that they are accepted as correct, despite the fact that they do not follow the rules.
- They are listed in the table below, together with the name that the family has if one insists on using family names that are based on a generic name.

Traditional Name	**Alternative**
Graminae	Poaceae
Palmae	Arecaceae
Cruciferae	Brassicaceae
Leguminosae	Fabaceae
Guttiferae	Clusiaceae
Umbelliferae	Apiaceae
Compositae	Asteraceae
Labiatae	Lamiaceae

Use of taxonomic hierarchy

- Subordinate categories; those below the rank of a species i.e subspecies, form, cultivar.
- Infra-specific categories are also used as intermediates below the species level.
- Forma – contains of population of genetically uniform individual.
- Also may be used for sporadic distinct variants that may occur from time to time within a population e.g when an albino plant emerges it forms a form.
- Cultivar – applies only to cultivated plants. They exist in single stands as controlled by man.

PRINCIPLES OF PLANT TAXONOMY

Botanical nomenclature

- Botanical nomenclature is the formal, scientific naming of plants. It is related to, but distinct from taxonomy.
- Plant taxonomy is concerned with grouping and classifying plants; botanical nomenclature then provides names for the results of this process.
- Botanical nomenclature deals with rules prescribing which name applies to that taxon and if a new name may (or must) be coined.
- Plant taxonomy is an empirical science, a science that determines what constitutes a particular taxon (taxonomic grouping, plural: taxa): e.g. "What plants belong to this species?" and "What species belong to this genus?".
- The definition of the limits of a taxon is called its 'circumscription'.

- In binomial nomenclature system a species name consists of two words- generic name and specific epithet
- NB: Generic names convey message and are nouns and can stand alone. Specific epithets cannot stand by themselves since are adjective and so must accompany generic names.
- Generic name must start with a capital letter while specific epithet must be started with a small letter. Sometimes a binomial name may look like a trinomial, but the two words of specific epithet must be joined by a hyphen e.g Hibiscus rosa-sinensis, but epithet underlying together. Also Capsella bursa-pastoris

Why Latin is used in botanical nomenclature?

- a) It is no longer spoken as a language in any country (dead language)
- b) It avoids multiplicity of languages and any national bias
- c) It was the language of European scholars.

- For a particular taxon, if two taxonomists agree exactly on its circumscription, rank and position (i.e. the higher rank in which it is included) then there is only one name which can apply under the ICN.
- The starting point for modern botanical nomenclature is Linnaeus' Species Plantarum of 1753.
- Botanical nomenclature is governed by the International Code of Nomenclature for algae, fungi, and plants (ICN), which replaces the International Code of Botanical Nomenclature (ICBN).
- The name was changed at the International Botanical Congress in Melbourne in July 2011 as part of the Melbourne Code which replaces the Vienna Code of 2005.

- Nomenclature deals with the application of a correct name to a plant or a taxonomic group. We have millions of species distributed in different geographical regions of the world.
- The Scientific names (Botanical name and Zoological name) of the living organism (Plants and Animals) are necessary because the same common name is used for different plants/Animals in different areas of the world.
- Swedish Botanist Carolus Linnaeus introduced Binomial Nomenclature.
- The Binomial nomenclature uses two Latin words to indicate the genus and the species.
- The first word is the genus and the second word is the species. Example- the botanical name of Dates is *Phoenix dactylifera*.

International Code of Nomenclature (ICN)

- It is also called the code. The code is divided into 3 divisions as follows;

Division 1

- It provides a set of six principles which form the very basis of the system of nomenclature as;

(i) **Principle I:** Botanical nomenclature is independent of zoological nomenclature

(ii) **Principle II:** The application of names of taxonomic group is determined by means of nomenclatural types (the element on which the botanical name of any rank is based i.e *Malva verticillaster*)-Type Principle

(iii) Principle III: The nomenclature of a taxonomic group is based upon priority of publication Priority Principle

(iv) 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 infraspecific cases. Uniqueness Principle

(v) Principle V: Scientific names of taxonomic group are treated as latin regardless of their derivation

(vi) Principle VI: The rules of nomenclature are retroactive unless expressly limited. RETROACTIVITY PRINCIPLE (PRINCIPLE VI)

Division 2

- This contains detailed rules, distributed over 75 articles, and recommendations. Names which contravene any one or more of the rules are considered illegitimate and cannot be maintained.
- Recommendations deal with subsidiary points and are intended to bring in greater uniformity in plant nomenclature.
- Names contrary to recommendations need not be rejected, but need not be followed as examples.

Division 3

- This gives detailed provisions for modifications of the code. This is followed by the following four appendices

  a) Names of hybrids and some special categories

  b) Names dealing with conserved families (Nomina familiarum conservada - nomen conservandum)

  c) Names dealing with conserved genera (Nomina generic conservada)

  d) Names dealing with conserved species (Nomina specifica conservanda et rejecienda)

International Botanical Congress

- International Botanical Congress (IBC) is an international meeting of botanists in all scientific fields, authorized by the International Association of Botanical and Mycological Societies (IABMS) and held every six years, with the location rotating between different continents.
- The current numbering system for the congresses starts from the year 1900
- The IBC has the power to alter the ICN (International Code of Nomenclature for algae, fungi, and plants), which was renamed from the International Code of Botanical Nomenclature (ICBN) at the XVIII IBC.
- Formally the power resides with the Plenary Session; in practice this approves the decisions of the Nomenclature Section.
- The Nomenclature Section meets before the actual Congress and deals with all proposals to modify the Code: this includes ratifying recommendations from sub-committees on conservation.
- To reduce the risk of a hasty decision the Nomenclature Section adopts a 60% majority requirement for any change not already recommended by a committee.

Year of adoption	Informal name
1905	*Vienna Rules*
1935	*Cambridge Rules*
1952	*Stockholm Code*
1969	*Seattle Code*
1975	*Leningrad Code*
1981	*Sydney Code*
1987	*Berlin Code*
1993	*Tokyo Code*
1999	*St Louis Code, The Black Code*
2005	*Vienna Code*
2011	*Melbourne Code*
2017	*Shenzhen, China*
2024	*Madrid, Spain*
2029	*Cape Town, South Africa*

Scientific names

- Taxonomist as nomenclaturists name taxa and determine new names for old taxa that have been remodeled, divided, united, transferred or changed in rank according to the IBC (International Botanical congress).
- They also determine the correct names for a specimen according to the classification system.
- Man has placed plants into categories and given them names with or without employing special technology and system.
- Centuries ago, each plant was known by a long, descriptive sentence which was cumbersome. Since the publication of “species plantanun “ by Linnaeaus in 1753, the forming of names in Latin for international use has been a fundamental task for botanists.
- The scientific or specific name of an organism is binary name of Generic name (genus) and Specific epithet.
- Examples, *Quercus alba* is the scientific/specific name of white Oak. *Quercus* is the generic name and alba is the specific epithet. Scientific names are italicize in print or underlined when typed or hand written.
- The initial letter of genetic name is always capitalized, the remaining lower case.
- The name of a genus is a noun and singular in number or word treated as such. The specific epithet is usually an adjective e.g. in *Quercus alba*, alba means white, but the epithet may be a noun in apposition e.g. *Pyrus malus*.
- *Malus* is the name for the genus for apple or a noun in the generative singular commemorating/honoring a person e.g. in Panicum ashei Pearson w.w. Pearson is a person.
- He is being commemorated by having a species and specific epithets. Generic and species names may be taken from any source whatsoever but are always treated as Latin.

How plants get their names

- The scientific names of plants are either Latin words or words that have been Latinized from some other language, most often Greek.
- The naming of plants happens in various ways – common names of plants evolve from country folk’s fanciful descriptions of their perceived uses, or appearance.
- Latin names, the correct botanical naming of plants, are based on a particular plants kinship with other similar or not so similar plants.
- Plant identification is based on the ways these plants relate to each other, mainly due to characteristics of blooms and leaf form and arrangement.

- Some of the differences are minute and microscopic. This leads to re-grouping plants at times into either a new genus or combining them with other genera to form a new one.
- The two groups of scientists and botanists responsible for this are known as ‘lumpers’ and ‘splitters’ for their preferred systems.
- Using a botanical key to narrow down the possibilities will give you an idea of which genus and species your plant belongs to. Each genus is grouped with others into a family, and also splits into different species

- Binomial nomenclature, a long way of saying two names, defines to which genus and species each plant belongs. Latin is used for the naming of plants, as it’s the same around the globe – even though common names may differ in other locations, the Latin botanical name will never alter.
- Naming of plants using the correct botanical names can be descriptive, using the appearance of the plant such as fuzzy, upright or coloured; or commemorative, using the habitat, or sometimes the name of the person who first made the discovery on a plant exploration expedition.

A Guide to Botanical Descriptive Names of Plants

Leaf Form:	**Plant Shape:**
acerifolia = maple like angustifolia = slender leaves aquifolius = spiny or prickly leaves buxifolius, buxifolium = boxwood like leaves ilicifolius = holly like leaves laurifolius = leaves like laurel parvifolius = small leaves populifolius = leaves like poplar salicifolia = willow like leaves Colours of Foliage or Flowers: Albus = white argenteas = silvery aureau = golden azureus = sky blue caesius = gray blue caeruleus, coeruleus = dark blue candidus = shiny pure white canus = ashy gray or hoary carneus = flesh coloured cereus = waxy citrinus = yellow coccineus = scarlet concolor = one colour creceus = yellow cruentus = bloody discolor = two colours or separate colours glaucus = covered with grey bloom or pruinose incanus = gray, hoary luteus = reddish yellow nigra = black purpureus = dark red or purple rubens, ruber = red or ruddy rufus – ruddy	adpressus = pressing against, hugging altus = tall arboreus = tree like capitatus = head like compactus = compact, densely growing confertus = crowded, pressed together contortus = twisted decumbens = laying down depressus = pressed down elegans = elegant, slender, willowy fastigiatus = upright, branches erect and close together humifusus = sprawling on the ground humilis = low, small, humble impressus = impressed upon nanus = dwarf procumbens = trailing prostrates = prostrate pumilis = puny, insignificant repens = creeping reptans = creeping scandens = climbing

Colours of Foliage or Flowers:	**Plant Characteristics:**
Albus = white	armutus = armed
argenteas = silvery	baccatus = berried or berry like
aureau = golden	barbatus = barbed or bearded
azureus = sky blue	campanulatus = bell or cup shaped
caesius = gray blue	ciliaris = fringed
caeruleus, coeruleus = dark blue	cordatus = heart shaped
candidus = shiny pure white	cornutus = horned
canus = ashy gray or hoary	crassus = thick or fleshy
carneus = flesh coloured	decurrens = running down the stem
cereus = waxy	-dendron = tree
citrinus = yellow	diffractans = shattering
coccineus = scarlet	diversi = varying
concolor = one colour	edulis = edible
creceus = yellow	floridus = free flowering
cruentus = bloody	fragilis = fragile, brittle
discolor = two colours or separate colours	fruticosus = shrubby
glaucus = covered with grey bloom or pruinose	fulgens = shiny
incanus = gray, hoary	gracilis = slender, thin or small
luteus = reddish yellow	grandis = large and showy
nigra = black	-ifer, -iferus = bearing or having – for example,
purpureus = dark red or purple	stoloniferus = having stolons
rubens, ruber = red or ruddy	laciniatus = fringed or torn edges
rufus – ruddy	laevigatus = smooth

Geographical Locale:	**Plant Characteristics:**
The suffix –ensis which means ‘of a place’ is added to place names to specify the habitat of origin. australis = southern borealis = northern campestris = of the field or plains canadensis = of Canada canariensis = of the Canary Islands carpensis = of the Cape of Good Hope area chilensis = of Chile chinensis = of China hortensis = of gardens insularis = of the island japonica = of Japan littoralis = of the seashore montanus = of the mountains riparius = of river banks rivalis, rivularis = of brooks saxatilis = inhabiting rocks tectorum = roof growing	lobatus = lobed maculatus = spotted mollis = soft, or softly haired mucronatus = pointed nutans = nodding or swaying officianalis = medicinal obtusus = blunt or flattened -oides = like or resembling – for example – jasminoides, like a jasmine patens = open spreading growth pinnatus = like a feather plenus = double, or full plumosus = feathery praecox = precocious, early blooming, early growing pungens = piercing radicans = rooting, especially along the stem reticulatus = net veined retusus = notched at blunt apex rugosus = wrinkled or rough sacharatus = sweet or sugary sagittalis = arrow like scabrous = rough feeling scoparius = broom like

Formation of specific epithets

- Each plant species has only one correct scientific name peculiar to that species alone. This is called a binomial and consists of a Generic (Genus) name and a Specific epithet.
- The specific epithet can be defined as the second part of a binomial or as the 'meaningful name'.
- The specific epithet can however never be used alone to stand for a species name of a plant. E.g Meru oak (*Vitex keniensis*) or the Kenya needle grass (*Aristida keniensis*). keniensis is the latinized term for Kenya as a country of origin for the plant.

- Specific epithets are formed from nouns, adjectives, participles etc by combining such words with a variety of prefixes and suffixes. Unlike English nouns, every Latin or Latinized noun has gender; either masculine (m), Feminine (f) or neuter (n).
- In most cases, each gender is indicated by a different ending e.g most nouns ending in – 'us' are masculine, nouns ending in – 'a' are nearly always feminine, while those ending with – 'um' are neuter.

- An adjective or other modifier must agree in gender with the noun it modifies.
- While a noun will have only one nominative ending depending up on its gender, a modifier will often have three different endings depending upon the gender of the word it is modifying.
- E.g the Latin adjective “hairy” appears with three different endings as it modifies the nouns Lathyrus, Lactuca and Gossypium which are respectively masculine, feminine and neuter.
- Thus Lathyrus hirsutus, Lactuca hirsuta and Gossypium hirsutum.

- Occasionally, the specific epithet is a noun in apposition in which case it carries its own gender regardless of that of the generic name it follows.
- In the binomial name Cypripedium calceolus, a species of lady’s slipper, the neuter genus name Cypripedium is followed by the masculine noun calceolus (a small shoe) in apposition but retaining its own gender

The most common latin endings:

m	**f**	**n**	**Meaning**
-us (e.g albus)	-a (e.g alba)	-um (e.g album)	White
-er (e.g niger)	-ra (e.g nigra)	-rum (e.g nigrum)	Black
-is (e.g brevis)	-is (e.g brevis)	-e (e.g breve)	Short
-er (e.g acer)	-ris (e.g acris)	-re (e.g acre)	Pungent

- Modifiers ending in –ans (‘elegans’ for ‘elegant’), -ens (‘repens’ for ‘creeping’) –or (‘bicolor’ for ‘with two colors’), -x (‘simplex’ for ‘simple’) use one ending for all three genders
- -E.g Ranunculus repens, Ludwigia repens and Panicum repens.

Types of Specific epithets

- **(i) Commemorative epithets**
- Are given generally to honour or commemorate the man or woman who first discovered a particular species. A specific epithet taken from the name of a man should be formed as follows:
- a) If the name ends in any vowel except ‘a’ (i.e e,i, o, u and then y), letter ‘i’ is added to the end of the name
- E.g *Andropogon greenwayi* for p.J. Greenway; *Convolvulus bussei* for Busse

- b) If the name ends in ‘a’, letter ‘e’ is added e.g *Sesamothamnus rivae* for D. Riva
- c) If the name ends in a consonant, ‘ii’ is added e.g *Ipomoea grantii* named after Grant

- d) If a name ends in ‘er’, only one ‘i’ is added e.g *Pseudobromus engleri* for Adolf engler
- e) If a woman’s name is used in the substantive form as an epithet, the ending will be feminine genitive singular for that word
- e.g *Crataegus coleae* for Ms. Cole; *C. beckwithae* for Florence Beckwith; *Cornus priceae* for Ms. Price.
- f) If the name is used as an adjective, it must agree in case and gender with the genus it modifies e.g *Turraea kokwaroana* for John kokwaro

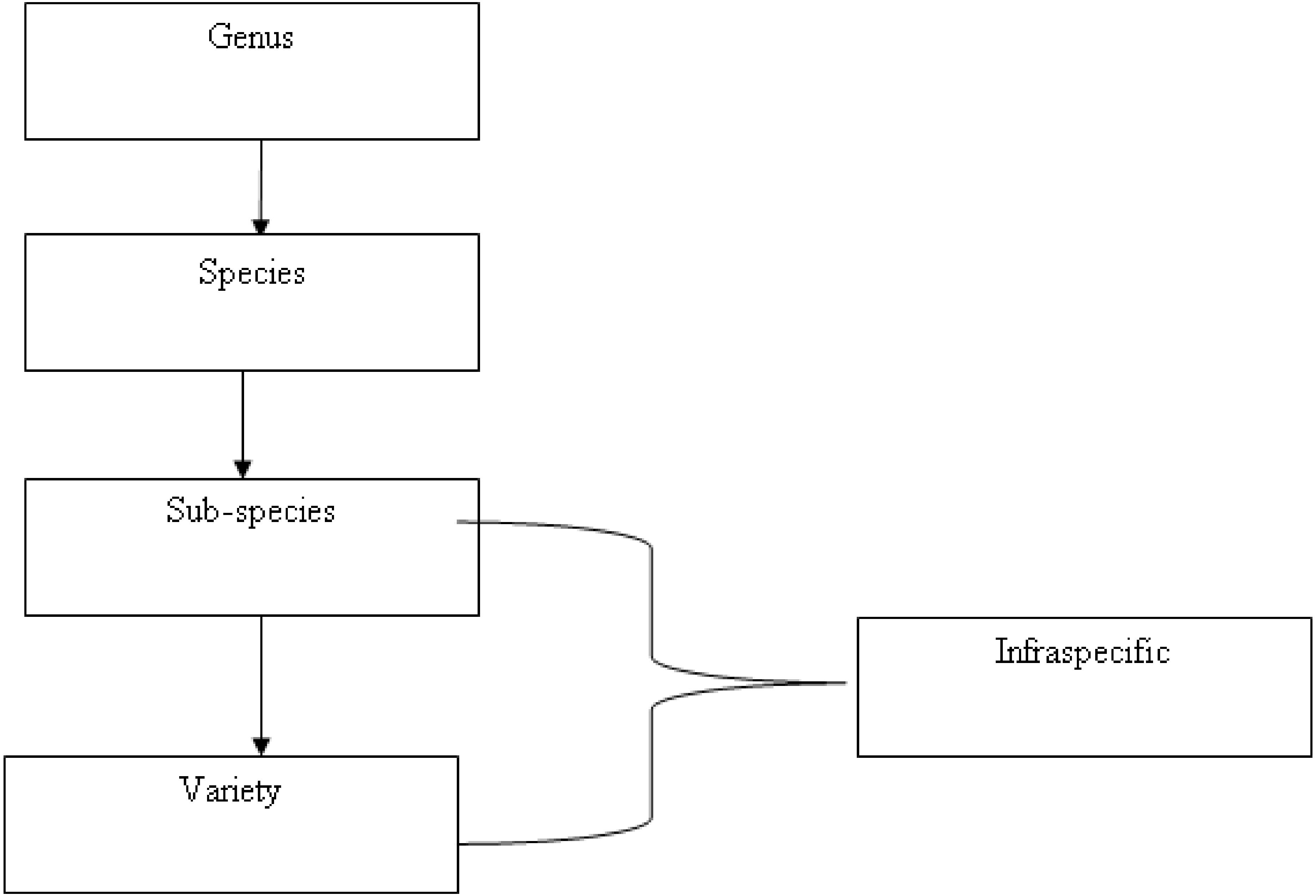
- **(ii) Geographical epithets**
- Is an epithet derived from a geographical name e.g *Euphorbia kibwezienzis* meaning from Kibwezi, *Ipomoea kituiensis* (from Kitui), *Kigelia Africana* (From Africa).

- **(iii) Descriptive epithets**
- These indicate or describe certain characteristics about a species such as colour of flower or fruit e.g *Croton megalocarpus* meaning large fruit.Can also describe habit of growth e.g *Celastrus scandens* meaning Climbing plant. OR shape of leaf e.g *Desmondium rotundifolium* meaning round leaved

Naming of infra specific taxa

- Are names below the species e.g. subspecies varieties and forms.
- In many wide ranging species there may be considerable variations in morphology.
- The morphological variance may become geographically isolated variation and therefore have sufficient difference that warrant to be called subspecies, varieties or forma names.
- If a species is divided into at least one infraspecific taxon or if species are combined, the original species undergoes some name modification, with a re-adjustment of names taking place.
- The original species takes on the duplicate name of the original name of specific epithet as its infraspecific name.
- The new infraspecific taxon is given a new name for example *Urtica dioica* L. Sub sp dioica becomes the typical taxon and *U. dioica* L. Subspecies gracilis (Ait) Selandra, the new combination.

- If a subspecies ‘ssp’ or variety ‘var’ is described in a species not previously divided into infraspecific taxa there’s automatically a “type” subspecies or variety.
- These bear the same epithet as species but is not followed by an authority.
- The code requires that the epithet be repeated and the original type specimen be the type of subspecies e.g. Obtusa: it creates 2 subspecies or varieties.
- They are: Former Vernonia obtusa Sub species obtusa
- New plant Vernonia obtusa subspecies Perkerii.
- When referring to a plant in a genus when we do not know which species it is, we use the generic name followed by 'sp.' ie: *Grevillea* sp. When referring collectively to some or all of the species in a genus we use the generic name followed by 'spp.' ie: *Grevillea* spp.
- Plant names are usually written in italics within a sentence or underlined, to distinguish them from other words. Family names are not italicised, nor are abbreviations like 'subsp.' or ‘sp.’


Genus
Species
Sub-species
Variety
Infraspecific

Typification

- Typification is the process of selecting a particular specimen or group of specimens as the official representation of a species or other taxonomic unit, such as a genus or family
- The Principle of Typification is one of the guiding principles.
- The International Code of Botanical or Zoological Nomenclature provides that any named taxon in the family group, genus group, or species group have a name-bearing type which allows the name of the taxon to be objectively applied.
- Type Specimen is the one representative of the taxon as follows:

- **Holotype:** A specimen designated by the author in the original publication (nomenclatural type).
- **Isotype:** A duplicate specimen of the holotype collected at the same time and place (may be in other herbarium).
- **Lectotype:** A specimen chosen from the author’s original material when no holotype has been designated.
- **Neotype:** A specimen selected when all original specimens have been destroyed

Author Citation/Effective Publication

- The meaning of a plant name is determined by the person(s) who first publishes it.
- This person (or these people) is known as the author(s) for the name. To be accurate, and complete, the name of a taxon should include a citation of the author or authors who originally described the taxon.
- The author citation expedites locating and determining the origin, date and description which helps determine the type and date of publication of the taxon e.g. *Bidens Pilosa* L.1753.
- Author citation helps one distinguish between two names. However, only the earlier name is legitimate (properly published, put in botanical journals).
- This citation helps in tracing the transfer of species from one genus to the other e.g. *Vernonia neveboranencis* (L) Minchax.
- Linnaeus put the plant in wrong genus but later Minchax put it in right genus and retained the specific epithet of Linnaeus. The first author is put in bracket

- In botanical nomenclature, author citation is the way of citing the person or group of people who validly published a botanical name, i.e. who first published the name while fulfilling the formal requirements as specified by the International Code of Nomenclature for algae, fungi, and plants (ICN).
- In cases where a species is no longer in its original generic placement (i.e. a new combination of genus and specific epithet), both the authority for the original genus placement and that for the new combination are given (the former in parentheses).

- In botany, it is customary (though not obligatory) to abbreviate author names according to a recognized list of standard abbreviations. *Calodendrum capense* (L. f.) Thunb. (Rutaceae), *Lantana camara* L.
- In many cases the author citation will consist of two parts, the first in parentheses, e.g. *Helianthemum coridifolium* (Vill.) Cout.
- This form of author citation indicates that the epithet was originally published in another genus (in this case as *Cistus coridifolius*) by the first author, **Dominique Villars** (indicated by the enclosing parentheses), but moved to the present genus *Helianthemum* by the second (revising) author (**António Xavier Pereira Coutinho**).
- Alternatively, the revising author changed the rank of the taxon, for example raising it from subspecies to species (or vice versa), from subgenus to Section.
- There are differences between the botanical code and the normal practice in zoology.
- In zoology, the publication year is given following the author names and the authorship of a new combination is normally omitted.
- A small number of more specialized practices also vary between the recommendations of the botanical and zoological codes.

The Principle of Priority

- Priority is a fundamental principle of modern botanical nomenclature and zoological nomenclature.
- Essentially, it is the principle of recognizing the first valid application of a name to a plant or animal.
- There are two aspects to this:
  - The first formal scientific name given to a plant or animal taxon shall be the name that is to be used, called the valid name in zoology and correct name in botany.
  - Once a name has been used, no subsequent publication of that name for another taxon shall be valid (zoology) or validly published (botany).

- Example: *Nymphea nouchali* Burm F. 1768; *N. Pubescence* Willd 1799 and *N. torus* Hook T; 1872 are names of the same species but if rule of Priority is applied the first name is the correct name and other two are synonyms.
- There are formal provisions for making exceptions to this principle.
- If an archaic or obscure prior name is discovered for an established taxon, the current name can be declared a nomen conservandum (botany) or conserved name (zoology), and so conserved against the prior name.
- Conservation may be avoided entirely in Zoology as these names may fall in the formal category of nomen oblatum i.e forgotten or obsolete.
- Similarly, if the current name for a taxon is found to have an archaic or obscure prior homonym, the current name can be declared a nomen protectum (zoology) or the older name suppressed (nomen rejiciendum, botany).

Regulations to the principle of priority

(i) Each family or taxon of lower rank with a particular circumscription, position and rank can bear only one correct name

(ii) For any taxon from family to genus comprehensive, the correct name is the earliest rightful one, validly published with the same rank

(iii) A name of a taxon has no status under this code unless it is validly published.

(iv)The application of both conserved and rejected names is determined by nomenclatural type.

(v) "When a name proposed for conservation has been provisionally approved by the general committee, botanists are authorized to retain it pending the decision of a later International Botanical Congress".

-Valid Publication of names is usually considered beginning in May 1753, the date of publication of Species plantarum vol. I by Linneaus.

Limitations of the Principle of Priority

1. Starting dates:

Principle of Priority starts with the Species Plantarum of Linnaeus published on 1-5-1753.

2. Limited only upto family ranks:

This principle does not apply over family rank.

3. The corrected name should not be outside the rank. Only when a correct name in the taxon is not available, a combination with other rank is allowed.

4. The application of the Principle of Priority resulted in numerous name changes.

- To avoid it a list of conserved generic and family names has been prepared and Published in the code with some changes.
- Such Nomina conservanda (non. cons) are to be used as correct name replacing earlier legitimate name, e.g., *Sesbania scop*, 1777 is the conserved genus as against *Sesban adam* 1763 and *Agati adam* 1763.

Rejection of Names

The rules for rejection of names are:

(i) Nomen nudunm (nom. nud):

-Name without description, without typification and Latin diagnosis etc. is rejected.

(ii) Tautonym:

-Botanical nomenclature does not allow tautonym (repetition of generic name), e.g., *Malus malus*.

-Repetetion of specific epithet in infra specific epithet does not constitute tautonym.

(iii) Later homonym:

-If a name which is already existing is given to another taxa once again then the later homonym is rejected.

(iv) Nomen ambiguum (nom. ambig):

-The name is rejected if it is used in different sense by different authors.

(v) Nomen confusum (nom. confus):

-The name should not be confusing.

(vi) Nomen dubium (non. dub):

-Dubious name i.e., with uncertain applications is also rejected.

Synonyms and Related Terminology

Synonyms:

- Is a name that is not correct for the circumscription, position, and rank of the taxon as considered in the particular botanical publication.
- It is always "a synonym of the correct scientific name", but which name is correct depends on the taxonomic opinion of the author.
- A name rejected due to misuse or difference in taxonomic judgement.

Basionym: The basionym is the first name ever given to a taxon.

- Further studies and revisions may reject the basionym as the most correct one, but it still is useful as a nomenclatural reference for that species.
- Also, according to the priority rules of the ICBN, after a taxonomic revision that results in a species being reclassified in another genus, the specific epithet must remain the same as the one in the Basionym.

- A short example: Linnaeus classified the Tea Plant as *Thea sinensis.* Some decades later, Sweet noticed that the genus *Thea* was not really different from the genus *Camellia*, and renamed all the Theas as Camellias. *Thea sinensis* became *Camellia sinensis*, because he had to keep the specific epithet the same as the original name (Basionym) for that species, given by Linnaeus.
- Also *Cassia siamea* revised to *Senna siamea*

Homonym:

- Is a name for a taxon that is identical in spelling to another such name, that belongs to a different taxon.
- The rule in the International Code of Botanical/Zoological Nomenclature is that the first such name to be published is the senior homonym and is to be used (it is "valid"); any others are junior homonyms and must be replaced with new names.
- It is, however, possible that if a senior homonym is archaic, and not in "prevailing usage," it may be declared a nomen oblitum and rendered unavailable, while the junior homonym is preserved as a nomen protectum

Tautonym:

- A case in which the name of genus and the name of species are the same. One example of a botanical tautonym is 'Larix larix'. The earliest name for the European larch is Pinus larix L. (1753)

Autonym

- Is a legitimate automatically created tautonym for infra-generic or infra-specific taxa. e.g Hypericum subgenus hypericum
- Section *hypericum*.
- *Hypericum perforatum* L. ssp *perforatum* var *perforatum*
- It’s also a name in which the final epithet is the same as that of the next higher taxon or the same as the generic name for the higher taxa if the next higher taxon is genus.

THE CONCEPT OF CHARACTER AND CHARACTER STATES

- A feature or observable attribute of a plant is called a character and the specific form or expression of the character is called character state. For example, flower color is a character with several states including red, yellow, white and blue flowers. All characters are not equally important for identification purposes.
- The most useful features are called "diagnostic" or "key" characters. These are given more "weight" when making decisions about a particular taxon.
- For example, fruits are diagnostic characteristics in the Mustard family (Brassicaceae); without fruits, these plants are difficult to identify.
- Some characters are rather variable (e.g., leaf shape, stem height, time of flowering) while other characters are fixed (i.e., floral characters). The source of the variation observed in these characters can either be environmental or genetic. One way to distinguish between them is to do transplant experiments.

- It is worth spending some time considering what a character is, and what it is not. Scientists do tend to use it in different ways. If you are aware of the different meanings that it may have, you will find it easier to determine how a particular author is using it.
- A character is a feature that can be measured, counted, described, or otherwise expressed. It is an abstract entity. Petal color is a character. Plant height is a character. Position 33 from the end of a gene is a character. Red is not a character; it is a character state.
- Characters have states. Red could be a character state for the character petal color; 3 cm could be a state for the character plant height 3 cm; cytosine is a possible character state for position 33 on a gene.
- In taxonomy, some characters are more equal than other characters, but which characters these are varies from group to group. First of all, one needs to decide if a character is a good taxonomic character for the plants that one is studying.

What makes a character a good taxonomic character?

- A good taxonomic character is one that is useful in determining to which group a plant belongs. Davis and Heywood (1973) suggested four criteria:

i. The character varies less within putative groups than between them. If this is not the case, either the character is not useful or the groups are bad.

ii. The character is genetically determined but does not have a high intrinsic genetic variability. For instance, if the offspring of the same pair of parents can have different states for the character, the character is not taxonomically useful.

iii. The expression of the character is not significantly modified by the environment.

iv. The pattern of variation in the character being examined correlates with the pattern of variation in other characters.

- As Davis and Heywood pointed out, there is circularity in taxonomy; it is inherent in criteria (i) and (iv). But spiral staircases are circular; they are still an effective means (though somewhat giddymaking) of moving from one floor to another. Circularity in taxonomy is of the spiral staircase kind.

Good for what?

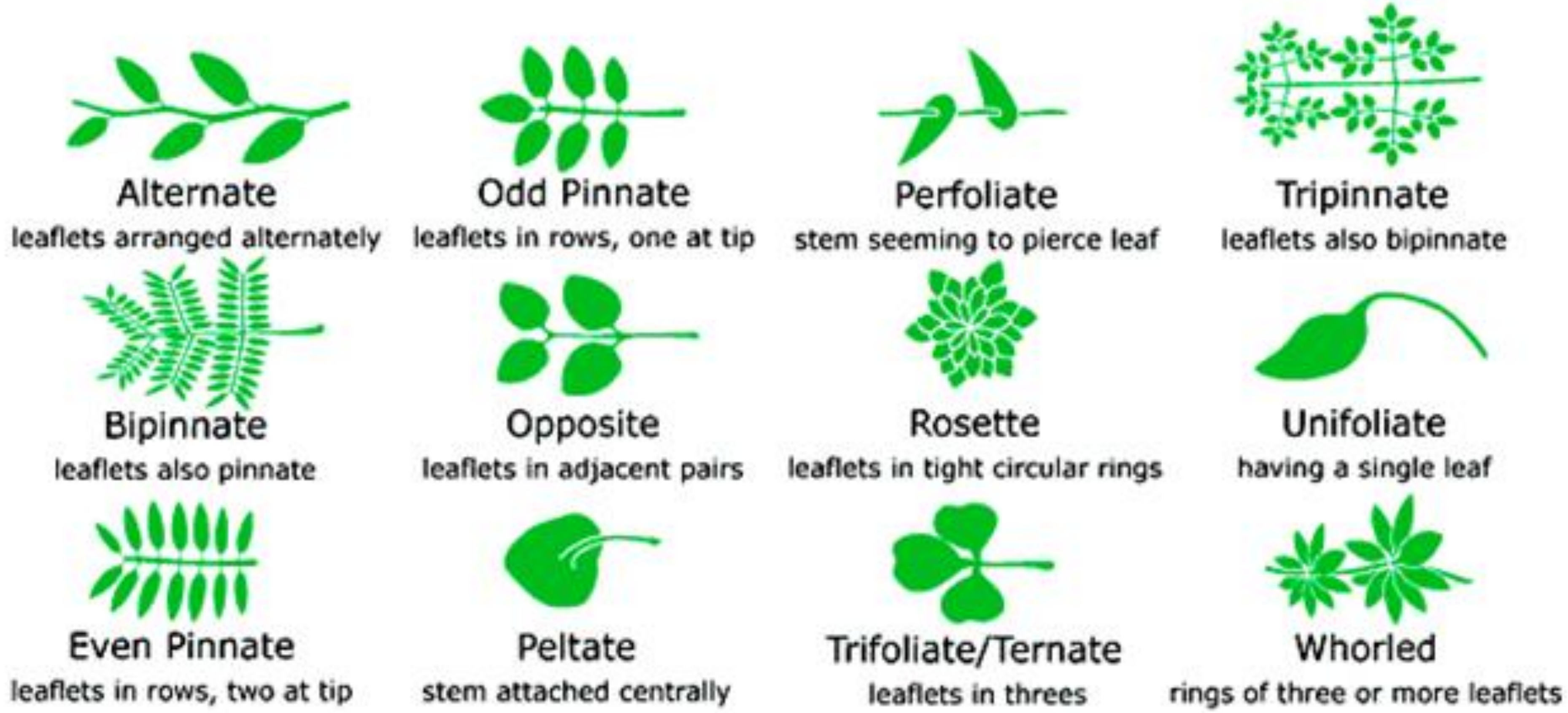
- The above discussion refers to taxonomic characters. Characters are also used for other purposes than circumscribing taxa, for instance for identification, diagnosis, and description.

Use of Plant morphological features

- Plant biologists use morphological features compared, measured, counted and described to assess the differences and similarities in plant taxa and use these characters for plant identification, classification and description.
- When characters are used in descriptions or for identification, they are called diagnostic or key characters; which can either be quantitative or qualitative.
- Quantitative characters are morphological features that can be counted or measured e.g A plant species with flower petals 10-12mm wide.
- Qualitative characters are morphological features that are not measurable e.g leaf shape, flower colours.

Character terminologies with regard to vegetative parts

Types of leaf arrangements (Phyllotaxy)



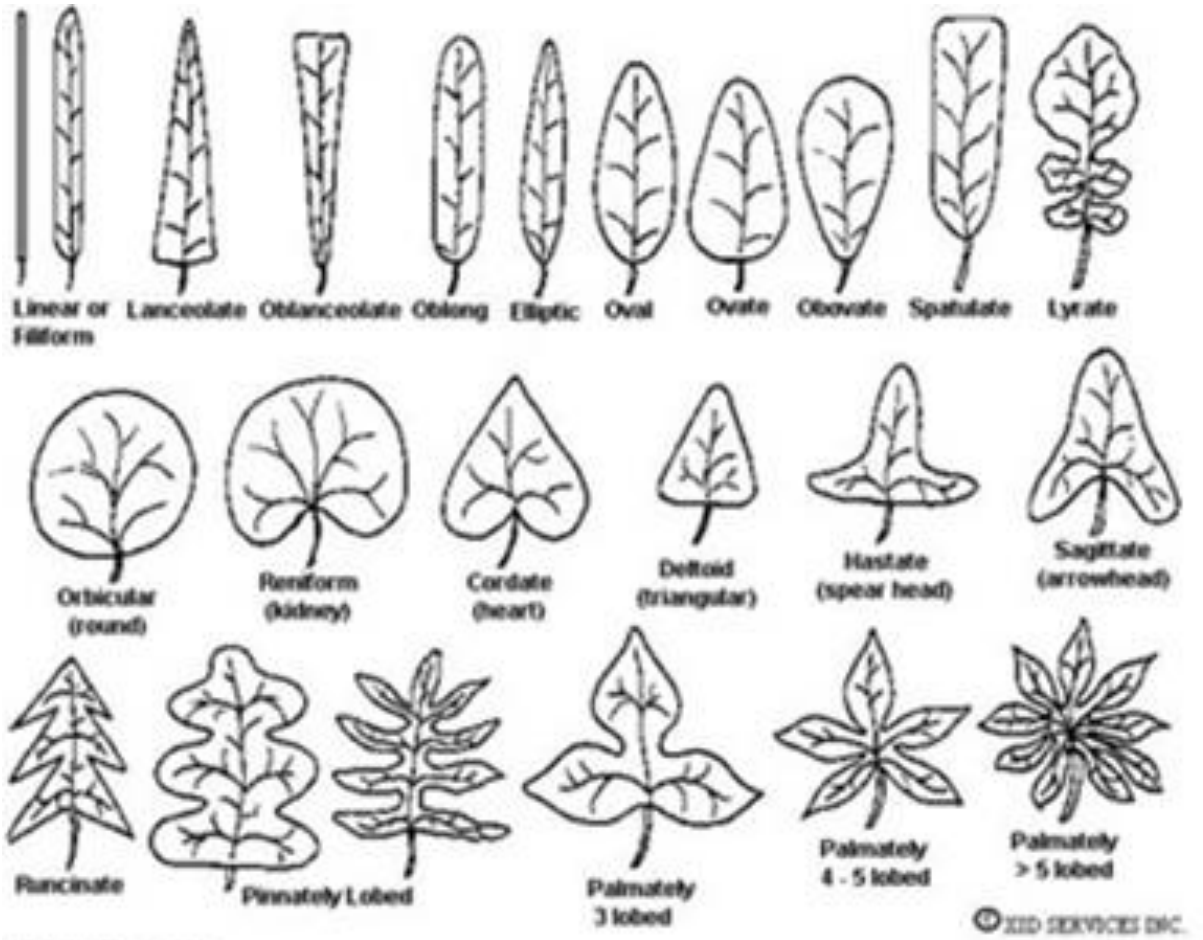
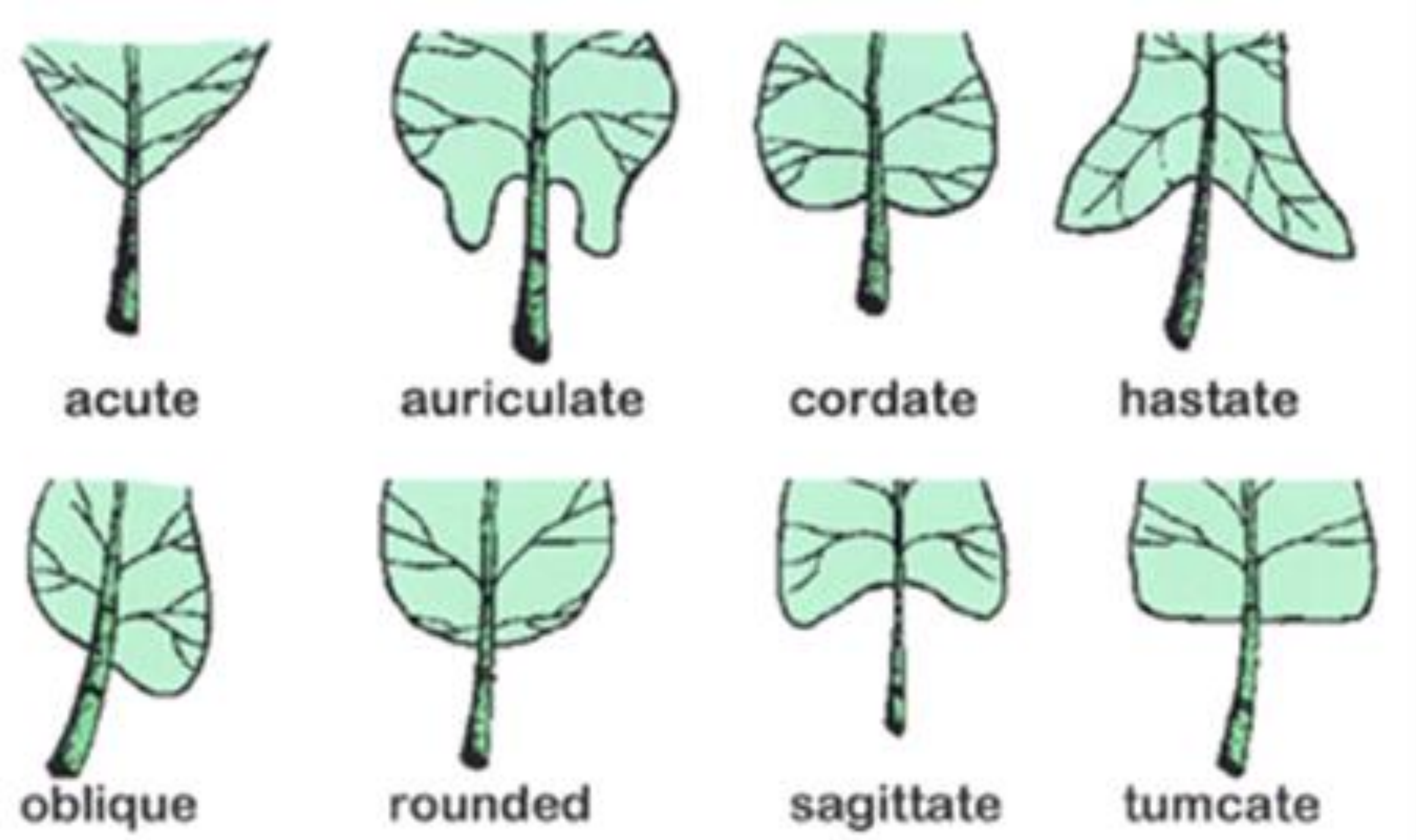
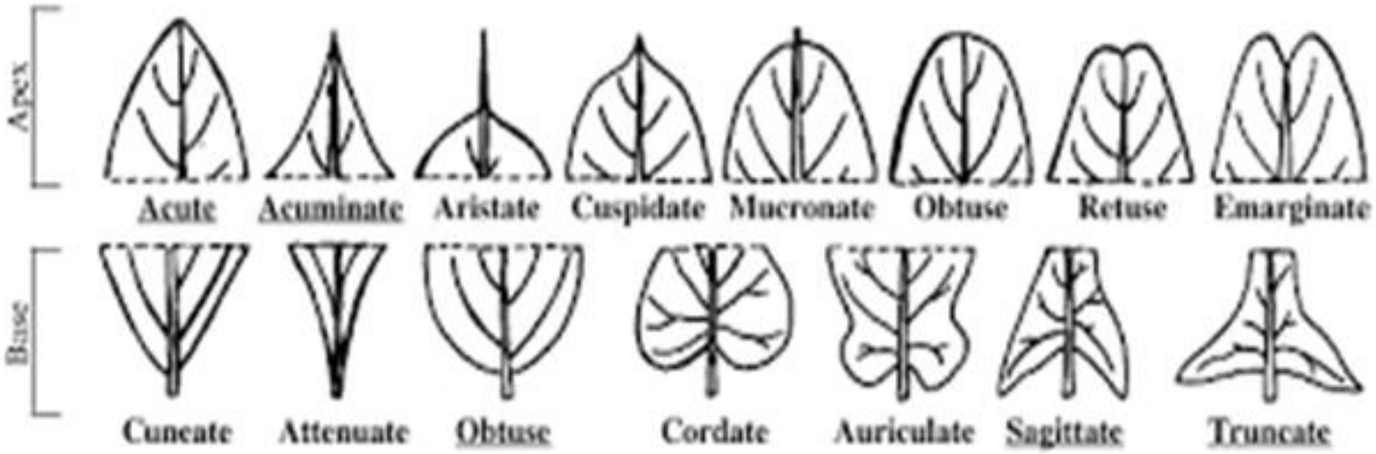


Figure 6. Leaf Shape

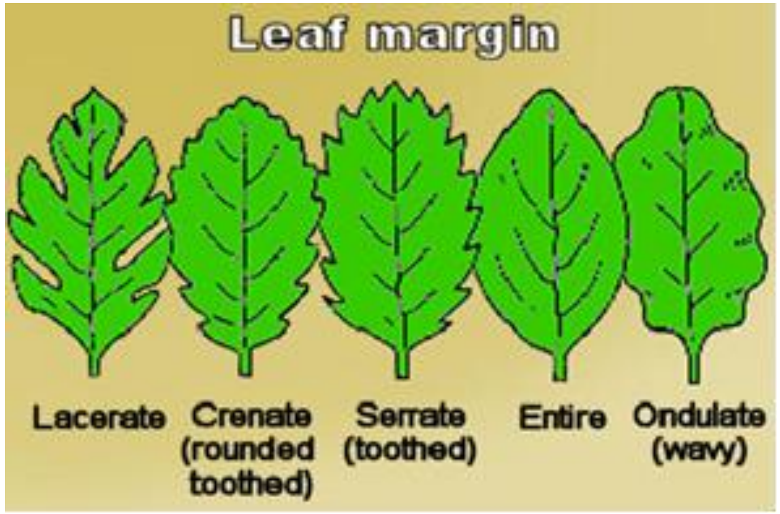
Leaf shapes

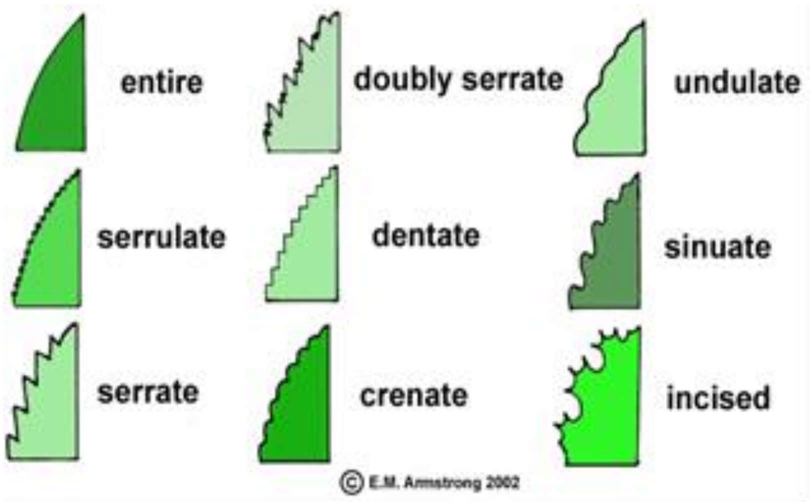

acute
auriculate
cordate
hastate
oblique
rounded
sagittate
tumcate

Leaf bases



Leaf apices





Leaf margins

Character terminologies with regard to flower parts

(i) Diocious plants: Both male and female flowers are found in separate plants i.e Flower imperfecti; e.g Carica papaya

(ii) Monoecious plants: The female and male flowers are in different parts of the same plant i.e Flower imperfecti; e.g Zea mais

(iii) Hermaphroditic plants: Both male and female parts are in the same flower of the same plant i.e Flower perfecti; e.g Solanum tuberosum

Ovary positions

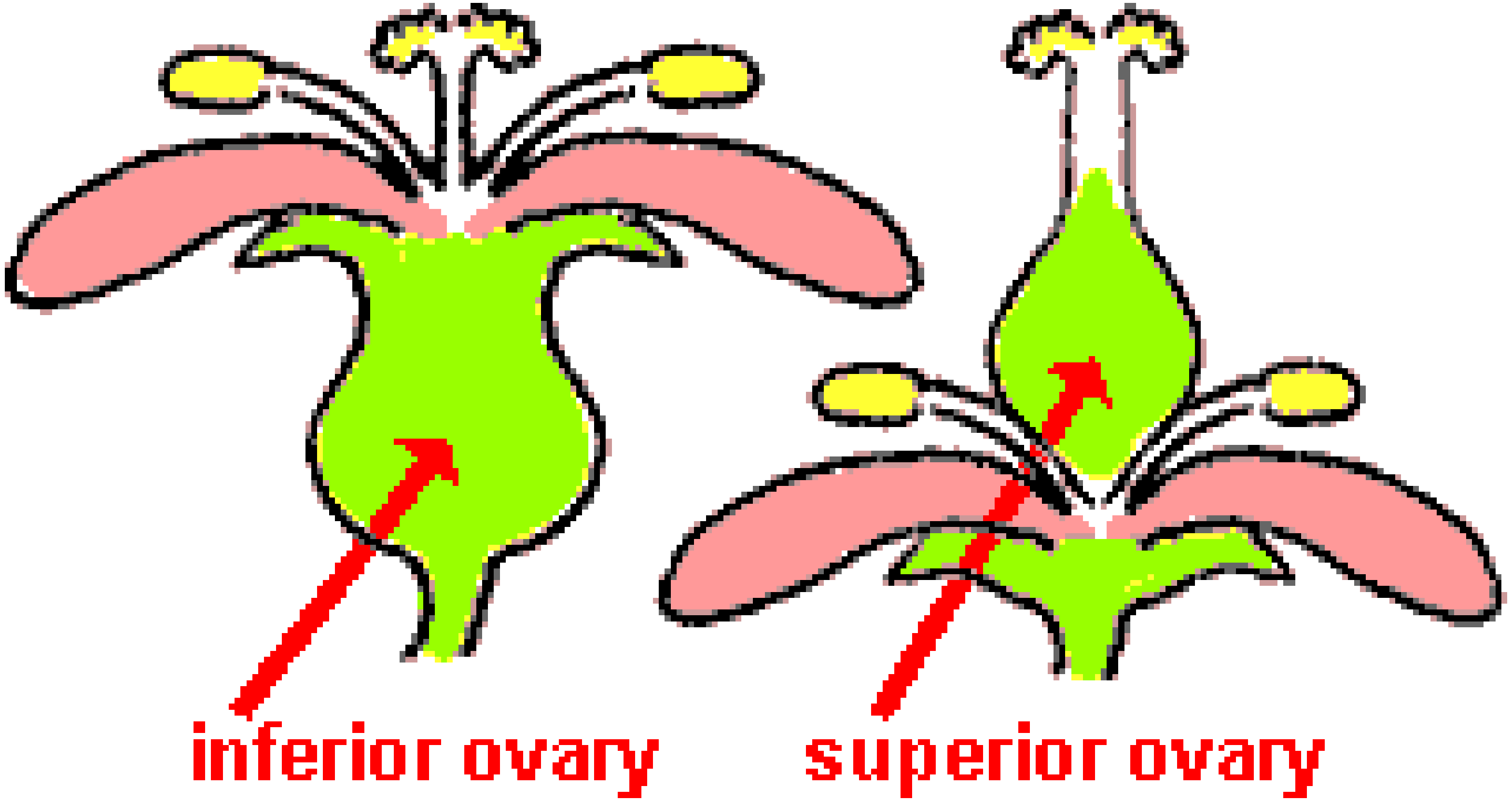
-
- (i) Hypogynous (Superior ovary)
- -Have the flower parts (Calyx, corolla and androecium) attached below the ovary to the receptacle e.g in Berries like Solanum spp

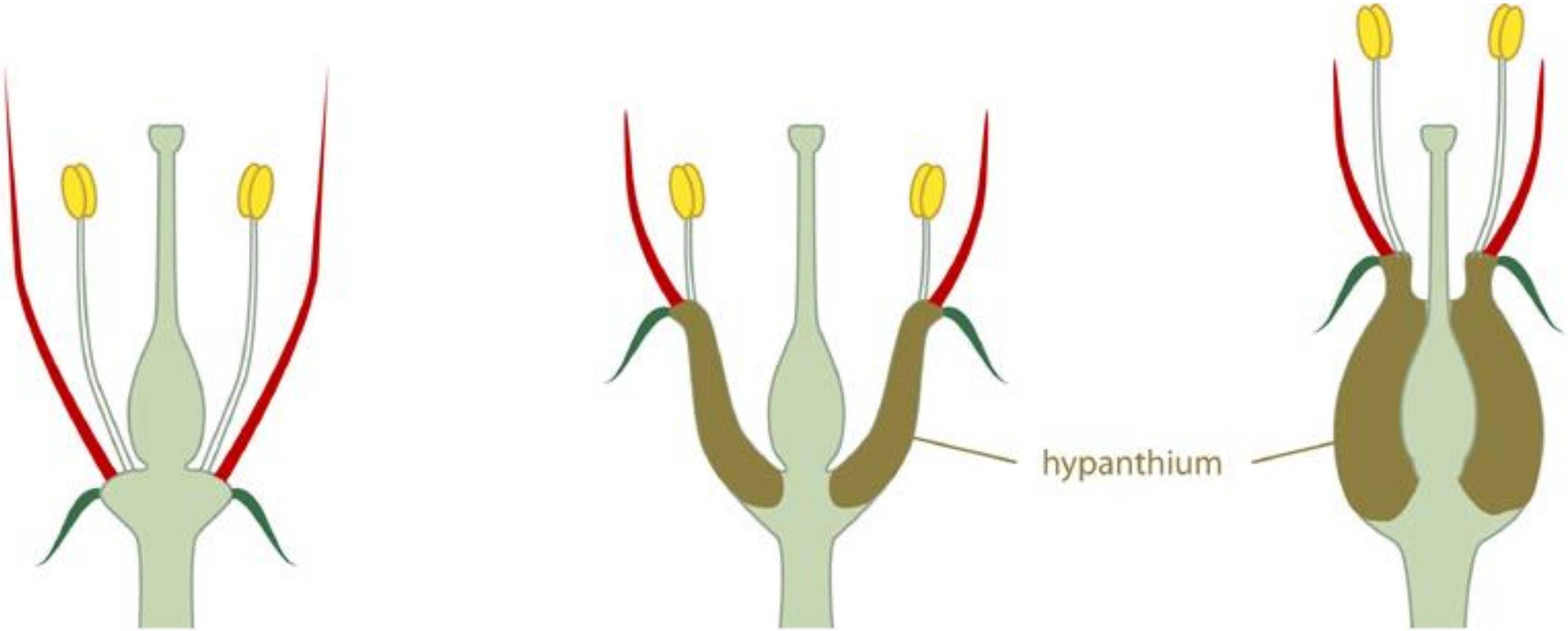
(ii) Epigynous ovary (Inferior ovary)

- -The flower parts (Calyx, corolla and androecium) are attached above the ovary e.g Water lily (Nymphaea odorata)

(iii) Perigynous ovary

- -Where the bases of the floral parts are fused into a cup-like structure surrounding the ovary e.g Legumes like Beans


inferior ovary
superior ovary



Ovary superior
Flower hypogynous
No hypanthium

Ovary superior
Flower perigynous
Hypanthium present

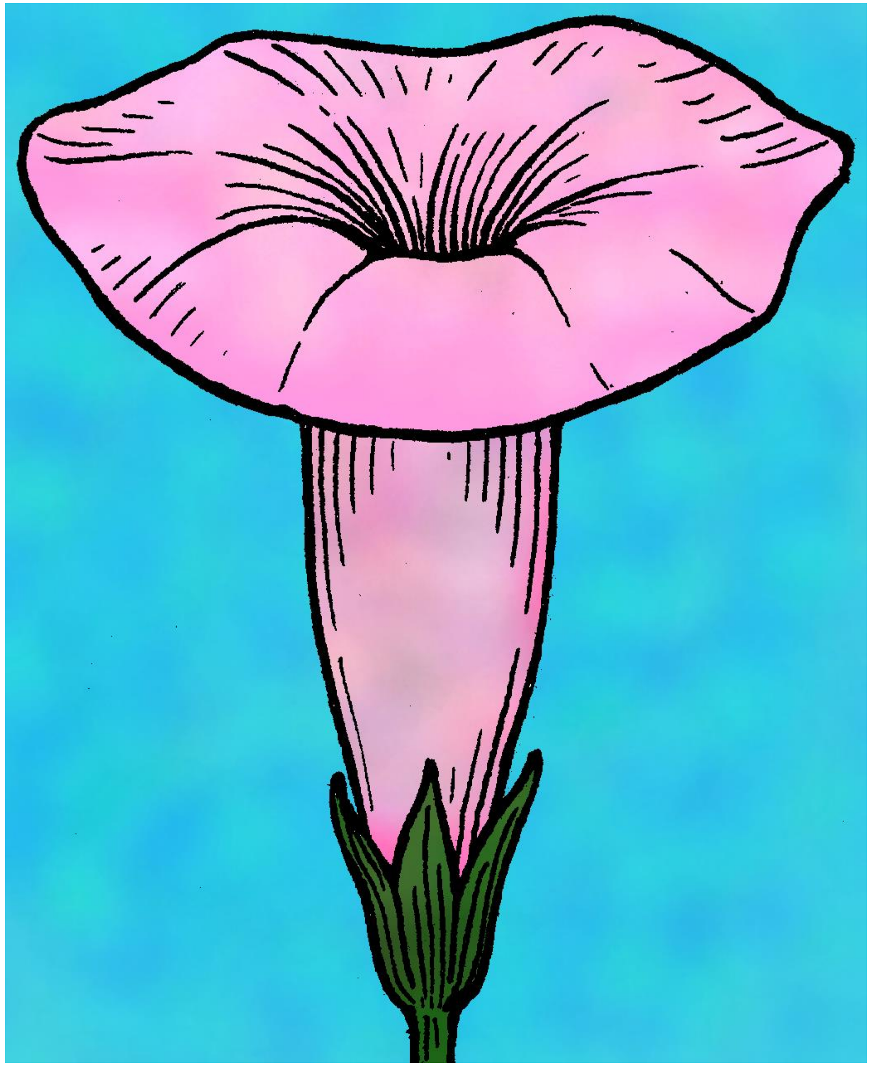
Ovary inferior
Flower epigynous
Hypanthium present

Union of Petals/Corolla

- (i) Gamopetalous or Sympetalous corolla
- -All the petals fuse to form a cylindrical or tube-like flower e.g Sweet potato

(ii) Polypetalous corolla

- -Where the corolla consists of separate petals
-



The corolla (C): Totality of petals in the flower

Corolla with free petals

Papaver spp.

Ranunculus spp.

Polypetalous or Apopetalous

Union of Sepals/Calyx

-

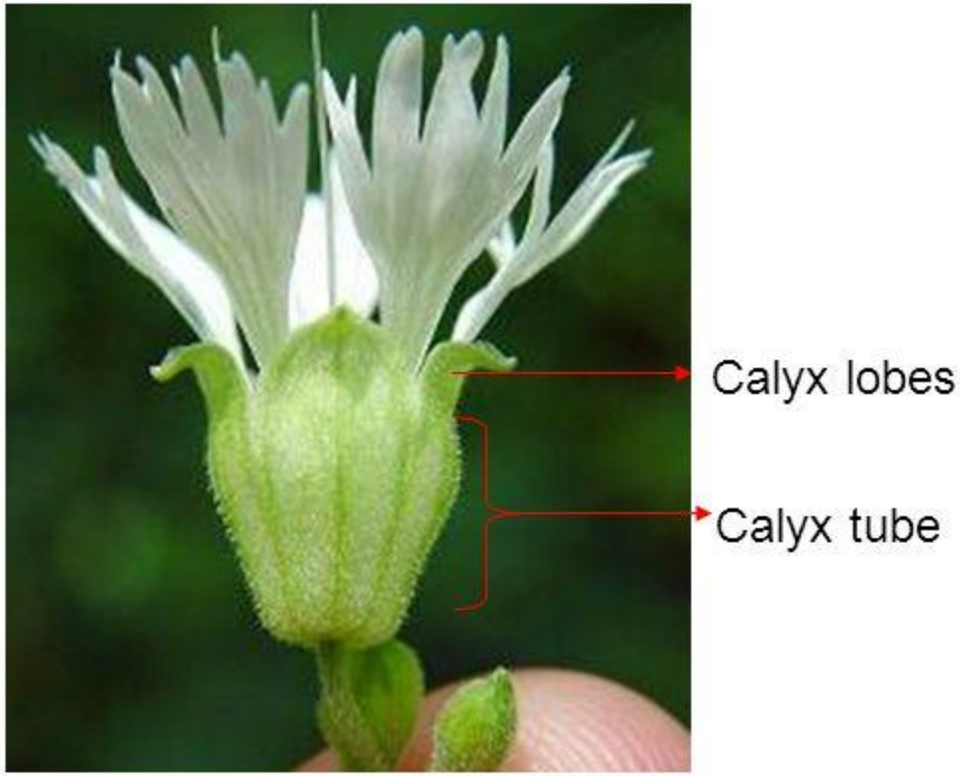
(i) Gamosepalous or symsepalous calyx

- -A flower that possesses a calyx consisting of fused sepals or calyx

The calyx (K): Totality of sepals in the flower.

Calyx with connate (united) sepals:

Fabaceae flower

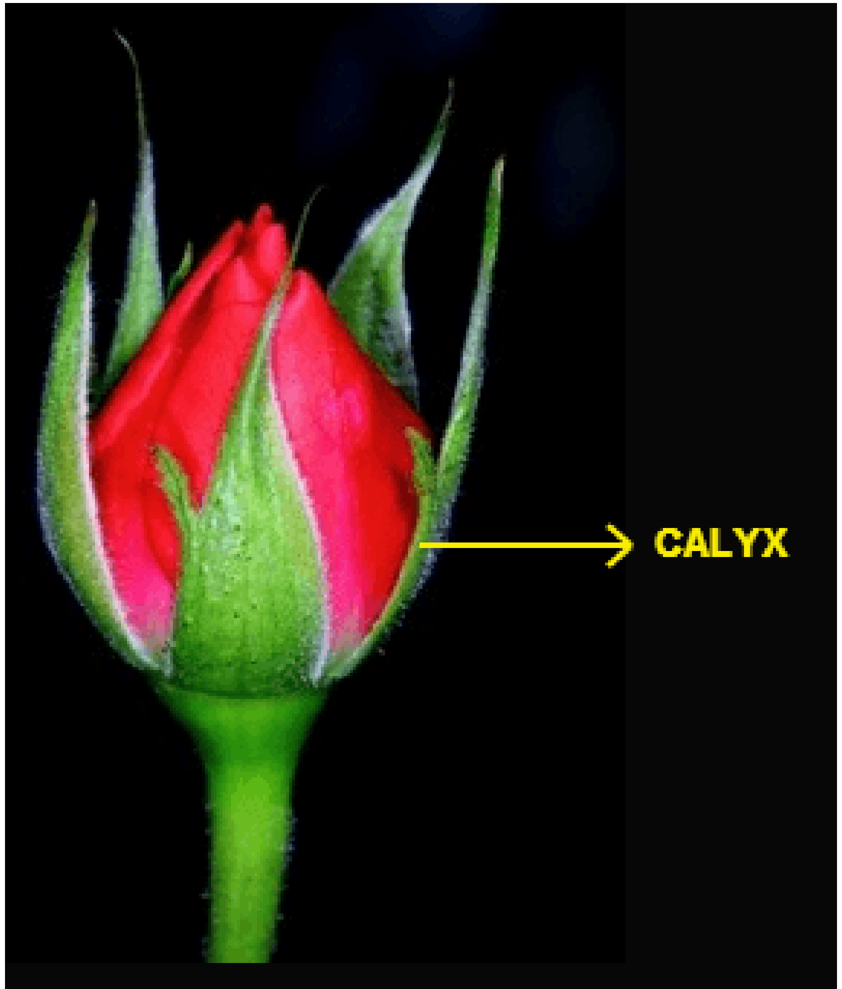


Silene spp.

Gamosepalous

(ii) Polysepalous calyx

-Where sepals are separate



- Union of Stamens
-

(i) Monadelphous flowers

- -Where stamen filaments are united into a single tube-like groups around the style e.g most legumes

(ii) Diadelphous flowers

- -Stamen with its filaments united into two sets e.g Beans

FLORAL SYMMETRY

- Floral symmetry describes whether, and how, a flower, in particular its perianth, can be divided into two or more identical or mirror-image parts.
- Uncommonly, flowers may have no axis of symmetry at all, typically because their parts are spirally arranged.
- Angiosperms (flowering plants) use a wide variety of structures, colors, and aromas to attract pollinators. These non-reproductive parts of a flower are called the perianth.
- The perianth consists of the petals (corolla) and the green cuplike structure at a flower's base, called the sepals, or calyx. Looking at a flower from above, if you were to cut it in half, through the perianth, the two halves might be relatively identical, identical only along one plane, or not identical at all.
- These different types of symmetry are radial, bilateral, or asymmetrical, respectively.

(i) Radial symmetry

- Orange lily (*Lilium bulbiferum*), and wild rose (*Rosa acicularis*) have radial symmetry. No matter how you cut them in half, both halves look the same.
- Flowers with radial symmetry are called ***'regular'*** or ***actinomorphic***.
- Actinomorphic also refers to 'regular' star-shaped flowers that can be divided into three or more identical sections.
- Each section looks the same, no matter how you rotate the flower.
- Even though each half may not contain a complete petal, they are still considered actinomorphic.

Orange lily displays radial symmetry

Wild rose displays radial symmetry

(ii) Bilateral symmetry

- Most people have bilateral symmetry.
- This means our left and right sides look very much alike, but our fronts and backs look very different.
- Some flowers, such as orchids and snapdragons, are the same way.
- Some flowers have only one line that can be cut to create a mirror image.
- These flowers are classified as **'irregular'** or **zygomorphic.**
- Zygomorphic flowers have bilateral symmetry and that line is called the sagittal plane.
- Lavender, olive, sage, mint, nasturtiums, basil, and rosemary flowers are zygomorphic.

Zygomorphic flower

(iii) Asymmetrical flowers

- An asymmetrical flower has no plane of symmetry

Asymmetric flower

FLORAL DIAGRAMS AND FLORAL FORMULAE

Floral Diagram

- A floral diagram is a diagram of a cross-section of the flower as it would appear if all floral parts were cut at the same level.
- It is the ground plan in graphic form to express the arrangement of floral parts as projected in transverse or horizontal plane.
- It represents young bud as seen in a transverse plane when all floral parts are supposed to be present in their natural arrangement.
- The floral parts are represented by concentric circles. The sepals are shown on the outside, petals, stamens and carpels are shown lying within each other.
- These diagrams usually represent the transverse section of flower and the union and reunion of its parts.

Indication of Floral Diagram

The floral diagram furnishes the following information:

1. Sex and symmetry of the flower.
2. Bracteate or ebracteate nature of flower.
3. Number of floral cycles e.g., tetracyclic or pentacyclic etc. (Tetracyclic contains only one whorl of stamen i.e Androecium. Pentacyclic refers to five whorls that are calyx, corolla, two whorls of stamen and single whorls of carpels).
4. Number of floral parts in each cycle.
5. Position of floral parts e.g., old sepal is posterior or anterior (e.g. Fabaceae).
6. Aestivation of calyx, corolla or perianth.
7. Cohesion and adhesion of floral parts (e.g., gamopetalous and/or epipetalous nature).
8. Anthers are dithecous or monothecous and introrse or extrorse.

-Monothecous anthers have a single lobe with two pollen chambers in it. They are also called bisporangiate as they have two pollen chambers. Dithecous anthers have two lobes with two pollen chambers in each

-Introrse oriented anthers facing inwards toward the stigmatic surface at dehiscence

-extrorse oriented anthers facing outward the flower at dehiscence

9. Arrangements of stamens, especially in relation to petals, whether there is one whorl or more than one whorl of stamens. Alternipetalous or obdiplostemonous; epipetalous.
10. Staminode if any.
11. Number of carpels, whether free or united, number of locules, number of ovules.
12. Type of placentation.
13. Cohesion and adhesion of floral parts is indicated by drawing connecting lines between them.
14. Modifications of the sepals or petals e.g. spur or boat shaped.
15. Abortive member by a cross at its assumed position.
16. Position of floral parts towards the mother axis or posterior side (Resupination occurs in orchid flowers).
17. Bract, when present occupies an anterior and bracteoles lateral positions.

What Is Mother Axis?

- Mother Axis is the axis (stem) upon which the flowers are borne.
- When the flowers are borne laterally upon it, the side of the flower towards the mother axis (or precisely towards the apex of mother axis) is known as the **posterior side** while the side away from it (the side of the flower towards the bract when it is present) is called as the **anterior side.**
- When the flower is solitary terminal, the flower terminates the mother axis and all sides of it have the same relation to the mother axis.
- However, when the flower is solitary, axillary the side of flower towards the stem is the posterior side and the side towards the subtending leaf is the anterior side.

Floral Formula

- Floral formula is a symbolic and numerical representation of various floral parts.
- It also furnishes information regarding symmetry, sexuality and interrelationship of various floral parts viz., calyx, corolla, androecium and gynoecium.
- It is sometimes found convenient to describe a flower by a simple and concise formula known as the floral formula.
- In this formula K represents calyx, C=corolla, P= perianth, A=androecium, G=Gynoecium.
- The number of members of a whorl is written after the symbol for a whorl, ∞ signifies a large and indefinite number.
- If the members are present in different whorls, the different whorls are written separately with a + sign between them.
- Thus, A2+2 means androecium of four stamens in two whorls of two each.
- When members are united (cohesion), the number is placed within first brackets. Adhesion is expressed by a line joining the two whorls.
- Superior or inferior position of gynoecium is denoted by a line below or above it.

Numerology of Symbols

- A number put just after the symbol represents the number of parts in that particular whorl. If the parts of a whorl are united then the number is bracketed e.g. If five free sepals are present the whorl is represented by K5 and if united it is represented by K(5).
- If there are more than one whorl of an organ, they are represented by the some of their representative parts. If a flower has three whorls of five stamens each, then the androecium is represented by A5+5+5.
- If one organ is united with other organ then an arrow is made. It starts from the top of one symbol and ends on the top of the symbol for the other organ with which it is united e.g., if each of the five petals bears the stamens, the union of two organs is represented as below;

$$C_5\ A_5.$$

- The epigynous condition of a flower is represented by a line placed above the number of carpels.
- While its hypogynous condition is represented by under-lining the number of its carpels e.g.
- The epigynous flower with five carpels is written G5 and the same type of hypogenous flower with five carpels is written as G5 but with a line above and a line below respectively
- Thus Epigynous flower is denoted as $\overline{G}$ and hypogenous flower as $\underline{G}$
- The missing organ is represented by putting a zero or 0 after its symbol. If the number of organs in a whorl is more than ten its symbol is followed by the mark of infinity or ∞.

Epiphyllous stamens

- The stamens that are connected to the perianth of the flower are referred to as epiphyllous stamens. The flowers of the Liliaceae family are mostly equipped with epiphyllous stamens.

Epipetalous stamens

- Epipetalous stamens are those that are connected to the petals. The flowers of the Solanaceae family are equipped with epipetalous stamens.

$\overset{\frown}{P\ A}$ – epiphyllous stamens

$\overset{\frown}{C\ A}$ – epipetalous stamens

- Symbols Used in Construction of Floral Formula

Symbol or abbreviation		Full form
Br	–	bracteate condition
Ebr	–	ebracteate condition
Brl	–	bracteolate
Epik	–	epicalyx
0 (zero)	–	absence of a particular whorl
∝	–	indefinite number of floral parts in a whorl
⊕	–	actinomorphic (regular) condition
o|o	–	zygomorphic (irregular) condition
K	–	calyx (sepals)
C	–	corolla (petals)
P	–	perianth (tepals)
A	–	androecium (stamens)
G	–	gynoecium (carpels)
♂	–	unisexual, staminate (male) flower
♀	–	unisexual, pistillate (female) flower
⚥	–	bisexual flower
( )	–	cohesion of floral parts in a whorl
( )	–	partial or slight cohesion of the parts
$\overset{\frown}{P\ A}$	–	epiphyllous stamens
$\overset{\frown}{C\ A}$	–	epipetalous stamens
$\underline{G}$	–	hypogyny (ovary superior)
G–	–	perigyny (ovary half-inferior)
$\overline{G}$	–	epigyny (ovary inferior)
G(2)	–	bicapellary syncarpous
$G\underline{(2)}$	–	bicarpellary syncarpous ovary superior
G2	–	bicarpellary free carpels
K_{2+2}	–	presence of two whorls of calyx, each of 2 sepals (Brassicaceae or Cruciferae)

How to Write Floral Formula

- In the writing of floral formula, one should start from bract and bracteole then symmetry and sex of flower, calyx, corolla, androecium and gynoecium.
- The number of parts of each organ is indicated in figures (1, …… 4, 5) after the relevant symbol (K, C, A, G).
- If the parts are free, the figure numeral is placed as such but if they are united, the numeral figure is placed inside bracket (see numerology of symbols).
- In bilabiate structure (zygomorphic), the number of parts broken into two figures depending upon the number of parts in the upper and lower lip.
- Adnation of members of different whorls is shown by joining the top of their symbols by a curved line $(C \frown A)$.
- A break in the alternation of parts of any two successive floral cycles is indicated by inserting a vertical line between the symbols of the two floral cycles.
- The position of ovary whether, it is superior, half inferior or inferior is shown by placing a horizontal line below in front and above the symbol of gynoecium respectively.

- A break in the alternation of parts of any two successive floral cycles is indicated by inserting a vertical line between the symbols of the two floral cycles.
- The position of ovary whether, it is superior, half inferior or inferior is shown by placing a horizontal line below in front and above the symbol of gynoecium respectively.

Examples of Floral Formula

- The following examples illustrate the methods of reading and constructing the floral formulae:

Lathyrus – o|o ⚥ K(5), C5, A(9)+1, G$\underline{1}$.

Ipomoea – ⊕ ⚥ K5, C(5), A5 G$\underline{(2)}$.

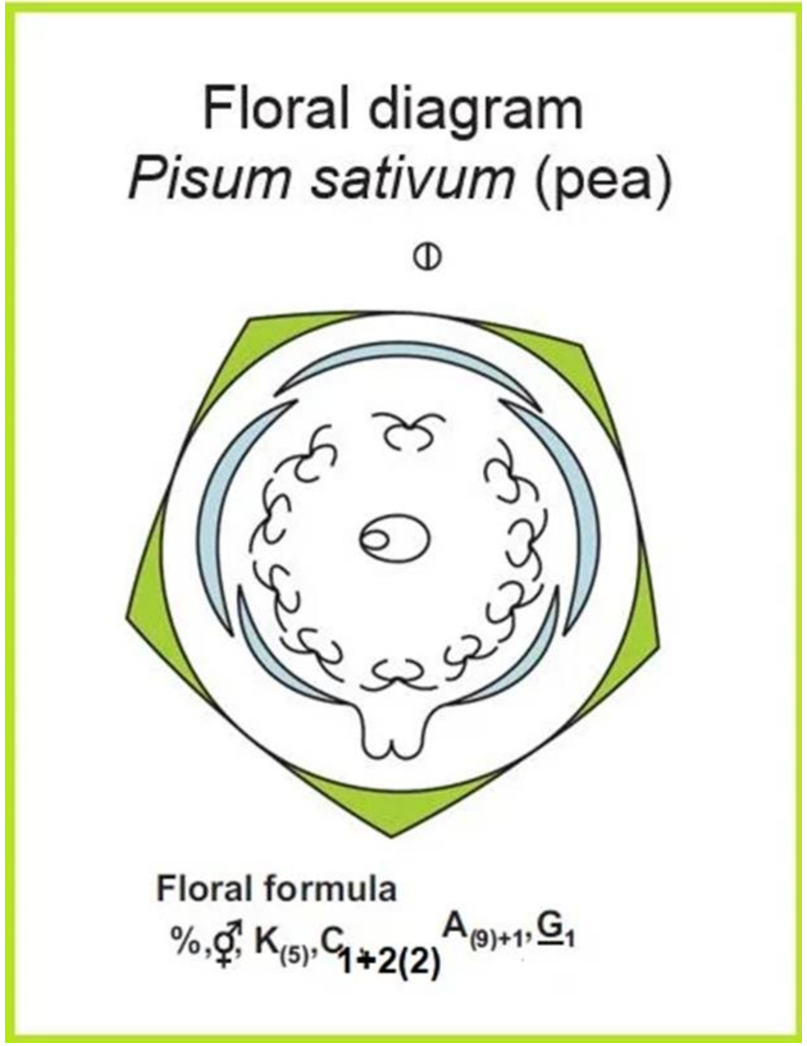
- The formulae read

Lathyrus:

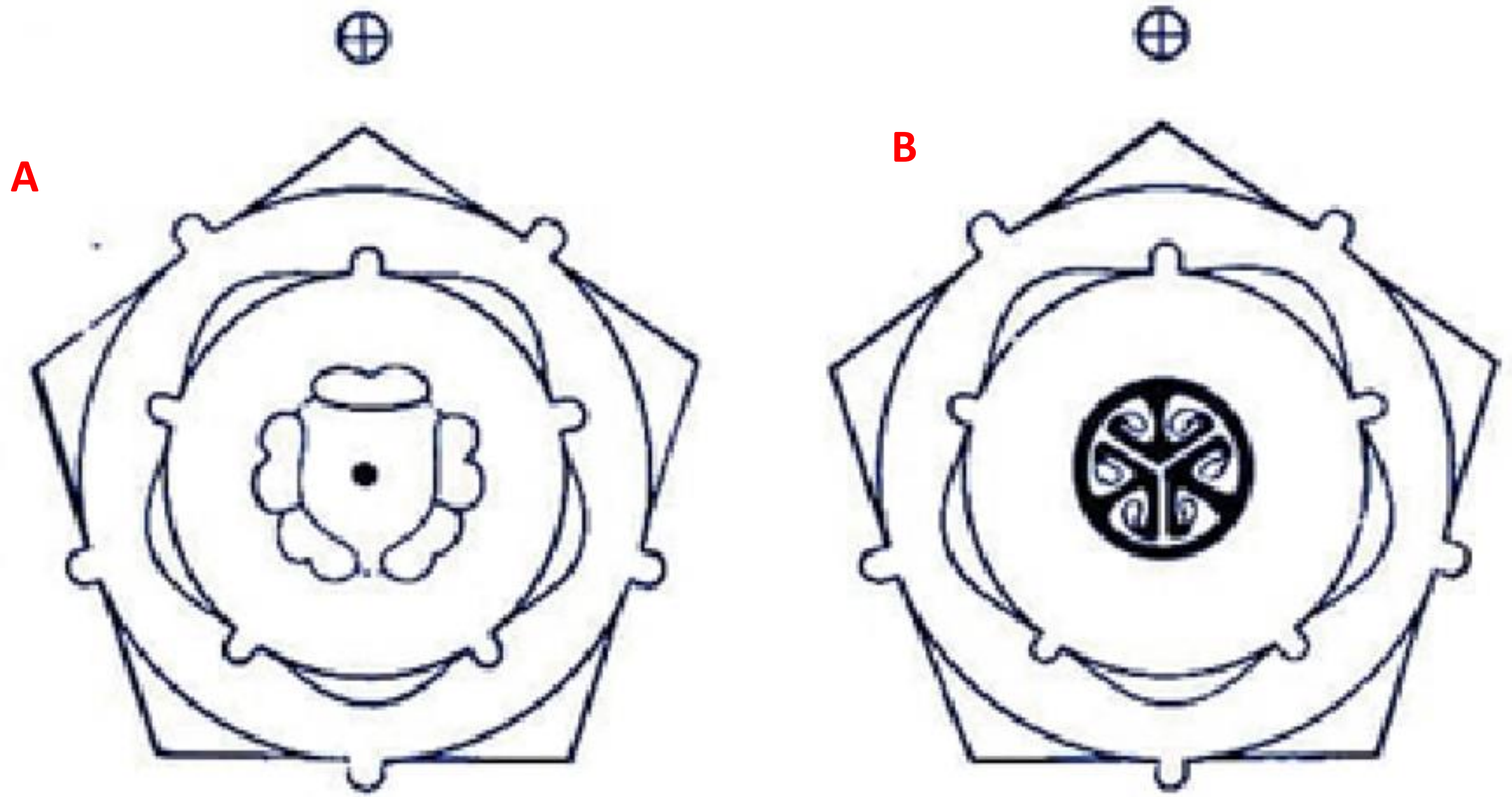
- Flower zygomorphic, hermaphrodite (bisexual), calyx gamosepalous with five sepals; polypetalous corolla with five petals; androecium with ten stamens, diadelphous (with 9 fused stamens and 1 free); gynoecium superior of one carpel.

Ipomoea:

- Flower actinomorphic, hermaphrodite (bisexual); calyx polysepalous with five sepals; corolla gamopetalous with five petals; androecium with five free epipetalous stamens both joined; gynoecium syncarpous with two superior carpels.



Family: Fabaceae (Luguminose)

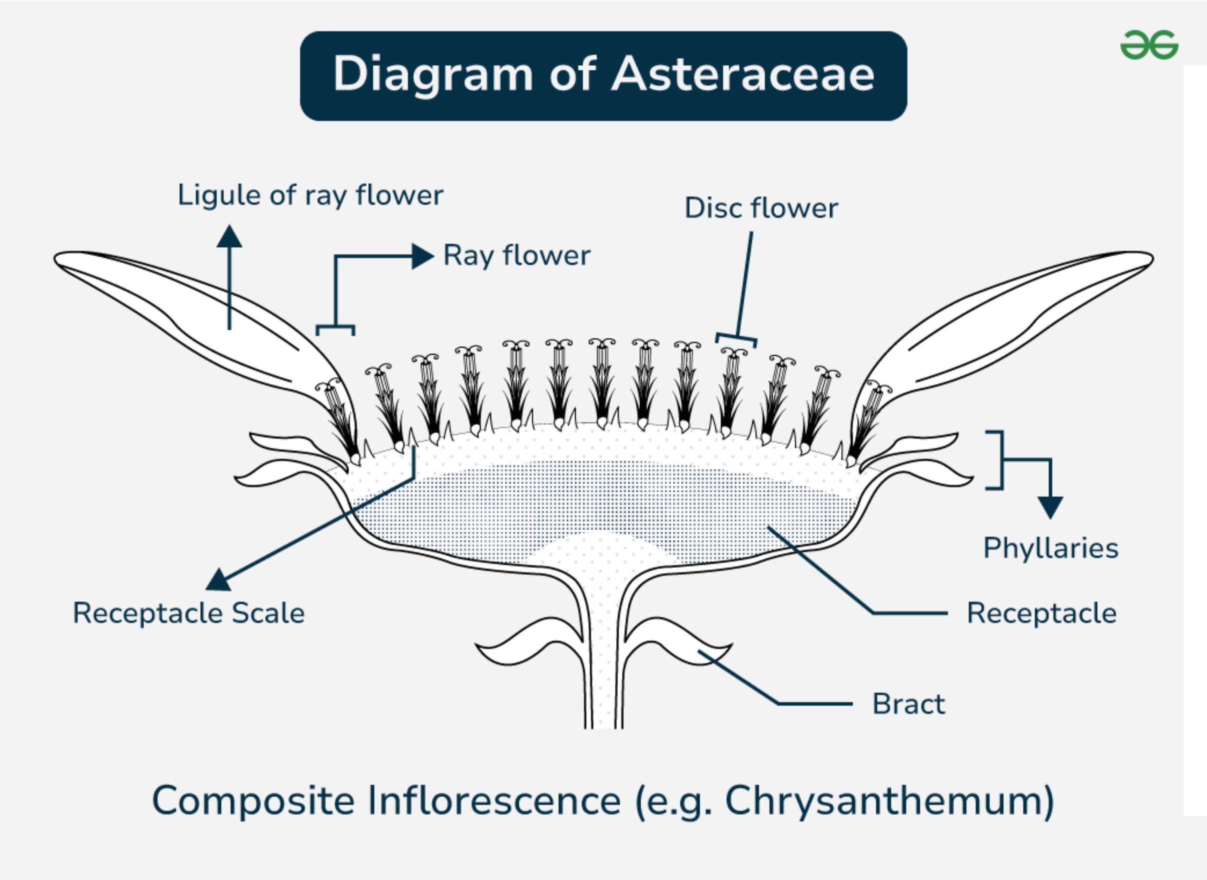


A Male Flower : Br or Ebr $\oplus$ ♂ $K_{(5)}$ $C_{5 \text{ or } (5)}$ $A_{(2)+(2)+1 \text{ or } (5)}$ G_0

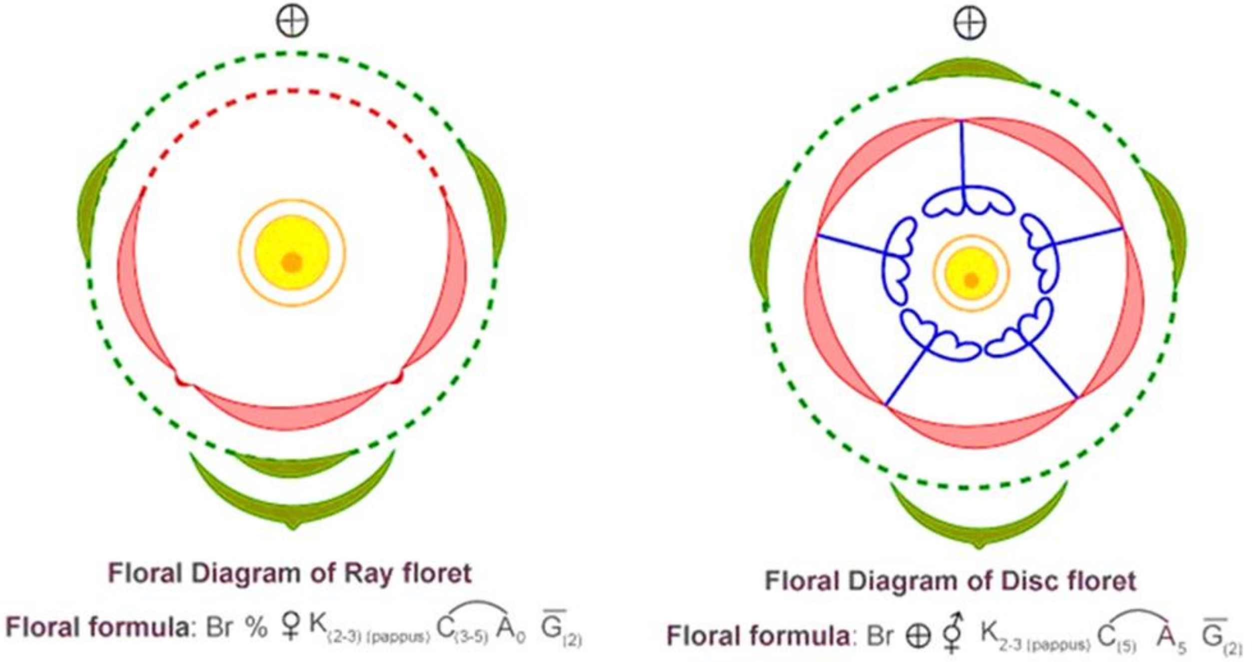
B Female Flower : Br or Ebr $\oplus$ ♀ $K_{(5)}$ $C_{5 \text{ or } (5)}$ A_0 $G_{(\overline{3})}$

A: Male flower of Cucurbitaceae (Compositae family)

B: Male flower of Cucurbitaceae (Compositae family)

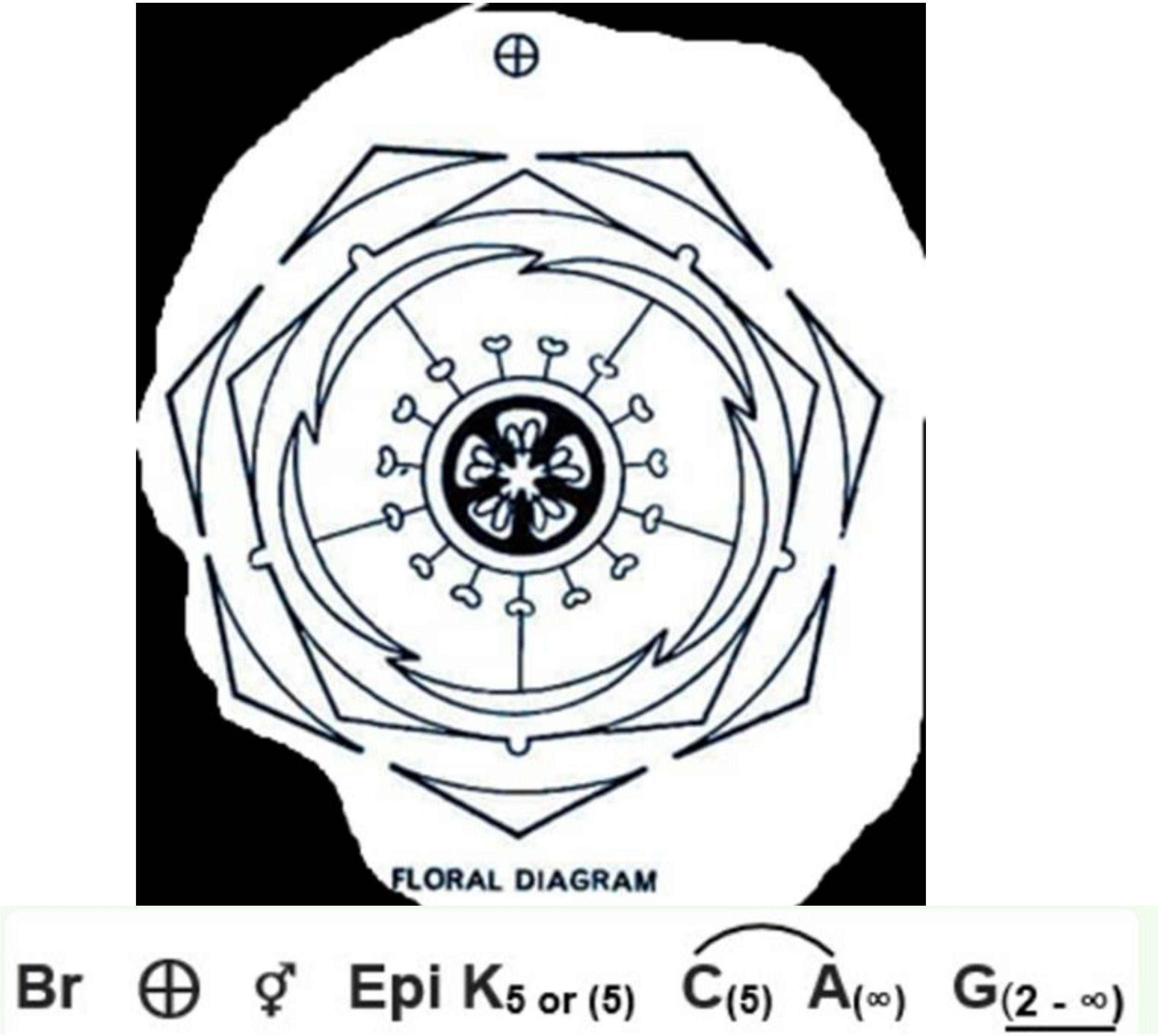


Flower of Asteriaceae (Compositae family)

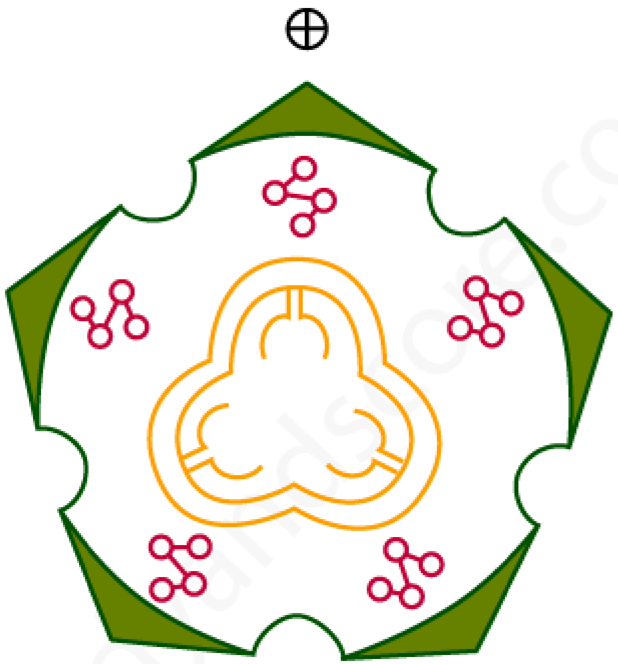


Floral diagram of Asteriaceae family

Family: Solanaceae



Family: Malvaceae

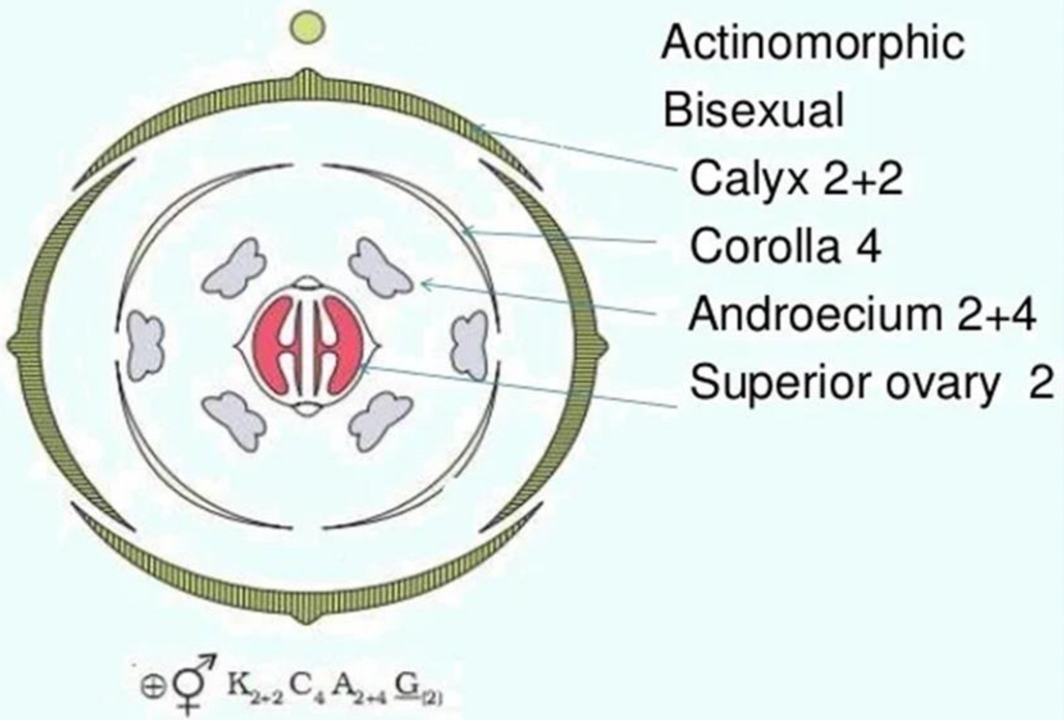


Floral diagram of *Euphorbia peplus*

Floral formula: Br, Ebrl, ⊕, ♂, $K_{(5)}$, $C_{(5)}$, A_{∞}, G_{0}

Br, Ebrl, ⊕, ♀, $K_{(5)}$, $C_{(5)}$, A_{0}, $G_{(3)}$

Euphorbiaceae (Female flower)- the formula below



Floral diagram with floral formula of Brassicaceae

Family: Brassicaceae (Cruciferae)

ARTIFICIAL AND NATURAL CLASSIFICATION IN TAXONOMY

Artificial classification

- The arrangement of organisms into a series of groups based on physiological, biochemical, anatomical, or other relationships. An artificial classification is based on one or a few characters simply for ease of identification or for a specific purpose; for example, plants are often arranged according to habit and habitat (marine plants, desert plants, dry land plants etc.) while fungi may be classified as edible or poisonous. Such systems do not reflect evolutionary relationships.

Natural classification.

- Is based on resemblances and is a hierarchical arrangement. The smallest group commonly used is the species. Species are grouped into genera (genus), the hierarchy continuing up through tribes, families, orders, classes, and phyla (phylum) to kingdoms and – in some systems – domains (In traditional systems of plant classification the phylum was replaced by the division.).

- Higher up in the hierarchy the similarities between members of a group become fewer.
- Present-day natural classifications try to take into account as many features as possible and in so doing aim to reflect evolutionary relationships (cladistics).
- Natural classifications are also predictive. Thus if an organism is placed in a particular genus because it shows certain features characteristic of the genus, then it can be assumed it is very likely to possess most (if not all) of the other features of that genus.

Taxonometrics

- Also called numerical taxonomy, it does not involve evolution. It depends on present day characters.
- As opposed to phylogenetic classification in which taxa are grouped on shared features, phenetic is grouping of taxa by overall similarity regardless of whether these similarities are primitive or advanced.
- This started in 1950 and1960s. Classification takes 60-100 characters, the basic unit of numeric taxonomy.
- It's operational taxonomic unit (OTU's) which is the lowest taxon to be studied in a particular investigation e.g. Family, genera, species, individuals etc are O.T.U's.
- You choose your O.T.U. to study then the characters to investigate and give them characters states or characteristic values.
- This result in a data matrix of character/states values i.e. O.T.U's × characters or O.T.U's × n. e.g. If one is classifying 10 O.T.U.S and using 10 characteristics then data matrix will consist of 10 x10 values.
- However, it's clear that many data are needed e.g. when you have tens of O.T.U and hundreds of characters and so one needs a computer.
- While using computers, character states need to be coded, or given values and the simplest method is the binary system e.g. using (+) and (-) or (1) and (0) values, so that a character can only occur in two states or alternatively and quantitative character states or values e.g. leaf long versus leaf short, stem hairy versus stem glabrous.

- The computer sort out (cluster) the OTU'S according to their overall similarities according to the number of character states or attributes in common.
- This process is called cluster analysis and it's the usual analytical method used in taxonometrics.
- This is usually achieved by prediction of a table of similarities or dissimilar coefficients rather by direct use of data matrix giving a measure of similarities or difference of all possible combination of pairs of OUT's.

X-STIC / OTUS	Inflorescence	Leaf character	Fruit cap	Corolla	
1	+	+	-	-	-

Phenetics versus Cladistics

Phenetics

- Also known as taximetrics, is an attempt to classify organisms based on overall similarity, usually in morphology or other observable traits, regardless of their phylogeny or evolutionary relation.
- The basic ideas of classical taxonomy, the classification of things to understand how they are related, influenced how biologists thought about the world.
- But, this system was not perfect, and so researchers looked for alternatives.
- Another major classification system is phenetics, in which organisms are classified into hierarchies of similarity, based solely on morphology.
- Basically, phenetics compared and categorized things based on their overall similarity of appearance. Here's how it works.
- Two species are compared, and shared characteristics are counted.

- Now, it's important to note that phenetics places no emphasis on certain traits over others; all shared characteristics are treated equally.
- A computer then processes this data through a numerical algorithm to create a similarity coefficient, the mathematical degree of similarity, with zero being no similarity and one being completely identical.
- With this you can create phenograms, creating clusters of things that are morphologically similar and, therefore most related.
- Phenograms are criticized because, although not subjective, they do not account for the fact that things may evolve similar physical traits without being related (Convergent vs Homologous morphology)
- For example, some Cactus vs some Euphorbia spp. look morphologically similar but are phylogenetically unrelated (in different families) due to convergent morphology.

- Many people contributed to the development of phenetics, but the most influential were Peter Sneath and Robert R. Sokal. Phenetics has largely been superseded by cladistics for research into evolutionary relationships among species.
- Phenetic techniques include various forms of clustering and ordination.
- These are sophisticated ways of reducing the variation displayed by organisms to a manageable level.
- In practice this means measuring dozens of variables, and then presenting them as two or three dimensional graphs.
- Much of the technical challenge in phenetics revolves around balancing the loss of information in such a reduction against the ease of interpreting the resulting graphs.
- Phenetic analyses do not distinguish between plesiomorphies - traits that are inherited from an ancestor (and therefore phylogenetically uninformative) - and apomorphies - traits that evolved anew in one or several lineages.

- Consequently, phenetic analyses are liable to be misled by convergent evolution and adaptive radiation. A typical error occurring in phenetic analysis is that basal evolutionary grades - which retain many plesiomorphies compared to more advanced lineages - appear to be monophyletic. Consider for example plants.
- These can be divided into two groups - gymnosperms, which retains ancient characters in phenotype and genotype, and angiosperms, which has more modern traits.
- But only the latter are a group of closest relatives; the former are numerous independent and ancient lineages which are about as distantly related to each other as each single one of them is to the angiosperms.
- In a phenetic analysis, the large degree of overall similarity found among the gymnosperms will make them appear to be monophyletic too, but their shared traits were present in the ancestors of all plants already.
- In general, phenetics is today recognized to provide too much unreliable information about the evolutionary relationships among taxa to remain a mainstay method.

Cladistics

- Cladistics can be defined as the study of the pathways of evolution. In other words, cladists are interested in such questions as: how many branches there are among a group of organisms; which branch connects to which other branch; and what is the branching sequence.
- The most common method of incorporating information into phylogenetic trees is called cladistics.
- Cladistics depict hypotheses about how organisms are related based on traits of ancestor and descendent species. Use of Cladistics was developed in the 1950s by a scientist named Willi Hennig.
- Over the next several decades, it became very popular and is still widely used today. A tree-like network that expresses such ancestor-descendant relationships is called a cladogram.
- Thus, a cladogram refers to the topology of a rooted phylogenetic tree.
- Whenever information on the evolutionary history of taxa is needed for a study, a researcher of today will generally try to analyze using cladistic methods.

- Cladistics is a particular method of hypothesizing relationships among organisms. Like other methods, it has its own set of assumptions, procedures, and limitations.
- Cladistics is now accepted as the best method available for phylogenetic analysis, for it provides an explicit and testable hypothesis of organismal relationships.
- The basic idea behind cladistics is that members of a group share a common evolutionary history, and are "closely related," more so to members of the same group than to other organisms.
- These groups are recognized by sharing unique features which were not present in distant ancestors. These shared derived characteristics are called synapomorphies.

What assumptions do cladists make?

There are three basic assumptions in cladistics:

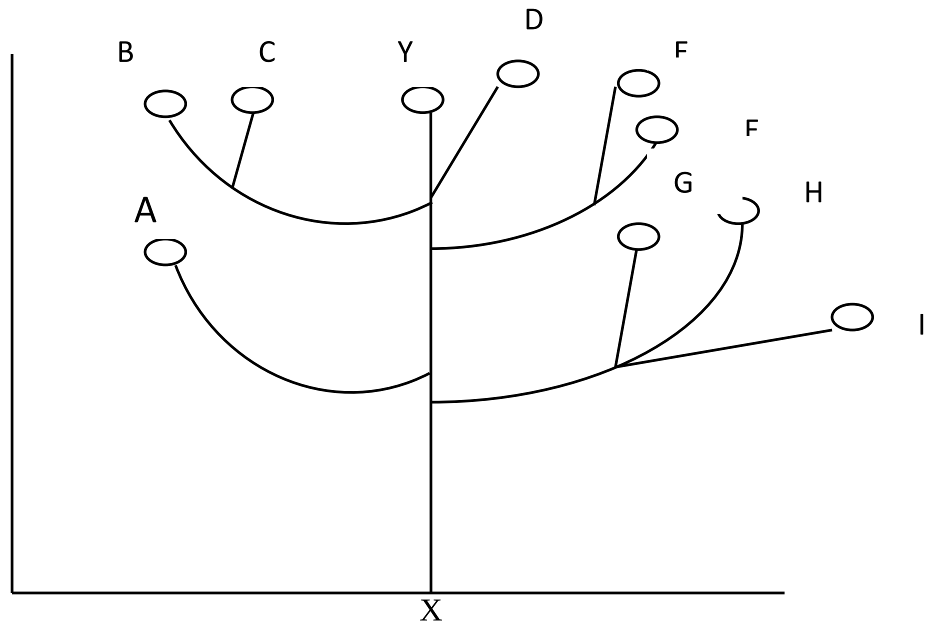
i. Any group of organisms are related by descent from a common ancestor.

ii. Is a general assumption made for all evolutionary biology.

iii. It essentially means that life arose on earth only once, and therefore all organisms are related in some way or other.

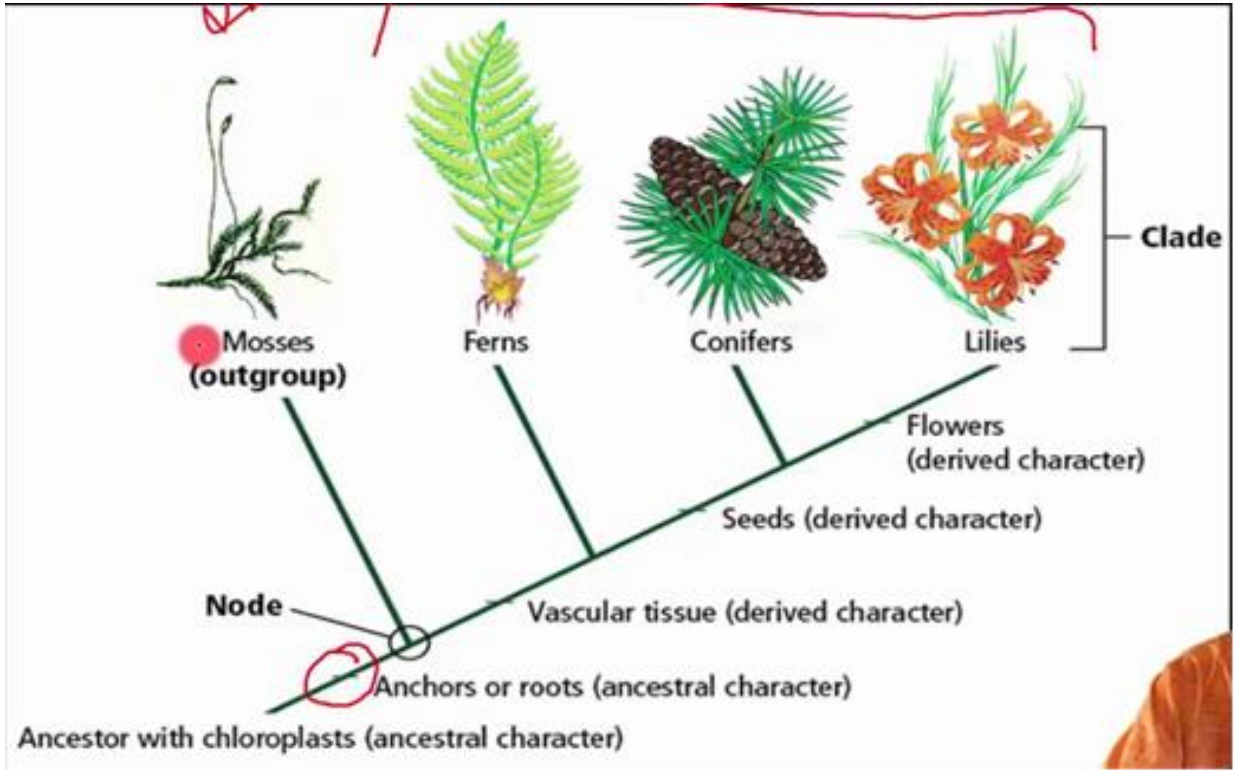
- Because of this, we can take any collection of organisms and determine a meaningful pattern of relationships, provided we have the right kind of information.
- Again, the assumption states that all the diversity of life on earth has been produced through the reproduction of existing organisms.

- It’s very difficult to see how one deduces as to which characteristic is primitive or advanced than the other, and this is a major source of controversy among taxonomist and so major critism for cladistics.
- Only homologous structures must be compared while comparing plant taxon.
- Different side branches represent different phylogenetic lines, present day taxa.
- This shows the evolution relationship of the present day taxa A-I. An X is the ancestor; XY is the trunk of the tree (Main line) of evolution that terminated before the advent of the present age.
- The common ancestor (X) transformed itself into another Y which also perished

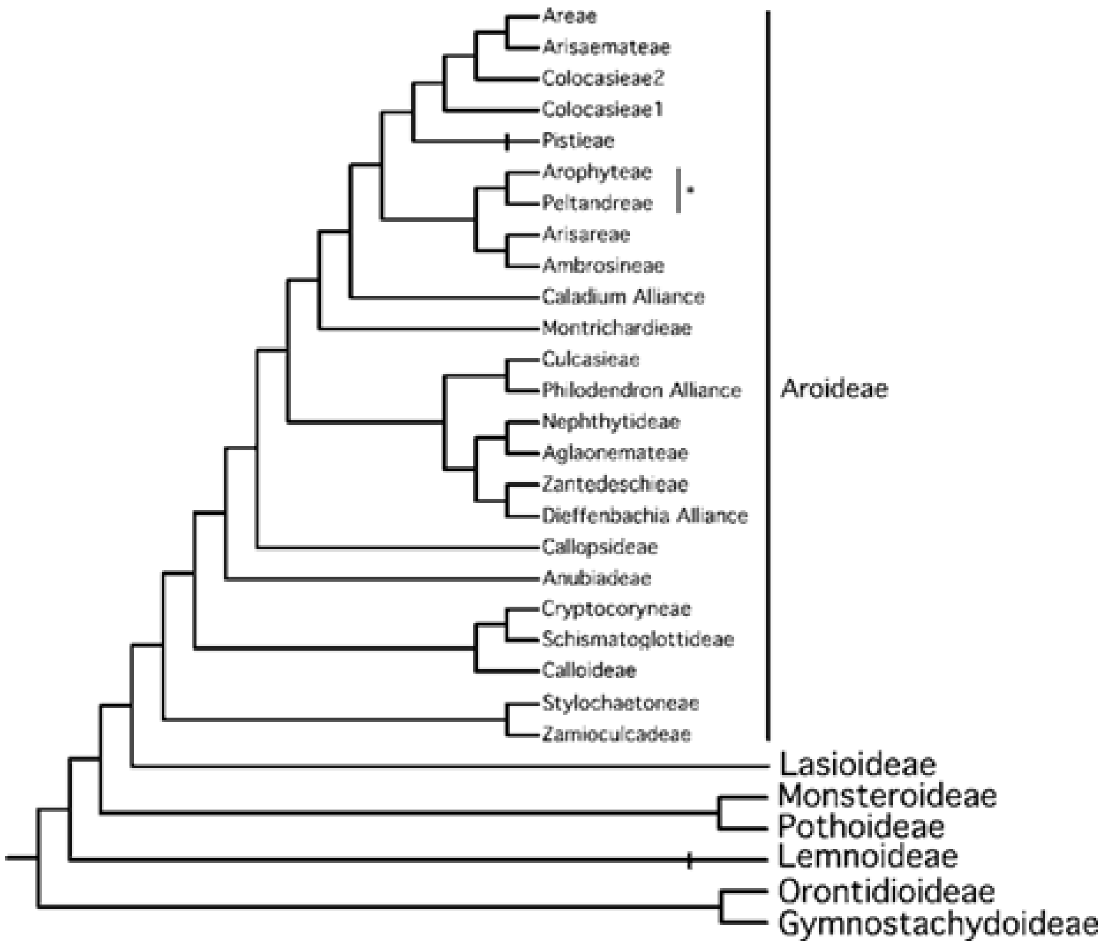


There is a bifurcating pattern of cladogenesis

- Is perhaps the most controversial; that is, that new kinds of organisms may arise when existing species or populations divide into exactly two groups.
- There are many biologists who hold that multiple new lineages can arise from a single originating population at the same time, or near enough in time to be indistinguishable from such an event.
- While this model could conceivably occur, it is not currently known how often this has actually happened. The other objection raised against this assumption is the possibility of interbreeding between distinct groups.
- This, however, is a general problem of reconstructing evolutionary history, and although it cannot currently be handled well by cladistic methods, no other system has yet been devised which accounts for it.
- Change in characteristics occurs in lineages over time. Assumes that characteristics of organisms change over time, is the most important assumption in cladistics.
- It is only when characteristics change that we are able to recognize different lineages or groups. The convention is to call the "original" state of the characteristic plesiomorphic and the "changed" state apomorphic.



Botanical Cladogram



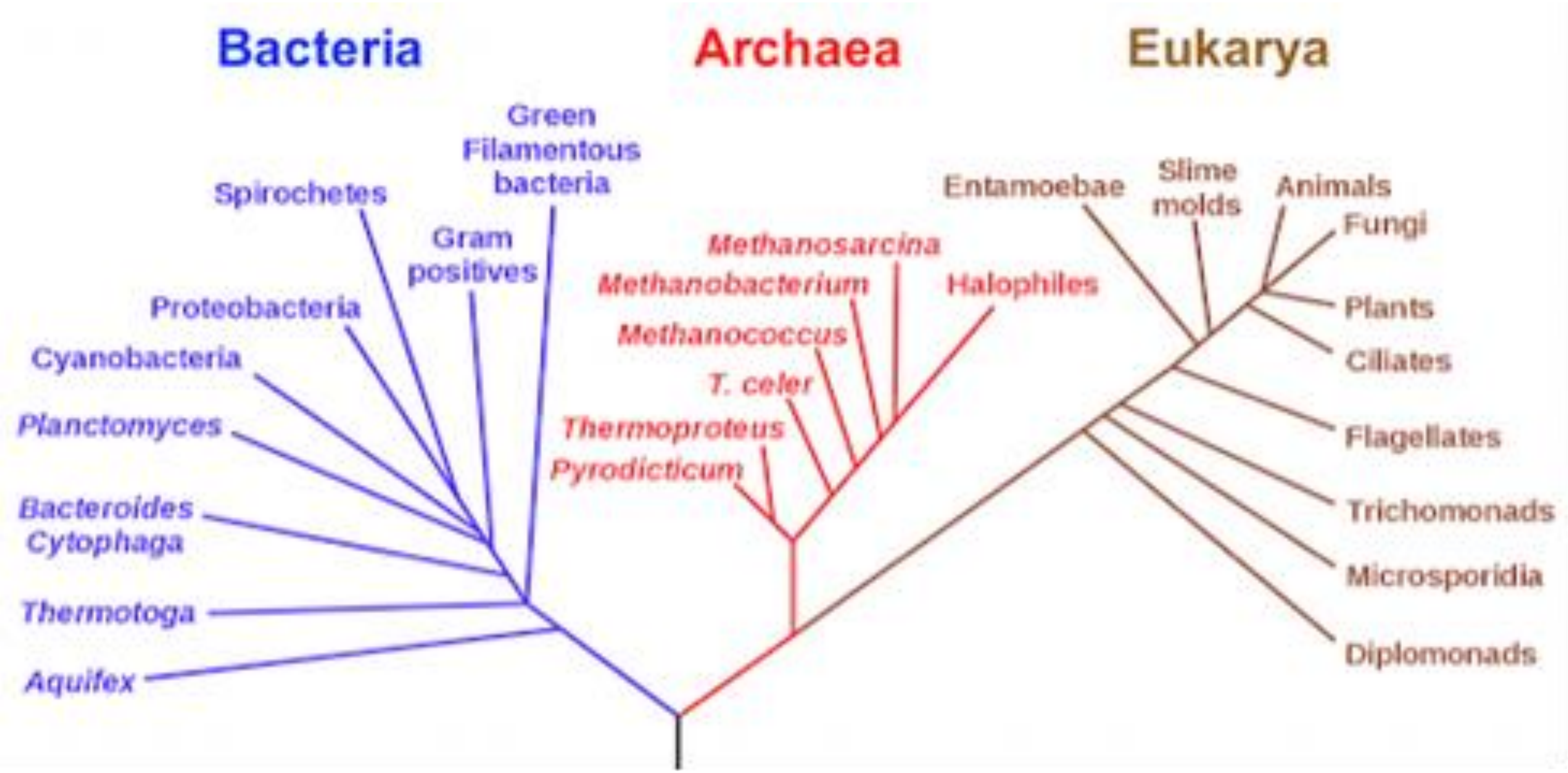
Cladogram of Araceae

Phylogenetics

- Is the study of evolutionary relation among groups of organisms (e.g. species, populations), which is discovered through molecular sequencing data and morphological data matrices.
- The term phylogenetics derives from the Greek terms phyle and phylon, denoting "tribe" and "race"; and the term genetikos, denoting "relative to birth", from genesis "origin" and "birth".
- Taxonomy, the classification, identification, and naming of organisms, is richly informed by phylogenetics, but remains methodologically and logically distinct.
- The fields of phylogenetics and taxonomy overlap in the science of phylogenetic systematics — one methodology, cladistics shared derived characters (synapomorphies) used to create ancestor-descendant trees (cladograms) and delimit taxa (clades).
- In biological systematics as a whole, phylogenetic analyses have become essential in researching the evolutionary tree of life.

Construction of a Phylogenetic Tree

- Evolution is regarded as a branching process, whereby populations are altered over time and may speciate into separate branches, hybridize together, or terminate by extinction.
- This may be visualized in a phylogenetic tree. The problem posed by phylogenetics is that genetic data are only available for living taxa, and the fossil records contains less data and more-ambiguous morphological characters.
- A phylogenetic tree represents a hypothesis of the order in which evolutionary events are assumed to have occurred. Cladistics is the current method of choice to infer phylogenetic trees.
- The most commonly-used methods to infer phylogenies include parsimony, maximum likelihood, and MCMC-based Bayesian inference.
- Phenetics, popular in the mid-20th century but now largely obsolete, uses distance matrix-based methods to construct trees based on overall similarity, which is often assumed to approximate phylogenetic relationships.
- All methods depend upon an implicit or explicit mathematical model describing the evolution of characters observed in the species included, and are usually used for molecular phylogeny, wherein the characters are aligned nucleotide or amino acid sequences.



Phylogenetic tree of Bacteria, Archaea and Eukaya

Main differences between Cladistics ad Phylogenetics

- A cladogram illustrates hypothetical relationships between species based on traits (mainly genetic).
- It’s called a cladogram because a group of related organisms (including living organisms and their common ancestors) is called a clade.
- Cladograms do not describe the process of evolution, and they don’t reflect the amount of difference between groups.
- Cladograms may be based on physical traits, genetic data such as DNA sequencing or, more often, a combination of both.
- A phylogenetic tree can also be created using genetics and physical characteristics.
- It’s worth noting that DNA doesn’t tell us exactly how species are related to each other, only that they are related.
- For some phylogenetic trees, the branch lengths represent time—these are technically called phylograms—whereas cladograms do not represent evolutionary time.

Sources of phylogenetic evidence

- Most of the data used in making phylogenetic judgments have come from comparative anatomy and from embryology, although those are rapidly being surpassed by systems constructed using molecular data
- Biologists who postulate phylogenies derive their most-useful evidence from the fields of paleontology, comparative anatomy, comparative embryology, and molecular genetics.
- Studies of the molecular structure of genes and of the geographic distribution of flora and fauna are also useful

THE SPECIES CONCEPT

- Species has been for long recognized as the basic unit of biology because it refers to a distinct biological entity and represents an important level of integration in nature.
- Every biologist, dealing with morphology, physiology biochemistry, molecular biology, cytogenetic etc is dealing with species and his finding are influenced by the selection of species.
- Plant and animal taxonomic category is defined and described in relation to it e.g A genus is a group of species, and a sub-species or variety is a part of a species.
- Taxonomists are actually concerned with two levels of grouping;
  - Grouping of individuals into species.
  - Grouping of their species into higher categories i.e. species and groups of species.
- Despite these, the definitions of species has long been a matter of great discussion and controversy among biologists.
- Various attempts have been made to arrive at a universal definition of a species and species concepts can be broadly be classified under the following different heading.

- Evolutionary biologists have suggested three main theoretical kinds of non-temporal species concept.
- It has been suggested that species exists because of interbreeding.
- This is discussed under biological and recognition species concept.
- Secondary, it has been suggested that species exist because of selection that maintains variation in the typed cluster we recognize as species.
- This is discussed under as the ecological species concept.
- A third possibility suggests that species exist because of genetic constraints on variability.
- In addition to these theoretical definitions, it has also been suggested that the species concept should not be tied to any particular theoretical idea leading to the phenetic species concept

Types of species concepts

1) The Biological species concept

- Defines species in terms of breeding.
- These are groups of interbreeding natural populations that are reproductively isolated from other such group.
- It's the most widely accepted concept today especially among Zoologists.
- It places the taxonomy of natural species within the conceptual scheme of population genetics.
- A community of interbreeding organism is, in population genetics termed as a gene pool.
- In biological species concepts, a gene pool becomes more or less identifiable as species.
- It explains why the members of species resemble one another and differ from other species.
- When two organisms breed within a species, their genes pass into their combined offspring, as the same process is repeated every generation, the genes of different organisms are constantly shuffled around the species gene pool.
- The shared gene pool, gives the species its identity. The movement of genes through species by migration and interbreeding is called gene flow.
- Taxonomists identify species by morphology not reproduction. The justification being, the morphological characteristics shared between individuals are indicators of interbreeding.

2) The recognition species concept

- The species has a specific mate recognition system.
- The species can be defined as a set of organism with a common method of recognizing mates. This is the recognition species concept.
- In practice, the recognition concept should be defined very similar or identical to biological concept and its possible to think of them as two version of a general reproductive species concept.

3) The phenetic species concept

- It applies phenetic classification to the species category.
- The phenetic species concept defines a species as a set of organisms that look similar to each other and distinct from other sets.
- The phenetists measures as many characters as possible in many organism as possible then recognizes phenetic clusters and multivariate similarities.
- The concept is thought of as a single expression of the way the species are recognized. Species are recognized by morphological characteristics.
- The phenetists thus define the species as groups of individuals with certain morphological characteristics. The species is defined by a large number of characteristics

4) Ecological species concept

- It supposes that ecological niches in nature occupy discrete zone with gaps between them. An ecological species is a set of organisms exploiting a single niche.

SPECIATION

- Speciation is the formation of new species from existing ones.
- Definition: It’s the development of population of freely interbreeding organisms adapted to their environment that are reproductively isolated from each other or is the process in which one species is transformed into another form.
- A pre requisite for speciation is effective isolation of 2 (or more) elements of species each of which becomes a separate species.
- There are two forms of speciation

(i) Gradual speciation- isolation by external mechanism (spatial)

(ii)Abrupt speciation

(i) Gradual speciation

- Isolation is by external mechanism usually partial and the two isolates become distinct entities by the gradual accumulation of genetic difference due to mutations.
- This concerns the mode of speciation where small genetic change takes place over a considerable length of time due to response to environment factors thereby rise to new species.
- Isolation is by external mechanism usually spatial and the two isolates become distinct entities by the gradual accumulation of genetic differences due to mutations.
- E.g. a situation where an existing species extends its range and in so doing , it may colonize areas which differ from the original habitat I.e. soil or climate conditions.

(ii) Abrupt speciation

- The initial isolation is genetical, often by the evolution of chromosomal differences particularly chromosomal number.
- The best known example of abrupt speciation is allopolyploidy which involves simultaneous genetic isolation and phenetic differentiation of new species and this represents an extreme though a very wide spread incidence of abrupt speciation.
- It results from the re-organization of chromosome which may involve exchange in their number.
- The initial isolation is genetical, often by the evolution of chromosomal difference particularly the chromosome number.
- It can take place in a number of ways i.e.

(a) Polyploidy

(b) Re-organization of the structure of chromosome

(c) Aneuploidy

(a) Polyploidy:-the term refers to containing more departure from the diploid state where plants have a set of two chromosomes (2n).

- It is the heritable condition of possessing more than two complete sets of chromosomes.
- Polyploidy plays a major role in speciation and diversification of almost all plants, bringing together new gene combinations and leading to reproductive isolation
- Polyploidy typically results in instant (abrupt) speciation—the new polyploid may be immediately isolated reproductively from its parent or parents
- This process greatly increases biodiversity and provides new genetic material for evolution.
- In this regard, studies of diverse species have shown that polyploid genomes are highly dynamic with diverse alterations in gene expression, gene content, physiology, and chromosome evolution.
- Variation in organism provide raw genetic material that is in constant with environmental condition making speciation possible.
- Variation in natural population is limited by the following factors.
  - Asexual reproduction
  - Stabilizing selection (is a type of natural selection in which the population mean stabilizes on a particular non-extreme trait value. This is thought to be the most common mechanism of action for natural selection because most traits do not appear to change drastically over time).

(b) Re-organization of the structure of chromosome

- At the level of the genome, chromosomes are organized in distinct nuclear neighborhoods, termed chromosomal territories, within which there is a further spatial organization of active and inactive elements.
- This chromosomal organization order can drastically be disrupted thus becoming a likely cause to speciation

(c) Aneuploidy

- The occurrence of one or more extra or missing chromosomes in a cell or organism.
- Aneuploidy refers to any chromosome number that is not an exact multiple of the haploid number of chromosomes
- A very extensive aneuploid series has been observed in plant genus *Carex* (n = 6 to 56).
- It is common among plants and has been, in fact, a major source of speciation in the angiosperms.
- Particularly important is **allopolyploidy**, which involves the doubling of chromosomes in a hybrid plant.

Variants (Models) of speciation

- There are four major variants or models of speciation: allopatric, peripatric, parapatric and sympatric

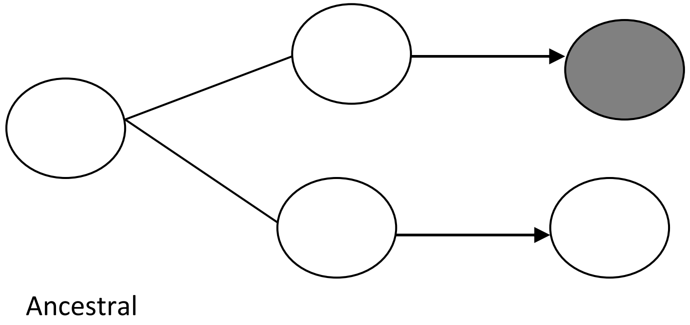
(i) **Allopatric speciation:** occurs when a species separates into two separate groups that are isolated from one another.

- A physical barrier, such as a mountain range or a waterway, makes it impossible for them to breed with one another.
- When two or more related species have widely separate and non-overlapping distribution are said to be allopatric.
- Allopatric is occupying completely separate non- adjacent areas.
- It occurs a result of two or more population diverging.
- Geographically isolated population cannot exchange genes, and they are reproductively isolated.
- When populations are not exchanging genes, they become morphologically different and are recognized as different species. There are two models of allopatric specification e.g The Warbugia ugandensis ssp ugandensis of Kenya and W. ugandensis ssp longifolia of Tanzania may be headed there!

- There are two models of allopatric specification

1) Dump bell model

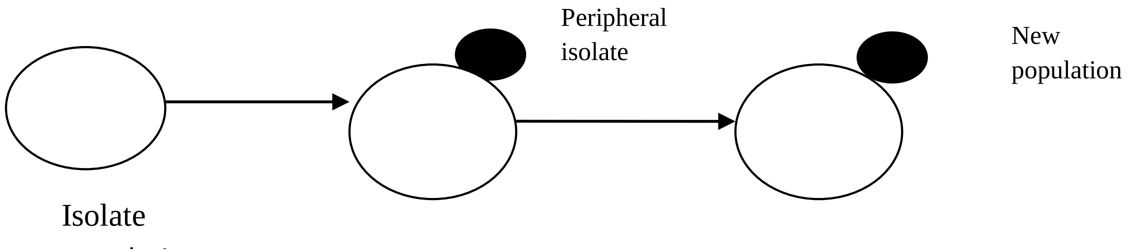
The dumb-bell model in which the ancestral species is divided into two roughly equal halves, each of which forms a new species.



2 different species

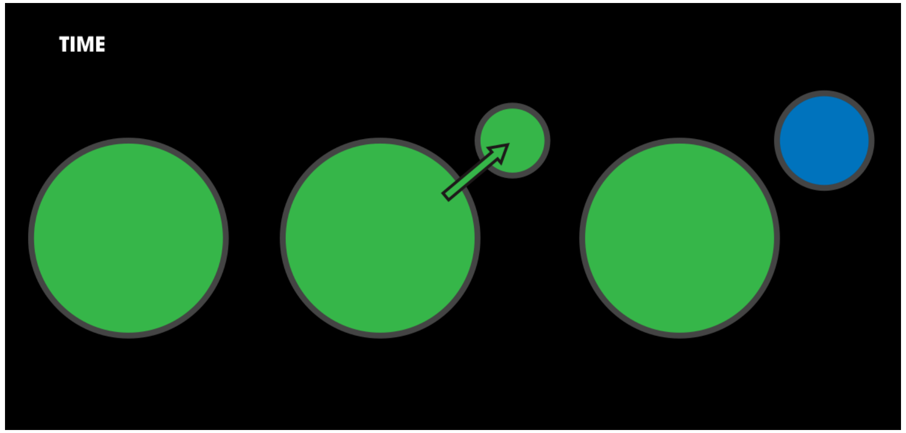
2) Peripheral isolate model

The peripheral isolate model, in which the new species forms from a population isolated at the edge of the ancestral species range.



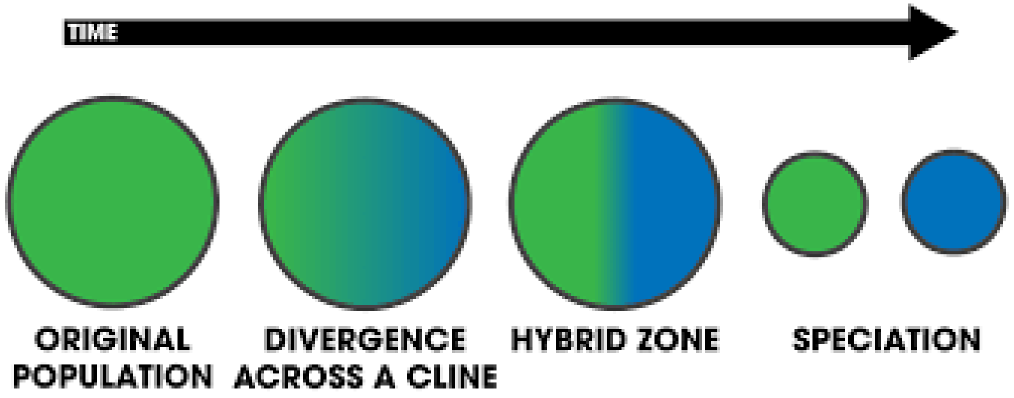
(ii) Peripatric speciation

- Is a mode of speciation in which a new species is formed from an isolated peripheral population.
- Since peripatric speciation resembles allopatric speciation, in that populations are isolated and prevented from exchanging genes, it can often be difficult to distinguish between them



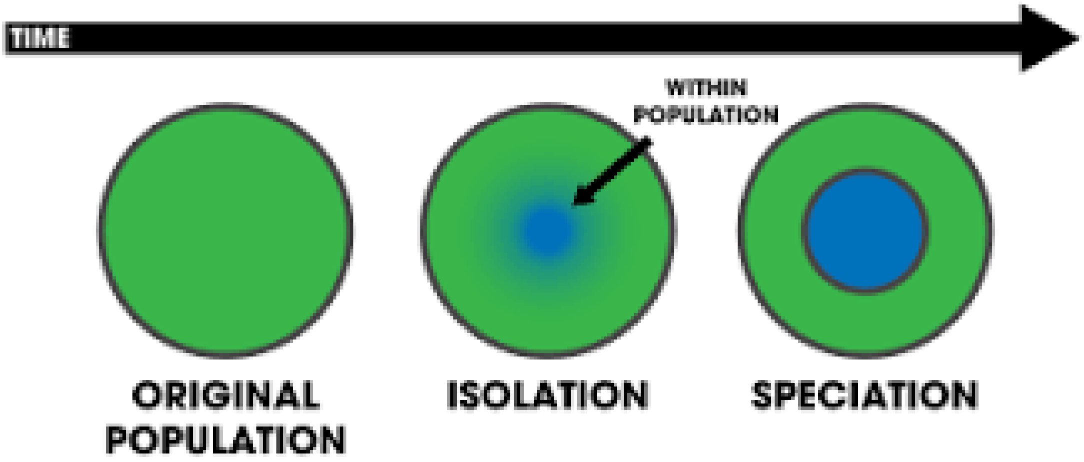
(iii) Parapatric – share a common boundary, but occupy adjacent areas.

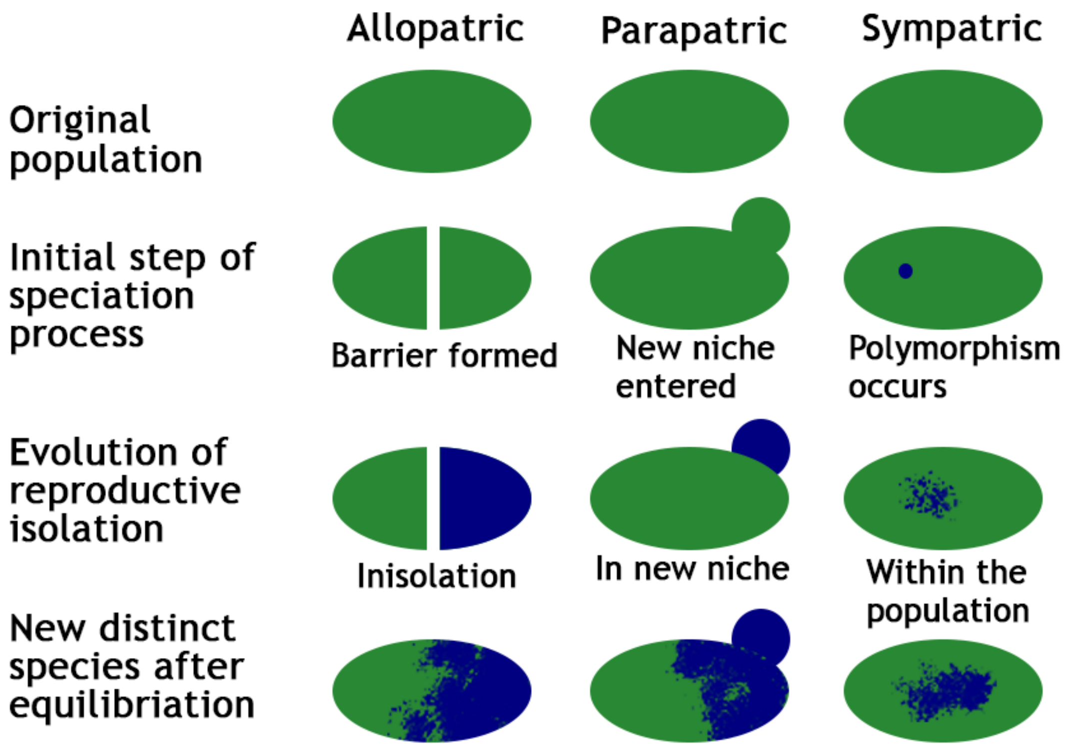
- Parapatry: occupying adjacent areas i.e. occupying separate areas that share common boundary.
- Parapatric speciation is speciation that occurs as a result of two or more population diverging while occupying adjacent areas (or allopatric areas).
- It begins with evolution of a hybrid zone.
- The full process is a cline first as a hybrid zone in which hybrids are selected to mate only with individuals of their own types.
- Cline is gradual change in population characteristics over a geographical area usually associated in environmental conditions.
- Or is the gradual sequence of difference within a species or a continuous range of variation within a species.



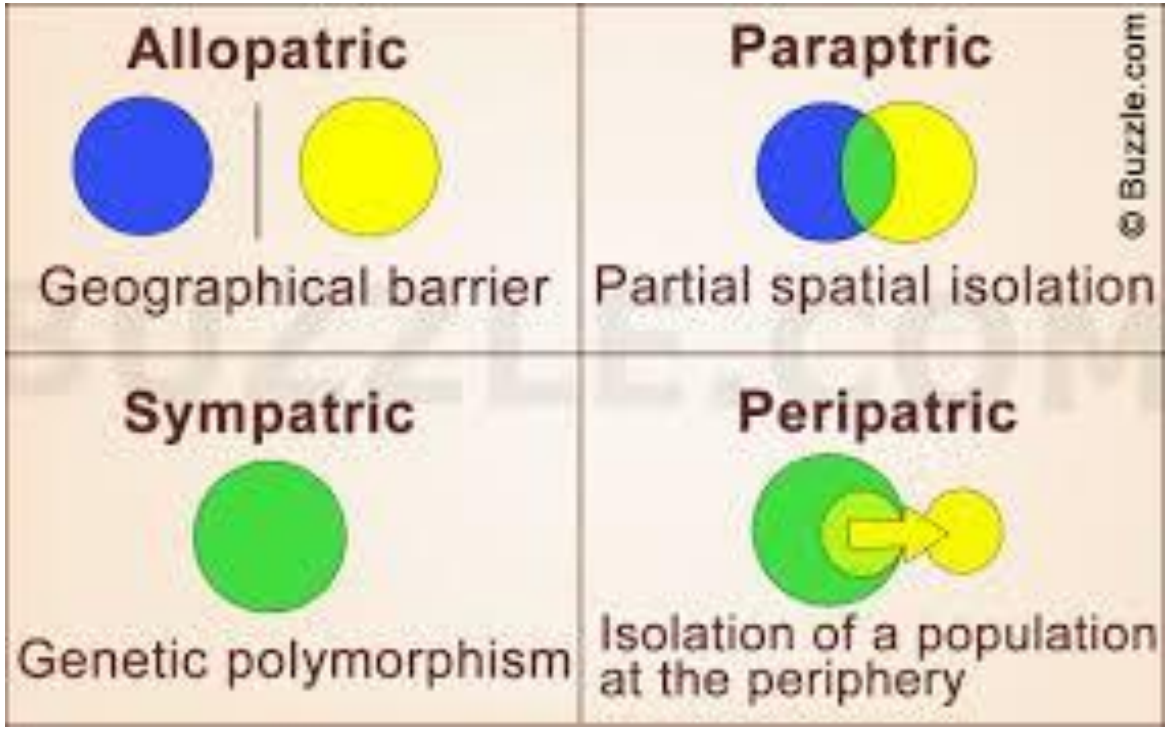
(iv) Sympatric speciation

- Two or more related species within a geographical distribution of which they have abroad overlapping zone are called sympatric.
- Sympatric: it means occupying the same geographical area.
- Sympatric speciation: is speciation that occurs as a result of two or more population diverging while occupying the same geographical area.





Allopatric
Parapatric
Sympatric
Original population
Initial step of speciation process
Barrier formed
New niche entered
Polymorphism occurs
Evolution of reproductive isolation
Inisolation
In new niche
Within the population
New distinct species after equilibriation



Allopatric
Geographical barrier
Paraptric
Partial spatial isolation
© Buzzle.com
Sympatric
Genetic polymorphism
Peripatric
Isolation of a population at the periphery

Isolation mechanism

- Refers to the reduction of interbreeding between population i.e. any mechanism that prohibits interbreeding from occurring between populations.
- They can be grouped broadly into three;

(i) Spatial isolating mechanism

(ii) Ecological isolating mechanism

(iii) Reproductive isolating mechanism

(i) Spatial isolating mechanism

- This results from the differentiation of recognizable population and species in topographically separate areas.
- Also known as allopatric/geographical or eco-geographical isolation.
- N/B: Spatial mechanism are independent of genetic changes in the plant species i.e. it's merely the presence of a barrier to prevent cross pollination or gene flow.
- Spatial isolation are brought about by two type of events i.e. Long distance disperse of spores and fragmentation of a formally continuous distribution as a results of change in climate, drought, continental drift, volcanism or glaciations.

(ii) Ecological isolation mechanism

- This is the separation of population and species by

a) Climatic conditions

b) Soil conditions

c) Competition from other organisms

- It tends to occur in sympatric population.
- Closely adjacent cross breeding population can diverge under intense environment selection pressures due to the process of sympatric ecological separation is the gradual sequences of differences within a species or a continuous range of variation within a species.
- It refers to all genetically controlled process which prevents successful hybridization between different species.

(iii) Reproductive isolation mechanism

- Are ways in which plants may not be able to interbreed.
- Are divided into pre-zygotic and post zygotic mechanism, according to whether they operate before or after sexual fusion.
- The mechanisms of reproductive isolation or hybridization barriers is a collection of mechanisms, behaviors and physiological processes that prevent the members of two different species that cross or mate from producing offspring, or which ensure that any offspring that may be produced is not fertile.
- These barriers maintain the integrity of a species over time, reducing or directly impeding gene flow between individuals of different species, allowing the conservation of each species characteristics.

(a) Pre-zygotic reproductive isolative mechanism

- They are those that act before fertilization to prevent the formation of hybrid zygote. They are eight types:
- They prevent the formation of hybrid zygote.

1. Geographical isolation

- Two species are separated geographically so that they don't come into contact e.g. *Larix decidua* in Europe and *Larix kaemperi* in Japan. The two species hybridize readily in hybridization.

2) Ecological isolation

- Two species occur in the same general area but are separated ecologically occupying different habitats
- e.g. *Silene alba* in light soils in open places and *Silene dioica* on heavy soils in shade or in areas of high rainfall. Their habitats overlap in some cases especially on roadsides verges and hybridization is then very common.

3) Seasonal isolation

- Two species occurs in same locality but flower at different seasons e.g. *Sanbucus racemosa* flowering 7-8 weeks later than *S. rugra.* Hybrids however occur in the exceptional flowering period overlap.

4) Temporary isolation

- Two species flower during same period but the pollen is released and/or the stigma are receptive at different times of the day e.g *Agrostis tennis* and *A. stolonifera* produce pollen grains at different times where the former flower in afternoon and latter in the morning .

5) Ethological isolation

- Ethology; the study of animal behavior, inter-fertile species are pollinated by different sorts of pollen vectors or on any particular forage and an individual keeps to one species.
- This can be where different pollinators preferentially visit one species over others.
- Hybrids arise from instances of vectors especially when flowers of the preferred species are rare.

6) Mechanical isolation

- Related, inter-fertile species have differently structured flowers which make it difficult for pollen nectars to transfer pollen to stigma of other flowers other than which it was obtained from.

7) Gametophytic isolation

- Cross-pollination takes place but the pollen tube fails to germinate or to reach and penetrate the embryo sac of the female parent. This is common isolating mechanism.

8) Gametic isolation

- Pollen tube release the male gamete to the embryo sac but gametic fusion and/or endospermic fusion does not take place.

(b) Post-Zygotic Isolation mechanism

- This is the isolation mechanism that occurs after fertilization
- These are those means of isolating mechanism that are aimed to prevent possible hybridization after fusion.
- There are six types of post-zygotic isolation mechanisms.

i) Seed incompatibility

- The zygote or immature embryo ceases development so that a mature seed is not formed.
- This is associated with failure of the hybrid endosperm to provide adequate nourishment for the developing embryo.

ii) Hybrid inviability

- In this case, the interspecific first filial generation of the hybrids is very vigorous but they often display a number of structural weaknesses in vegetative phase and this is as a result of incompatible genetic and cytoplasmic interaction between the two parents.
- The interaction is unfavorable and always leads to death.
- Germination occurs but the result and F1 hybrid dies sometimes before the production of flowers.

iii) Non fitness of F1 hybrids

- The F1 hybrids reach maturity but are not successful competitors ecologically and therefore die off.
- Usually this relates to the availability of suitable ecological niche which may be different from those of either parent and is often coupled with ecological isolation.

iv) F1 Hybrid sterility

- The F1 hybrids are fully viable but sterile and don’t contribute to future generation. Sterility may be manifested from early stages e.g flower bud abortion to late (F2 embryo abortion) stages

v) F2 hybrid inviability

- In these situations, the viability is delayed until the F2 generation or even later.

vi) Non fitness of F2 hybrids

- It is a case of disability delayed until a later generation.
- This isolating mechanism is exemplified by those many situations in which two species are fully fertile and produce fully fertile hybrids yet the two parents remain recognizable as distinct entities and are often both more common than the hybrids.

Plant variation and evolution

- Variation is any difference between cells, individual organisms, or groups of organisms of any species caused either by genetic differences (genotypic variation) or by the effect of environmental factors on the expression of the genetic potentials (phenotypic variation).
- Variation may be shown in physical appearance, metabolism, fertility, mode of reproduction and other obvious or measurable characters.
- Natural variation in plants refers to the genetic diversity of a single plant species in the wild.
- Natural variation is a valuable source of beneficial traits for plant breeding.

- The phenotype an organism has depends on two things:

1. Genotype: the genes it inherited

- Genes are passed on from the parent in sex cells.
- The combining of genes from the mother and father creates genetic variation.
- Only identical twins have the same genotype.
- There is lots of genetic variation in a population.

2. Environment: the place it lives in

- The conditions the organism grows and develops in also affects its
- appearance.
- Examples include scars in animals, or smaller and yellow leaves in plants

- Genetic variation is introduced by mutations in the sequence of DNA.
- Genotypic variations are caused by differences in number or structure of chromosomes or by differences in the genes carried by the chromosomes
- Individuals with multiple sets of chromosomes are called polyploid; many common plants have two or more times the normal number of chromosomes, and new species may arise by this type of variation.
- A variation cannot be identified as genotypic by observation of the organism; breeding experiments must be performed under controlled environmental conditions to determine whether or not the alteration is inheritable

- Environmentally caused variations may result from one factor or the combined effects of several factors, such as climate, food supply, and actions of other organisms.
- Phenotypic variations also include stages in an organism’s life cycle and seasonal variations in an individual.
- These variations do not involve any hereditary alteration and in general are not transmitted to future generations; consequently, they are not significant in the process of evolution.

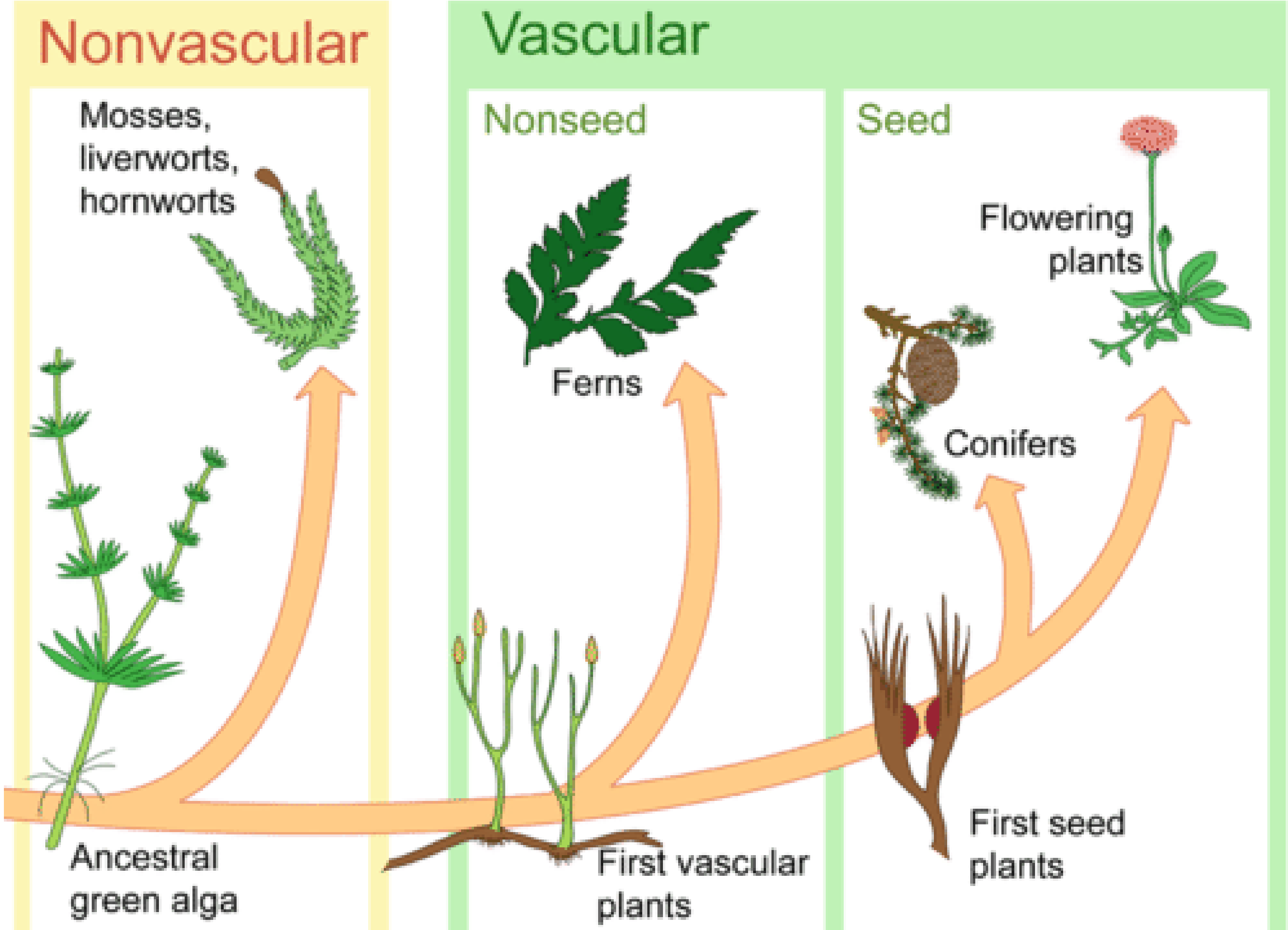
- Variations are classified either as **continuous**, **or quantitative** (smoothly grading between two extremes, with the majority of individuals at the centre, e.g plant height in plant populations); or as **discontinuous, or qualitative** which is the type of variation where individuals fall into a number of distinct classes or categories, and is caused by genes
- Discontinuous variation in plants can be seen in traits such as flower colour, seed shape, and leaf arrangement.
- A discontinuous variation with several classes, none of which is very small, is known as a **polymorphic variation**.
- The separation of most higher organisms into males and females and the occurrence of several forms of a butterfly of the same species, each coloured to blend with a different vegetation, are examples of polymorphic variation.

Evolution in plants

- Evolution is a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of a new species.
- **Theory of Evolution:** All species have evolved from simple life forms that first developed more than three billion years ago.
- Evolution occurs because of natural selection.
  - Mutations occur which provide variation between organisms.
  - If a mutation provides a survival advantage the organism is more likely to survive to breeding age.
  - The mutation will then be passed onto offspring.
  - Over many generations, the frequency of the mutation will increase within the population

- This may cause one population of a species to become so different that they can no longer interbreed to produce fertile offspring, meaning that they have become a new species i.e speciation.
- The pattern in plant evolution has been a shift from **homomorphy** to **heteromorphy.**
- Homomorphy is similarity of form with different fundamental structure
- Heteromorphy is deviating from the usual form i.e exhibiting diversity of form or forms e.g heteromorphic pairs of chromosomes and therefore leading to diversity if morphological forms

- Plants are thought to have evolved from an aquatic green alga protist.
- Later, they evolved important adaptations for land, including vascular tissues, seeds, and flowers.
- Each of these major adaptations made plants better suited for life on dry land and much more successful



Nonvascular
Vascular
Mosses, liverworts, hornworts
Nonseed
Seed
Flowering plants
Ferns
Conifers
Ancestral green alga
First vascular plants
First seed plants

- Plants evolved a number of adaptations that helped them cope with these problems on dry land.
- One of the earliest and most important was the evolution of vascular tissues.
- Vascular tissues form a plant’s “plumbing system.”
- They carry water and minerals from soil to leaves for photosynthesis.
- They also carry food (sugar dissolved in water) from photosynthetic cells to other cells in the plant for growth or storage.
- The evolution of vascular tissues revolutionized the plant kingdom.
- The tissues allowed plants to grow large and endure periods of drought in harsh land environments

- In addition to vascular tissues, these early plants evolved other adaptations to life on land, including lignin, leaves, roots, and a change in their life cycle.
- ***Lignin*** is a tough carbohydrate molecule that is hydrophobic ("water fearing"). It adds support to vascular tissues in stems. It also waterproofs the tissues so they don't leak, which makes them more efficient at transporting fluids. Because most other organisms cannot break down lignin, it helps protect plants from herbivores and parasites.
- ***Leaves*** are rich in chloroplasts that function as solar collectors and food factories. The first leaves were very small, but leaves became larger over time.
- ***Roots*** are vascular organs that can penetrate soil and even rock. They absorb water andminerals from soil and carry them to leaves. They also anchor a plant in the soil. Roots evolved from rhizoids, which nonvascular plants had used for absorption.
- Land plants evolved a dominant diploid sporophyte generation. This was adaptive because diploid individuals are less likely to suffer harmful effects of mutations. They have two copies of each gene, so if a mutation occurs in one gene, they have a backup copy. This is extremely important on land, where there's a lot of solar radiation.
- Many nonvascular plants went extinct as vascular plants became more numerous. Vascular plants are now the dominant land plants on Earth.

SIGNIFICANCE OF CLASSICAL TAXONOMY AND BIOSYSTEMATICS

- Classical taxonomy is also called as systematics. Modern taxonomy is called as biosystematics.
- In classical taxonomy, classification is based on morphology. In modern taxonomy, classification is based on phylogenetic relationships of the organisms.
- In classical taxonomy, only a few individuals were studied. However, in modern taxonomy, the large number of individuals were studied.

Classical Taxonomy

- Classical taxonomy deals with the classification of species in which species is considered as basic unit.
- In this, an organism is classified into domains, kingdoms, phylum, class, order, family, genus and species. In this, the organism is classified using both morphology and phylogeny.
- Let's start with one of the earliest forms of scientific classifications, in which organisms were categorized first into larger, then more specific groups, which we call classical taxonomy.
- All living things are grouped into domains, kingdoms, phylum, class, order, family, genus, and finally species, the most specific classification.
- So, for example, humans belong to the domain of Eukaryotes, which we share with everything from flowers to sharks to algae, but humans, and humans alone, are the species Homo sapiens. See how that works?

- Classical taxonomy creates these rankings by looking at how things relate to each other genetically, meaning through shared ancestry and appearance.
- This means using both morphology, the form and structure of organisms, and phylogeny, evolutionary history, to classify living things.
- While this was accepted for a long, long time, classical taxonomy is no longer the most accepted system due to the fact that it relies on the subjective judgment of the researcher more than pure, scientific facts.

Biosystematics

- Biosystematics is simply known as "the study of biodiversity and its origins" and it is an art as much as science.
- In a broader sense, it is a science through which organisms are discovered, identified, named and classified with their diversity, phylogeny, spatial and geographical distributions.
- It is a science that provides indispensable information to support many fields of research and beneficial applied programmes.
- Biosystematics is a synthetic branch which uses the characters and data from many disciplines like morphology, anatomy, cytology, genetics, palynology, embryology, ecology, plant geography, phylogeny, physiology, phytochemistry, evalution and paleobotany. Hence, biosystamatics is an integrative and unifying science.

- The experimental taxonomy is also known as ‘Biosystematics’, which was first advocated by the ecologist F.E. Clements (1905).
- In 1920 the Swedish botanist Turresson laid foundation to it. Camp and Gily in 1943 coined the term ‘Biosystematics’. It is originally coined from the word ‘biosystematy’.
- Biosystematics is the taxonomic application of the genecology, is the study of the genotypic and phenotypic variation of species in relation to the environments in which they occur.
- It is the union of taxonomy and genetics. The biosystematics is mainly concerned with genetical, cytological and ecological aspects of taxonomy and it must involve the studies in the experimental gardens.

Scope and Significance of Biosystematics

Biosystematics has broad scope in the following branches to generate fundamental knowledge of living organisms.

i. Experimental taxonomy: In the sense of experimental taxonomy it provides data on variations, adaptations, and evolutionary dynamics of populations and species.

ii. Biodiversity: To make an inventory of diversity of life forms.

iii. Ecology and Environment: For protection and conservation of natural habitats and ecosystems of the earth.

iv. Evolution and Biogeography: to demonstrate the evolutionary implications and its effects on phylogeny. To provide information on distribution patterns of various organisms of universe.

v. Biological Resources: For management and conservation of plant, animal and microbial genetic resources and their sustainable use.

vi. Agriculture: To develop sustainable practices in agriculture, forestry, industry, and urban development to ensure health and wealth of environment.

vii. Biotechnology: By using genetic diversity of organisms developing new varieties in crops, new strains for medicines and analyzing DNA patterns for forensic uses.

Practical applications of experimental taxonomy or biosystematics

1. Babcock (1926) studied the cytogenetics of genus Crepis and produced a 'classical model' with combined applications of cytology, genetics and taxonomy.

2. The experimentalist Jens Clausen has studied taxonomy and cytogenetics of genus Viola

and published fruitful results.

3. In *Phleum pratense* L. (Poaceae) there are diploid and hexaploid groups which are practically intersterile and occoupy ecologically different habitats. The cytogenetics study revealed that these two groups may correspond to var. typicum Beck., and var. nodosum (L.) Richt. and together fall within the subspecies vulgare.

4. T. G. Tutin has studied the different races of *Poa annua* L. (Poaceae) a remarkable species which is capable of growing different habitats and found several cytogenetic variants.

5. A.A. Maassoumi (2009) has published the experimental taxonomy of the genus *Salix* L. (Salicaceae) in Iran. He recognized 31 species (earlier 12 species were reported in Iran) and 7 hybrids with the help biosystematics studies.

Molecular taxonomy

- Molecular taxonomy is the discipline of classifying organisms based on variations in protein and DNA in order to make fine taxonomic categorizations not solely dependent on morphology.
- Is the classification of organisms on the basis of the distribution and composition of chemical substances in them.
- Molecular techniques in the field of biology have helped to establish genetic relationship between the members of different taxonomic categories.
- DNA and protein sequencing, immunological methods, DNA-DNA or DNA-RNA hybridization methods are more informative in the study of different species.
- The data obtained from such studies are used to construct phylogenetic trees. Fitch and Margoliash (1967) made first phylogenetic tree based on molecular data.
- This tree was so close to the already established phylogenetic trees of the vertebrates that the taxonomists realized significance of molecular data and this made them understand that other traditional methods are although important but molecular evidences could be final or confirmatory evidences.

- Taxonomy, sometimes called systematics, is the study of categorizing organisms into logically related groupings.
- Historically, the way to perform taxonomy was to examine physical characteristics of organisms and classify species according to the most commonly held traits.
- Unfortunately, this method of systematizing plants and animals assumed that because they have common physical traits, they have common ancestry.
- A gross form of this miscategorization might take place, for example, if one suggested that since both mushrooms and ivy can grow on the sides of trees, they are closely related.
- The two species certainly have common physical traits but only vaguely resemble each other. It is such a realization that motivated systematists to begin using molecular differences to compare species and populations.
- Molecular taxonomy uses variations in protein and deoxyribonucleic acid (DNA) molecules to determine how similar, or dissimilar, sets of organisms are. These molecular differences provide a much more accurate taxonomic picture.

Molecular Taxonomy and Evolution

- The real power of molecular systematics is that it allows the examination of how species have changed over evolutionary time, as well as of the relationships between species that have no common physical characteristics.
- Molecular changes can be used to explore phylogenetics (how populations are related evolutionarily and genetically).
- It has been suggested that the amount of change that takes place in DNA over time can act as a molecular clock, gauging how much evolutionary time has passed.
- The clock is set by first examining geological and historical records to determine how long two species have been physically separated.

- By examination of the number of molecular changes that have occurred between those species over that known time, a time frame of change can be established.
- Genes are thought to evolve and mutate at a constant, predictable rate, giving rise to this evolutionary clock hypothesis.
- There are three major domains of life: prokaryotes (modern bacteria), Archae bacteria (descendants of ancient bacteria), and eukaryotes (cellular organisms with nuclei and organelles).
- Similarly, we have primitive plants that gave rise to gymnosperms and later angiosperms.
- All these organisms share a common ancestry of hundreds of millions of years.
- All species over time are connected to one another through a web of interlacing DNA as they reproduce, separate to become new species, and reproduce again.
- All organisms carry their ancestors' genetic information with them as a bundle in each cell, and the more closely related organisms are to one another, the more similar the contents of that bundle will stay over time.
- Humans share common genes, unchanged over millennia, with all other organisms—from the bacterium Escherichia coli to barley to gophers.
- The more important the job of a gene, the less it changes over time; this concept is called conservation. Conservation is the force that keeps a biological or genetic link between every species on earth.

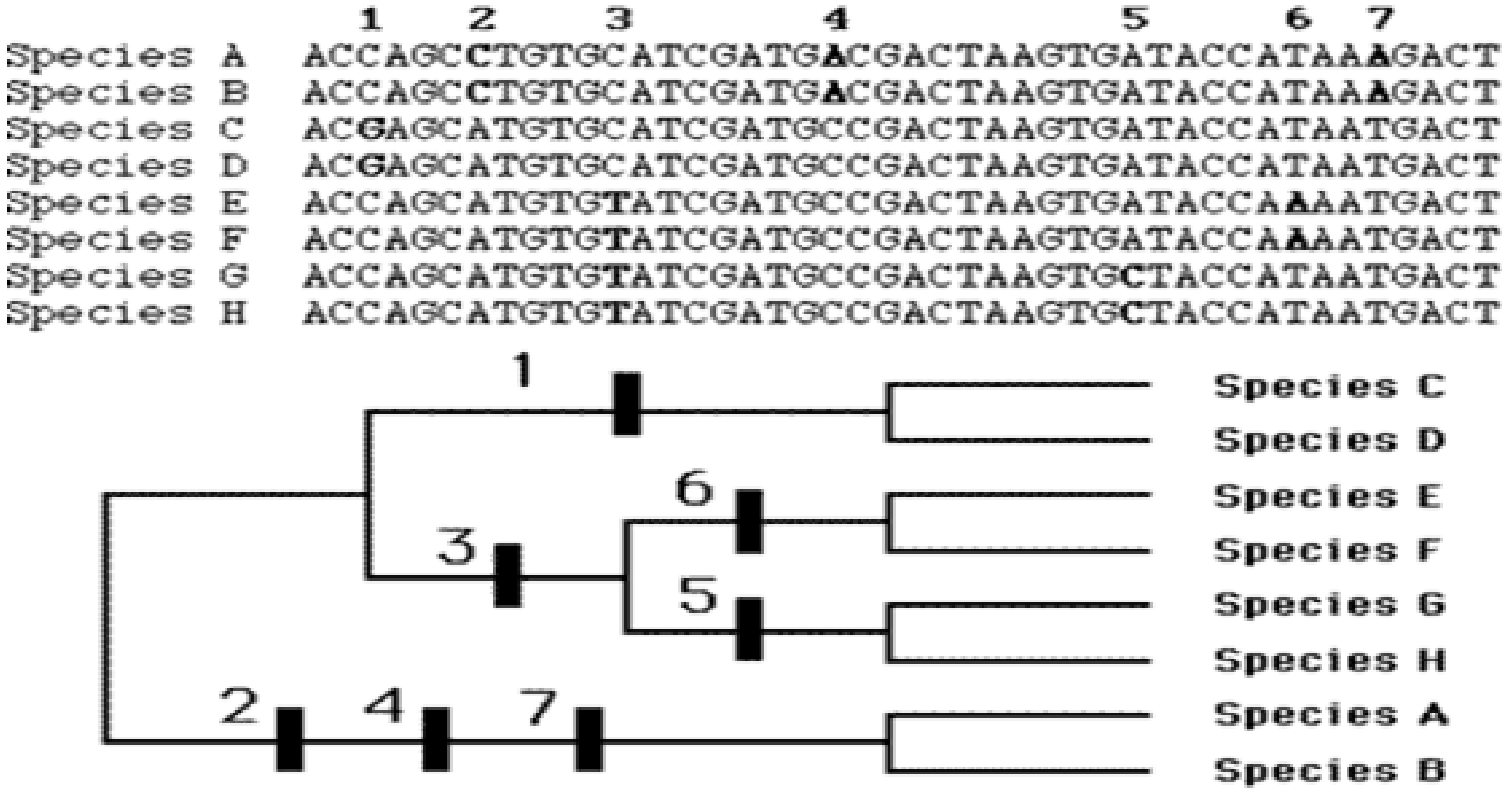
Protein-Level Analysis

- Proteins were the earliest biomolecules used to study phylogenetics. Initially, protein differences could be studied only at the grossest levels.
- It was found that populations of organisms could be distinguished based on possessing different alleles (genetic sites) that made proteins possessing the same function but with different chemical structures.
- These enzymes were called isozymes. Isozymes can be separated and compared for size by employing a technique called gel electrophoresis.
- Gel electrophoresis uses a slab of gelatin-like medium and an electric field to separate molecules on the basis of size and electric charge.
- The genetic similarity of two different species can be determined based on common molecular weight of the isozymes. Proteins are composed of strings of the twenty amino acids common to all life on earth. It is possible to ascertain the amino acid sequence of a protein.
- If the amino acid sequence of the same protein is ascertained among several different species, that sequence should be more similar between closely related species than more distantly related species. These differences allow taxonomists to gauge similarity of populations.
- Antibodies are biomolecules that are able to recognize and bind very specifically to other molecules. Biologists employ antibodies that specifically recognize molecules at the surface of cells to test relationships between species.
- Antibodies that recognize cell-surface molecules on one species should recognize those same molecules in closely related species, but not from distantly related species, allowing a researcher to gauge similarity between species.

DNA-Level Analysis

- The most common method used to establish taxonomic relationships is to compare DNA sequences between species.
- DNA is the double-stranded, polymeric molecule that encodes the proteins that direct the inner workings of all cells.
- The DNA molecule is structure like a ladder, with rungs formed by pairings of four molecules, the bases guanine (G), adenine (A), thymine (T), and cytosine (C).
- These bases, arranged in unique order, are read by special enzymes and encode messages that are translated into proteins.
- Sequences encoding for the same protein can change between species. In taxonomy, DNA sequences are obtained from several populations of organisms. Analysis of these sequences allows one to obtain a picture of how different populations have changed over time.
- This DNA sequencing may be used to compare many different types of DNA: regions that encode for genes, do not encode for genes, reside in chloroplast DNA, or reside in mitochondrial DNA.
- Another common method of DNA phylogenetic analysis is called restriction mapping.

- In this method, DNA from different species is subjected to enzymatic treatment from proteins called endonucleases.
- These endonucleases have the ability to cleave DNA into fragments.
- Where the enzymes cleave the DNA is determined by the DNA sequence itself.
- The size and pattern of the fragments created by this treatment should be more similar in related species than in unrelated species.
- A fairly new method of DNA analysis examines repetitive DNAs, called microsatellite sequences, that are found in all eukaryotic organisms. Microsatellite sequences are short arrangements of bases, such as GATC, repeated over and over.
- The number of repeats at a particular genetic location is usually more similar in related species than in unrelated ones.
- The differences in these repeated sequences are called “simple sequence polymorphisms” and are detected by a special enzymatic reaction called the polymerase chain reaction.
- Once detected, the fragments are separated and compared for size by means of gel electrophoresis.



DNA-level analysis

Chemotaxonomy

- Chemical systematics is the study of chemical variation in different organisms and their relationships and this approach of taxonomy in which chemical features of plants are used in developing classifications or in solving taxonomic problems is called Chemotaxonomy.
- Data from chemistry of plant products is termed phytochemistry.
- The science of chemotaxonomy or chemical taxonomy is used for the classification of plants on the basis of their chemical constituents.
- All the living organisms produce secondary metabolites that are derived from primary metabolites.
- The concept of chemotaxonomy has been elaborated in the past century.
- The principles, procedures and results of investigations of chemical variation of plant groups can be applied mainly for two purposes:
  - a. To provide taxonomic characters which may help in plant classification and may improve the existing systems of plant classification.
  - b. To have additional knowledge of phylogeny or evolutionary relationships of plants.
- Chemotaxonomy has been used in all the groups of the plant kingdom starting from the simple organisms, such as fungi and bacteria, up to the most highly advanced and specialized groups of angiosperms and at all levels of the hierarchy of classification in plants, starting from the rank of Variety up to the rank of Division.
- Chemical characters are particularly of high taxonomic value when they are stable, unambiguous and not easily, if at all, changeable.

- The use of chemical characters in plant classification has a long history. Since the early 1960s, phytochemical characters started to attract the attention of plant taxonomists.
- However recently, due to the development of new and powerful analytical techniques and the speed and simplicity of these techniques, it has been possible to screen a large number of individuals in a very limited time and utilize such information in plant taxonomy.
- The various data from these studies confirms early ideas that phytochemical characters correlate quite well with other types of characters and should be considered seriously in taxonomy.
- However, at the same time, chemotaxonomy should not be considered as more indicative of relationship than other characters such as external morphology, anatomy, cytology, etc. and as a replacement of other taxonomic characters, but at best a major source of new characters and information.
- The new ideas and facts that are still being obtained from all other existing sources of taxonomic evidence should not be ignored.
- The chemical characters are considered more important, only when they show a high degree of correlation with other features

Stages in Chemotaxonomy:

- Hegnauer recognized six chief stages in a phytochemical study, reconciling the need for informed chemical procedure and a project design satisfying formal taxonomic requirements:
- (i) Choice of a group, taxonomic survey and sound sampling.
- (ii) Choice, mastery and modification of suitable chemical techniques in a pilot survey.
- (iii) Full analysis of all material.
- (iv) Interpretation and comparison with data from all other sources.
- (v) Adjustment of classification as necessary, and
- (vi) Treatment of any evolutionary relationship as indicated by the new data.

Chemotaxonomic Classification

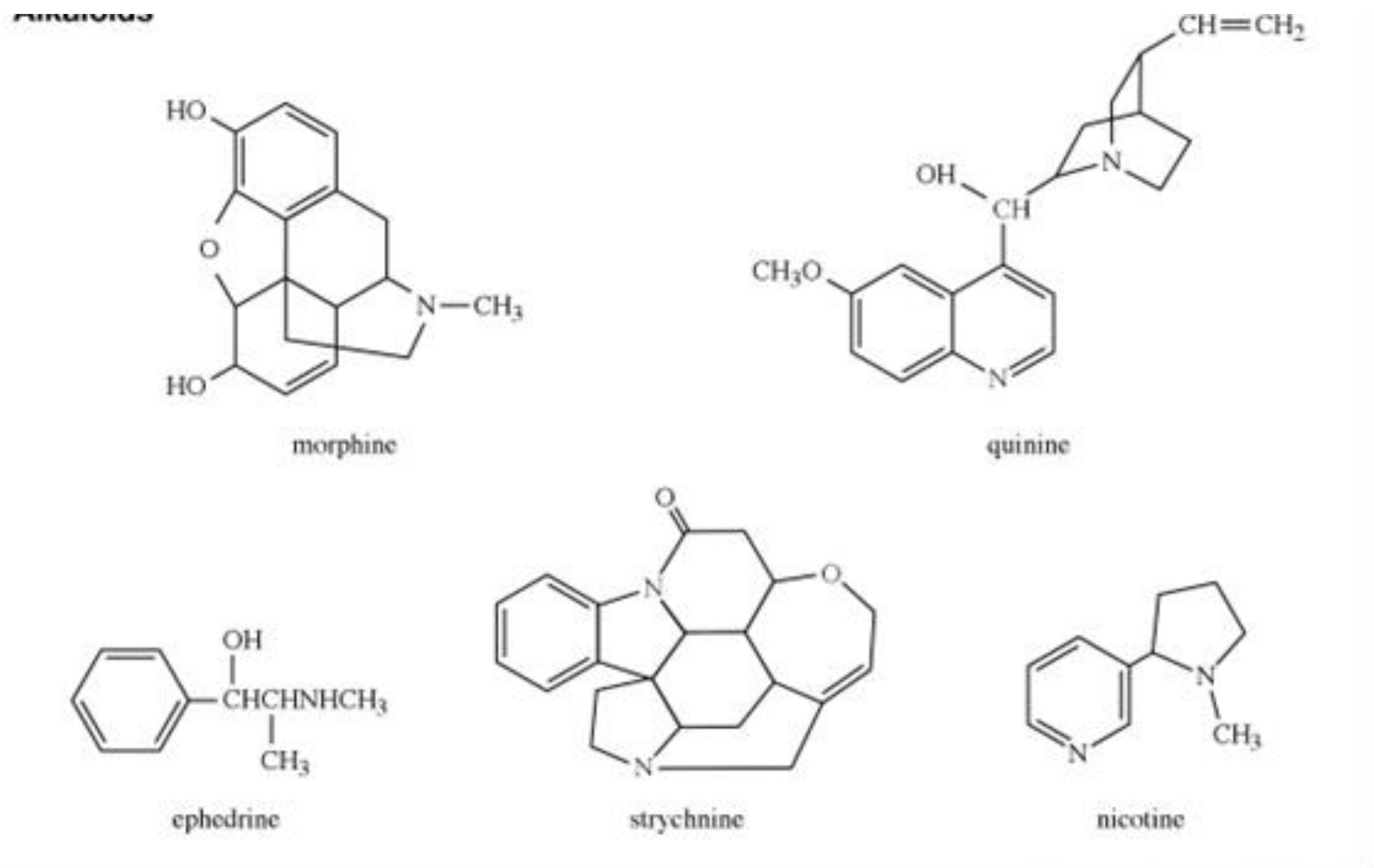
- The phenolics, alkaloids, terpenoids and non-protein amino acids, are the four important and widely exploited groups of compounds utilized for chemotaxonomic classification.
- These groups of compounds exhibit a wide variation in chemical diversity, distribution and function.
- The system of chemotaxonomic classification relies on the chemical similarity of taxon.
- Three broad categories of compounds are used in chemotaxonomy: primary metabolites; secondary metabolites and semantices.

Primary metabolites

- Primary metabolites are the compounds that are involved in the fundamental metabolic pathways.
- Most of the primary metabolites are of universal occurrence and utilized by the plant itself for growth and development.
- These compounds are ubiquitous in nature and hence play little role in chemotaxonomic classification.
- However, these molecules sometimes serve as useful chemotaxonomic behavior on the basis of their quantities.
- For example, carbohydrate sedoheptulose is present in genus sedum in large quantity.
- Therefore, the accumulation of sedoheptulose in the species of genus sedum serves as a useful chemical character in chemotaxonomy.
- The water soluble polysaccharides (WSP) are also used as chemotaxonomic markers. The gas liquid chromatographic analysis on WSP from annatto tree (Bixa Orellana L.) showed hemispherical type contained 38% rhamnose, while conical and ovate types contained 17% and 34% glucose, respectively.
- Thus, glucose and rhamnose content of WSP could be used to distinguish the three landraces of annatto trees.

Secondary metabolites

- Secondary metabolites are the compounds that usually perform non-essential functions in the plants.
- They are used for protection and defense against predators and pathogens.
- These compounds are of restricted occurrence and hence very useful for chemotaxonomic classification.
- Some of the major group of secondary metabolites includes glycoside, alkaloid, volatile oil, flavonoid, plant phenols and terpenoid.



Different types of alkaloids

BOTANICAL DESCRIPTIONS AND LITERATURE

- Descriptions are in botanical English, which is mostly composed of nouns, adjectives, and conjunctions. Descriptive botanical English does not contain verbs and has few articles (e.g. "the" is not used and "a" is used only when necessary).
- Descriptions will follow the conventional order (i.e., habit, duration, sex, roots, stems, leaves, inflorescences, flowers, fruit, seeds).
- Each major part of a description will be in a separate sentence with semicolons used to separate subparts.
- At the beginning of each sentence and after each semicolon there must be a noun, and all the description until the end of the sentence or until a semicolon must refer back to that noun.
- Commas are used to separate the various components within the sentence.
- Note that a series with the use of "and" or "or" is treated as a single component. If two alternate states of a structure exist, they will be separated by the word "or," and when several alternate states exist, each state will be separated by a comma with the final state preceded by a comma followed by "or" (e.g., "petals white or pink" and "petals white, pink, or blue").
- If a range of shapes is found in a structure the word "to" will be used (e.g., "leaf blade oblong to ovate"). If a structure is meant to be described as intermediate in shape rather than a range between two extremes, a dash "" is used (e.g., "leaf blade lanceolate-ovate").
- When characters are given in series, a comma will separate each component of the series and before the final "and" (e.g., "branchlets, petioles, and peduncles tomentose").

- The general order that a structure should be described is as follows: color, shape, dimensions, texture, surface characteristics, base, margin, apex. Example Olea capensis.
- The Black Ironwood tree, is an African tree species belonging to the olive family (Oleaceae). Olea capensis is widespread in Africa.
- It is found almost throughout Africa south of the Sahara from the east in Somalia, Kenya, Ethiopia and Sudan, south to the tip of South Africa, and west to Cameroon. Sierra Leone, and the Islands of the Gulf of Guinea.
- It occurs in bush, littoral scrub and evergreen forest. Olea capensis is known by a variety of common names including:
    - Afrikaans: ysterhout
    - English: black ironwood, East African olive, Elgon olive, ironwood, ironwood olive
    - Swahili: loliondo, mushargi
    - Trade names: loliondo, mutharage, mutharagi, olive

Description

- Olea capensis is a bushy shrub, or a small to medium sized tree, up to 10 metres (33 ft) in height, occasionally reaching 40 metres (130 ft).
- Bark: light grey, becoming dark grey and vertically fissured with age; a characteristic blackish gum is exuded from bark wounds.
- Leaves: light to dark green and glossy above and paler green below; petiole often purplish, 0.3-1.7 cm long; lanceolate-oblong to almost circular, 3-10 x 1.5-5 cm.
- Flowers: white or cream and sweetly scented, small and in many flowered axillary or terminal heads, 3-15 cm long.
- Fruit: when ripe they are somewhat succulent purplish drupes; ovoid up to 2 x 1 cm.

Taxonomic Literatures

What are the Taxonomic Literature

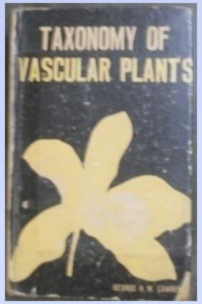
- Literarures in Systematic Botany or commonly known as Taxonomic literature refers to all inclusive writings (published or unpublished) and numeric and graphic representations that relate to classification, identification, nomenclature, description and relationship of organisms and taxa. Collection consists of books, manuscripts, magazines, journals, films, tapes, drawings, illustrations and paintings.

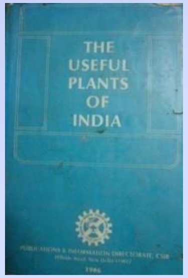
TYPES OF LITERATURES IN SYSTEMATIC BOTANY

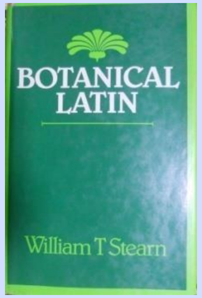
1. General Literatures in systematic Botany.
2. General Index
3. Botanical Glossaries and Dictionaries
4. Floras and Manuals
5. Monographs and Revisions (Conspectus and Synopsis)
6. Periodicals or Journals or Current Literatures (Indian and Foreign)
7. Abstracts and Guides
8. Bibliography

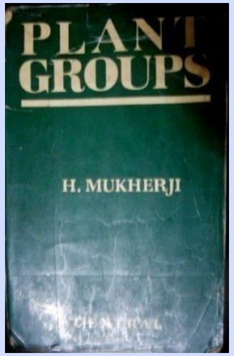
GENERAL TAXONOMIC LITERATURES

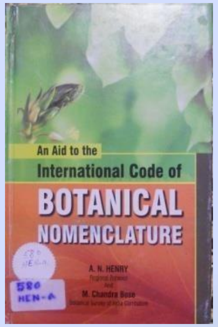
1. Important recent and classical literatures
2. Evolutionary background
3. Nomenclature
4. Terminology and description of taxa
5. Identification of plants to families
6. Accounts of plants families
7. Books on different types of plants
8. Distribution of general reference work
9. Icones(Illustrations)











Icons (Illustrations)

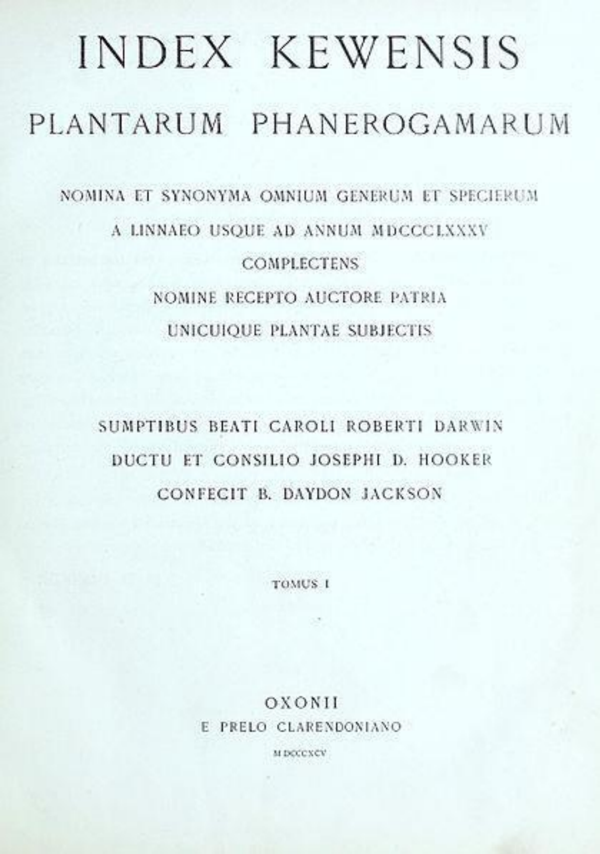
An **icon (from Greek word for "image") is a work of art, most commonly a painting. Many workers who have prepared botanical drawings by artists under their careful observation are reffer as Icons in the context of taxonomic literatures.**

Some of important icons are as follows:

i.Roxburgh Icons– (1824). It was published in 35 volumes, containing 2533 plates,

ii.Illustrations of Himalayan Plants – (1885). By J.D.Hooker .

iii.Wight's Icons – (1838 – 1853. It was published in 6 volumes, containing 2101 plates. Reprinted in 1963 from Madras.



2. General Index

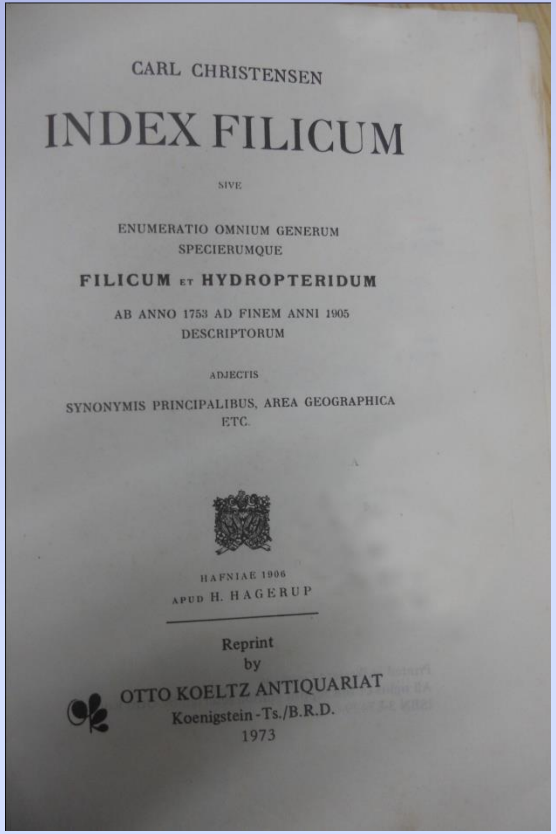
These are compiled volumes and continuously being compiled in respect to names of flowering plants published throughout the world till date. An index provides an alphabetic listing of taxa with reference to their publication. Index serves as an aid to locating quickly the source of original publication of a name.

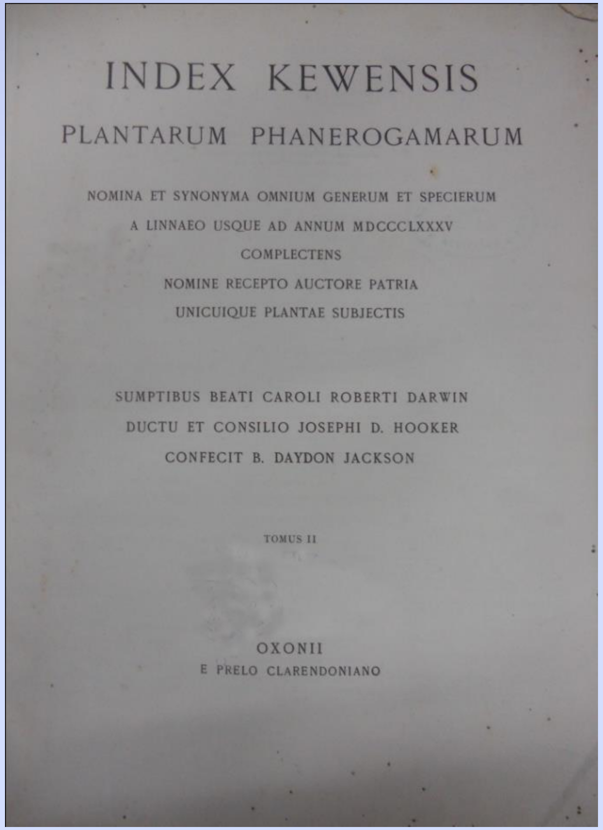
e.g. **The International Plant Names Index (IPNI)** is a database of the names and associated basic bibliographical details of seed plants, ferns and lycophytes. Its goal is to eliminate the need for repeated reference to primary sources for basic bibliographic information about plant names.

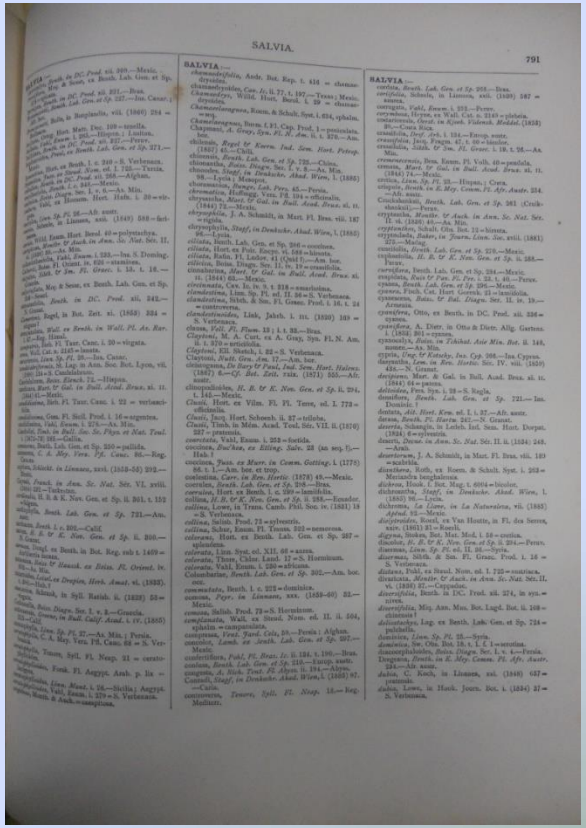
Index Kewensis : 2 vols., 21 Suppls.(Oxford : 1893-2000) Since 1885, the Royal Botanic Gardens, Kew, has been indexingnames of seed plants at the level of genus and species published since 1753, and of all ranks from family downward since supplement 16, and making them available in a series of bound volumes, the Index Kewensis.

Index Londinensis: Oxford : 1929-1931; Suppl. 1941 – Illustrations of vascular plants (Flowering Plants, Ferns and Fern Allies) can be located through this index

Index Filicum – Index for Pteridophytes.Similar to *Index Kewensis, but for ferns. Started in Copenhagen in 1906.*







Index Muscorum – Index for Bryophytes

Index NominumGenericorum (ING)

A 3-volume work published in 1979 under the series Regnum Vegetabile. The first supplement appeared in 1986. It has now been put on the database and can be directly accessed through the Internet.

Index Herbariorum: Also available on the internet.

Gray Herbarium Card Index: Began at Harvard in 1890. Lists ferns, allies, seed plants of the western hemisphere. Duplicates in part, *Index Kewensis.*

Torrey Card Index: *Author index to publications.*

3. Botanical Glossaries and Dictionaries

Alphabetic listing of terms or subject matter with explanation of meaning.

Botanical Glossaries: **A glossary is an alphabetical list of different terms with their explanations.**

A Glossary of Botanical Terms – B.D.Jackson (1928) – 4th Edn.

Botanical Dictionaries: **A botanical dictionary may include lists and description of all known genera of certain plant group.**

i) *A Dictionary of the Flowering Plants and Ferns* – J.C.Willis (1973), 8th edition by H.K.Airy Shaw, Cambridge.

ii) *A Dictionary of Economic Products of India* – G.Watt (1889-1896), Reprinted – 1972, Calcutta.

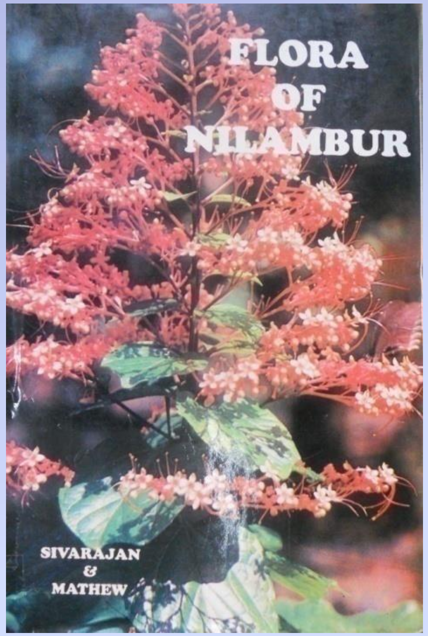
iii) *Mabberley's Plant Book* – D. J. Mabberley, (2008) .Cambridge. University Press. Cambridge.(3rd edn.).

4. Floras and Manuals

Flora :

A flora is an inventory of the plants of a defined geographical region.

List of the Flora maybe found in the *Geographical Guide to the Floras of the World* by S.K.Blake (Part I, 1941 ; Part II, 1961) and *Guide to the Standard Floras of the World* by Frodin(1984).



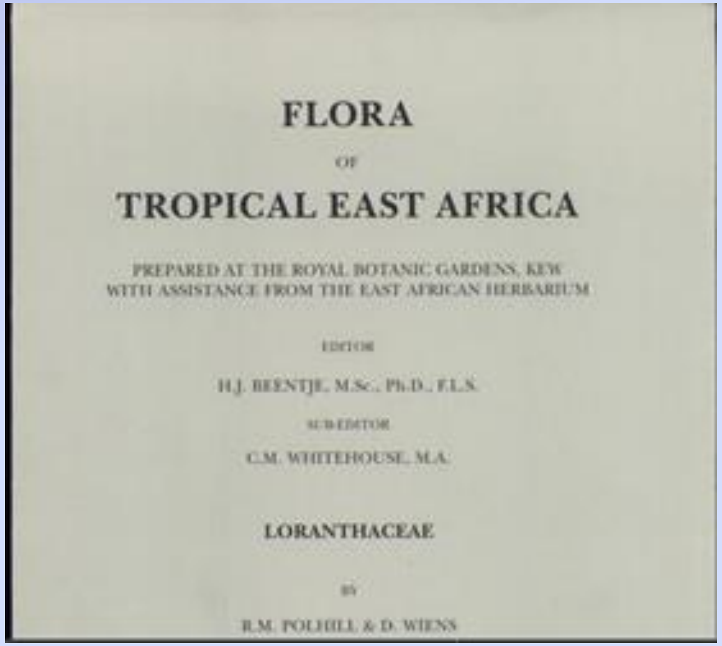
i) Local flora covers a limited geographical area, usually a state, city, a valley or a small mountain range.

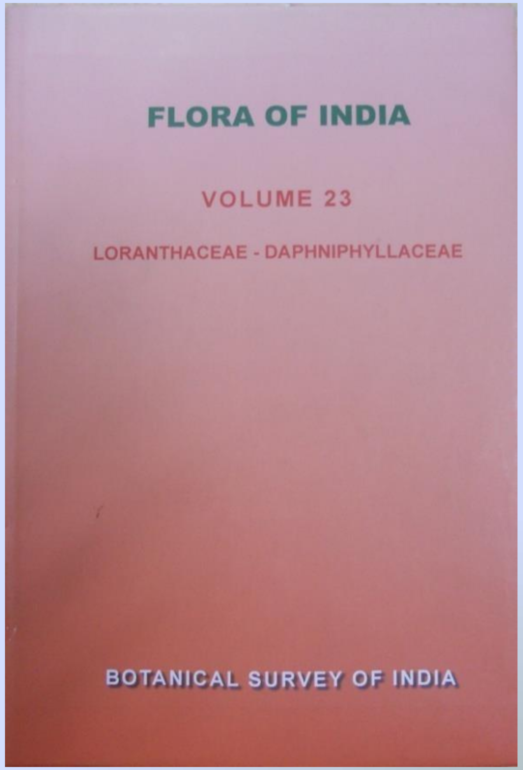
Examples: *Flora of Nilambur* by V. V. Sivarajan and P. Mathew (1997).

ii) <u>Regional Flora</u> includes a larger geographical area, usually a large country or a botanical region.Examples: *Flora of British India* by Sir J.D. Hooker (1872-97), ***Flora Malesiana*** **by C.G.Steenis (1948).**

iii) <u>National Flora</u> is a flora covering a country. Example: *Flora of India* (vol 1-5, 12,13 & 23) BSI, Kolkata.

iv)<u>Continental Flora</u> covers the entire continent. Example: *Flora Europaea* (vols. i-v by T.G.Tutin et al.- 1964-1980)





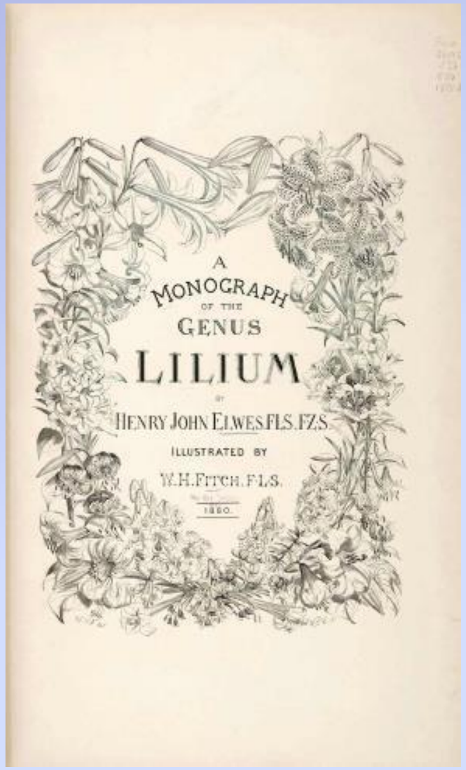
- **Manuals:** A manual is a more exhaustive treatment than the flora, always having keys for identification, description and glossary but generally covering specialized groups of plants.

  - A more exhaustive treatment than flora.
  - No collection number provided.
  - Citations are usually absent.
  - Keys, descriptions, glossary in more details

  e.g. Manual of Cultivated Plants – L.H.Bailey (1949)

Monographs and Revisions
(Conspectus and Synopsis)

Monographs: A monograph is a comprehensive taxonomic treatment of a taxonomic group, generally a genus or a family, providing all taxonomic data relating to that group.

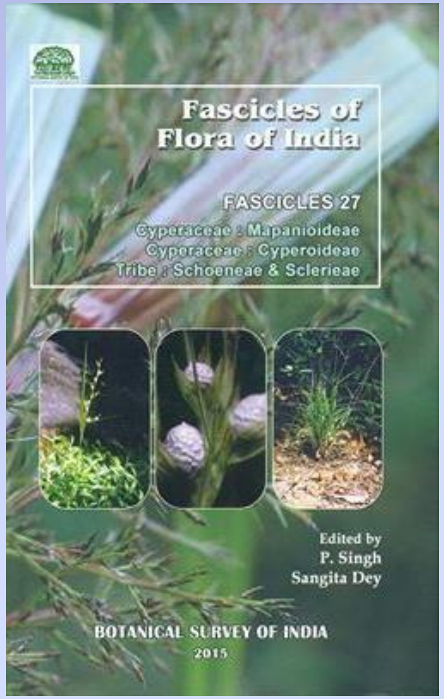


- **A comprehensive taxonomic treatment of a small taxa (genus or a family).**
- **Usually with worldwide scope.**
- **Exhaustive descriptions sometimes with illustrations.**
- **It is a Biosystematic study.**

Examples: *A monograph of the Genus Avena* – B.R.Baum (1977)

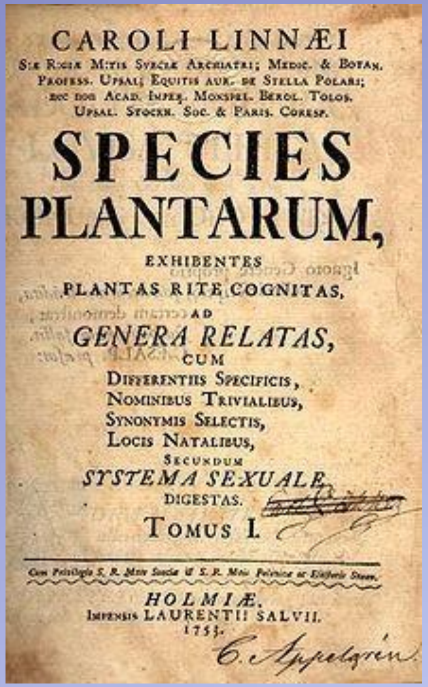
Revision

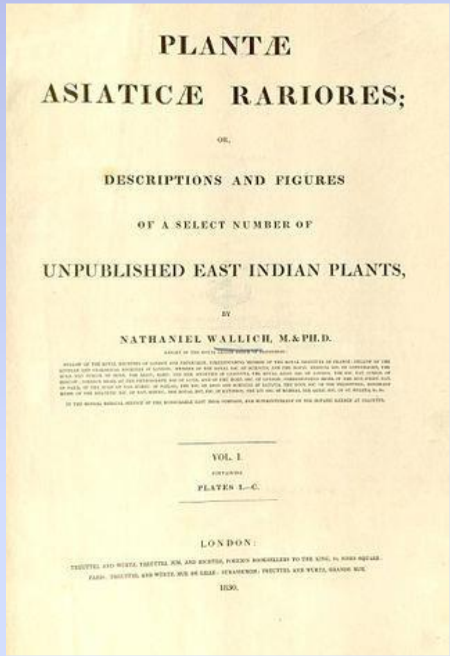
A revision is less comprehensive than a monograph incorporating less introductory material and including a synoptic literary review. A revision includes a complete synonymy but the descriptions are shorter and confined to diagnostic characters.



- Complete Synonymy.
- Descriptions shorter, usually confined to diagnostic characters
- Mainly based on herbarium studies.

Example: Fascicles published by BSI on different taxa.


CAROLI LINNÆI
S:æ R:iæ M:tis Sveciæ Archiatri; Medic. & Botan. Profess. Upsal; Equitis Aur. de Stella Polari; nec non Acad. Imper. Monspel. Berol. Tolos. Upsal. Stockh. Soc. & Paris. Coresp.
SPECIES PLANTARUM,
EXHIBENTES
PLANTAS RITE COGNITAS,
AD
GENERA RELATAS,
CUM
DIFFERENTIIS SPECIFICIS,
NOMINIBUS TRIVIALIBUS,
SYNONYMIS SELECTIS,
LOCIS NATALIBUS,
SECUNDUM
SYSTEMA SEXUALE
DIGESTAS.
TOMUS I.
HOLMIÆ,
IMPENSIS LAURENTII SALVII.
1753.


PLANTÆ
ASIATICÆ RARIORES;
OR,
DESCRIPTIONS AND FIGURES
OF A SELECT NUMBER OF
UNPUBLISHED EAST INDIAN PLANTS,
BY
NATHANIEL WALLICH, M.&PH.D.
VOL. I.
PLATES I.—C.
LONDON:

Conspectus: ***A conspectus is an effective outline of a revision listing all the taxa, with all or major synonyms, with or without short diagnosis and with brief mention of the geographical range .***

Example: *Species Plantarum* – C. Linnaeus (1753)

Synopsis: **A synopsis is a list of taxa with much abbreviated diagnostic distinguishing statements often in the form of keys.**

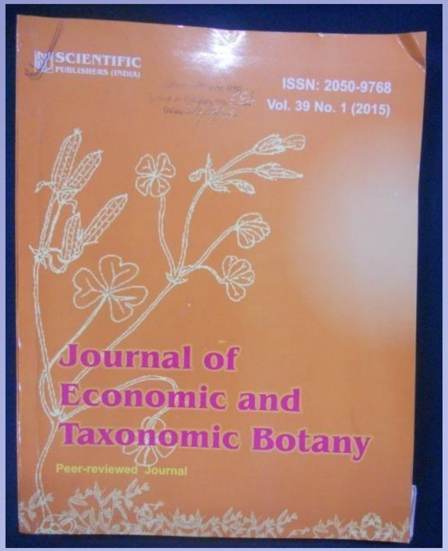
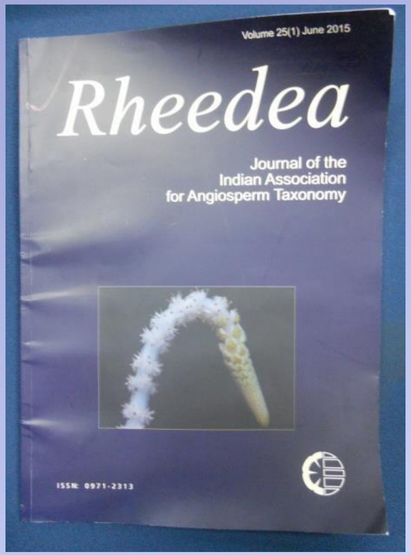
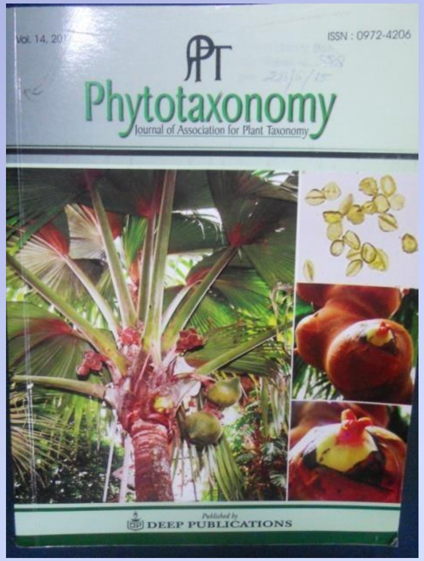
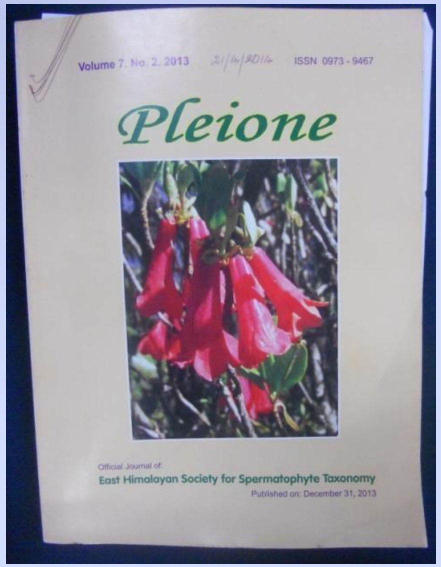
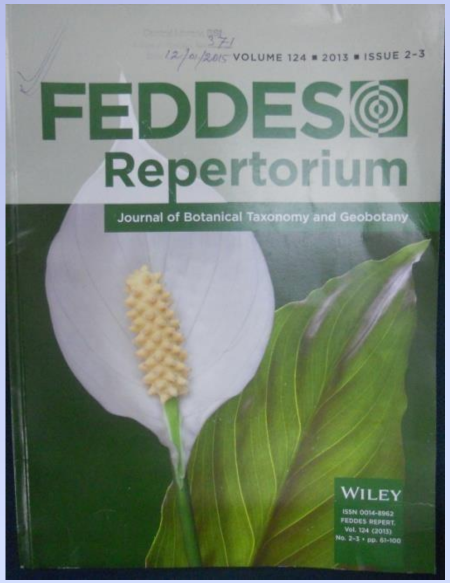
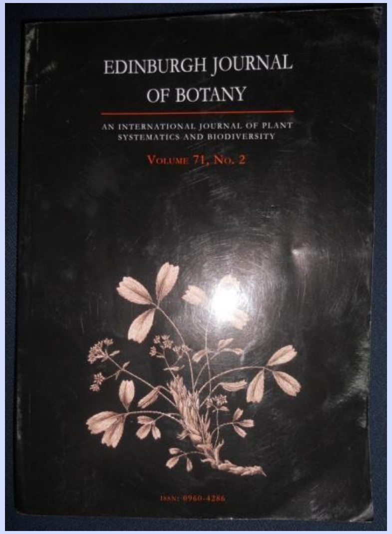
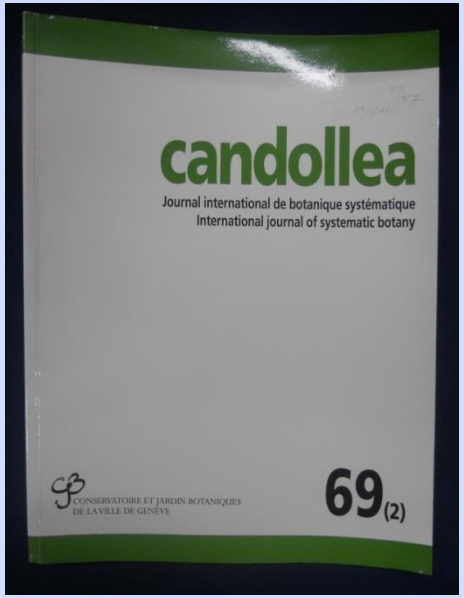
Example: Synopsis of the Genera and Species of Indian Labiatae enumerated in the Catalogue of the Collections in Dr. Wallich's charge published in Wallich's *'Plantae Asiaticae Rariores'* by G.Bentham (1830).

6. Periodicals or Journals or Current Literatures

Periodicals are publications which are issued at regular intervals, such as journals, magazines, etc. They are also often referred to as serials. Periodicals usually consist of a collection of articles. Periodicals can offer some advantages over books depending upon information .

Some Indian Journals on Botany :

1. ***The Bulletin of the Botanical Survey of India**, Kolkata, Bull.Bot. Surv. India.*
   Now Known as ***Nelumbo.***
2. ***Indian Forester**,* Dehra Dun, *Indian For.*
3. ***Journal of the Botanical Society of Bengal**.* Dept. of Botany, University of Calcutta . Kolkata, *J.Bot.Soc. Ben.*
4. ***Rheedea**, Indian Association for Angiosperms Taxonomy,Calicut, Rheedea*
5. ***Phytotaxonomy,*** Association for Angiosperm Taxonomy, Dehra Dun.


SCIENTIFIC PUBLISHERS (INDIA)
ISSN: 2050-9768
Vol. 39 No. 1 (2015)
Journal of Economic and Taxonomic Botany
Peer-reviewed Journal

Volume 25(1) June 2015
Rheedea
Journal of the Indian Association for Angiosperm Taxonomy
ISSN: 0971-2313

ISSN : 0972-4206
Phytotaxonomy
Journal of Association for Plant Taxonomy
DEEP PUBLICATIONS

Volume 7. No. 2. 2013
ISSN 0973-9467
Pleione
Official Journal of:
East Himalayan Society for Spermatophyte Taxonomy
Published on: December 31, 2013

VOLUME 124 ▪ 2013 ▪ ISSUE 2-3
FEDDES Repertorium
Journal of Botanical Taxonomy and Geobotany
WILEY

EDINBURGH JOURNAL OF BOTANY
AN INTERNATIONAL JOURNAL OF PLANT SYSTEMATICS AND BIODIVERSITY
VOLUME 71, NO. 2

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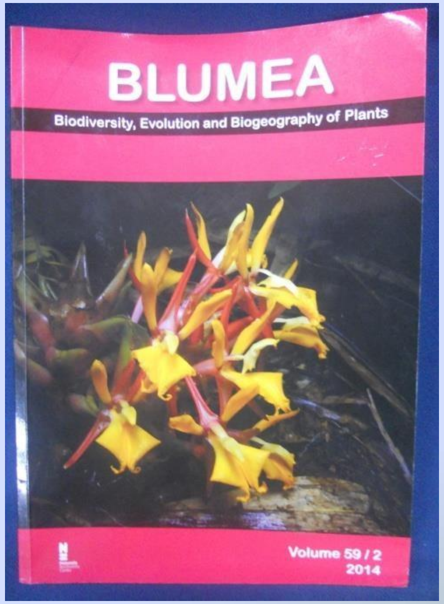
Journal international de botanique systématique
International journal of systematic botany
CONSERVATOIRE ET JARDIN BOTANIQUES DE LA VILLE DE GENÈVE
69(2)

BLUMEA
Biodiversity, Evolution and Biogeography of Plants
Volume 59 / 2
2014

7. Abstracts and Guides

Abstracts provide a summary of various articles published in various journals throughout the world.

Examples: *Biological Abstract, The Kew Record of Taxonomic Literature.*

Guides are useful to help taxonomist to locate relevant literature concerning a taxonomic group or a geographical region.

Example: Guide to the Standard Floras of the World – D.G. Frodin (1984).

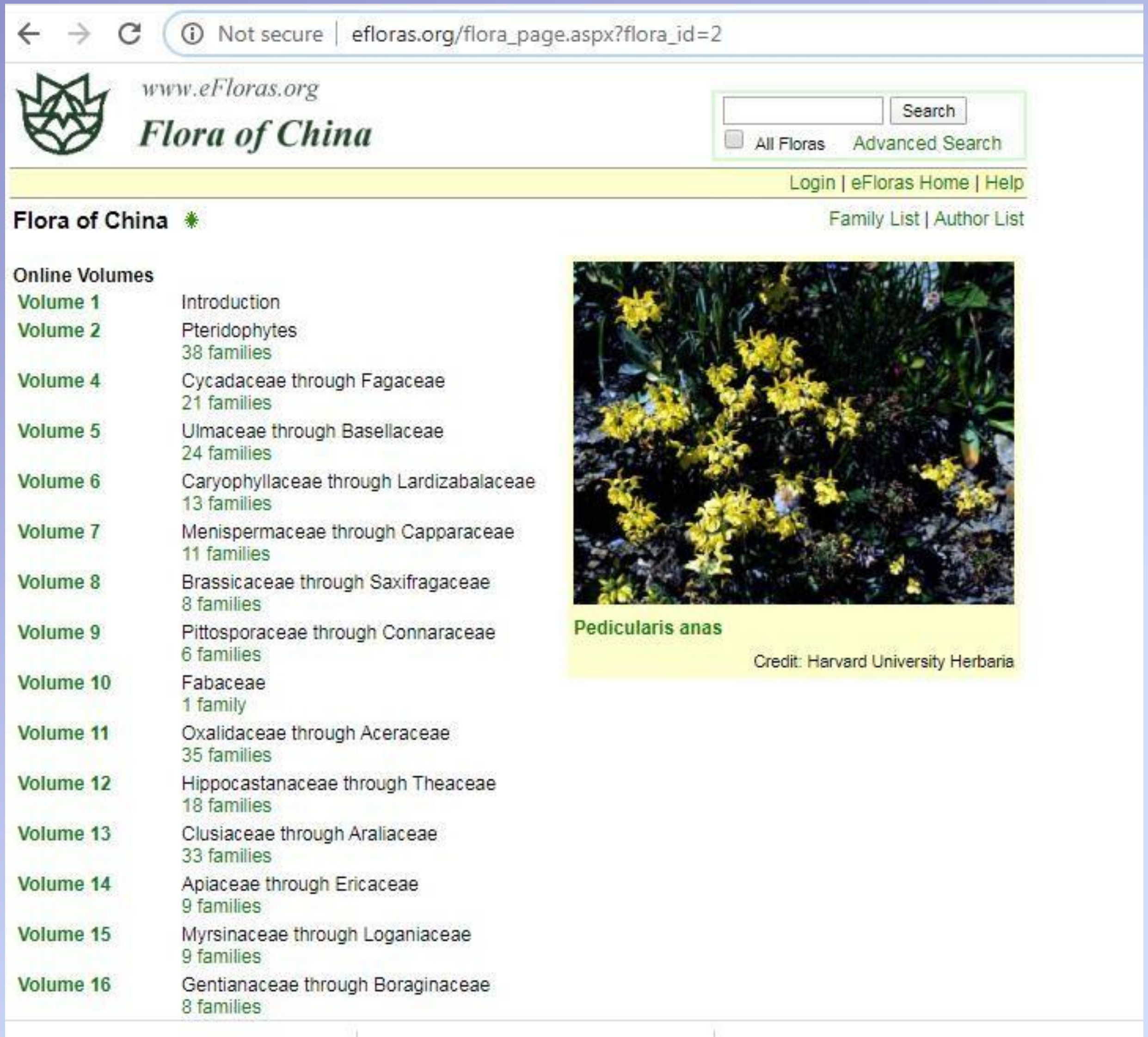
8. Bibliography

This is a list of names of publication of books and scientific literature on specific topics during a specific period.

Example: *An Annotated and Bibliography of Taxonomic Botany of Penninsular India* –Karthikeyan, Nayar and Raghavan (1959-1978) ;

Bibliography of Flora and Ethnobotany of West Bengal.

(2010) – Sunit Mitra, Subhajit Bandyopadhyay and Sobhan Kumar Mukherjee (ISBN : 978-81-924956-0- 6). Siliguri, West Bengal, India.



9. E-Flora

E-Flora is any Flora which is published online or available online for access to everyone.

Example: *e-Flora of China*

Available on

http://www.efloras.org/flora_page.aspx?flora_id=2

Types of identification keys

- The commonly used botanical/ is the dichotomous key
- Keys are usually dichotomous meaning that the questions have exactly two possible answers which should be direct opposite (e.g leaves less than 10 mm long vs leaves more than 10 mm long, not leaves more than 10 mm long vs senated).
- A pair of alternatives is called a couplet, each of the two alternative is a lead. The information provided after leads which can either be the name of a taxon, a reference to a sub-key or (most of them) the number of two next couplet is here called a direction. There are two main types of keys
- i) Indented (yoked key)
- ii) Bracketed (Justaposition/parallel keys)
- Keys consist of a series of couplets or mutually exclusive pair of statements. Each statement (lead) of a pair leading onto a further couplet. At each couplet, a decision to follow one lead or other has been taken so that the number of possible taxa of which the unknown specimen can be identified is successfully reduced until there's only one possibility. The essential difference between these two layouts is that in the bracketed key, the two leads of each couplet appear together whereas in the indented keys all the possibility arising from the first lead are dealt with before the second lead is dealt with.
- The indented key has advantages when the key is short, as the pattern of characters is clearer & when the key is long, there's much wastage of page space and the user has to often turn pages to find the two halves as a couplet.

- Plant identification or Diagnostic Keys are devices consisting of contrasting statements or proposition requiring the identifier to make comparisons & decision based on statements in the key or related to the material to be identified.
- Keys don’t offer descriptions of the plants concerned but state only the essential diagnosis characters by means of which the taxa can be identified.
- Ideally, they use most conspicuous and clear cut characters without special regard to those considered taxonomically the most important.
- Most common keys are Bracketed and indented keys. All the keys are dichotomous.

Types of Single Access Keys (Dichotomous keys)

- **1. Indented key (yoked key)**
- Indents the leads of the couplet a equal distance from the left margin.
- The two choices are labelled 1 and1’ or 1a and 1b.

Advantage

- The relationship of the divisions is apparent to the eye
- Disadvantage
- The alternatives may be widely separated and wasteful of space
- Generally only used for short keys

- **2. Bracketed key (Parallel key)**
- Both choices are given side by side.
- Choices are numbered/lettered.

Advantages of bracketed key

- It is most commonly used
- The couplets are composed of alternates which are side by side for ready comparison
- It is economical in space
- It may be run forward or backwards by following the numbers

Disadvantage

- The relationship of the divisions is not apparent to the eye

Indented key (yoked key) on Rhododendron

- 1a.Flowers in shades of red

    2a. Flowers blood red, leaves oblong-ovate, leathery and thick matty texture- R.sikkimense

    2b.Fowers crimson red, leaves broad, oval to elliptic oblong, shiny green above- R.fulgens

- 1b.Flowers in shades of rose pink

    3a. Calyx 3-5 mm long, leaf undersurface covered by brown hair- R.wallichi

    3b. Calyx 1-2 mm long, leaf undersurface glabrous- R.campanulatum

Bracketed key (parallel key) on Rhododendron

- 1a. Flowers in shades of red--------go to 2
- 1b. Flowers in shades of rose pink------go to 3
- 2a.Flowers blood red, leaves oblong-ovate, leather and thick matty texture……R.sikkimense
- 2b.Fowers crimson red, leaves broad, oval to elliptic oblong, shiny green above- R.fulgens
- 3a. Calyx 3-5 mm long, leaf undersurface covered by brown hair- R.wallichi
- 3b. Calyx 1-2 mm long, leaf undersurface glabrous- R.campanulatum

Example of bracketed/justaposition/parallel keys

- Linked Key Style (also called “parallel”, “juxtaposition” or “bracketed” style):
- 1. Ovule solitary, basal 2
- – Ovules numerous, axile or free-central 3
- 2. Perianth green, membranous or absent; filaments free ....Chenopodiaceae
- – Perianth translucent and papery; filaments often united below ....Amaranthaceae
- 3. Placentation axile; leaves alternate ....Saxifragaceae
- – Placentation basal or free-central; leaves usually opposite 4
- Nested Key Style (also called “yoked” or “indented” style):
- 1. Ovule solitary, basal
- 2. Perianth green, membranous or absent; filaments free ....Chenopodiaceae
- 2. Perianth translucent and papery; filaments often united below ....Amaranthaceae
- 1. Ovules numerous, axile or free-central
- 3. Placentation axile; leaves alternate ....

How to Use a Dichotomous Key

- A dichotomous key, consists of a series of paired descriptions, called couplets.
- Beginning with the first pair of descriptions, read each thoroughly.
- Then examine the specimen and decide which description is most appropriate.
- In a printed dichotomous key you will find at the end of each description either a name or a number, indicating the next couplet to examine.
- In the computerized dichotomous key, you simply click on the graphic to move to the next couplet or the species or group identified.
- Continue in this manner until all the couplets have been exhausted, or until you reach a conclusion as to the identity of the specimen.
- Writing down the numbers of the couplets you go to in the key may help define problem areas in case an incorrect identification is made.
- The identification key presented in this knowledgebase was prepared for use in identifying only those species presented here.
- As there are thousands of species, be aware that using this key on a species outside the key's range will result in erroneous identification.

Key Development e.g for Acacia trees

- Reliable manuals of forest trees should be consulted.
- These include manual such as tree and shrubs of East Africa among others
- Field trips are carried out at different seasons and colored photographs are taken for the different organs of the different Acacia species.
- From the field observations, photographic data, and the literature reviewed, the characteristic
- Features of each Acacia species and variety are detected.
- These features are then put into contrasting couplets, whereupon by the method of elimination, a dichotomous key is developed.
- The main botanical characters adopted for constructing the key are shown below
- Main characteristics used in developing the acacia key

Morphological Organ	Detailed Morphological Characters
Thorns	presence, number at node, length and straightness
Leaves	number of pinnae and leaflets and their sizes
Stem	single, multi; and size
Crown	shape, size
Inflorescence	type: head or racemose; color
Fruit	pods shape, size, color and texture

-Depending on the botanical features detected from the field, photography work and
-Literature, a dichotomous botanical/dendrological key is developed.
-The key identifies, by scientific name (and common local names when found) twenty seven Acacia species and varieties
-The key is shown in table below

No.	Feature	Species
10	Spines short and curved (rarely straight) →20	
	Spines long and straight →100	
20	Spines claw-like, pinnae two pairs	*Acacia mellifera* (Vahl) Bent
	Trees larger in size, 2-3 pairs of pinnae, taller stem of crimson bark	*Acacia laeta* R. Br. Ex Benth
30	Bark black, smooth, powdery, whitish*→ 40	*Acacia polyacantha* (Willd.)
40	Spines in 3's, pod pale brown and hairy* → 50	*Acacia senegal* (L.) [Hashab
	Pod dark brown smooth and leathery	*Acacia asak* (Forssk.) Willd
50	White inflorescence, pod green-yellowish*→60	*Acacia hamulosa* Benth.
60	Spines many and scattered	*Acacia ataxacantha* DC.
70	Spines short and straight, inflorescence globose, pods orange & twisted*→80	*Acacia albida* Del. (*Faidhe* [Haraz]
80	Spines very small, inflorescence creamy*→90	*Acacia etbaica* Schweinf.
90	Pods indehescent and dark brown	*Acacia farnesiana* (L.) Willd
100	Inflorescence creamy, pods red and smooth	*Acacia negrii* Pichi.
110	Bark smooth and powdery, pod crescent-shaped →120*→130	
120	Bark reddish	*Acacia seyal var. seyal* Del.
	Bark whitish or creamy	*Acacia seyal var. fistula* Oliv. [Talhabiad]
130	Many pinnae, long brown pods	*Acacia hockii* De Wild.
	With blackish galls at the base of spines 140	*Acacia drepanolobium* (sjostedt.)
	Two types of spines, long and short*→180	
150	Both types of spines straight, leaflets relatively large and many	
155	Tree crown dense, umbrella-shaped, and pod flat	*Acacia gerrardii var. negeve*
	Crown narrow, pod narrow and acute	*Acacia gerrardii va* Chaudhary.
160	Large tree, crown irregular, pods contorted	*Acacia tortilis* (Forssk.) H *radiana* (Savi)
170	Smaller, multi-stemmed, dark bark	*Acacia tortilis* (Forssk.) H *tortilis*
	Relatively larger tree, bark lighter in color	*Acacia tortilis var. spiroca* Ex A.
180	Tree with umbrella-shaped crown, long spines →190*→210	
190	Spines>8 cm, pinnae>14 pairs	*Acacia siberana* [Kok]

Valid Publication

- A valid publication is a name that must be accompanied by a description of the plant to which it is applied or atleast by a reference of a previously effectively published description.
- Effective publication means that the name must be published in printed matter and made available to the public or made available in places where botanic research is carried out.
- This two basic conditions must be fulfilled before a properly formulated name can have any status in botanical nomenclature. A name that does not meet the requirements of the code, its rejected as nomen nudum.
- Names of family and lower taxa except those of certain hybrids published on or after 1st Jan 1958 are valid only if nomenclatural types are indicated.
- New names or combination published on or after 1st jan 1953 are not validly published without a clear indication of a rank of the taxon.
- It must be clearly indicated whether it’s a new genus i.e in botanical book is written or if it’s a new species then indicated species nova (sp nova), if it’s a new combination (combination nova = comb nov.).

Use of Apomixis in plant taxonomy

- Apomixis is a type of asexual reproduction in plants that allows them to create offspring that are genetically identical to the parent plant
- In apomixis, a plant creates a seed-like structure that contains an embryo that forms without fertilization.
- The embryo is a clone of the parent plant, and the seed also contains the endosperm, which provides food for the embryo.
- Once the seed matures, it can be dispersed, germinate, and grow into a new plant that is identical to the parent plant.

- The presence of apomixis in families is positively correlated with the number of genera per family. For example, 50% of families with more than 40 genera contain at least one apomict.
- Case studies of diverse families have shown strong correlations between the presence of apomixis in intra-familial taxa and the total number of genera in those taxa
- Apomixis is a reproductive mechanism that bypasses the sexual process and allows a plant to clone itself through seed.
- E.g In Pennisetum, a chromosomally unreduced egg cell develops into an embryo in an embryo sac derived from a vegetative nucellar cell. This type of apomixis is called **apospory.**

- Apospory is a reproductive process in plants where an egg cell develops into an embryo without fertilization by sperm.
- It's a type of apomixis, a reproductive mechanism that bypasses the sexual process
- Apomixis is a genetically controlled asexual reproduction method that produces seeds without fertilization. It has many uses in plant breeding, including:

1. Developing superior cultivars
2. Developing true-breeding hybrids
3. Commercial production of hybrids
4. Incorporating genes into new genotypes
5. Shortening the time required to develop a new variety
6. Creating forage cultivars

- Apomixis is a reproductive mechanism that can be important in plant taxonomy because it can impact the biogeographic distribution of cytotypes and genetic variation at the population level. Here are some ways apomixis is important in plant taxonomy:

(i) Taxonomic units

- In modern systematics, taxonomic units are phylogenetic groups that reflect common diversification processes. However, it can be difficult to define species in agamic complexes where apomixis occurs.

(ii) Geographic differences

- The relative proportions of apomictic and sexual species can differ geographically. For example, in the fern genus Pteris, the highest frequencies of apomixis were found in Asia, the Indian subcontinent, and Malesia and Indochina.

(iii) Facultative apomixis

- Facultative apomixis is a reproductive process in plants where both sexual and apomictic seeds are produced
- Facultative apomixis exists at the population and individual levels, making it difficult to correlate sex and apomixis with speciation and extinction rates on a phylogenetic tree.

TAXONOMIC RESOURCES

Herbarium

- A herbarium is a collection of plant samples preserved for long term study.
- These materials may include pressed and mounted plants, seeds, woods sections, pollen, microscopic slides, frozen DNA extractions and fluid preserved flowers or fruits, all are generally referred to as herbarium specimens.
- The term herbarium also refers to a building where pressed plants on sheets are stored or the scientific institute that not only stores but researches these specimens.
- Worldwide, there are 300 million specimens. Herbaria are usually associated with Universities, Museums or Botanical gardens.
- The first is believed to have been established in 1570 in Bologna, Italy by Luca Ghini.
- There are now around 4000 herbaria in over 165 countries. A world catalog of public herbaria called Index herbarium is published periodically by the International Association for Plant Taxonomy.
- Herbarium has been described as the back bone of taxonomy. A modern herbarium includes; Diverse collection of flowering plants e.g gymnosperm, fern mosses, liverworts, lichens, fungi, algae and fossils.

List of largest herbaria in the world

- 1) Natural history museum
- 2) Royal botanical Garden , KEW, London
- 3) Linear society of London
- 4) Le Jordrin Des Plantes- French
- 5) Upselle- swedon
- 6) Copenhagen- Denmark
- 7) Gurcy Herbarium- Harvard University
- 8) New York botanical garden. New York
- 9) Linder society of London
- 10) University of Florida Herbarium (oldest). Has 470,000 specimens it's the 4th largest herbarium in the southern western United States. Most specimens are vascular plants, both pressed and mounted specimens
- Founded in 1902 in Amani, Tanzania, the East African Herbarium (EA) at the National Museums of Kenya maintains the largest botanical collection in tropical Africa with over 1 million specimens, comprising mostly vascular plants

Preparations of herbarium specimen (Herbarium techniques)

- Herbarium specimen are accurately documented and stored in accordance to laid down rules.
- The material are usually in dried form, mounted on a sheet, but depending upon the material may also be kept in alcohol
- or their preservatives. To preserve their form and color, plants collected in the field are spread flat on sheets
- on newsprint and dried usually in a plant press between blotter or absorbent papers.
- The specimens which are then mounted on sheets of stiff white paper are labeled with all essential data e.g date and place found, description of the plants, altitude and special habitat conditions. The sheet is then placed in a protective case.

- As a precaution against insect attack, the pressed plant is frozen or poisoned and the case disinfected. Conifer cones and palm fronds may be stored in labeled boxes because they are bulky, so cannot be mounted.
- Representative flowers or fruits may be dipped in formaldehyde to preserve their three dimension structure.
- Small specimen i.e. Mosses and Lichen are often air dried and packaged in small paper envelopes.
- No matter the methods of preservation, a detailed information on where and when the plant was collected, habitat, color (since it may fade over time) and the name of collector is usually included.
- All the materials are then placed into pigeon holes in herbarium cabinets.
- When collecting the specimen, always two are collected of same species (identical), one should be pressed, these type is referred to as holotype.

Purpose of collecting plant specimens

- Herbarium specimens are used for a variety of purposes. They:

1) allow and support accurate identification of plants, algae, lichens and fungi
2) provide a permanent record for a species occurring at a particular time and place
3) form the basis of reliable distribution, habit and habitat information
4) document the introduction and spread of invasive weeds over time
5) are the reference point for the application of the scientific names
6) provide the basic biological material for taxonomists, ecologists and other researchers
7) serve as vouchers for seed collections, toxicological cases, biochemical analyses and biodiscovery.

Voucher specimens

- Voucher specimens are specimens collected of taxa that are the subject of research or investigation, generally resulting in a publication in a scientific journal or report.
- If lodged in a recognised herbarium, they will endure in the collection for many years, and their identity can be checked and verified at any future time from the voucher reference in the publication.
- This means that research and survey data will remain useful many years after publication, even though names and classifications change.
- The advent of genetic techniques in plant taxonomy has increased the need for well -annotated, correctly identified specimens to be stored as vouchers for published sequences, reducing the need to resample at a future time

- Collection of botanical material involves two activities
  - Gathering the specimens
  - Recording the information.

Collecting equipment

For general collecting you may require

1. Plant press that is light enough to carry around. This should include only a few cardboard
2. Corrugates, and a few dozen sheets of newspaper.
3. A field press with many more corrugates and more newspaper.
4. Spare corrugates and newspaper and some sheets of foam for bulky items
5. Secateurs to cut and trim specimens
6. GPS for recording an accurate latitude and longitude. Alternatively, mark the position on a
   topographic map.
7. A field notebook and pencil. This can be a pocket - sized notebook or a book of pre-printed
   specimen labels may be used.
8. Large and small plastic bags, to hold specimens temporarily
9. Small brown paper bags for collecting fruits, seeds, bryophytes and lichens
10. A hand lens
11. Gloves, for handling prickly plant material or plants with corrosive sap
12. Tie -on tags, often called jewellers tags
13. Felt tipped pens and pencils for numbering collection and writing notes

- For collecting specimens from trees you will need:

1. a throwing rope
2. a hard hat
3. binoculars to help you locate the optimum material.

Plant press

Selecting the plant material

- Select vigorous, typical specimens. Avoid insect-damaged plants.
- Choose individuals that show the variation in leaf, flower and fruit size.
- It may be important to show morphological variation, involving the collection of individuals of different sizes or ages.
- Collect at least two sets of specimens (duplicates) and number each set.
- Keep one set for your reference, and send the duplicate set to the Herbarium for identification or as a voucher if required.

- A good specimen includes stems, leaves, flowers and fruits.
- Basal parts of grasses, sedges, ferns and bulbous plants are essential for identification.
- Underground parts e.g. tubers, rhizomes are important for some plant groups.
- The plant material should be fertile i.e. in flower or fruit (both if possible), as these characteristics are often vital for identification.
- Some time should be spent looking at a number of individuals, and choosing one with a number of flowers or more mature fruits.

Features of the plant

- When collecting from trees or large shrubs, distinctive or notable features should be recorded, for example branching habit, height and width of the plant and details of the bark.
- You may need to collect more than one specimen to show the range of variation that is present, for example mature and immature parts, juvenile and adult leaves, coppice shoots.
- If the plant is dioecious, with male and female flowers on different plants, collect from each plant and label the specimens A & B.

Handling plants during collection

- For best results, specimens should be pressed within a few minutes of being removed from the plant.
- Many species wilt and fade soon after collection.
- A day press is convenient for short trips
- If specimens cannot be pressed at the point of collection, for example if it is raining or on steep terrain, they may be stored in large plastic bags.
- The bags should be kept moist, and the specimens not jammed in too tightly.
- Make sure that each bag is correctly labelled, using one bag per collection site.
- However, storing specimens in plastic bags is not recommended
- because it is easy for specimens to become damaged or mixed and they are more likely to go mouldy

Data to be recorded in the field

- Many botanists use a small notebook to record information about the specimens they collect, and the sites at which they collect them.
- The following information should be recorded before you leave the collection site, otherwise the chance of giving erroneous information is greatly increased.

1. A preliminary descriptive locality.

- This can be modified later after consulting maps, but the preliminary locality reminds you about which site it is.

2. GPS location. This can be recorded as latitude and longitude.

3. Habitat (site) data, including landform, slope, dominant plant species, structural formation, for example “open forest”, “open woodland”, “shrubland” or regional ecosystem.

- Soil type and geology should be added if known. Record whether the collection site was a disturbed site such as a roadside, burnt area or grazed paddock.

4. Information about the individual species collected at the site, particularly height, form, presence of rhizomes, presence and colour of sap in cut stems, colour of new growth and flower colour.

- Flower colour often changes on drying.
- Also record the relative abundance of the species, particularly for rare or threatened species or weeds.

Pressing and Drying specimens

- It is essential to dry the specimens fairly quickly, to prevent the onset of fungal attack. Fungus affected specimens are of limited value to a Herbarium.
- In warm environments, the damp papers and corrugates must be replaced daily.
- In drier inland areas, every 2 or 3 days will suffice.
- After changing the papers and corrugates, the specimens should be again tightly packed in the press, otherwise they will not remain flat

- At the first paper change, adjust any undesirable features of the specimen, for example folded leaves, leaves all showing the same face, flowers obscured by leaves.
- Such adjustments will not be possible once the specimen has fully dried.
- Look for any evidence of insect attack, especially caterpillars in flowers, and remove any insects found

Writing a final label to accompany the specimen

- The data that accompanies a herbarium specimen is just as important as the specimen itself.
- Even a very good quality specimen is of no use to a Herbarium unless it has a written label with the information detailed below:

1. **Collector’s name:** [mandatory] the name(s) of the person/people who collected the specimen,

- preferably no more than 2 people. Don't include everyone who was on the trip.

2. Collector's number: [optional] A unique number, usually sequential, given by the collector as a private record.

3. Date of collection: [mandatory

4. Botanical name: [optional] If you are unsure of the identity it is still helpful to suggest a name, or at least a genus or local name
5. Locality: [mandatory] A written description of the precise collection locality is necessary, as well as a latitude and longitude reading. A GPS location alone is not sufficient. The locality description should be detailed enough to enable any person to revisit the approximate place of collection.

- Commonly, the description includes distance and/or direction from a town or a well known locality that is on a readily available map.
- It should be meaningful to someone not familiar with the local area

6. Plant use: It is important to indicate the local socio-economic uses of the plant as this can be critical information for research

Identification

- Plant identification requires that you have as much of the plant as possible, and in some occassions this cannot be accomplished if you are dealing with a sterile specimen.
- Makes use of identification keys

- Multiple plant identification books are available for use at local libraries
- Try to find a book that uses an illustrated glossary to assist in defining terms you might encounter when using the dichotomous key to identify your collection.
- It is always helpful to use a book that includes line illustrations, if not images of plants.
- Make sure the text you are using is both relevant and current to your geographic area

Mounting

- There is an art to the mounting of plant specimens to their archival quality cardstock backing.

- Mounting a collection on heavy cardstock provides the plant specimen with the physical support that is required to allow the specimen to be continually handled and stored with a minimum of damage.
- Use acid-free paper of good quality (100% cotton rag is used in the herbarium).
- Elmer's glue works well because it is of near-archival quality.
- The label is always glued down first in the lower right-hand comer.

- Determine which side of the dried plant demonstrates the best characteristics and position it on the paper before applying glue.
- Then, turn it over and outline the edges of all parts with a thin stream of glue.
- Turn the plant back over and carefully place it on the paper, blotting up excess glue as you gently press it to the paper.
- Any pieces of plant that become detached should be placed in a paper envelope glued to the sheet (often called a “fragment pack”).
- Place a sheet of wax paper over the entire specimen, and then place weights or heavy books on top of the specimen until the glue dries

Preservation and Storage

- Herbarium specimens will last hundreds of years if properly cared for.
- Preserved herbarium specimens provide secure and easily accessible collection for scientific research

- Herbarium specimens will last for hundreds of years if properly cared for.
- The best conditions for storage include low temperature, low humidity, low light, and infrequent handling.
- Certain beetles will destroy plant specimens.
- You can kill insects in dried plant specimens by freezing them for three or four days, and keep them pest-free in a tightly-sealed plastic bag.
- In a herbarium, plants are stored in folders within airtight cabinets.

- Any dried plant material is frozen before entering the herbarium, and the space is periodically treated with a pyrethrin spray (an organic insecticide made from chrysanthemums).
- In the herbarium, plants can be organized alphabetically by the plant family to which they belong, then by the genus, then by geographic area and the species to which they belong
- Can also be organized phylogenetically based on evolutionary relationships
- This organization facilitates the use of the herbarium by researchers and the public.

Grass
Ottawa, Canada
Near stream
Maple - Birch

Preservation agents of herbarium specimens

- Silica gels are reliable substances to preserve field collected leaves for molecular studies of variations in DNA.
- Chemical treatment i.e. Ethanol, Carney's solution, chloroform. Ethanol results in DNA degradation, so silica gel is the best.
- Drying tissues also preserve DNA integrity at least over several month periods.
- Arsenic chloride and mercury II chloride are used to control beetles and fungi but are not discharging because of cumulative poisoning.
- Mercury II sublimes and makes it dangerous.
- Myetoy plus i.e. *Luryl chloroprnate* with pyrethrum is used.

FUNCTION OF THE HERBARIUM

- Herbarium of today is a resource, training and science institution that serve as a;
- As a reference center-A herbarium is a fundamental resource of identification of plants by practicing taxonomist field species, conservationists, nationalize and environmentalists.
- As a documentation faculty- A herbarium is a requisitory for collection of historic significant such as types of new taxons, representation of new discoveries, economically important introductions, set of specimens providing the basis for floristic, revisionality, Monographic studies and collections showing interpretation of different authorities through the years.
- As a data store house-Its collection are used by genetists studying for new sources of DNA materials, chemists studying alkaloids pharmacists and other researchers
- The herbarium is an educational resource, routinely develops and maintains collections for courses in local flora, horticulture, gene taxonomy, advanced systematics and special groups of plants such as aquatic fungi, grasses and trees.
- Its collection serves as standard resource for graduate students working on problem selection and visibility in advanced degree programmes.

- The herbarium, like a library is a service institutions, collection constitutes a vast reservoir of facts about plant, some of these collection are no longer replaceable.
- Herbarium are laboratories for much systematic research, the plant collections are basic to scholarly research taxonomists and training of student in systematic.
- Are used for studies in which the differences between plant species are evaluated and described (monographs) or in which the species growing in a region are reported (floras).
- Plant systematic is the core research emphasis for herbarium staff. Herbarium specimens are also useful in many other disciplines. Example of other uses includes:
  - **Agronomy /forestry** -: Locate wild plants that have potential as new crops and forage , document plants used as crops and forage, locate and identify relatives of cultivated species for use in breeding program, identify and document.
  - **Ecology-:** Locate and document plant communities or individuals species, identify and document invasive species.
  - **Entomology-**: Locate food plants and habitat for insects, document pollination ecology.
  - **Forensic-:** Identify plant fragments that might yield evidence in legal cases, in some cases plant fragments may be used to determine if a person has lived in a certain place.
  - **History-:** Retrace of early naturalist track down early place names, determine historic plant ranges.

Botanic gardens and Arboretum

- A botanical garden or botanic garden is a garden with a documented collection of living plants for the purpose of scientific research, conservation, display, and education.
- In a botanical garden, plants are labelled with their botanical names appended
- Botanical gardens provide information on the protection of endangered species and propagation of rare plants.
- Botanical Gardens help us to study different types of plants.
- It preserves those plants which are endangered.
- Used for scientific research.
- Helps us to understand the nature of the plants.
- Botanical gardens devote their resources to the study and conservation of plants, as well as making the world's plant species diversity known to the public

- A botanic garden can have all kinds of plants: bushes, shrubs, bedding plants, flowers, vegetables, herbs, trees.
- Some of the ways in which plants can be arranged and featured include natural settings, fields, beds, around walkways, in ponds and in sitting areas.
- Greenhouses may be a part of the botanic garden.
- They present opportunities to grow and display plants in climate-controlled areas so that exotic plants and plants that will not grow outside their native climates can be studied

- An arboretum is a specialized botanical garden that features trees and other woody plants but may also include other kinds of plants.
- An arboretum is a “botanical garden” containing living collections of woody plants intended at least partly for scientific study, but also to inspire curiosity and build knowledge about plants and wooded landscapes in order to enhance life, preserve nature, and advance sound stewardship practices.

- Although the birth of the “garden” dates back to the Zhou dynasty in China, the modern concept of a botanical garden originated in Europe (Italy's Padova Botanic Garden was built in 1545).
- Today, there are about 2500 botanical gardens in the world
- Together, these botanical gardens cultivate more than 6 million accessions of living plants, representing around 80,000 taxa, or about one-quarter of the estimated number of vascular plant species in the world
- These gardens thus play a central role in the ***ex situ conservation*** and exploration of global plant biodiversity
- Indeed, one of the targets of the Global Strategy for Plant Conservation (GSPC) is to have 70% of the world's threatened plant species conserved ex situ
- Botanical gardens also have an important role in the preservation of species necessary for human use and well-being and this role is likely to become increasingly important as climate change becomes more severe

- The range of scientific activities conducted by botanical gardens often includes conservation, propagation, horticulture, seed science, taxonomy, systematics, genetics, biotechnology, education, restoration ecology, public education, and much more
- Plant diversity is currently being lost at an unprecedented rate, resulting in an associated decrease in ecosystem services.
- Currently about a third of the world's 300,000–450,000 vascular plant species face extinction due to a variety of devastating anthropogenic activities, including over-harvesting, over-exploitation through destructive agricultural and forestry practices, urbanization, environmental pollution, land-use changes, exotic invasive species, and global climate change
- Therefore, botanic gardens come handy to restore these plant species, their habitats and ecosystems that are being lost as a result of these factors

- An organization needs to meet the following criteria to be considered a botanic garden:
  1. A reasonable degree of permanence
  2. An underlying scientific basis for the collections
  3. Proper documentation of the collections, including wild origin
  4. Monitoring of the plants in the collections
  5. Adequate labelling of the plants
  6. Open to the public
  7. Communication of information to other gardens, institutions and the public
  8. Exchange of seed or other materials with other botanic gardens, arboreta or research institutions
  9. Undertaking of scientific or technical research on plants in the collections
  10. Maintenance of research programs in plant taxonomy in associated herbaria

IDENTIFICATION, RELATIONSHIPS AND DISTRIBUTION OF GYMNOSPERM AND ANGIOSPERM TREES

History and Distribution of Gymnonosperms and Angiosperms

- The flowering plants (angiosperms), also known as Angiospermae or Magnoliophyta, are the most diverse group of land plants. Angiosperms are seed-producing plants like the gymnosperms and can be distinguished from the gymnosperms by a series of synapomorphies (derived characteristics).
- These characteristics include flowers, endosperm within the seeds, and the production of fruits that contain the seeds.
- The ancestors of flowering plants diverged from gymnosperms around 245–202 million years ago, and the first flowering plants known to exist are from 140 million years ago.

- They diversified enormously during the Lower Cretaceous and became widespread around 100 million years ago, but replaced conifers as the dominant trees only around 60-100 million years ago.
- There are between 700 and 900 extant or currently living species of Gymnosperms.
- It is widely accepted that the gymnosperms originated in the late Carboniferous period.
- This appears to have been the result of a whole genome duplication event around 319 million years ago.
- Early characteristics of seed plants were evident in fossil progymnosperms of the late Devonian period around 380 million years ago.
- It has been suggested that during the mid-Mesozoic era, pollination of some extinct groups of gymnosperms were by extinct species of scorpionflies that had specialized proboscis for feeding on pollination drops.

- The scorpionflies likely engaged in pollination mutualisms with gymnosperms, long before the similar and independent coevolution of nectar-feeding insects on angiosperms.
- Conifers are by far the most abundant extant group of gymnosperms with six to eight families, with a total of 65-70 genera and 600-630 species (696 accepted names).
- Conifers are woody plants and most are evergreens.
- The leaves of many conifers are long, thin and needle-like, others species, including most Cupressaceae and some Podocarpaceae, have flat, triangular scale-like leaves.
- Agathis in Araucariaceae and Nageia in Podocarpaceae have broad, flat strap-shaped leaves.
- Cycads are the next most abundant group of gymnosperms, with about 130 species.
- The other extant groups are the 75 - 80 species of Gnetales and one species of Ginkgo. Classification of Plants into Gymnonosperms and Angiosperms.
- Higher plants are often divided into two main groups: angiosperms and gymnosperms

- Angiosperms include all flowering plants which are often again divided into monocotyledonous and dicotyledonous plants.
- Both gymnosperms and angiosperms have vascular tissue and both produce seeds.
- However, the seeds of angiosperms are surrounded by the wall of the ovary of the flower which forms the fruit, whereas gymnosperms do not possess this structure.
- Ggymnosperms seeds are described as naked (Gymnosperm from the Greek: gymnos - naked, sperm - seed).
- Cuppressus lusitanica needles, Encephalartos sclavoi cone, about 30 cm long. Botanists place the angiosperms in the group (division) Angiophyta but the Gymnosperms do not form a coherent group and are separated into four divisions.

(i) Coniferophyta

- The Coniferophyta or conifers, are the most well known and dominant gymnosperms on the planet today.
- This group includes the Pines, Spruces, Junipers, Cedars, Yellowwoods etc.
- The high latitudes of the northern hemisphere are dominated by extensive forests of conifers.
- Pines of major economic importance provide much of the wood and paper pulp used today.
- In the pine family (Pinaceae) and other conifer families which produce cones, the seeds are borne naked on the surface of the scales of the cones.
- The cone forms a rigid protection for the seeds. In other families e.g. Yellowwoods (Podocarpaceae) and Junipers (Cupressaceae) the seeds are surrounded by berry-like structures.
- Although these may appear superficially like fruit they are not the same structures as the fruit of angiosperms.

(ii) Cycadophyta

- The cycads fall into this group including the genus Encephalartos from Southern Africa.
- These are slow growing palm-like plants with leaves which are borne together on the top of the trunk.
- The seeds are carried on the surface of the scales of cones in Encephalartos.

(iii) Gingkophyta

- This group contains only a single living species, Gingko biloba from China.

(iv) Gnetophyta:

- This is a mixed group of plants with certain characteristics in common with the Angiosperms (e.g. the xylem contains vessels and they have pollen-producing structures which superficially resemble stamens).
- The division includes a genus of tropical lianas (Gnetum), the joint-firs (Ephedra) and the very strange plant Welwitschia mirabilis which grows in the Namib Desert in Namibia.
- NB The oldest living organisms on earth are found amongst the gymnosperms and include the Welwitschia, some of which are between 1000 and 2000 years old and the Bristle-cone pine of the south western USA, some of which are estimated to be 4500 years old.
- The gymnosperms also contain the tallest trees, the Californian redwoods, which may reach 82m in height.

Angiosperms features

- Angiosperms have encased seeds and reproduce by methods of flowering.

- They possess an ovary which contains the seed which produces the fruit of the tree.
- Angiosperms themselves are split into monocots which have one leaf, and dicots which have two or more leaves.
- Monocots are commonly woody stemmed and are of large size. Bamboo is a typical example of a monocot.
- The anatomy of monocots is totally different to that of dicot trees. Dicot trees are further divided into twenty-five taxonomical Families.
- Dicots are responsible for producing the majority of hard wood.
- The kind of fruit usually associated with the angiosperm class of tree; include the acorn of the oak tree, and the cherry of the cherry tree.

Gymnosperms features

- All of the gymnosperm class of tree is of soft wood. The softwoods are further sub divided into four families.
- The family Cupressaceae includes the juniper, cypress, and cedar trees.
- Taxaceae contains the yew trees. Family Taxodiaceae contains the redwoods.
- The Pinaceae family contains the pine, fir, spruce, and larch trees.

Angiosperm Derived Characteristics

- Flowers
- The flowers, which are the reproductive organs of flowering plants, are the most remarkable feature distinguishing them from other seed plants.
- Flowers aid angiosperms by enabling a wider range of adaptability and broadening the ecological niches open to them.
- This has allowed flowering plants to largely dominate terrestrial ecosystems.

Bud of a pink rose

- Stamens with two pairs of pollen sacs. Stamens are much lighter than the corresponding organs of gymnosperms and have contributed to the diversification of angiosperms through time with adaptations to specialized pollination syndromes, such as particular pollinators. Stamens have also become modified through time to prevent self-fertilization, which has permitted further diversification, allowing angiosperms eventually to fill more niches. Reduced male parts, three cells. The male gametophyte in angiosperms is significantly reduced in size compared to those of gymnosperm seed plants. The smaller pollen decreases the time from pollination — the pollen grain reaching the female plant — to fertilization. In gymnosperms, fertilization can occur up to a year after pollination, whereas in angiosperms, fertilization begins very soon after pollination.

- The shorter time leads to angiosperm plants' setting seeds sooner and faster than gymnosperms, which is a distinct evolutionary advantage. Closed carpel enclosing the ovules (carpel or carpels and accessory parts may become the fruit). The closed carpel of angiosperms also allows adaptations to specialized pollination syndromes and controls. This helps to prevent self-fertilization, thereby maintaining increased diversity. Once the ovary is fertilized, the carpel and some surrounding tissues develop into a fruit. This fruit often serves as an attractant to seed-dispersing animals. The resulting cooperative relationship presents another advantage to angiosperms in the process of dispersal. Reduced female gametophyte, seven cells with eight nuclei. The reduced female gametophyte, like the reduced male gametophyte, may be an adaptation allowing for more rapid seed set, eventually leading to such flowering plant adaptations as annual herbaceous life-cycles, allowing the flowering plants to fill even more niches.

Endosperm

- In general, endosperm formation begins after fertilization and before the first division of the zygote. Endosperm is a highly nutritive tissue that can provide food for the developing embryo, the cotyledons, and sometimes the seedling when it first appears. These distinguishing characteristics taken together have made the angiosperms the most diverse and numerous land plants and the most commercially important group to humans. The major exception to the dominance of terrestrial ecosystems by flowering plants is the coniferous forest.

NOMENCLATURE SURVEY OF SELECTED FAMILIES FROM THE FLORA OF EAST AFRICA

Introduction to Angiosperm Families

- In the description of Angiosperms, family is the most useful taxonomic unit. Ranks higher than family are not of much practical significance and are used mostly in classification systems and academic discussions.
- The taxonomic category genus also does not get much importance as plants are scientifically described in binomial nomenclature.
- Use of only the generic name isolated from the specific name may lead to confusion.
- The genus Solanum includes several species of which Solanum tuberosum alone represents the potato plant.
- Hence, potato can be described only as Solanum tuberosum and not just as Solanum.
- The size of angiosperm families is highly variable. Some families contain a single species (monotypic family) some have a single genus with several species (unigeneric family).
- The number of species determines size of the family. Let us have a look at one representative of the angiosperm families; Solanaceae

Brief Description of some Angiosperms and Gymnosperms Families

SOLANACEAE

- the nightshade, or potato, family of flowering plants (order Solanales),
- with 102 genera and nearly 2,500 species, many of considerable economic importance as food and drug plants.
- Among the most important of these are the potato (*Solanum tuberosum*); eggplant (*S. melongena*); tomato (*Lycopersicon esculentum*); garden, or capsicum, pepper (*Capsicum annuum* and *C. frutescens*); tobacco (*Nicotiana tabacum*); deadly nightshade, the source of belladonna (*Atropa belladonna*); the poisonous jimsonweed (*Datura stramonium*) and nightshades (*S. nigrum*, *S. dulcamara*, and others); and many garden ornamentals, such as the genera *Petunia*, *Lycium*, *Solanum*, *Nicotiana*, *Datura*, *Salpiglossis*, *Browallia*, *Brunfelsia*, *Cestrum*, *Schizanthus*, *Solandra*, *Streptosolen*, and *Nierembergia*.

- Members of the Solanaceae family are found throughout the world but are most abundant and widely distributed in the tropical regions of Latin America, where about 40 genera are endemic.
- Very few members are found in temperate regions, and only about 50 species are found in the United States and Canada combined. The genus Solanum contains almost half of all the species in the family, including all the species of wild potatoes found in the Western Hemisphere. The poisonous alkaloids present in some species of the family have given the latter its sombre vernacular name of “nightshade.”
- Members of the family are characterized by solitary or clustered flowers with sepals and petals, five in number and fused; five stamens; and a superior ovary (i.e., one situated above the attachment point of the other flower parts), composed of two fused carpels (ovule-bearing segments)

Lycopersicon esculentum (Tomato)

Key to Solancaeae genera

1	Fruit a berry, sometimes firm or slightly dry	2
	Fruit a capsule	13
2	Flowers solitary or in few-flowered clusters at nodes	3
	Flowers in definite racemose, cymose, subumbellate or panicle-like inflorescences	8
	Back to 1	
3	Calyx enlarged in fruit, becoming larger than berry and often enclosing it	4
	Calyx not or scarcely enlarged in fruit, always shorter than berry	6
	Back to 2	
4	Corolla pale blue to mauve	*Nicandra*
	Corolla yellow or yellow-green, often with dark spots	5
	Back to 3	
5	Mature berry yellow or yellow-green	*Physalis*
	Mature berry bright red	*Withania*
	Back to 4	
6	Corolla stellate with lobes as long as tube	*Capsicum*
	Corolla tube narrow, funnel-shaped or urn-shaped, with lobes much shorter than tube	7
	Back to 3	
7	Spinescent shrubs or herbs	*Lycium*
	Non-spinescent scrambling or climbing herbs	*Salpichroa*
	Back to 6	
8	Leaves pinnatisect; corolla yellow and berry red (previously Lycopersicon)	*Solanum*
	Leaves entire or lobed; corolla white, blue to dark purple, rarely pink, if yellow, orange-yellow or green yellow then berry white or black, never red	9
	Back to 2	
9	Corolla lobes valvate in bud	10
	Corolla lobes rolled or folded	11
	Back to 8	
10	Corolla orange-yellow or green-yellow; anthers versatile with connective small; berry white or black	*Cestrum*
	Corolla pink; anthers basifixed with connective large and conspicuous; berry dark red (previously Cyphomandra)	*Solanum*
	Back to 9	

ASTERACEAE (Compositae)

- Asteraceae or Compositae (commonly referred to as the aster, daisy, composite, or sunflower family), is a very large and widespread family of flowering plants (Angiospermae).
- The family includes over 32,000 currently accepted species, in over 1,900 genera (list) in 13 subfamilies.
- In terms of numbers of species, the Asteraceae are rivaled only by the Orchidaceae.
- Which is the larger family is unclear, because of the uncertainty about how many extant species each family includes.
- Nearly all Asteraceae bear their flowers in dense heads (capitula or pseudanthia) surrounded by involucral bracts.
- When viewed from a distance, each capitulum may appear to be a single flower. Enlarged outer (peripheral) flowers in the capitula may resemble petals, and the involucral bracts may look like a calyx.
- The name Asteraceae comes from the type genus Aster, from the Ancient Greek ἀστήρ, meaning star, and refers to the star-like form of the inflorescence.
- The alternative name Compositae is still valid under the International Code of Nomenclature for algae, fungi, and plants.
- It refers to the "composite" nature of the capitula, which consist of a few or many individual flowers.

- Most members of Asteraceae are annual or perennial herbs, but a significant number are also shrubs, vines, or trees.
- The family has a cosmopolitan distribution, with species ranging from subpolar to tropical regions, colonizing a wide variety of habitats.
- The largest proportion of the species occur in the arid and semiarid regions of subtropical and lower temperate latitudes.
- The Asteraceae may represent as much as 10% of autochthonous flora in many regions of the world.
- Asteraceae is an economically important family, providing products such as cooking oils, leaf vegetables like lettuce, sunflower seeds, artichokes, sweetening agents, coffee substitutes and herbal teas.
- Several genera are of horticultural importance, including pot marigold (Calendula officinalis), Echinacea (coneflowers), various daisies, fleabane, chrysanthemums, dahlias, zinnias, and heleniums.
- Asteraceae are important in herbal medicine, including Grindelia, yarrow, and many others.

- On the other hand, many Asteraceae are considered weeds in various circumstances.
- Of these, many are invasive species in particular regions, often having been introduced by human agency.
- Examples include various tumbleweeds, Bidens, ragweeds, thistles, and dandelion.
- Dandelion was introduced into North America by European settlers who used the young leaves as a salad green.

The common Sunflower *(Helianthus annuus)*

ANACARDIACEAE (Mango family)

- A family of dicotyledonous trees and shrubs, often with resinous bark.
- Its members are mostly tropical but some are found in temperate regions.
- In some species the resin is an important source of tannin, and in others it is used for gum, mastic, turpentine and varnish.
- The leaves are simple or compound, usually alternate, the flowers small and regular with three to five sepals, three to five petals, three to ten stamens (occasionally many) and the fruit commonly a drupe
- Genera that are represented in East Africa include *Anacardium, Mangifera, Rhus, Schinus*

POACEAE (Gramineae)-(Grass family)

- Poaceae or Gramineae is a large and nearly ubiquitous family of monocotyledonous flowering plants known as grasses.
- It includes the cereal grasses, bamboos and the grasses of natural grassland and species cultivated in lawns and pasture.
- The latter are commonly referred to collectively as grass.
- With around 780 genera and around 12,000 species, the Poaceae is the fifth-largest plant family, following the Asteraceae, Orchidaceae, Fabaceae and Rubiaceae.
- The Poaceae are the most economically important plant family, providing staple foods from domesticated cereal crops such as maize, wheat, rice, barley, and millet as well as feed for meat-producing animals.
- They provide, through direct human consumption, just over one-half (51%) of all dietary energy; rice provides 20%, wheat supplies 20%, maize (corn) 5.5%, and other

- Grasses have stems that are hollow except at the nodes and narrow alternate leaves borne in two ranks.
- he lower part of each leaf encloses the stem, forming a leaf-sheath.
- The leaf grows from the base of the blade, an adaptation allowing it to cope with frequent grazing.
- Grasslands such as savannah and prairie where grasses are dominant are estimated to constitute 40.5% of the land area of the Earth, excluding Greenland and Antarctica.
- Grasses are also an important part of the vegetation in many other habitats, including wetlands, forests and tundra.
- Though they are commonly called "grasses", seagrasses, rushes, and sedges fall outside this family.
- The rushes and sedges are related to the Poaceae, being members of the order Poales, but the seagrasses are members of order Alismatales

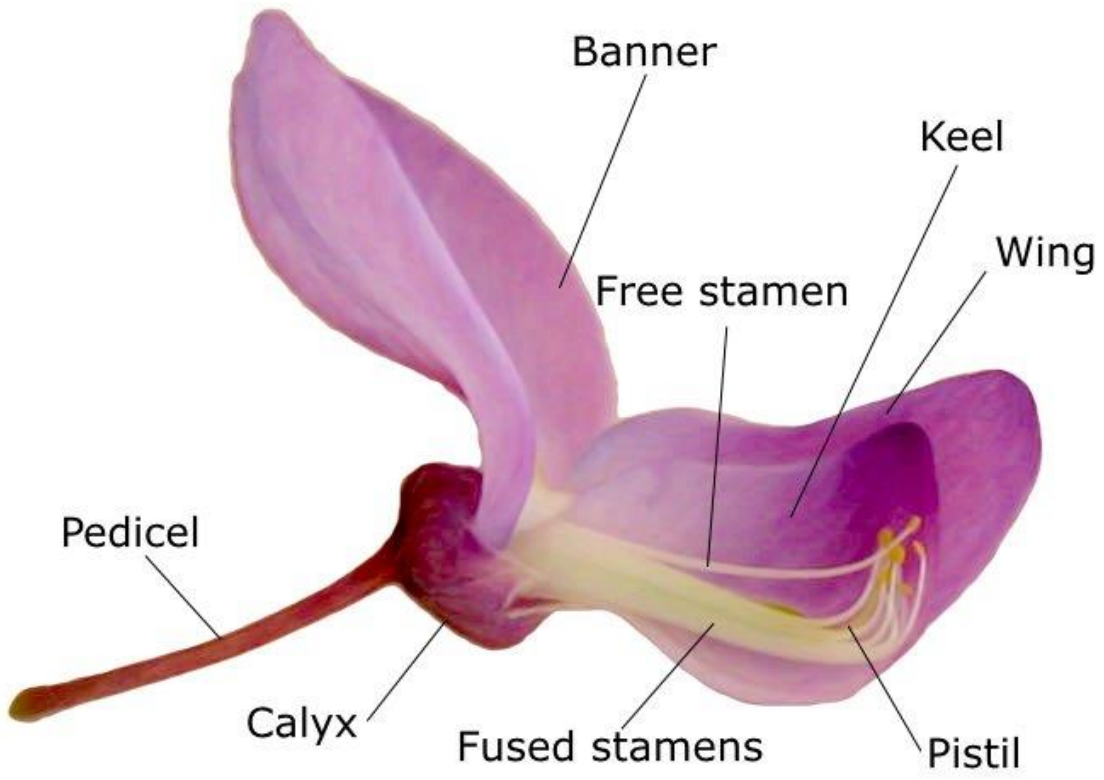
FAMILY FABACEAE (LEGUMINOSAE)

- Fabaceae or Leguminosae (the pea or bean family) are the Legumes
- The Fabaceae is one of the largest families of flowering plants with 18,000 species classified into around 650 genera
- The Fabaceae is an extremely diverse family.
- The Fabaceae constitute one of humanity's most important groups of plants.
- Legumes are used as crops, forages and green manures.
- They also synthesise a wide range of natural products such as flavours, drugs, poisons and dyes.

Characteristics Of Fabaceae

- Legumes are a significant component of nearly all terrestrial biomes, on all continents (except Antarctica).
- Some are fresh-water aquatics, but there are no truly marine species.
- The species within the family range from dwarf herbs of arctic and alpine vegetation to massive trees of tropical forest.
- The principal unifying feature of the family is the fruit, a pod, technically known as a Legume.
- The Legume is modified in many ways to facilitate dispersal by animals, wind and water.
- The family is usually divided into three sub-families: Papilionoideae, Caesalpinioideae and Mimosoideae.
- These sub-families are sometimes recognised as three separate families: Papilionaceae, Caesalpiniaceae and Mimosaceae.
- The three subfamilies are generally identifiable by their flowers.

(i) Subfamiy: Papilionoideae e.g Beans



- The Papilionoideae is the largest of the three subfamilies with about two-thirds of all the genera and species of the family.
- It is also the most widespread, extending further into temperate regions than the other two subfamilies.
- The majority of the species are herbaceous, although there are some trees and shrubs, e.g. Laburnum and Gorse (*Ulex*).
- Papilionoideae are easily recognised by their characteristic papilionaceous (butterfly-like) flowers.

- The flower is irregular (zygomorphic) and is made up of five petals; a ‘banner’ petal, two wing petals, and two petals partially fused together to form a boat-shaped keel.
- The keel encloses the stamens, which are not visible externally.
- The Papilionoideae contains most of the important leguminous crop species such as the Soya Bean (*Glycine max*), Common Pea (*Pisum sativum*), Chickpea (*Cicer arietinum*), common Bean (*Phaseolus vulgaris*), Lentil (*Lens culinaris*) and Peanut (*Arachis hypogaea*).

(ii) Subfamily Caesalpinioideae: e.g *Delonix regia, Senna seamea*

- The majority of the Caesalpinioideae are tropical or subtropical trees and shrubs.
- The flowers of the Caesalpiniceae are irregular (zygomorphic) with five petals which are not differentiated into standard, wings and keel.
- The stamens are visible externally.
- Several species in this subfamily are well-known tropical ornamentals such as Flamboyant (*Delonix regia*), Barbados Pride (*Caesalpinia spinosa*) and the Pride of Bolivia (*Tipuana tip*).
- Alexandrian Senna (*Senna alexandrina*) is a commercially grown medicinal plant, known for its purgative qualities.

- The pride of Bolivia

(iii) Subfamily Mimosoideae e.g Acacia

- Like the Caesalpinioideae, the majority of the Mimosaceae are tropical or subtropical trees and shrubs.
- The Mimosaceae are characterised by their small, regular (actinomorphic) flowers crowded together, generally into spikes or heads which resemble a pom-pom.
- The stamens have become the most attractive part of the flower, the five petals inconspicuous.
- The leaves are predominately bipinnate.
- Examples of genera within this subfamily are *Acacia* and *Mimosa*. Certain

Economic Importance Of The Fabaceae

- In terms of economic importance the Leguminosae is the most important family in the Dicotyledonae.
- Legumes are second only to the Grasses (cereals) in providing food crops for world agriculture.
- In comparison to cereal grains the seeds of Legumes are rich in high quality protein, providing man with a highly nutritional food resource.
- The major staple foods such as beans, soya, lentils, peas and chickpeas are all legumes.
- The total world value for leguminous crops is thought to be approximately two billion US dollars per annum.
- Many more legumes are local food plants.
- In addition to those legumes cultivated for human consumption many yield important fodders, green manures and forages, e.g. *Lupinus* (Lupin), *Medicago* (Alfalfa) and *Trifolium* (Clover).

- Legumes are utilised for a variety of other purposes including timber, medicine, tannins and gums.
- Various species of *Lonchocarpus* and *Derris* are the source of rotenone, which is used as an insecticide, fish poison or molluscicide.
- Some Legume trees yield valuable resins, used in varnishes, paints and lacquers, e.g. *Copaifera* and others are the source of dyes, e.g. *Indigofera* which is cultivated for a blue dye.
- Play a critical role in nitrogen fixation
- The economic importance of the family is likely to increase as human pressure places greater demand on marginal land.
- Many Legume species are characteristic of open and disturbed places and are thus well adapted to grow under poor conditions.

- *Acacia* species are extremely important economically. An extract from the bark of the Golden Wattle (*Acacia pycnantha*) is used in tanning, several species, such as Australian Blackwood (e.g. *Acacia melanoxylon*) provide useful timbers and some (e.g. *Acacia senegal*) yield commercial gum arabic, which is used in a wide range of industrial processes.

Other families

S/No	Standard name	Former name	Common name
1.	Arecaceae	Palmae	The palm family
1.	Apiaceae	Umbelliferae	The carrot family
1.	Lamiaceae	Labiatae	The mint family
1.	Brassicaceae	Cruciferae	The cabbage family