5th SEM B. Sc BOTANY

CALICUT UNIVERSITY

ANGIOSPERM MORPHOLOGY & SYSTEMATICS

2018 ADMISSION

Prepared by

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Syllabus

BOT5B06T ANGIOSPERM MORPHOLOGY& SYSTEMATICS

[Total 99 hours: Theory 63, Practical 36]

ANGIOSPEM MORPHOLOGY Theory 18 - Hrs. [1hr. per week]

I. Morphological description of a flowering plant; Plant habit 1 hr.
a. Root: Types - Tap root, fibrous root; Modifications - Definition with examples -Storage, aerial, pneumatophores, buttress.
b. Stem: Habit - Acaulescent, Caulescent, Cespitose Prostrate, Repent, Decumbent, Arborescent, Suffrutescent (Definition with examples only); Modification - Underground, Aerial, Subaerial with examples.
c. Leaves: Lamina, petiole, leaf tip, leaf base, stipule, pulvinus; Phyllotaxy; types - simple and compound; shapes of lamina; leaf tip; leaf base; leaf margin; leaf surface features: hairiness - tomentose, glabrous, scabrous, strigose, hispid.
II. Inflorescence: racemose, cymose and specialised (cyathium, hypanthodium, coenanthium verticillaster, thyrsus).
III. Flower: Flower as a modified shoot - detailed structure of flowers – floral parts -their arrangement, relative position, cohesion and adhesion - symmetry of flowers - floral diagram and floral formulae.
IV. Fruits – simple, aggregate and multiple with examples; Seed structure -dicot and monocot - albuminous and exalbuminous, aril, caruncle; Dispersal of fruits and seeds - types and adaptations.

References

1. Gangulee, H.C., J.S. Das & C. Dutta. 1982. College Botany (5th Ed.) New Central Book Agency, Calcutta.

2. George, H.M. Lawrence. 1951. Introduction to Plant Taxonomy. Mac Millan comp. Ltd., New York.
3. Simpson, M. G. 2006. Plant Systematics. Elsevier Academic Press, London
4. Ananta Rao T. Morphology of Angiosperms.

SYSTEMATICS Theory: [2 ½ hrs. per week]

Module-I

1. Components of systematics: identification, description nomenclature and classification; objectives and importance of systematics.
2. Development of Plant systematics: Folk taxonomy, Herbalists, Early taxonomists: Caesalpino, Bauhin, Linnaeus; Natural systems; Phylogenetic systems;Phenetics; Cladistics (Brief account of various phases).

3. Systems of classification: Artificial – Linnaeus; Natural – Benthem and Hooker (detailed study); Phylogenetic – Hutchinson; Angiosperm Phylogeny Group system – (introduction only).

Module - II

1. Detailed study (systematic position, distribution, common members, diagnostic features, description from habit to fruit, economic importance.of the following families.

Annonaceae, Malvaceae, Rutaceae, Fabaceae with sub families, Myrtaceae, Cucurbitaceae, Rubiaceae, Asteraceae, Apocynaceae, Asclepiadaceae, Solanaceae, Acanthaceae, Lamiaceae, Euphorbiaceae, Liliaceae and Poaceae.

Module- III

1. Taxonomic structure – Hierarchy; Concepts of taxa: Species – Biological, Phenetic and Phylogenetic; Genus; Family.
2. Taxonomic character – concept, primitive and advanced characters, sources, comparative morphology, vegetative, reproductive, Macro and micromorphology, modern trends in taxonomy, cytotaxonomy, chemotaxonomy, numerical taxonomy, molecular taxonomy and phylogenetics.
3. Contributions of eminent Taxonomists viz Hendrich van Rheed, WilliamRoxburg, Robert White and G. S. Gamble.

Module - IV

1. Plant nomenclature – Limitations of common name, ICBN, Principles(introduction only); Typification (holotype, isotype, syntype paratype and lectotype); Priority – merits and demerits; Effective and valid publication; Author citation.
2. Plant identification – Keys; indented and bracketed, construction and applications.
3. Taxonomic information resources – Herbarium preparation and maintenance, Herbarium types: International- Kew (K); National-Central national herbarium (CAL), MH Coimbatore. Botanic Gardens: RBG, Kew, IGB, Kolkotta; TBGRI and Malabar botanicl Garden, Olavanna , Kozhikode.
4. Taxonomic literature- Floras, Monographs, Revisions, Journals and online resources & Databases.

References

1. Sivarajan, V.V. 1991. Introduction to Principles of Plant Taxonomy. Oxford & IBH, New Delhi.
2. Sporne, K.R. 1974. Morphology of Angiosperms. Hutchinson University Press London.
3. Radford, A.E. 1986. Fundamentals of plant systematics. Harper & Row Publishers, New York.
4. NaiK, V.N. Taxonomy of Angiosperms. TATA McGraw Hill, New Delhi
5. Burkill, I.H. 1965. Chapters on the History of Botany in India, Delhi.
6. Gurucharan Singh, 2001. Plant systematics - Theory and Practice. Oxford & IBH, New Delhi.
7. Davis, P.H. & V.H. Heywood, 1963. Principles of Angiosperm Taxonomy. Oliver & Boyd Ltd.,London.
8. Henry, A.N. & Chandrabose An aid to International Code of Botanic Nomenclature.
9. Jeffrey, C. 1968. An introduction to Plant Taxonomy, London.
10. Simpson, M.G. 2006. Plant Systematics. Elsevier Academic Press, London
11. Stuessy, T.F. 1990. Plant Taxonomy – The systematic evaluation of Comparative data. Columbia University Press, New York.

12. Sharma, B.D. et al. (Eds.) Flora of India vol. I. Botanical Survey of India, Calcutta.
13. Sambamurthy A..S.S. 2005;Taxonomy of Angiosperms, i.K. International Pvt. Ltd, New Delh.
14. Pandey, S.N. & S.P. Misra. 2008. Taxonomy of Angiosperms. Ane Books India, New Delhi.
15. Sharma, O.P. 1996. Plant Taxonomy. TATA McGraw Hill, New Delhi.
16. Bharati Bhattacharyya 2009; Systematic Botany, Narosa Publishing House Pvt. Ltd., New Delhi.

MORPHOLOGY

1:Morphological description of a flowering plants

- Angiosperms are the flowering plants which bear seeds within closed cases, called fruits (Anggeion=case or vessel; Sperma= seed)
- Angiosperm morphology is the study of the external characteristics of flowering plants, significant for identification classification and description of flowering plants.
- Plant differentiated to roots, stem, leaves, flowers, fruits & seeds.
- Typical plant has two main portions-
  Shoot system- stem, leaves, flowers, fruits & seeds
  Root system- roots, root hairs and root cap.

  ❖ Root system
- Underground portion of plants
- Non-green, non-photosynthetic, positively geotropic, negatively phototropic and positively hygroscopic.
- Leaves, buds, nodes, internodes are absent
- It develop from the radicle of germinating embryo, during seed germination radicle grows vertically downward deep into the soil and forms primary roots.
- Primary roots give rise to lateral roots and into tertiary also.
- Roots develops from other than radicle known to be adventitious roots.
- In submerged water plants like Hydrilla and Utricularia root system poorly developed or absent
- In free floating hydrophytes , root system function as a balancing organ.
- Region of primary roots
  1. Root apex& root tip
  2. Zone of elongation
  3. Zone of maturation or root hair region
  4. Permanent region
- Types of root system
  1. Taproot system
     Main root / primary root → secondary roots/ lateral roots → tertiary roots
  2. Fibrous root system
     Characteristics of monocots, thin, fibre like profusely branched roots with almost similar length, arising from the base of stem.
     Not grow deep in the soil.

3. Adventitious root system
   Rots develops any parts of plants other than radicle
   Underground stem- Potato
   Aerial stem – Banyan tree
   Stem cuttings- Tapioca
   Leaves- Bryophyllum
   Weak stemmed Betel wine, Pepper – roots from internode to climb upon support

- Tap root modification
  1. Storage roots
     Root specialized for food storage / storage roots
     - Conical tubers
       Cone shaped tubers, broad at the top and progressively tapering towards the tip
       Eg: Carrot(*Daucus carota*)
     - Fusiform tubers
       Spindle shaped tubers , with tapering end and broad and swollen at middle part.
       Eg. Raddish (*Raphus sativus*)
     - Napiform tubers
       Swollen and globular base and suddenly and sharply tapering and tail –like apex
       Eg: Beetroot (*Beta vulgaris*)
     - Tuberous roots
       Thick and fleshy roots, with rich storage of food and without specific shape
       Mirabilis jalapa (4'o clock plant)
  2. Pnumatophores
     Negatively geotropic and porous respiratory roots specialized for gas exchange. They contain air spaces inside and bear numerous small openings on the surface, called pneumatothodes, gas exchange takes place.
     Eg. Mangroves – Rhizophora , Avicennia
  3. Buttress roots
     Roots growing from the base of the tap root to provide extra support to the tree. They may ridge like out growth c
     In buttresses roots, a part of trunk is also included , so they are partly a root modification and partially a stem modification.
     Eg. Bombax Terminalia
- Adventitious root modification
  1. Modification for food storage
     - Tuberous root
       Swollen, irregularly shaped storage roots, which occur singly
       They are developed from the basal aerial stem eg . Sweet potato (*Ipomoea batatus*)
     - Fasciculated roots
       Clusters of swollen storage roots, arising from the nodes of stem base. Often they form a thick bundles or fasciculi, hence named fasciculated roots.
       Dahlia, Asparagus, tapioca

- Moniliform roots
  Beaded storage roots, with swellings at frequent intervals eg.
  Portulaca, Momordica
- Nodulose roots
  Storage roots become suddenly swollen, after a short distance.
  Arises from the stem eg. *Curcuma amanda* (mango ginger)
- Annulated roots
  Ringed roots, with a series of ring-like swellings (annulations) throughout the length. Look like a pile of discs, placed one above the other
  Eg. Psychortia.

- Modification for mechanical support
  Aerial adventitious roots develops to give additional support
  Four types
  1. Prop roots / piller roots
     Piller like and woody aerial roots, growing vertically downward to the soil from horizontal branches
     Penetrate into soil and serve as columns or pillars (props) for supporting horizontal branches. Eg. *Ficus bengalensis*(banyan tree). It called prop roots
  2. Stilt roots
     Clusters of aerial adventitious roots , growing obliquely downwardto the soil from basal nodes of the main stem to support the plant.
     Usually found in plants growing near the banks of rivers, ponds, paddy field etc.
     Eg. Pandanus , rhizophora,- roots arises from all around the stem at different heights. These roots support the trunk which may be in a withering state dueto action of water.
     Other eg. *Zea mays, Saccharum*

  3. Climbing roots
     Branched adventitious roots for support
     Found in weak stemmed climbers like betel wine (*piper betal), piper nigrum*, pothos- roots arises from nodes for climbing on the supporting object.
     .
  4. Clinging roots
     Roots for fixing the plant on the bark of the host tree. Common in epiphytes
     Eg. Vanda
- Modification for nutritional purpose
  For nutritional requirements
  1. Haustoria
     These are parasitic roots or sucking roots of parasitic plants.
     Specialized aerial adventitious roots, penetrate to the host plant, establish connection with its vascular system and absorb water and food materials eg. Striga, loranthus, cuscuta

Striga- root parasite, nutrients absorb from roots of host.

Loranthus-green leaved partial stem parasite on variety of trees. Its photosynthetic as well as parasitic. Sucking or absorbtive haustoria pierce to the cortex of the host plant , reach vascular region , establish connection with xylem bundles and absorb water and mineral nutrients.

Cuscuta- obligatory stem parasite. Twisted around the stem of host plant. absorbtive haustoria penetrate to vascular region , establish connection with xylem and phloem and absorb water and prepared organic nutrients

2. Assimilatory roots

   Chlorophyll bearing and photosynthetic (assimilatory) aerial roots

   Eg. 1. Trapa-aquatic plant with submerged photosynthetic roots

   2.Tinospora- aerial roots long, slender, freelybhanging, chlorenchymatous cortex at roots.

3. Velaman roots or epiphytic roots

   Moisture absorbing,chlorophyll containing photosynthetic aerialroots of orchids, aroids, epiphytes- which grow on other plant

   Velaman roots freely hang in air, absorb atmospheric moisture and CO2 and carry out photosynthetic. Velaman roots have two kind of tissues outer velaman tissue for absorbing water, waterfilled tissue. Without living protoplast. Light can pass through this for photosynthesis.

Shoot system

- Consist aerial parts include stem, leaves, fruit, flowers and seeds

1) STEM

- Aerial, ascending and axial portion of plant
- Develops from plumule of embryo
- Positively phototropic and negatively geotropic
- Differentiated into nodes and internodes
- Leaves, axillary branches, adventitious roots also arise.
- The upper angle between the leaf base and the stem is called axil.
- Buds are undeveloped and condensed shoots with a terminal meristem.
- In some case these bud enclosed by undifferentiated leaves, called budscales.
- Based on position buds can be recognized to
    1. Terminal or apical buds- at tip of stem
    2. Axillary buds- at leaf axils
    3. Accessory buds- located at nodes, little away from leaf axil.- give rise to lateral branches.
    4. Radical buds- from roots eg. Ipomoea
    5. Foliar or epiphyllous buds- from leaves eg. Bryophyllum, Kalanchoe.
    6. Cauline buds- Adventitious buds develops on stem

➢ Strength of stem

1. Strong stem

Strong enough to support the top weight of the plant and also to maintain an erect posture

2. Weak stem

   Aerial stem, very weak and hence cannot stand erect, without a support. So they trail or creep over the ground (trailers and creepers) or climb or wind around a solid support (climbers and twinners)

- Plant habit

Based on nature of stems, plants classified in to

1. Herbs

   Small, short living plants with short living, with soft and non-woody stem and scale less and naked buds.

2. Shrubs

   Long-living, short and bushy plants with woody stem. They profusely branched from the base. Eg. Ixora, Citrus, Hibiscus

3. Trees

   Large and long- living woody plants, with tall and extensively branching stem. Their branches arises from some distance above the soil. Eg. Mango tree, ficus

   Forms of trees- based on stem

   a) Caudex

      Main axis or trunk is straight, unbranched and columnar with crowns of leaves. Eg. Tree ferns and palms

   b) Excurrent

      Main stem or trunk goes on growing giving out branches in acropetal succession . tree appears conical. Eg. Polyalthia

   c) Deliquescent

      The main stem has spreading canopy with irregular branches due to the suppression of apical buds and the vigorous development of lateral buds eg. Mangifera, ficus

      Culms- the stem of grasses and sedges, with solid nodes and hollow internodes eg. Bambooo

- Based on life span, plants classified into

- Ephemerals

  Short –living herbaceous plants. Live only for few weeks and repeat their life cycle several times in one year or one season. Produce flowers only once in their life. Eg. Peperomia

- Annuals

  Herbaceous plants , complete their life cycle in one year or one season. They produce flowers in only once in their life. The time taken to complete the life cycle may ranges from a few months to an year. Eg. Paddy, Tobacco, Coriander

- Biennials

  Live for two years or two seasons. During first season, they complete the vegetative growth and produce plenty of food. This food stored in certain organs of the plant. During the second season , stored food used for producing flowers, fruits and seeds. First season – vegetative growth, second season – sexual reproduction. Eg. Raddish, Carrot

- Perennials

  Plants lives for several years, and mature plant produce flowers and fruits every year. Mostly fruits and flowers every year. Mostly trees and shrubs.eg. Mangifera, Tamarindus

  Perennial herbs- Turmeric, Ginger
- Multiennials

  Plants grows for number of years but do not produce flowers every year. Eg. Bamboo, Strobilanthus

- Monocarpic plants

  Perennials or multiennials plant produce flowers and fruits only one in their life time and then perish.

  After several years of vegetative growth, they suddenly produce a large number of flowers by making use of all stored food. Soon after flowering they will die. Eg. Agave, Bamboosa

  Ephemerals, annuals and biennials are considered as monocarpic.
- Plants, flowering many time in life called polycarpic plants.

- Branching of stem
- Monopodial branching

  Main stem is formed from a single terminal bud and it bears branches in acropetal succession eg. Causuarina, Polyalthia, Pinus
- Sympodial branching

  The main stem stops growing after a period, and stem elongation continues by the successive development of lateral branches, just behind the apex.

  Here terminal buds stops it growth after a short period and further growth of the stem continues by the activity of the axillary buds near the tip. Eg. Mangifera, Gulmohar.

AERIAL STEM

- Weak aerial stem- stem is weak and unable to stand erect.

  Weak stem may either horizontally on the ground, or may grow up by supporting themselves on neighboring objects.

  They are two major groups

  1). Weak stemmed horizontal plants

  a). Caulescent stem- leaf bearing stem above the ground and erect.

  b).Acaulescent stem- short and highly condensed stem, bearing unbranched inflorescence and clusters of leaves at the ground level.

  c).Caespitose- loose and closely matted stem, or the stem growing densely in turfs. Eg. Cyperus

  d). Prostrate- trailing stem which grows parallel to the ground

  e) Repent- prostrate and rooting stem which crawls along the ground.

  f) Procumbent-prostrate stem, trailing fully flat on the ground throughout. Eg. Evolvulus

  g). Decumbent- stem lies on the ground, but rises at the apex. So the stem is prostrate for most of distance, but erect terminally Eg. *Tridax procumbens*

h). Suffrutescent – somewhat shrubby stem in which many branches die after flowering, leaving a persistent woody base.

2). Weak stemmed climbing plants

-major two classes

a). Twiners

- ✓ Plants which coil or wind around a support.
- ✓ Stem is slender, with long internodes, tip of stem exhibits a peculiar rotatory movement in air, known as nutation. The movement causes the stem to rub against the support. The stem is exceedingly sensitive to contact, and the side which rubs against the support gets irritated. So as the growth becomes less on that side, while on the opposite side, growth is normal.

  Twiners make themselves erect and expose their leaves to sunlight eg. Clitoria.

b). climbers- classified into 5 types based on nature of climbing organ

- ✓ Tendril climbers

  Tendrils are slender, spirally coiled, spring like structures.

  Highly sensitive to contact and when they come across any support, they behave just like the stem of the twiners and coil round the support.

  Tendrils are modified parts of plants

  Terminal bud transformed into tendril eg. Cissus

  Axillary bud transformed to tendril Eg. Pssiflora

  Stipules modified to tendril Eg. Smilax

  Terminal leaf let of pinnately compound leaf modified to tendril Eg. *Pisum sativum*

  Tip of leaf modified to tendril eg. Gloriosa

  Petiole modified to tentril Eg. Clematis
- ✓ Hook climbers

  Hooks are much stronger than thicker.

  After catching hold of the support, they thicken considerably and become woody eg. Artabotrys- hooks are found opposite to leaves.

  Hooks are modified flower stalk.
- ✓ Thorn stragglers

  Number of thorns develop on the stem. And these thorn point downwards, so thst the stem clings to the support firmly. These thorn may be mere superficial structures, developed all over the stem. They are clled emergences or prickles eg. Lantana, Solanum, Rose.

- ✓ Root climbers

  Plants climb with the help of aerial adventitious roots developed at the nodes eg. Betal vine, Pepper
- ✓ Lianas

Large, woody,perennial climbers, with very long stem growing from ground level to the canopy of trees. They are abundant in tropical forests. They differ with woody stem than thin and weak stem Eg. Allamanda, Bougainvilae

MODIFICATION OF STEM

- Primary function holding and conduction
- Secondary function
    - Mechanical support
    - Food storage
    - Perennation
    - Vegetative propogation

1. Underground stem modification
2. Sub- aerial stem modification
3. Aerial stem modification

<u>Underground stem modification</u>

- For perennation, storage of food materials and vegetative propogation.
- Non-green and superficially very much resemble roots.
- Distinguished from roots by the presence of nodes, internodes, scale leaves and axillary and terminal buds.
- Underground stem modifications are
    - ✓ Rhizome
    - ✓ Corm
    - ✓ Stem tuber
    - ✓ Bulb

1. **Rhizome** eg. Ginger, Turmeric, Canna

- Horizontal, short,thick,fleshy and irregularly branched underground stem, with nodes,highly condensed internodes, terminal buds, leaf scars.
- Nodes bears adventitious roots, and small, thin and white scale leaves
- Axils of scale leaves bears axillary buds
- The terminal buds of the rhizome grows out of the soil and give rise to green shoots and flowers during growing season. At the end of the season, the green aerial portion dies out and further growth of the rhizome is taken up by the axillary bud nearest to the terminal bud.

2. **Corm** eg. Amorphophallus, Colocasia, Dioscorea

- It is short, thick, massive and nearly spherical base of an underground stem axis, with nodes, internodes, scale leaves, apical and axillary buds, and adventitious roots.

- Adventitious roots hold the corm is erect posture and hence they are also termed contractile roots or pull roots.
- Store house of reserve food
- Corm is massive, swollen and slightly spherical. On this a prominent terminal bud, surrounded by numerous scale leaves.
- Each scale leaves have small buds in axil.
- Terminal bud develops to vegetative shoot. Many adventitious lateral buds are also be present.
- They are produced from nodes and are protected by scale leaves. They can grow to daughter corms or cormlets.

3. **Stem tuber** eg. Potato, Helianthus, Cyperus.
    - Swollen tips of underground stem branches(stolon).
    - Rich storage of reserve food
    - In potato stem tuber is terminal, swollen. Fleshy and merely spherical, with distinct nodes and inrternodes
    - On nodal region- crescent scar enclosing small depression. Scar represents the leaf scars. And it bears axillary buds.
    - Leaf scar+ axillary buds known to be eye of potato.
    - Possession of leaf scar and axillary buds indicates the stem nature of potato.
    - Stem tubers are produced in a peculiar manner. Some of the branches of the main stem, which are near the soil, instead of growing normally, bend down and grow into the soil. The ends of these branches swell out due to the accumulation of food and become tuber.
    - A end of growing season , the motherplant dies, new plants develop from tuber.

4. **Bulb** Eg.Onion,Garlic, Garden lilly

- Highly condensed and reduced underground stem
- It found in monocot
- Scale leaves are arranged concentrically and these are fleshy, waterstoring and food storing
- Inner scale leaves are fleshy and outer one are dry
- Outer scale leaves called tunica,protective in function
- In the centre there is a terminal bud surrounded by axillary bud
- Terminal bud give rise to flowering shoot
- Axillary buds give rise to bulblets
- Adventitious roots are formed in tufts at the base of the disc.

<u>Sub-aerial stem modification</u>

- weak stemmed branch produce modified branches
- they can grow in ground and below the soil
- which may or may not produce roots. And those one produce roots called creepers.
- No roots produced called trailers.
    - ✓ Runners eg. Oxalis, Centella
        - Horizontal creeping plants with long internodes
        - Each node it produce leaf towards the upperside and root towards the lowerside

- Daughter plants are formed by the death of internode or runner

✓ Suckers eg.Chrysanthimum
- It is formed from the axillary bud of sub –terranian plant
- It is underground adventitious lateral branches
- It is shorter and stouter than runners
- This suckers horizontaly grown for sometime

✓ Stolon eg. Mentha, Jasmin
- A slent of lateral branches arisen from the base of main stem. Which grow upward and bend downward.

✓ Offset eg. Eichornia, Pistia
- It found in hydrophytes
- Somewhat similar to that of runner
- Internode bears leaves to upperside and root to the lowerside.

Aerial stem modification

✓ Tendrils
- For climbing and mechanical supportprotection, vegetative propogation, water storage and photosynthesis.
- Long slender, spirally coiled threadlike structure
- Leaf tendril- gloriosa
- Stem tendrils are modification of apical bud,axillary bud and stipules
- Terminal bud- Vitis
- Axillary bud- Passiflora
- Stipules- Trichosanthus

✓ Thorns
- Sharply pointed hard woody structure
- From axillary bud eg. Citrus
- It protects from herbaceous animals

✓ Phylloclade eg. Opuntia
- Green, flat, globus, photosynthetic stem
- Xerophytic adaptation for absorption and water storing also. To reduce water loss
- Leaf absent or modified as scales or spines to reduce water loss
- Node bears spines and leaves and flowers also

✓ Cladodes eg. Asparagus
- Green, flat and photosynthetic
- Functions as leaf
- Xerophytic adaptation
- Modification of axillary buds in Asparagus
- Leaf reduced to scales or spines
- Cladodes are sickle shaped.

LEAF

- Thin and flat outgrowth of stem
- The upper angle between the leaf base and the stem is called axil.
- Leaves developed from meristematic called leaf primordium.
- Primary functions-photosynthesis, transpiration, respiratory gas exchange.
- Based on posture – leaves are two types
    1. Dorsiventral or bifacial leaves- held horizontally, with distinctly different upper and lower surface. So the anatomy of upper and lower surfaces differs due to unequal light exposure.
    2. Isobilateral or equifacial leaves- leaves stand almost vertically erect so that both the surfaces are very much similar, or almost identical. Both surfaces have same internal structure.
- The leaf surface, that is continuous with the surface of the stem above the point of leaf insertion, known as upper or ventral or adaxial side, and the opposite side is known as lower or dorsal or abaxial side.
- Heterophylly : the condition which the plant bears two types of leaves at its life cycle.
  Eg. *Artocarpus heterophyllus*
  Limnophylla heterophylla

PARTS OF DICOT LEAF

1. Leaf base
    - ✓ Basal portion of leaf attaches to the stem.
    - ✓ Protects small buds in axil.
    - ✓ In some plants leaf base is swollen known to be pulvinus base. Pulvinate leaves eg. Mimosa, Mango tree, Legumes.
    - ✓ In Mimosa pulvinate leaves cause sleeping movement.
    - ✓ In monocot leaves, leaf base has sheath like expansion called sheathing leaf base. It partially or completely encircled the stem.Eg. Grass
    - ✓ In dicots,paired leafy lateral outgrowths given out from the base called stipules.
    - ✓ Stipules absent in monocots.
    - ✓ Stipules may be spiny, scaly, glandular or photosynthetic.
    - ✓ Occasionally in get modified to enclose and protect the axillary buds eg. Ficus.
    - ✓ Leaves with stipules- stipulate leaves eg.Hibiscus, Ixora
    - ✓ Leaves without stipules – Exstipulate leaves eg. *Mangifera indica*
2. Petiole
    - ✓ Leaf stalk, connects lamina to the stem, exposes the lamina to sunlight and transports water and nutrients.
    - ✓ Leaves with petiole-petiolate eg. Ficus,Hibiscus

- ✓ Leaves without petiole- sessile Eg. Calotropis,Zinnia.
- ✓ Petiole wing shaped in Citrus.
- ✓ In Acacia petiole is flat structure called phyllode.
- ✓ In Clematis, Smilax, petiole modified to tendrils
- ✓ petiole modified into spongy and bulb like in Eichhornia- Help for floatation

3. Lamina or leaf blade
   - ✓ Is green, thin and expanded part of the leaf.
   - ✓ For photosynthesis, transpiration, gas exchange
   - ✓ Leaf tip- leaf apex
   - ✓ Edge or border of lamina – leaf margin
     It is toothed or serrated eg. Hibiscus, Rose
     Wavy- Eg. Polyalthia
     Lobed- Eg. Tapioca
   - ✓ Petiole extended throughout the length of lamina as strong vein called mid -vein or mid rib.
   - ✓ Midrib gives out branches to the sides called veins. Veins branch and re-branch in to veinlets.
   - ✓ Leaf surface is smooth and curved, with a waxy coating. It may bears hairs.

PARTS OF MONOCOT LEAF

- Sheathing leaf base, completely or partially encircle the stem.
- Petiole is absent in grass. In some plants it is modified into rachis.
- In some monocots, a pair of small pair of outgrowths from the junction between leaf base and petiole called ligule.eg. Grassess
- Lamina of leaves- isobilateral with parallel venation.

LEAF VENATION

- Parallel venation- monocots
  Horizontal venation-Eg. Musa. Longitudinal venation– Eg. Grasses
- Recticulate venation- dicots
- Monocot plant with recticulate venation-eg. Aroids, Dioscorea
- Dicots plant with parallel venation. Eg .Alstonia, Calophyllum

TYPES OF LEAVES

1). Simple leaves- with single lamina

2). Compound leaves

- Lamina divided into segments called leaflets or pinnae.
- Individual leaflet may be stalked or sessile and free from each other.

- All of the leaflets connected on a common stalk called rachis.

Types of compound leaves

1). Pinnately compound leaves

Leaf lets arranged on both sides of rachis. Eg. Neem, Moringa.

a) Unipinnate leaves
Rachis bears leaflets in opposite or sub opposite pairs.
Two types
1). Paripinnate leaves- leaflets ends in even numbers. Eg. Tamarindus, Cassia.
2). Imparipinnate leaves- leaflets end in odd numbers. Eg. Neem, Murraya.

b) Bipinnate leaves

Rachis bears secondary axes (rachillae), which bear leaflets on the sides. So, the leaves pinnate twice. Eg. *Mimosa pudica.*

c). Tripinnate leaves

Pinnately compound leaves in which the secondary axes produce tertiary axes to which leaflets are attached. So, the leaves pinnate thrice. Eg. Moringa

d).Decompound leaves

Pinnately compound leaves, which pinnate more than thrice. Eg. Coriander

2).Palmately compound leaves

Leaves in which leaflets are attached to the tip of rachis, just like fingers of our palm.

Five types

1) Unifoliate- palmately compound leaf with single leaflet eg. Citrus
2) Bifoliate – with two terminal leaflet Eg. Bauhinia
3) Trifoliate- with three terminal leaflet Eg. Oxalis, Mentha
4) Quadrifoliate-with four terminal leaf lets Eg. Marselia
5) Multifoliate – with more than four terminal leaflets Eg. Bombax

PHYLLOTAXY

- Arrangement of leaf on stem and branches
- Main purpose of phyllotaxy to provide sufficient light to leaves.
- Three main kind of phyllotaxy
  1). Alternate phyllotaxy-leaves on alternate nodes. Each node bears single leaf.

It is two types

Spiral-alternate leaves arranged spirally on stem. eg. Hibiscus

Distichous- alternate leaves arranged vertically on the two sides of the stem Eg. Annona

2).Opposite phyllotaxy-two leavesarranged on each node in opposite directions.

Two tyes

Deccusate-adjescent pairs of leaves are arranged at right angles to each other . eg. Ixora, Clotropis

Superimposed- Adjescent pairs of leaves arranged one above the other in same plane. Eg. Guava.

3).Whorled phyllotaxy – leaf arranged in three or more leaves arise from each node in the form of a whorl or circle around the stem. Eg. Nerium, Alstonia.

MODIFICATION OF LEAVES

- Modified for protection, nutrition and climbing

It include

1. Leaf tendrils
   Long, spirally coiled spring like leaves.
   Help for climb on a support in weak stemmed plants.
   Eg. Pisum- terminal leaflet modified to tendril
   Lathyrus-entire leaf modified
   Gloriosa-leaf tips modified to tendril
2. Leaf spines
   Sharply pointed structure. Characteristics of xerophytes like Opuntia, Asparagus
   In opuntia axillary buds modified to spines
3. Leaf scales
   Thin, stalkless, membraneous structure. Eg, Onion, Garlic.
   In onion each scale leaves protect centrally located axillary bud. Scales are fleshy due to storage of water and food.
4. Pitcher
   Flask shaped modification of leaf lamina for tapering insects.
   Found in insectivorous plants like Nepenthus, Sarracenia
   In Nepenthus, leaf lamina modified to pitcher.
5. Phyllode
   Flat and leaf like modification of petiole or rachis. It is xerophytic adaptation to reduce transpiration. In this case normal leaf lets fall at early stage. Then,rachis develops to a phyllode Eg. Acacia, Parkinsonia.

II. Inflorescence

- Inflorescence means a bunch or group flowers in an axis.
- Position of inflorescence, axillary or terminal.
- Stalk of inflorescence called peduncle
- Individual flowers may be sessile (without stalk) or pedicellate (with stalk).
- In some plants like Lotus and Onion a large peduncle originate from the bottom.
  At the tip of the peduncle flowers will produced. This long peduncle called scape.
- In onion 3 or 4 flowers are produced in the tip.
- Bract & Bracteoles
  Pedicel arises from the axil of a very small greenish, or brownish leaf like structure on the peduncle, called bract.
  Highly reduced and modified leaves and their arrangement on the peduncle is the same as that of leaves on a vegetative shoot.
  It differs from leaf based on colour, shape and size.
  Bracteoles are the bract like reduced structure arises from the axil of leaves.
- Flowers with bract – bracteate
- Flowers without bract – ebracteate
- Flowers with bracteoles-bracteolate
- Flowers without bracteoles – ebracteolate
- Kinds of bracts
  - Sterile or empty bract
    In Pine apple bracts will not produce flowers
  - Leafy bract
    In bougainvillea the bract is modified and brightly coloured
  - Spathe
    Some bract protect or cover the inflorescence, when they are young such bracts called spathe
    Eg. *Cocos nucifera* (coconut)
  - Involucre
    In some flowers a number ofbracts cover the inflorescence.
    Eg. *Tridax procumbens*
  - Epicalyx
    Number of bracteoles seen below to calyx
    Eg. *Hibiscus rosa-sinensis*

KINDS OF INFLORESCENCE

I. Racemose /indefinite inflorescence

- Main axis grow indefinitely and continuously

- Flowers are arranged on acropetal succession (base contain older and apex contain younger flowers or buds)
- Inflorescence axis or rachis never ends in flower.
- In some inflorescence rachis modified to a flat roundish structure called receptacle.
- The arrangement of flowers in a receptacle is centripetally (younger one towards center, older one towards periphery). Eg. Head inflorescence

1. Raceme or Simple raceme eg. *Crotalaria*
    - Stalked flowers arranged on a unbranched axis in acropetaly .

2. Compound raceme or Panicle eg. *Mangifera indica*
    - stalked fowers are arranged acropetaly on a branched axis.

3. Spike eg. *Achyranthus aspera*
    - Sessile flowers are arranged acropetaly on unbranched axis.

4. Compound spike Eg. *Amaranthus spinosus*
    - Sessile flowers are arranged acropetaly on branched axis.

5. Spadix Eg. Anthurium, *Colocasia*
    - It is characteristic inflorescence of family araceae.
    - Variation of spike inflorescence , in which rachis is fleshy and the flowers are covered with one or more membraneous structure called spathe.
    - In spadix , the axis bears female flowers towards the base, neutral flowers towards middle and male flowers at apex.
    - Tip of axis left bare as appendages.

6. Compound spadix eg. *Cocos nucifera*
    - Axis is branched and each branch be a spadix. It bears female flowers on the base and male flowers towards the apex.
    - The total inflorescence covered by a stiff and leathery boat shaped spathe.

7. Mixed spadix eg. *Musa*
    - It is characteristic inflorescence of genus *Musa*.
    - Cymose group of flowers are arranged acropetaly on fleshy inflorescence axis.
    - Each cymose group is subtended by a colourful spathe, which will fall of upon opening.
    - The cymose group of flowers are arranged in such a way that the older spathe subtending the next tender.

8. Catkin or Amentum eg. *Acalypha indica*

- Variation of spike.
- Inflorescence axis is thin and weak.
- Unisexual flowers are arranged acropetal order.
- A catkin is usually a drooping down forming a pendulous structure.
- Simply catkin is a pendulous spike with weak axis.

9. Corymb eg. *Caesalipinia pulcherrima*
   - Inflorescence axis is not much elongated. But pedicel or stalk of flower longer and longer as the flower is placed lower and lowerin the inflorescence axis.
   - So that, all the flowers are more overless seen in the same level.

10. Umbel eg. *Biophytum*
    - Characteristic inflorescence of umbelliferae.
    - Inflorescence axis is very much short. A number of flowers with similar stalk appear as a cluster.
    - Flowers are arranged centripetaly. (peripheral-older, center-young).

11. Compound umbel eg. Coriander
    - The main axis of umbel branched.
    - Each branch will form a simple umbel.

12. Capitate eg. *Mimosa pudica*
    - Characteristic inflorescence of Mimosaceae family.
    - It is a special type of inflorescence in which a large number of sessile flowers grow from a suppressed rachis giving more over less special structure.
    - Capitate is different from head, thus the capitate having no receptacle and have a condensed rachis.

13. Head or Capitulum eg. *Tridax procumbens*
    - Characteristic inflorescence of Asteraceae family.
    - Here the rachis form a flattend more over less convex receptacle. On which the florets are arranged in a centripetal manner(older ones periphery, younger ones center.)
    - Whole capitulum surrounded by three or four bract called involucre.
    - In Sunflower and Tridax etc. two types of floret can szee. Floret towards the periphery called disc floret (female). And floret towards the center called ray floret (bisexual).
    - No difference among florets of *Chrysanthemum*.
    - In both ray and disc calyx modified into pappus. These pappus helps for dispersal of fruit.
    - Head inflorescence considered as more perfect inflorescence. Here a single visit of an insect will pollinate very large amount of flowers.

14. Spikelet or Locusta eg. Rice, Wheat, Maize
    - Characteristic inflorescence of graminae or poaceae family
    - Inflorescence axis is branched and the flowers are arranged in a spike like manner.
    - Unit of compound inflorescence called spikelet
    - The flowers are arising from the axis of bract called lemma
    - The lemma is owned by palea
    - Each flowers have 3 stamens, one ovary with two feathery stigma.
    - The inflorescence is covered in a boat shaped bract called Glumes
    - In rice each spikelet consist of single flower. And each inflorescence axis is branched to panicle. So it is called panicle.
    - In maize, female inflorescence is spadix of spikelet and male inflorescence as panicle of spikelet.

II. Cymose / definite inflorescence

- Inflorescence axis ends in a flower/flower bud
- It stops its growth activity quite early
- Further growth by lateral branches from the axis
- Basipetal arrangement-older ones in top and younger ones in the basal region of axis
- It is less common compared to racemose inflorescence

1.Solitary cyme eg. *Hbiscus rosa-sinensis*
- Simplest type of cymose inclorescence .ie pedicel ends in a flower bud.
- Position of the flower bud is axillary or terminal
  -terminal solitary cyme- eg. *Gossypium*
  -axillary solitary cyme - eg . *Hbiscus rosa-sinensis*

2. Simple cyme eg. Jasmine
- Consist of a cluster of three flowers
- One terminal and two lateral flowers
- Inflorescence axis ends in a flower bud. It has two bracteoles. From the axil of each bracteoles flower develops.
- Older ones seen towards the periphery called centrifugal arrangement of flowers.
-

3. Monochasial cyme
- Peduncle ends in a flower. It has two bracteoles. One is suppressed and other one produce single lateral pedicel which also ends in a flower bud
- Two types

A. Helocoid cyme eg. *Hamelia patens*

- Inflorescence axis ends in a flower bud
- It has two bracteoles. One is suppressed. Other one produce lateral peduncle. Which also end in a flower bud. And the further branches are arise from a single side or single plane

B. Scorpioid cyme eg. *Heliotropium*

- Inflorescence axis terminate in a flower
- It has two bracteoles. One is suppressed and other will produce lateral branches, which also end in a flower bud.
- Like this branching occurs alternatively to left and right (bothside) and all of them ends in a flower bud.

4.Dichasial cyme eg. *Clerodendron, Ixora*

- It resembles dichotomous branching
- Inflorescence main axis ends in a flower bud.
- It has two bracteoles from these two lateral branches arises, which also ends in a flower bud.
- It can easily divided in to small groups of three flowers.
- Arrangement of flower is centrifugal

5. Polychasial cyme eg. *Calotropis*

- Inflorescence axis ends in a flower bud.
- From the axil of flower bud more than two lateral pedicels are formed, which also end in a flower bud.

III. Special type of inflorescence

1. Hypanthodium
   - Characteristics inflorescence of the genus *Ficus*
   - Here the receptacle modified into hollow cup-shaped structure, which open exterior by means of ostiole
   - Ostiole covered by downwardly hanging hairs
   - Sessile and unisexual flowers are arranged in the inner wall.
   - Sterile, male and female flower are seen
   - Male flowers towards the ostiole
   - Female flowers towards the base
   - Sterile flowers towards the middle

2. Cyathium
   - Characteristics inflorescence of genus *Euphorbia* under family Euphorbiaceae

- Involucre modified into cup-shaped structure
- Inflorescence contain, involucre contains single female flower in the center which is surrounded by numerous male flowers in centrifugally.,
- Female flower is reduced into tricarpellary syncarpous, trilocular ovary with axile placentation
- Male flowers reduced into single stamen. But the filament have a node which represent the thalamus.
- One or two necteries also seen in involucre.

3. Verticillaster eg. *Leucas aspera*
    - Characteristics inflorescence of labiatae or lamiaceae
    - Members of this family have opposite leaves
    - Inflorescence are develops from each of two opposite axils. Opposite cymose developing on either side and meet around the stem
    - Each inflorescence is a dichasial cyme in initial stage, and it is reduced yo a scorpioid cyme on two side. So it bend around the stem and node and meet together and it act as a false whorl or verticel around the stem.

4. Thyrsus
    - Cymose group of flowers are arranged in raceme manner.
    - Main peduncle produce cymose group of flowers in the axil of leaf or bracts in acropetal sucession.
    - Each cymose group with three flowers, central one is oldest.

III.Flower

- It is a reproductive organ
- Stalk of the flower called pedicel
- Flower has a short stalk called thalamus
- Nodes, internodes and specialized floral leaves are present
- The axis is so condensed, so we cannot distinguish the node and internode in thalamus
- Floral leaves are arranged spirally or cyclically on thalamus
- Flower is regarded as the modified shoot

Flower as a modified shoot

Evidences

1. Homology of the flower bud

- Position of the flower axillary and terminal , the buds developed in the same way both in shoot and flower
- In the axile there is an axillary bud, which may develop to lateral branches or a flower hence, flower is a modified shoot
- Sometime floral bud transformed into vegetative bud eg. *Agave*

2. Shoot nature of the thalamus
    A. Thalamus region is condensed, so the shoot nature of thalamus cannot be identified or distinguishable.
    There are some exceptional cases
    a) Anthophore
    An elongated axis between calyx and corolla
    b) Androphore
    An elongated axis seen in between corolla and androecium
    eg. *Passiflora*
    c) Gynophore
    An elongated axis between androecium and gynoecium
    Eg. *Cleome*
    d) Gynandrophore
    It is also called androgynophore
    Gynophore+ Androphore
    B. Growth of thalamus limited by carpels, sometime thalamus grows beyond gynoecium and produce leafy shoot above first flower.
    Eg. Rose
    C. In *Polyalthia longifolia* thalamus bears spirally arranged carpel. This carpel elongate like an ordinary stem and produce aggregate fruit
3. Leafy nature of floral organs
    1. Arrangement of floral organs
    Floral leaves are arranged spirally or cyclically, it strongly support the phyllotaxy of the leaf eg. *Nymphae*
    2. Transition of floral members
    Transition from sepal to petal, petal to stamen, stamen to carpel.
    This transition of floral members is visible in *Nymphae*

Parts of flower

- Floral organs arranged in a one above other
- Outer most whorl called sepal, its unit called calyx
- The second whorl called petal, it unit called corolla
- Stamen collectively called androecium
- Innermost whorl called carpel, collectively called gynoecium
- In some plants calyx and corolla not distinguishable and have only one accessory word which can neither be termed as calyx nor corolla, so it is called perianth or tepal
  eg. Coconut

- The flower having perianth called apetalous flower.
- Flower with 4 floral whorl called complete flower eg. *Hibiscus*
- If one floral whorl is absent it is said to be incomplete flower eg. Nutmeg, *Cucurbita*
- Gynoecium and androecium are essential whorls
- Corolla and calyx are non-essential whorls
- If both essential whorls present in a flower called bisexual flower or hermaphrodite or perfect flower
- If one essential whorl is absent it is called imperfect or unisexual or diclinous flower
- Unisexual flowers either male- staminate flower, female pistilate flower
- If male and female flowers on same plant called monoecious eg. *Cucurbita*, Maize
- If male and female plant quite separate from each other called dioecious eg. *Gracinaria*, Nutmeg
- In some plant staminate, pistilate and bisexual flowers are seen , it is known to be polygamous eg. *Mangifera*, Cashew
- Dichlamidous flower is a complete flower, whereas monochlamydous flowers with all essential whorl and one non-essential whorl eg. Coconut

Symmetry of flowers

1. Regular or actinomorphic
    - Calyx, corolla, male and female reproductive organs are in uniformly size and shape and are proportionally arranged around the thalamus
    - Flower can into two equal halves through any plane called actinomorphic or regular flower eg. *Hibiscus*
2. Irregular or zygomorphic
    - Calyx, corolla, male and female reproductive organs are in not uniformly size and shape and are not proportionally arranged around the thalamus
    - Flower can into two equal halves through single plane called zygomorphic eg. *Leucas*
3. Asymmetrical
    - Flower which cannot give equal halves through any plane of cutting eg. *Canna*

Arrangement of floral organs

- Floral organs are arranged in a single strata called cyclic
- Floral organs are in different strata called spiral
- In *Annona* calyx, corolla arranged cyclically whereas reproductive structures arrange spirally. It is called hemicyclic or spirocyclic

1. CALYX

- Outermost whorl
- Individual unit called sepals

- Venation and structure resembles to leaf functions
- Functions
    - Protection of essential organs and delicate petals
    - It helps the disposal of fruit (pappus)
    - Sepals are green , it perform photosynthesis
    - When sepals are attractive or bright coloured, attract insect for pollination.
- Sepals are usually green
- Some case calyx is brightly coloured, this petal like sepal called petalloid sepal.
  Eg. *Mussaenda*
- Pappus-sepal modified into hair like structure eg. Asteraceae family
- One of the calyx is modified into tubular structure called spur. The calyx is called spured calyx eg. Balsm
- Normally sepals are entire in nature, sometimes it is toothed Eg. Rose
- Calyx is gamosepalous or polysepalous
- Gamosepalous- Individual units are fused with one another and it tip is free Eg. Hibiscus
- Polysepalous- individual unit s or sepals are free from one another eg. *Annona*
  Four different kinds of sepals
    1. Caducous
       Sepals/calyx fall of soon after flowering eg. Poppy
    2. Decidous
       Sepals fall off with petal eg. Mustard
    3. Persistent
       Calyx persist on fruit eg. Brinjal
    4. Acrescent
       Sepal persistent and continue to grow as a loose jacket around the fruit
       eg. *Physalis*

2. COROLLA

- Single unit of petal
- Second whorl of floral leaves, seen in between calyx and androecium
- Corolla are thin and delicate and attractive
- Attract insects for pollination
- Some time it may be sweet smelling eg. Rose
- It may succulent or green in colour eg. Annona
- Gamopetalous-petals fused eg. Datura
- Polypetalous- petals free eg. Hibiscus
- In polypetalous flower, the small stalk like portion called claw, the expanded upper portion of petal is limb
- In gamopetalous flower, lower tube like portion called tube,upper expanded portion is limb
- There is some appendages inside the corolla called coronal appendages or corona
- In *Crotalaria* corolla is butterfly like , it is called pappilionaceous
- Corolla may be regular or irregular

AESTIVATION

- The mode of arrangement of sepal or petal in a flowerbud

1. Valvate aestivation
   Adjacent petal or sepal in a whorl does not overlap with one another eg. *Annona*
2. Valvate-induplicate aestivation
   Adjacent sepals or petals are just touch one another but margins are folded eg. *Datura*
3. Twisted or contorted
   Overlapping is regular in one direction. One margin of the sepal or petal overlaps the next members on one side. While its other margin is overlapped by previous one, which gives a twisted appearance eg. Petals of *Hibiscus*
4. Imbricate
   Overlapping is there but they do not have any particular order
   1. Desending/ Vexillary eg. *Crotalaria*
      - Characteristic inflorescence of papilionaceae family
      - It have different sized petal
      - The posterior or big petal called vexillum or standard petal
      - The second type of petal called lateral or wing petal
      - Third boat shaped carina or keel petal
      - One petal completely in and one completely out and one partially in or out
   2. Ascending imbricate eg. *Caesalpinia*
      - Posterior petal is completely inside and posterior petal is completely outside and one is partially out and in.
5. Quincuncial eg. Sepals of *Allamanda*, petals of Guava
   - Overlapping is not regular in one direction
   - 2 petal is completely inside 2 completely outside, one is in and out.
6. Induplicate- convolute
   - Combination of twisted and induplicate
   - In this corolla is gamopetalous, irregular and have narrow tubular lower portion, broad circular spreading upper portion. The upper portion have 5 triangular outwardly radiating whitish portions and in this whitish portion is thick
   - In between thin and delicate corolla
   - In buds, all the portions are folded inwards and corolla twisted
   - And have a thickened portions are exposed (in bud).

3.ANDROECIUM

- Male reproductive organs
- Some stamens which is attractive and expanded called petalliod stamen eg. Canna
- Stamens are arranged in concentrically
- Stamens may be free, means free from petals
- Stamens may be epipetalous, means stamens attached with petals
- A stamens have three different part

1. Filament: slender stock of stamen, terminally bears anthers.
   -Sometimes filaments does not bears anther lobe called staminode.
   -In some flowers filaments are shorter than corolla tube, which is inserted in it. Called inserted or included stamen.
   -In some flowers filament are longer than corolla and this stamen seen outside called exerted or protruded

2. Anther: fertile portion of stamen, consist of two similar halves

   Each half have two lobes, each lobe has two sporangium. Hence it is called

   tetrasporangium

3.Connective: sterile portion, which connect the lobes

- Various types of fusion in stamen
  a) Monadelphous eg. *Hibiscus, Crotalaria*
     The filaments of all set of stamen in a flower fused to form a tube
  b) Diadelphous eg. *Clitoria*
     The filaments are fused to form two sets of tube or two bundles.
  c) Polyadephous Eg. *Bombax*
     Filaments of stamen are fused to form more than two bundles
  d) Synandrous eg. *Cucurbita*
     -Characteristic inflorescence of Cucurbitaceae
     - filaments and anthers of all stamens fuse to form a bundle

e) Syngenecious eg. *Helianthus*

- characteristic of Asteraceae

- anther lobes are fused but filaments free

Attachment of anthers

- Attachment filament with anthers

1. Adnate – filamentsattached throughout the length of anther lobe eg. *Michelia*
2. Basifixed- Filaments attached to the anther lobe eg. *Solanum*
3. Dorsifixed- filaments attached to the backside of the anther eg. *Bauhinia*
4. Versatile – seen in poaceae family. Filaments attached middle of the anther

Arrangement of anthers

1. Diplostemonous
   Stamens are arranged in 2 whorls and each whorl contains equal number of stamens.
   Outer whorl is opposite to sepal, inner whorl opposite to petal eg. *Murraya*
2. Obdiplostemonous
   Stamens are arranged in 2 whorls and each whorl contains equal number of stamens.
   Outer whorl is opposite to petal, inner whorl opposite to sepal eg.*Citrus*

Length of stamen

- In Mustard and Raddish , there is 6 stamens – 4 long and 2 short. All long stamen in same length and short stamens at same length. This condition called tetradynamous
- In *Thunbergia* and *Leucas*, there is 4 stamens- 2 long and 2 short. Longer with same length and short stamens also. This condition called didynomous

Dehiscence of anthers- break down of anthers and release of pollen grains

1. Longitudinal – anther open by a vertical slit in each lobe which wides and gradually liberate pollen. Commonest method eg. Cucurbits
2. Apical or porus- pollengrains are liberated by a pore or hole on apical region of anther eg. *Solanum*
3. Valvular – it opns by a shutter like opening at its top. Pollengrains liberated through it eg. *Barberry*
4. Transverse- a transverse slit is formed through which pollengrains are liberated.

4.GYNOECIUM

- Individual units called carpels.
- Carpels are composed of megasporophyll
- Flowers with single carpel- monocarpellary
- Flowers with many carpel- polycarpellary
- In polycarpellary gynoecium may be syncarpous or apocarpous
  Syncarpous- carpels fused eg. *Hibiscus*
  Apocarpous- carpels free eg. *Vinca*
- Gynoecium with three parts
  1. Ovary: basal swollen portion. Ovary may be single chambered- unilocular or it may be multi-chambered –multilocular
     Ovules is connected to the ovary by a stalk called funicle
  2. Style: slender middle portion , which connects stigma to ovary
     It hold stigma in correct position.
  3. Stigma: flat terminal portion. It has the function to receive pollen grains. Stigma secretes a sugary substance to promote pollination.

Cohesion of carpel

1. The fusion of carpel throughout their entire length (ovary, style and stigma) eg. *Citrus*
2. Fusion of carpel in the lower part of ovary
3. Fusion of ovary, style and stigma free eg. *Hibiscus*
4. Fusion of style and stigma but ovary free eg. *Catharanthus*
5. Fusion of stigma but style and ovary free eg. *Calotropis*

Placentation

- Placenta is the tissues in the ovary, in which future ovule are formed
- Placentation is the mode of arrangement of placenta
- Types of placentation

1. Marginal
   - Characteristic to papilionaceae family
   - Usually seen in monocarpellary/multicarpellary, apocarpous, unilocular ovary
   - Placenta bearing ovules are borne on the ventral suture
2. Parietal placentation
   - Usually found in unilocular ovary
   - Ovary bearing placentas are borne on innerwalls of ovary, which from periphery to centre eg. Pappaya
   - In cruciferae ovary become two chambered by the formation of false septum
   - It is also seen in cucurbitaceae
   - In Cucurbits, ovary is tricarpelary and unilocular
3. Axile placentation
   - Usually found in multicarpellary, bicarpellary, syncarpous ovary
   - Placenta bearing ovules are found on the center axis, ovules are arranged from center to periphery eg. Malvaceae family
4. Basal placentation
   - In monocarpellary unilocular ovaries
   - Rarely in bicarpellary unilocular ovary
   - One or two ovaries seen on the base of thalamus eg. Asteraceae

5. Pendulous placentation
   - ovules found on the top of the ovary, or just opposite to basal
   - ovules are hanging from down from top to bottom
   - Seen in Combritaceae famiy

6. Free central placentation

   -ovules bearing placenta on the central axis of thalamus, the axis is formed by the elongation of thalamus. Eg. Ten ‘o clock plant

7. Superficial placentation

   - seen in multilocular, multicarpellary syncarpous eg. *Nymphae*

   - it is overdevelopment of axile placentation, in which placenta bearing ovules are borne on all the inner walls of chambers. So that ovules are found all around

Types of flowers

- Based on the position of thalamus or arrangement of thalamus
  1. Hypogynous flower/ superior ovary
     - Below gynoecium
     - Thalamus is slightly swollen, convex shaped or conical with calyx, corolla, androecium are borne on successively on it
     - Thalamus is terminated by pistil/ gynoecium, so that ovary is in superior in position. So that ovary called superior ovary

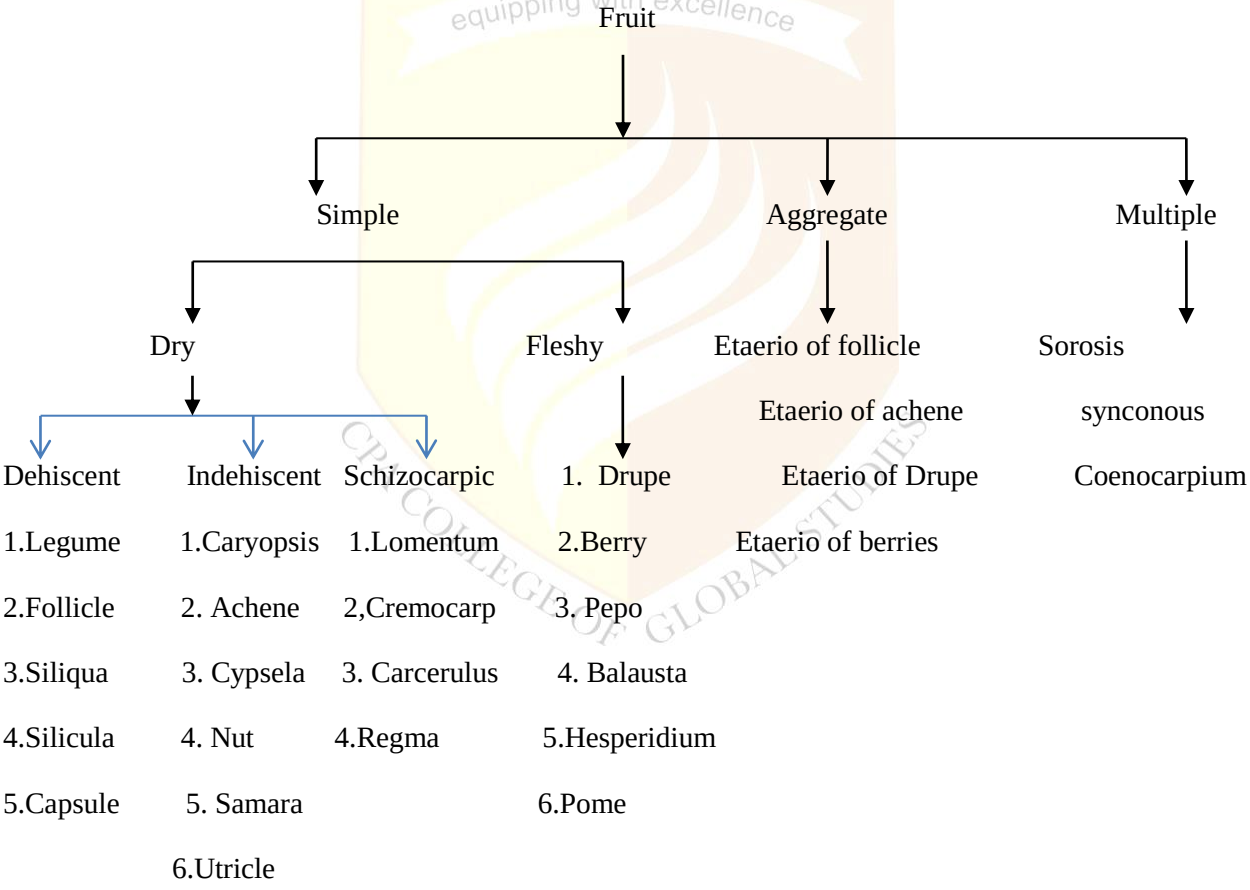
2. Epigynous flower/inferior ovary
    - Thalamus is modified into cup shaped structure which is fused with calyx.
    - Ovary is below to non-essential whorl.
    - Ovary is inferior.
3. Perigynous ovary/half inferior/half superior
    - Thalamus is modified into a flat structure.
    - Gynoecium arranged at the ring of the margin.
    - Perigynous ovary is the characteristic of leguminosae/ fabaceae

IV.Fruits

- Fruit means ripened and fertilized ovary contain one or more seeds.
- Pollination stimulate growth and development of ovary and it prevent abscission.
- Thus pollen grain secrete auxine and it induces the growth of carpel.
- Some changes occurs in the formation of fruit from ovary.
    1. Ovary begins to enlarge by cell division and enlargement
    2. Succulent parenchyma develops within the ovary
    3. Cell get loaded with acids, sugars and flavoring substances
    4. Dissolution of the existing wall in some cell and formation of septa in others. It alter the nature and appearance of ovary
    5. Transformation of ovary wall to fruit wall or pericarp
- After maturation some biochemical changes occurs
    1. Conversion of starch to sugar
    2. Decrease of acid content
    3. Breakdown of chlorophyll
    4. Production of esters (smell)
    5. Formation of ethylene
- Formation of fruit without fertilization called parthenocarpy. Such fruits are parthenocarpic fruits.
    - Natural parthenocarpic fruit- banana, pine apple
    - Artificial parthenocarpic fruit- watermelon, grapes
- Significance of fruit
    a) Seed protection: fruit form a case or vessel around the seed.
    b) Seed dispersal: if it valued by any animal, then it is easily carried by them.
    c) Chemical defense: usually immature fruit have palatable taste and repellence. It may disappear on ripening.
- Parts of fruits
    1. Seed-developing from ovule
    2. Pericarp- differentiated to outer epicarp, middle mesocarp and inner endocarp
- Kinds of fruits
    1. True fruits- developed from ovary

2. False fruits- developed from other than ovary
    a) Apple- thalamus modified to fruit
    b) Cashew-modification of pedicel/peduncle
    c) Pineapple-calyx is modified into fruit.

Classification of fruits



I. Simple fruit

- Single fruit developed from single ovary
- Here the ovary must be monocarpellary unilocular or multicarpellary syncarpous.

- Most diverse types of fruit among fruits
    1. DRY FRUITS- fruit wall dry at maturity

    A. Simple dry dehiscent
        - Fruit wall dries at maturity and burst open automatically to discharge the seeds.
            a) Legume eg. pea
            - Characheristics of family pappilionaceae
            - Develops from monocarpellary, unilocular and perigynous ovary with marginal placentation
            - Dehisces along the sutures from apex to base

            b) Follicle eg. Calotropis
            - Develops from monocarpellary, superior and unilocular ovary with marginal placentation and many seeds.
            - Dehisces along one suture, usually ventral one

            c) Siliqua eg. Mustard
            - Characteristic of family crusiferae
            - Develops from bicarpellary, syncarpous and superior ovary with parietal placentation
            - Pericarp dehisces into two valves

            d) Capsule
            - One or more chambered fruit develops from multicarpellary, syncarpous superior or inferior ovary
            - Contain many seeds
            - Derived from syncarpous pistil commonly known as capsule.
            - Variously named according due to their dehiscence

                a. Loculicidal capsule eg. *Abelmoschus esculentus*
                - Common in Malvaceae
                - Pericarp split open middle of the locule and separate into valves
                - Number of valves equal to number of locules

                b. Septicidal capsule eg. *Ricinus communis*
                - Dehisces along the partiotion or septa between the locule
                - Dividing capsule into component carpel

                c. Septifragal capsule eg. *Datura*
                - Dehisces longitudinally in such a way that the valves break away from the partition.

                d. Porus capsule Eg. Opium
                - Characteristic fruitof papaveraceae
                - Dehiscence of fruit occur by the formation of number of porus on the top of ripe fruits through which the granular seeds are liberated, when the fruits are shaken by wind.
                - It is called Censor mechanism.

B. Simple dry indehiscent

- Never splits open at maturity and seeds are liberated through decay of pericarp or accidental destruction

a).Caryopsis eg. Rice

- Characteristics of Poaceae
- Develops from small, single-seeded,unilocular,superior ovary
- Seedcoat completely fused with the pericarp.

b). Achene eg. *Mirabilis*

- Fruit wall not completely fused with seed coat as in caryopsis.

c).Cypsela eg. Tridax

- Characteristic of family Asteraceae
- One seeded fruit developing from a bicarpellary syncarpous unilocular inferior ovary with basal placentation.
- Fruit with persistent pappus- dispersal mechanism-parachute mechanism.

d). Nut eg. Cashew

- Develops from a bicarpellary to multicarpellary syncarpous, unilocular superior ovary.
- With tough and stony pericarp.
- True fruit is nut.
- False fruit modification of fleshy peduncle.

e). Samara eg. Ailanthus

- One or two seeded wing fruit developing from a monocarpellary or bicarpellary syncarpous ovary.
- Wings thin and membraneous, helps for dispersal of fruit.
- Wings is the modification of pericarp.

f). Utricle eg. Amaranthus

- Modified achene.
- Characteristics of Amaranthaceae and Chenopodiaceae.
- Small seed occupied by a portion of the fruit.

C. Simple dry Schizocarpic fruit

- Intermediate between dry and indehiscent fruit
- Never dehisces longitudinally instead it break transversely into one or two seed containing fragments called mericarp.
- Seeds liberated by the decay of pericarp.

a). Lomentum eg. *Mimosa pudica*

- Elongated fruit, develops like pod.

- Develops from monocarpellary, superior ovary with one or two seeds
- At maturity pod become constricted between the seeds
- Some times break into a number of one or two seed containing mericarp.
- Characteristics of mimosaceae.

b).Cremocarp eg. Coriander

- Two seeded
- Develops from bicarpellary syncarpous inferior ovary.
- Characteristics of family Umbelliferae.
- At maturity fruit spilt into one seeded mericarp.
- Each mericarp is born on an elongated axis called carpophore, which is the prolongation of thalamus into ovary.

c).Carcerulus eg. *Ocimum*

- Characteristics of Lamiaceae.
- Develops from bicarpellary syncarpous superior ovary
- At maturity split into one seeded segment.

d). Regma eg. *Hevea*

- Characteristics of Euphorbiaceae
- Develops from tricarpellary, syncarpous trilocular superior ovary.
- At maturity split into one seeded segments called cocci.

2. Fleshy –pericarp fleshy

a).Drupe eg. Mango, Coconut

- With hard endocarp
- Mesocarp fleshy in Mango, fibrous in Coconut.
- Endosperm is edible part of coconut.

b). Berry or Bacca eg. *Lycopersicon esculentum*

- Develops from multicarpellary, syncarpous superior or inferior ovary
- Seed is hard part, other parts are fleshy.
- In Papaya, Musa, Grapes.
- In the beginning the seeds attached to the placenta later it become loose in the pulp.

c). Pepo eg. Cucurbits

- Characteristics of Cucurbitaceae
- It develops from multicarpellary syncarpous inferior ovary with parietal placentation

- Seeds embedded in the pulp, attached to placenta.

f). Balausta eg. *Punica granatum*

- Many seeded many chambered fruit
- Develops from multicarpellary, syncarpous multilocular inferior ovary.
- Pericarp leathery
- Calyx is persistent, found at the tip of the fruit.
- Seed coat form the edible fleshy part.

g). Hesperidium eg. *Citrus lemon*

- Characteristic fruit of Rutaceae.
- Develops from multicarpellary, multilocular, syncarpous superior ovary with axile placentation.
- Epicarp leathery, have many glands of aromatic oil.mesocarp is the white fibers fused with epicarp.
- Epicarp and mesocarp together form the rind
- Endocarp thin and pepary.

h). Pome eg. *Pyrus malus*

- Fleshy fruit surrounded by fleshy thalamus, that forms the edible part.
- Develops from 2 or more carpellary syncarpous inferior ovary.

II. <u>Aggregate fruit</u>

- Cluster of fruit develops from apocarpous ovary of a single flower.
- All of which ripe together and aggregate as a unit in a common receptacle.
- Each fruit let represent single ovary of an apocarpous pistil or gynoecium.
- The group of fruit are called Etaerio.

1. Etaerio of Follicle eg. Vinca
   - Number of follicle together on a single pedicel.
2. Etaerio of Achene eg. Naravelia.
   - In Naravelia and clematis , fruitlets are provided with persistent style, helps for the dispersion by wind.
3. Etaerio of Drupe eg. Rasberry
   - Fruit with a single pedicel.
4. Etaerio of Berry Eg. Polyalthia
   - Characteristics of Annonaceae
   - In annona many berries arrangedon a fleshy thalamus, epical portion ofvthe individual fruitlet together form a fruit, hence it is similar to a multiple fruit.

III. <u>Multiple fruit</u>

- Massive, fleshy, compound fruit formed from entire inflorescence.

1. Sorosis eg. Artocarpus

- Develops from spike, spadix, or catkin.

2. Synconus eg. Ficus
   - Develops from Hypanthodium inflorescence
   - Receptacle form a hollow succulent cavity, opening out by a smsll apical pore.
3. Coenocarpium eg. Ananas
   - Multiple fruit formed by the fusion of ovaries, floral parts and receptacles of many flowers.
   - With a fleshy axis.

SEED

- Fertilized ovule undergoes a series of development and becomes the seed
- Two integuments become the seed coat. Outer testa, inner tegmen
- Two different types of seeds
  1. Exalbuminous seed eg. Pea
  2. Albuminous seed eg. Rice
- Dispersal of fruit and seeds

  -distribution of seeds or fruit on different mode.

  1. Dispersal by wind
  2. Dispersal by water
  3. Dispersal by animals
  4. Dispersal by the explosive bursting of fruit

SYSTEMATICS

I. MODULE 1

- Systematics is the scientific study of the kinds, diversity and interrelationship of organisms. Or it is the study of the diversity and natural relationship of organism.
- Systematics includes collection, observation, identification and classification.
- Systema-system of classification
- Importance of systematics
  - ✓ It presents a vivid picture of the magnificent biodiversity of our planet and enebles us to make a deep inquiry into it.
  - ✓ Provide valuable information regarding the phylogeny of life, the mechanisms of organic evolution, and the role of natural selection of evolution.
  - ✓ Reveals the interrelationship among and between different kinds of organisms.
  - ✓ Brings to light the evolutionary implication of biodiversity.
  - ✓ Provides a very convenient method for understanding the extant and extinct organism.
  - ✓ Provides a universally accepted system of biological nomenclature.
  - ✓ Serves as basic tool for the preparation of an inventory of the flora and fauna.
  - ✓ Considerably accelerates the growth of other branches of biology.
  - ✓ Plays a significant role in the study of economically important organisms and also in the growth of applied biology.
- Modern systematics is the hierarchial system of natural classification, introduced by Linnaeus.

- Linnaeus –father of modern systematics.
  - Books-*Species Plantarum* (5900 species of plants)
  - *Systema Naturae* (4300 species of animals)
- New systematics is based on phylogenetic considerations, so that it reflects the ancestral relations and evolutionary history of species.
- Lamarck and Charles Darwin proved that species characters are dynamic and mutable and they undergo slow changes. On the basis of these ideas, Julian Huxley, Hubbs and others proposed the concepts of biosystematics, in distinction with classical systematics.
- New trends in systematics

  Old morphological species concepts got replaced by the new concepts of biological species like ecological, cytological, biochemical, molecular.

  1. Morphological approach
     - Morphological features (morphological and micro morphological) are taken as consideration for classification.
  2. Ecological approach
     - Ecological aspects like ecological niche(sum total of the food relations, nutritional habits, response and tolerance, utilization of resources, interaction with other species of an organism) considered for the classification.
     - Each species have its own ecological niche which is different from other species in the same community.
  3. Cytological approach
     - Cytological features of a species like karyotype or chromosomal complement and the DNA content of cells, are very valuable in taxonomy.
     - Number, size and morphology of chromosome and the amount of genomic DNA constant among each species.
     - Help to determine phylogenetic relationship of closely related species.
  4. Biochemical approach
     - It includes enzymology, histochemistry.
     - Here the segregation and detection of species based on different biochemical characteristics.
  5. Molecular taxonomy
     - Recently emerged branch of taxonomy.
     - Includes data based on amino acid sequence of proteins, nucleotide sequence of the genes which governs the synthesis of these protein (DNA sequencing).
     -
- Disciplines of systematics

  Systematics encompasses six basic components or disciplines\

  1. Description
     - ✓ Listing of the inherent features or attributes of organisms for identifying and classifying them.
     - ✓ Detailed and accurate description is most essential for correct identification and classification.
  2. Identification
     - ✓ Detection of the exact species to which the organism under study belongs.

- ✓ It is the process of finding out a known or unknown (named or unnamed) taxon for determining the exact systematic position or rank of a particular organism.
- ✓ Identification based on deductive reasoning in individual species.

3. Phylogenetics
   - ✓ Phylogeny of organism, evolutionary relationship within and between different taxonomic levels.
   - ✓ Findings related with the affinities or similarities and differences between different groups of organisms.
4. Classification
   - ✓ Ordering or grouping of organism based on their morphological, anatomical, physiological, biochemical and phylogenetic and other interrelationship.
5. Taxonomy
   - ✓ Theoretical study of classification, including it bases, principles, procedures and rules (Simpson).
   - ✓ It encompasses the rules for constructing classification, the technical procedures used in classification, and the theoretical foundations on which classification is based.
   - ✓ First proposed by A.P. De Candolle(1813) for the theoretical study of plant classification.
6. Nomenclature
   - ✓ Scientific system of naming the taxonomic groups or taxa that are recognized in classification.
   - ✓ Formal naming of taxa in a scheme of classification.
   - ✓ Binomial nomenclature of Linnaeus (1753).

II. Systems of classification

- Ordering or grouping of organism based on their morphological, anatomical, physiological, biochemical and phylogenetic and other interrelationship called classification.
- Four major systems of classification can be recognized, namely practical, artificial, natural and phylogenetic classification.
  1. Practical classification
     - Classification based on the utility and economic importance of organisms.
     - Plants classified into crop plants, weeds, fruit trees, timber trees and fiber plants etc.
     - Here totally unrelated organisms are brought into the same group, without considering their similarities, ancestry and interrelationship.
  2. Artificial classification
     - Classification based on easily observable superficial resemblances in morphology, habit, mode of life, adaptations etc.
     - It was adopted by early systematists, such as Theophrastus, Pliny and Linnaeus.
     - Classification of plants into herbs, shrubs and trees base on habits.
     - Classification based on floral characters like number of stamen and carpel- Linnaeus sexual system of classification.

- Similar and related organisms are placed in separate groups, and totally unrelated and dissimilar forms are brought into the same group.
- Classification on the basis of superficial similarities does not give any idea about the evolutionary relationship of organisms.

LINNAEAN SEXUAL SYSTEM OF CLASSIFICATION

- Carlous Linnaeus proposed a sexual system based on the numerical relations of floral parts.
- In this classification plants are basically included under 24 classes based on the number and nature of the stamens.
- Each taxa with
  1. Generic name.
  2. Its trivial name (specific epithet of binomial system)
  3. Short descriptive adjectives.
  4. Reference to previous works
  5. Original home.
- Linnaeus did not give any importance to specific epithet. Later taxonomist found the binomial nomenclature very suitable and retained it.
- Classification including 24 classes

  Monandria – single stamen
  Diandria- 2 stamen
  Triandria to decandria - 3 – 10 stamens
  Dodecandria – 11 – 19 stamens
  Etc.
- In his treatise *Genera Plantarum* (1737), described all the genera known to and accepted by him.
- The genera were grouped in 24 classes based on the number and morphological arrangement of stamens. These classes subdivided into orders based on number of pistils; unisexuality considered.
- He published his treatise *Species Plantarum* (1753), it is a two volume hand book contains 6000 species under 1000 genera.
- His descriptions were limited to twelve words. These were followed by references to important earlier works in which the species had often been more fully described and figured; then followed a note on the generic name give the binomial nomenclature.
- *Species Plantarum*, use of binary names, provides the starting point (1753) for the modern botanical nomenclature under the international code.
- **Merits and demerits of Sexual system of classification**
  - ✓ Only merit of this artificial system is that it helps to quickly and easily identify plants making use of one or few characters.
  - ✓ In this system, gymnosperms were placed in the class 14, along with the angiosperm family Labiatae.
  - ✓ Dicots and monocots are not considered separately in many cases, families or orders of dicots and monocots were mixed up and put together eg. Class

gynandria (20) contains Orchids and Pistia of monocots and Grewia, Passiflora etc. of dicots.

- ✓ The families and genera having no relationship and connecting link are put together, whereas related families and genera are not put together.
- ✓ The classes' monoecia, dioecia and polygamia are most unsatisfactory because monoecious or dioecious condition may arise in any family.eg. Monocot Globba (Zingiberaceae family) and dicot Mangifera (Anacardiaceae) have only one stamen and so they are grouped under Monandria.

- In another work, *Philosophica Botanica* (1751) Linnaeus enumerated 67 natural orders. As palms, orchids, conifers, conifers, composites, borages represent natural groups. Some natural orders are mixed with monocots and dicots appearing together.

3. Natural classification

- Classification based on morphological, anatomical, physiological, embryological and behavioral similarities.
- Closely similar organisms are placed in homogenous groups.
- Natural classification was proposed by John Ray, Bentham and Hooker's system of classification.
- It gives a clear picture of the natural relations among organisms. Since it is a rational approach, it could enjoy wide acceptance.

BENTHAM & HOOKER'S NATURAL SYSTEM OF CLASSIFICATION

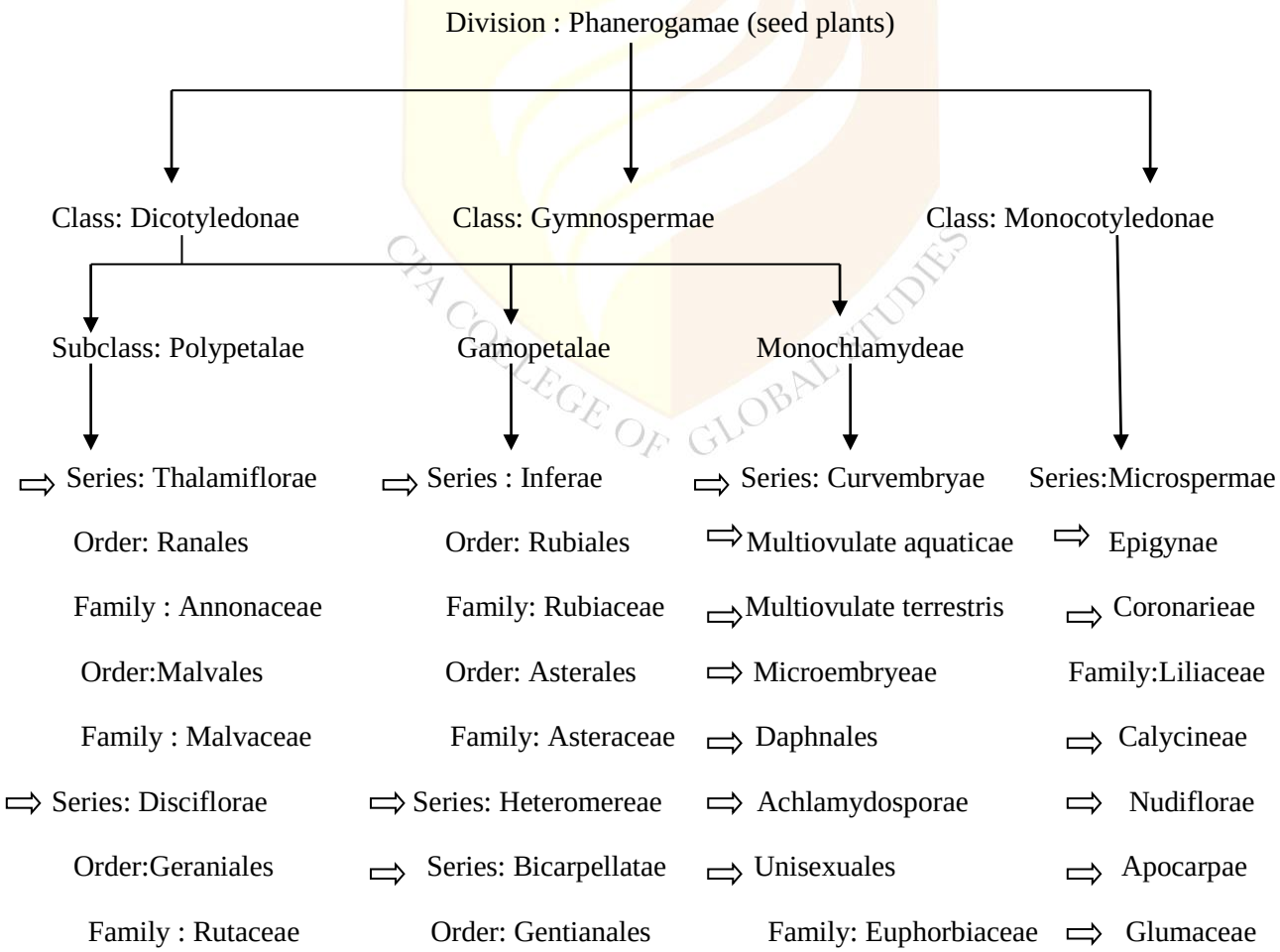
- George Bentham (1880-1884) and Joseph Dalton Hooker (1817-1911), two well-known English botanists, jointly published a system of classification of seed plants
- Its one of the most elaborate natural systems of classification published in *Genera Plantarum* (1862-1884), a three volume work in Latin.
- 97,205 species of plants grouping under 7569 genera and 202 natural orders (now treated as families) beginning from Ranunculaceae to Gramineae.
- The classification was a refined version of the system proposed by A.P.de Candolle.
- The system of classification is Pre-Darwinian in concept of fixity of species.
- J.D. Hooker was the director of Royal Botanical Garden Kew. J.D.Hooker publications-flora of British India (7 volume), Index Kewensis .

- **Salient features**
  - ✓ The classification covers only the seed plants or Phanerogams.
  - ✓ 97,205 species of flowering plants are classified under 202 families starting from Ranunculaceae and ending in Graminae.
  - ✓ Monocotyledons are placed after Dicotyledons.
  - ✓ Gymnosperms are treated as a separate group and placed it in between dicots and monocots.
  - ✓ Dicotyledons are divided into Polypetalae, Gamopetalae and Monochlamydeae.

- ✓ The series Disciflorae (characterized by the presence of a well-developed staminiferous disc) is created newly- a group not recognized by earlier workers.
- ✓ The sub-class monochlamydeae is divided into 8 series on the basis of terrestrial or acquatic habitats.

- **Merits**
  - ✓ The system is natural and very practical. Classification is based on actual observation and examination of specimen and herbaria.
  - ✓ Descriptions are accurate at all level, and easy to follow up to the family level.
  - ✓ The system provides information about geographical distribution.
  - ✓ The classification begins with Ranales which is now universally considered as the most primitive among angiosperms.
  - ✓ Monocots are placed after dicots. In dicots, the dichlamydeous Polypetalae and Gamopetalae were placed before the Monochlamydeae.
  - ✓ The placement of Gamopetalae after Polypetalae is justifiable since the union of petals is considered as an advanced feature over the free condition.
  - ✓ A special feature of this system is the addition of the new series Disciflorae. The three series of Polypetalae namely Thalamiflorae, Disciflorae and Calyciflorae show gradual evolutionary advancement from hypogyny to epigyny passing through transitional perigynous condition.
  - ✓ The placement of Heteromerae in Gamopetalae before Bicarpellatae is justifiable.
  - ✓ The position of Cucurbitaceae and Umbelliferae at the end of Polypetalae is appropriate. These two families form a connecting link between Polypetalous and Gamopetalous families.
  - ✓ Creation of the sub-class Monochlamydeae and the arrangement of certain series on the basis of acquatic and terrestrial characteristics are curious.
  - ✓ Among Monochlamydeae, families with unisexual flowers are placed after the families having bisexual flowers.
  - ✓ The series Glumaceae having many advanced characters and extremely reduced flowers has been rightly placed at the end of monocots.
- **Demerits**
  - ✓ Classification is post Darwinian, its concept is Pre-Darwinian. So it does not consider evolutionary and phylogenetic relationships.
  - ✓ Gymnosperms are placed wrongly in between dicots and monocots, and the phylogenetic importance of naked seed is not duly recognized.
  - ✓ Some closely related families are placed apart. Eg.,Chenopodiaceae and Caryopyllaceae.
  - ✓ Monochlamydeae is treated as a subclass. But it is only an artificial group.
  - ✓ The placing of Asteraceae at the beginning of Gamopetalae is not justifiable.
  - ✓ The advanced family Compositae is placed at the beginning of Gamopetalae. Similarly, the advanced family Orchidaceae is treated at the beginning of monocots.

- ✓ Retention of Nyctaginaceae, Polygonaceae, Amaranthaceae and Chenopodiaceae in Monochlamydeae is unnatural because they are related to orders having differentiated perianth.
- ✓ While classifying Gamopetalae and Monocotyledons, the authors ignored the fundamental basis of polypetalous grouping.



⇨ Series: Calyciflorae Family: Apocynaceae ⇨ Ordines Anomali Family: Gramineae

Order: Rosales Order: Polymoniales

Family : Leguminosae Family: Solanaceae

Subfamily: Papilionaceae Order: Personales

Subfamily : Mimosaceae Family: Acanthaceae

Subfamily : Caesalpiniaceae Order: Lamiales

Order: Myrtales Family : Lamiaceae

Family: Myrtaceae

Order: Passiflorales

Family: Cucurbitaceae

4. Phylogenetic or evolutionary classification
   - Extended form of natural classification.
   - Based more on genetic relations and evolutionary history of organisms(evolutionary history of a group is called phylogeny).
   - The system of classification reflects both ancestry and evolutionary relations of organisms.
   - Here the classification mainly denotes the primitive and advanced characters in consideration.
   - Proposed by Engler, Prantl and Hutchinson.

ENGLER & PRANTL'S SYSTEM OF CLASSIFICATION

- Classification proposed by Adolf Engler and Karl Prantl.
- This is the first recognized true phylogenetic system in which families are arranged according to the increasing complexity of the flower, fruit and seed development. In this classification, the groups are built up in a stepwise manner to form a generally progression series.
- It was first published in 20 volumes in the monumental work,"*Die Naturalichen Pflanzen-Familien"(*1897-1915).
- It provides keys and description for the known genera of algae, fungi, bryophytes and higher vascular plants.
- This system is still in use in many herbaria all over the world.
- This classification including 14 divisions from schizophyta to embryophyta Siphonogama.
- Engler and Prantl recognized 280 families of flowering plants, including those of gymnosperms.

- In the system families of higher vascular plants are arranged in accordance with increasing complexity of flowers.
- Here naked flowers with a bract like perianth considered as most primitive, and those with well differentiated calyx and corolla are considered to be advanced one. And fusion of petals probably represents a more highly evolved stage.
- In this system monocots are placed before dicot, and orchids are considered to be more evolved then grasses.
- Those angiosperms divided into 2 classes, namely monocotyledoneae and dicotyledoneae.
- Monocotyledeae further divided into 11 seriesand 45 families.
- Dicotyledoneae into 2 subclasses, Arachichlamydeae and Metachlamydeae. Including 33 series, 199 families and 11 series , 56 families respectively.
- Gymnosperms are placed before angiosperms.
- Here the flowers without perianth are considered primitive. At the same time, with a single whorl of perianth or with two-whorled perianth and distinct sepals and petals are considered advanced.
- Unisexual flowers are considered primitive, and bisexual ones are considered as derived ones.
- Zygomorphy and epigyny are advanced evolutionary lines.
- The family Orchidaceae regarded as the highest developed family and Typhaceae is regarded as the most primitive family.

5. Phylogeny group system
    - Most recent classification.
    - In the late 1990's , an informal group of botanists from major institutions of the world that have been carrying out the analysis of plant genetic material came together under the title of the Angiosperm Phylogeny Group or APG.
    - Their intention was to provide a widely accepted and more stable point of references for angiosperm classification.
    - The first attempt at a new system was published in 1998 (APG I). three revision have been published, in 2003 (APG II), 2009 (APG III) and 2016(APG IV), each superseding the previous system.
    - This system was initiated by Mark W. Chase & Peter F. Stevens with contributions of many taxonomists.
    - APG, shows that the monocots form a monophyletic group(clade), but that the dicots do not.(paraphyletic).
    - Monophyletic refers to a group that consist of a common ancestor plus all descendants of that ancestor. Paraphyletic refers to the group that includes a common ancestor plus some, but not all, descendants of that common ancestor.
    - The groups in this system are regareded as monophyletic clades.
    - The diversity of flowering plantsis not evenly distributed. Nearly all species belongs to the eudicots(75%), monocot(23%) andmagnolids (2%) clades. And the remaining 5 clades includes 9 families.

- There are somany revision taken after APG I. including addition and deletion of groups. Initially it contains 462 families and 40 monophyletic orders, later on it changed.
- Family containing a single genus and orders containing a single family are avoided where this is possible without violating the over-riding requirement for monophyly.

MOULE 2: Study of Angiosperm families

ANNONACEAE

- Commonly known as Custard apple or *Annona* family.
- Largest family of order Magnoliales, with 129 genera and about 2,120 species.
- Family consists of trees, shrubs and woody climbers found mainly in the tropics and a few species extend into temperate regions.
- Many species are valuable for their large pulpy fruits, some for timbers and others ornamentals.
- Bark, leaves and roots of several species are important in folk medicine and others are important sources of perfume and spice.
- Plants have simple leaves with smooth margins that are alternately arranged in two rows along the stems.
- Flowers in some species are borne directly on large branches or on the trunk.
- Flowers are radially symmetrical and usually bisexual.
- In most cases the 3 sepals are united at the base.
- Petals may be 3 or 6 in brown, yellow, or greenish in colour.
- Many stamens in a spiral, and many pistils, each with a one chambered ovary
- **Diagnostic characters**
  1. Perennial woody trees, shurbs or woody climbers; no herbs.
  2. Leaves simple, two ranked, exstipulate, glands are present.
  3. Flowers fascicled or solitary.
  4. Flower small bisexual, hemicyclic, hypogynous and actinomorphic; sweet scented (*Artabotrys*).
  5. Perianth outer whorl sepalloid; small; lobes free and valvate aestivation.
  6. Stamens many, free, acyclic, spiral arrangement of stamens on the convex thalamus, stamens with short and thick filaments. Connectives thick and broad and sometimes surpass the anther lobes; stamens hooded; anther linear and extrorse.
  7. Gynoecium polycarpellary; apocarpous; carpels spirally arranged, acyclic, marginal or basal placentation, anatropous ovule.
  8. Fruit eterio of berries or drupes; seeds endospermic; endosperm ruminate.

- **Vegetative and reproductive characters.**
  1. **Habit** -Mostly mesophytic shrubs and trees, often aromatic. *Artabotrys* and *Unona* are hook stragglers.

2. **Root** – Tap root.
   Stem- Erect, branched; monopodial in *Polyalthia* and *Cananga*, sympodial in *Artabotrys*.
   Leaves-Simple, alternate, exstipulate, margins entire or wavy (*Polyalthia*), pinnately recticulate venation. Leaves are gland-dotted in *Annona.*
3. **Inflorescence** – Solitary cyme and various types.
4. **Flowers**- Regular, bisexual, actinomorphic, spirocyclic (perianth- cyclic, stamen, carpel- spiral), trimerous, hypogynous.
5. **Perianth** – Mostly in 3 whorls, each consisting of 3 members, outer calyx-like (sepalloid), inner corolla- like (petalloid), thalamus forms a large convex or conical structure above the perianth.
6. **Calyx**- Sepals 3, valvate aestivation, free or connate below, green in colour.
7. **Corolla**- Petals 3 (single whorl) or 6 (two whorls with 3 petals), valvate aestivation.
8. **Androecium**- stamens numerous, spirally arranged and closely packed on the conspicuous thalamus. Short filament with a prominent dithecous anther, connectives is prolonged to form a hood at the top. Dehiscence of anther is longitudinal.
9. **Gynoecium**- carpels many, apocarpous, closely arranged in the thalamus in a spiral manner. Each carpel with ovary style and stigma; single basal anatropous ovule in *Annona*; ovary superior; marginal or basal placentation.
10. **Fruit**-aggregate of free berries in *Polyalthia, Artabotrys*. In Uvaria, each carpel develops into an elongate fruit which is constricted inbetween the seeds. In *Annona Squamosa* it is aggregate of berries.
11. **Seeds**-with endosperm, endosperm ruminate.

- **Economic importance**.
  Ornamentals- *Polyalthia, Cananga odorata , Artabotrys uncinatus.*
  Fruit- *Annona squamosa, A. muricata, A. cherimolia, A. reticulata, Asimina triloba (*paw paw*), Porcelia saffordiana.*
- **Common plants**:

  Annona angustifolia (Native to Brazil)

  Annona cherimola (Cherimoya)

  Annona dioica (Native to Bolivia)

  Annona glabra (Alligator apple)

  Annona muricata (Mullanchakka)

  Annona reticulata (Chakkapazham)

  Annona squamosa (Seethapazham)

  Annona tomentosa (Native to Bolivia and Brazil)

  Asimina triloba (Paw paw)

Cananga odorata (Ylang-ylang)

Oxandra lanceolata (Lancewood)

Polyalthia korinti

Polyalthia longifolia (Aranamaram)

Rollinia mucosa (Native to America)

Uvaria narum (Anakoori)

Uvaria ovata

MALVACEAE

- *Hibiscus* or mallow family.
- 243 genera and at least 4225 species of herbs, shrubs and trees.
- Cosmopolitan in distribution, members are mostly confined to tropical regions.
- **Diagnostic characters**
  1. Herbs or shrubs with stellate pubescence on vegetative parts.
  2. Presence of mucilage in the cortex and pith.
  3. Leaves stipulate and alternate.
  4. Flowers bisexual, actinomorphic and hypogynous.
  5. Presence of epicalyx in some genera.
  6. Monadelphous stamens with monothecous, reniform anthers.
  7. Multicarpellary, syncarpous, superior ovary with ovules on axile placenta.

- **Vegetative and reproductive characters.**
  1. **Habit** –Herbs (*Abutilon, Sida, Urena*), shrubs (*Hibiscus, Gossypium*) or tree (*Thespesia, Kydia*).
  2. **Root**- Tap root
     Stem –Erect, branched.
     Leaves- Simple or palmately lobed, alternately spiral, stipulate, leaf margin serrated or entire leaves with acute apex.
  3. **Inflorescence**-Solitary axillary cyme in *Hibiscus*, solitary terminal cyme in *Gossypium*, axillary or terminal panicle in *Kydia*.
  4. **Flower**- Bracteates, bracteolate, bisexual, actinomorphic, hypogynous, pentamerous, cyclic and complete. Unisexual in *Napaea* and polygamodiecious in *Kydia*.
  5. **Epicalyx** –An epicalyx or involucral bracteoles formed of bracteoles is present in most members. Epicalyx is formed of 2 or more involucral bracteoles. In *Malva* it is formed of 3 bracteoles, in *Hibiscus* it is 5 to many, many in *Althaea*. Epicalyx is absent in *Sida* and *Abutilon.*
  6. **Calyx-** Sepals 5, free or united at the base. Valvate aestivation.

7. **Corolla**- Petals 5, either free or adnate at the base with staminal tube. Twisted aestivation in most plants
8. **Androecium**- Stamens numerous and monadelphous. Staminal tube is formed by the union of the filaments of all the stamens. It is divided into numerous filaments at the top in *Sida*. The filaments of the stamens are given off at all levels from the apically 5-toothed stamina tube in *Hibiscus*. Anthers reniform, monothecous, dehisces by transverse slits at the top. Pollengrains large and spinulose.
9. **Gynoecium**-Carpels 3 to many, syncarpous, superior. Style is terminal, single or divided apically. The number of stigma may be the same as that of carpels or double the number of carpels. Ovules are one to many in each chamber on axile placenta. Insect pollination.
10. **Fruit**- Loculicidal capsule in *Abelmoschus esculentus*. In *Malvaviscus*, it is berry. It is schizocarp formed of many mericarps in *Sida* and *Abutilon*. The loculicidal capsule breaks open violently to disperse the seeds.
11. **Seed**-reniform or ovoid and glabrous hairy or woolly.
    The epidermal outgrowths on the seeds of cotton help in dispersal by wind. In *Sida* and *Urena* hooks are developed on mericarp.

- **Economic importance**

Ornamental plants: *Hibiscus rosa-sinensis, H. mutabilis, H. hirtus, H. schizopetalus, Malvaviscus penduliflorus, Thespesia populnea, Abutilon hybridum* etc.

Commercial plants: *Gossypium arboreum, G. barbadense, G. herbaceum* and *G. hirsutum*- cotton yielding.

Abelmoschus esculentus- vegetable.

Hibiscus cannabinus, H. sabdariffa- for edible leaves and fibre.

Medicinal plants: roots of *Sida alnifolia* for rheumatism, *Abelmoschus moschatus* to cure stomach ache. *Hibiscus rosa-sinensis* etc.

- **Common plants**

Abelmoschus esculentus (Ladies finger)

Abutilon indicum

Gossypium arboreum

Gossypium herbaceum (Cotton)

Hibiscus cannabinus

Hibiscus hirtus

Hibiscus hispidissimus

Hibiscus Mutabilis (Changing rose)

Hibiscus rosa-sinensis (China rose)

Hibiscus schizopetalus

Sida acuta (Anakurunthotty)

Sida alnifolia

Sida cordifolius

Sida rhombifolia

Thespesia populnea(Poovarash)

Urena lobata (Uthiram)

RUTACEAE

- The *Citrus* family of flowering plants composed of 160genera and about 2070 species.
- Mostly includes woody shrubs, tree and few herbaceous perennials and is distributed throughout the world, especially in warm temperate and tropical regions.
- The family comprises economically important fruit trees as well as several ornamental species.
- The perfect flowers arranged in inflorescence, which facilitates pollination by insects such as small flies and bees. The flowers are conspicuous for their colour, fragrance and nector.
- **Diagnostic character**
  1. Plants are aromatic due to oil glands in leaves.
  2. Leaves are pinnately compound or unifoliate compound, shiny, gland dotted; exstipulate, alternate, rarely opposite, petioles winged.
  3. Inflorescence axillary panicles or solitary or cymose clusters.
  4. Flowers bisexual, polygamous or unisexual, pentamerous or trimerous or tetramerous, hypogynous, actinomorphic rarely zygomorphic, thalamus concave, sepals 3-5, polypetalous, gland dotted, aromatic.
  5. Disc presents below the ovary; disc is cushion like.
  6. Stamens 3-10 or many, free or polyadelphous, obdiplostemonous.
  7. Gynoecium 2,4 or 5 carpellary, syncarpous, locules as many as carpels, ovules 1-2 or several in each locule; axile placentation, disc below the ovary.
  8. Fruit hesperidium or capsule.
  9. Seed endospermic.
- **Vegetative and reproductive characters**
  1. **Habit**- Shrub (*Murraya exotica*), evergreen shrub (*Glycosmis pentaphylla*), tree (*Aegle marmelos,Citrus*), herb (*Ruta graveolens*).
  2. **Root**-Tap root
     Stem-erect, branched.
     Leaves- Simple or compound leaves, alternate rarely opposite, exstipulate, usually pinnately compound (*Murraya*), trifoliate (*Aegle)*, unifoliate (*Citrus*). Leaves are aromatic, shining and gland dotted.
  3. **Inflorescence**-Axillary or terminal, rarely solitary or fascicled (*Triphasia, Citrus*), terminal paniculate or corymbose cymes (*Murraya*).

4. **Flower**-Usually actinomorphic, bisexual, and pentamerous; rarely unisexual (*Toddalia*) or polygamous (*Feronia*). Zygomorphic (*Dictamus*).
5. **Calyx**-Sepals 5 or sometimes 4, free or variously united. In some zygomorphic genera, calyx become gamosepalous and tubular; imbricate or quincuncial aestivation.
6. **Corolla**-Petals 5 or sometimes 4, polypetalous.
7. **Androecium**- Stamens 3-5, or as many as petals in male flowers of *Toddalia, Evodia*. 3+3 in *Triphasia*, 4+4 in *Acronychia*, 5+5 in *Murraya* (long and short stamens), obdiplostamonous in *Glycosmis* and *Chloroxylon*, stamens numerous and free in *Aegle*, in *Citrus* numerous stamens are in polyadelphous. Anthers dithecous and longitudinal dehiscence. Staminodes are seen in female flowers of *Toddalia*.
8. **Gynoecium**- Syncarpous, carpels varies according to genus; pentacarpellary in *Toddalia*, tricarpellary and trilobed in *Chloroxylon* and *Triphasia*, bicarpellary in *Murraya*,multicarpellary in *Citrus*. Style usually stout and prominent, stigma capitate and sticky, ovary superior. Usually axile placentation but in *Feronia* numerous ovules are in parietal placentation. In each carpel there are usually 2 ovules. A pistilode is present in male flowers of *Toddalia*.
9. **Fruit**- berry in *Murraya*, hesperidium in *Citrus*, loculicidal capsule in *Chloroxylon* and *Ruta*..
10. **Seed** – endospermic or non-endospermic.

- **Economic importance**

  Ornamental plants- *Ruta graveolens, Murraya paniculata*.

  Fruit- different species of *Citrus*; *Citrus limon, C. aurantium, C. sinensis, C. medica, C. paradisi, C. reticulata, C. aurantifolia.*

  As sacred tree in hindu religion- *Aegle marmelos* leaves.

  For flavouring curries- *Murraya koenigii* leaves are used.

- **Common plants**

  Aegle marmelos

  Citrus aurantifolia.

  Citrus aurantium

  Citrus medica

  Citrus paradisi

  Citrus reticulata

  Citrus sinensis

  Citrus limon

  Glycosmis pentaphylla

  Murayya koengii

  Murraya exotica

Ruta graveolens

LEGUMINOSAE

- One of the largest families of flowering plants in the World..
- Approximately 690 genera and 17,000 species distributed Worldwide.
- This family classified into three subfamilies
  1. Papilionaceae
  2. Caesalpiniaceae
  3. Mimosaceae
- **Diagnostic character common for three subfamilies.**
  1. Leaves alternate, leaf base pulvinate, stipulate or exstipulate, simple or compound leaves.
  2. Racemose inflorescence.
  3. Flowers bisexual, perigynous and pentamerous.
  4. Androecium of diplostemonous origin; but showing many variations.
  5. Monocarpellary unilocular gynoecium with marginal placentation which develops pod or legume dehiscing by the dorsal suture.
  6. More or less cup shaped receptacle.
  7. Fruit legume or lomentum.

SUB-FAMILY PAPILIONACEAE

- **Diagnostic characters**
  1. Tap root with nodules
  2. Pinnately compound leaves with pulvinous leaf base.
  3. Racemose inflorescence
  4. Pentamerous, perigynous and strictly zygomorphic flowers.
  5. Papilionaceous corolla with descendingly imbricate aestivation.
  6. Stamens 10, monadelphous or diadelphous.
  7. Monocarpellary, half inferior or half superior ovary with marginal placentation.
  8. Fruit is legume
- **Vegetative and reproductive characters**
  1. **Habit**-mostly herbs, some are trees. Annual herb (*Tephrosia*), annual shrub (*Sesbania*), climbers(*Dolichos* and *Clitoria*), tendril climbers (*Lathyrus* and *Pisum*), climbing shrub (*Abrus*), perennial shrub (*Aeschynomene aspera*), trees (*Pterocarpus, Pongamia*). *Ulex* show xerophytic adaptation.
  2. **Root** – normal tap root with root nodules.
     Leaves- simple or compound imparipinnate, alternate, stipulate, stipules leaf like (foliaceous in *Pisum* and *Lathyrus*), leaf base pulvinate. Leaves of *Desmodium* show turgor movements, leaves are spinosus in *Ulex*, entire leaf modified into tendril in *Lathyrus* and terminal leaflet modified into tendril in *Pisum sativum*.
  3. **Inflorescence**- usually racemose type, corymbose raceme or a terminal panicle (*Cajanus*), axillary solitary (*Cicer*), terminal or lateral panicle (*Dalbergia).*
  4. **Flowers**- bisexual, strongly zygomorphic, perigynous, pentamerous.

5. **Calyx**-sepals 5, gamosepalous, irregular, valvate aestivation. Calyx is 2- lipped in *Aeschynomene*.
6. **Corolla**- petals 5, free, irregular, descendingly imbricate (vexillary) aestivation. Posterior largest standard petal, lateral 2 wing petals, anterior 2 keel petals.
7. **Androecium**- 10 stamens, diadelphous (9+1) or monadelphous. Stamens opposite to standard petals.
8. **Gynoecium**-monocarpellary, with short stalk, flattend ovary, terminal style that ends in a capitate stigma, ovary unilocular with many ovules on marginal placentation.
9. **Fruit**-straight or twisted legume or lomentum in *Desmodium*. Seed is endospermic.

- Economic importance
  Seeds of following plants used as pulse:
  Glycine max, Phaseolus vulgaris, P. aureus, P. mungo, V. sinensis, Cajanus cajan, Dolichos lablab, Arachis hypogaea, Cicer arietium,
  Vegetable: *Pisum sativum, Dolichos lablab*
  Ornamentals: *Sesbania grandiflora, crotalaria aculeata, Lathyrus odoratus, Erythrina indica, Piptanthus nepalensis.*
  For furniture: timber of *Dalbergia sissoo* used.
- **Common plants**
  Abrus precatorious

  Arachis hypogea

  Cajanus cajan

  Cicer arietinum

  Clitoria ternatea

  Crotalaria aculeata

  Crotalaria nana

  Crotalaria pallida

  Crotalaria retusa

  Dolichos lablab

  Erythrina indica

  Glycine max

  Indigofera tinctoria

  Lathyrus odoratus

  Phaseolus aureus

Phaseolus mungo,

Phaseolus vulgaris

Piptanthus nepalensis

Pisum sativum

Pongammia pinnata

Sesbania grandiflora

Tephrosia purpurea

Vigna sinensis

SUB-FAMILY MIMOSACEAE

- **Diagnostic characters**
  1. Tropical or subtropical in distribution.
  2. Mostly shrubs or trees: rarely herbs.
  3. Leaves bipinnate, never simple.
  4. Cymose head or cylindrical spike inflorescence.
  5. Bisexual, actinomorphic, pentamerous or tetramerous , perigynous flowers.
  6. Sepals 5, gamosepalous.
  7. Petals 4-5, gamopetalous tubular with valvate aestivation.
  8. Stamens numerous or 10 in number and very rarely 4 as in *Mimosa*; filaments are brightly coloured; free (*Acacia*) or slightly united at the base as in *Albizzia*.
  9. Gynoecium monocarpellary, marginal placentation.
  10. Fruit is lomentum; seeds non-endospermous.

- **Vegetative and reproductive characters**
  1. **Habit**-Mostly shrubs or trees; tree (*Enterolobium*), shrub (*Acacia*). *Acacia* and *Prosopis* are xerophyte, *Neptunia* is a hydrophyte, *Entada* is tendril climber.
  2. **Root**-Tap root.
     Stem- Erect and branched.
     Leaves- Bipinnately compound, alternate and stipulate; stipules modified into spines in *Acacia*. Petiole modified into phyllode. Leaves of *Mimosa* shows sleeping movement.
  3. **Inflorescence**- Usually globose head; pedunculate, elongated spike (*Prosopis*) or condensed cymose head (*Enterolobium, Albizzia*)
  4. **Flower**-Bisexual, actinomorphic, regular, pentamerous and perigynous; flowers of *Mimosa* is tetramerous. Polygamous in *Entada*.
  5. **Calyx**- Sepals 4-5, gamosepalous,clearly toothed, valvate. In *Mimosa* it is minutely toothed

6. **Corolla**- Petals 4 or 5, united, valvate, tubular; in *Prosopis* petals are connate at the base.
7. **Androecium**- Stamens 4 or 10 to numerous; 4 in *Mimosa*, in Acacia 10 to numerous and free, in *Prosopis* 10 stamens, free and slightly exerted. In *Albizzia* numerous stamens are united at the base by means of filaments.
8. **Gynoecium**- Monocarpellary , ovary sessile or stalked, style filiform and stigma minute. Many ovules in the unilocular ovary on marginal placenta.
9. **Fruit**-Legume or lomentum. Seed is non- endospermous.

- **Economic importance**

  Acacia senegal- yields gum Arabic
  Acacia arabica- pods and foliage are used as fodder for cattle and the bark is used in tanning.
  Acacia catechu – very hard wood and used for plough making.
  Albizzia lebbeck – use as fodder, bark, leaves, flowers, seeds used in medicine.

- **Common plants**

  Acacia arabica

  Acacia auriculiformis

  Acacia catechu

  Acacia nilotica

  Acacia senegal

  Adenanthera pavonina

  Albizzia lebbeck

  Entada pursaetha

  Enterolobium barinense

  Enterolobium barnebianum

  Mimosa pudica

  Neptunia acinaciformis

  Prosopsis spicigera

  Samanea saman (cheeni)

SUB-FAMILY CAESALPINIACEAE

- The subfamily with approximately 135 genera, distributed in tropical and subtropics of world.

- Most plants are wild, but many are cultivated for their beautiful flowers and timber.
- **Diagnostic characters**
  1. Mostly trees and shrubs; rarely herbs.
  2. Inflorescence mostly raceme or panicle.
  3. Flowers bisexual, slightly zygomorphic, pentamerous and perigynous.
  4. Sepals 5, free or slightly fused and imbricate.
  5. Corolla shows distinct 5, free petals; ascendingly imbricate aestivation, odd petal smallest and innermost.
  6. Stamens 10, in 2 whorls of 5 whorls of each; some may be reduced to staminodes as in *Caasia* sp.; usually free and of variable lengths.
  7. Gynoecium monocarpellary, with marginal placentation.
  8. Fruit is long, legume; seed in some cases is endospermous. Pollination mostly entemophilous but ornithophily in *Bauhinia*.

- **Vegetative and reproductive characters**
  1. **Habit**-Mostly shrubs or trees; *Parkinsonia* shows xerophytic adaptation, *Cassia* is undershrubs or shrubs, trees (*Tamarindus*), climbing species of *Bauhinia* show coiled tendrils formed from the axillary buds.
  2. **Root**-Tap root.
     Stem-Erect, branched, woody. Sometimes they are herbaceous or climbing.
     Leaves-Large pinnately or bipinnately compound leaves and stipulate. Stipule either small or auriculate or spiny (*Parkinsonia*), the main rachis is modified into a spine and the flattened secondary rachises or phyllodes arise on it. In *Bauhinia vahlii* conspicuous circinately coiled branched tendrils are present in the axils of the leaves which are simple; leaf base is typically swollen and pulvinate.
  3. **Inflorescence**- A many flowered raceme, terminal corymb (*Caesalpinia pulcherrima*) or like corymbose panicle (*Saraca*).
  4. **Flower**-Big and showy and forming a clusters; bracteate, ebracteolate, complete, bisexual, perigynous and pentamerous.
  5. **Calyx**-5 green sepals, united or free, may be only 4 in some (*Saraca* and *Tamarindus*). Sepals are petaloid in genera where petals are completely absent. Valvate aestivation (*Delonix*) or imbricate (*Cassia, Saraca*).
  6. **Corolla**- Petals 4-5, aestivation is ascendingly imbricate. Anterior 2 petals are completely suppressed or represented by glands or bristles in *Tamarindus*. Petals are absent in *Saraca*.
  7. **Androecium**-10 stamens, diplostemonous, but diadelphous in some, monadelphous in *Tamarindus*. Anthers are dithecous, basifixed or versatile, dehiscing by longitudinal slits or by pores in *Cassia.* In some species of *Cassia* and other species stamens are sterile.
  8. **Gynoecium**-Monocarpellary or rarely bicarpellary, apocarpous in *Saraca*; ovary is cylindrical with terminal style and capitate stigma, ovary unilocular with numerous ovules on marginal placentation.
  9. **Fruit**-Legume and rarely samara as in *Pterolobium*. Seeds endospermic or non-endospermic.
- **Economic importance**

Ornamentals- *Bauhinia purpurea, Cassia fistula, Bauhinia varcigata, Caesalpinia pulcherrima, Poinciana regia, Saraca indica.*
Used as stain or dye – *Haematoxylum campechianum*
Commercial- *Parkinsonia aculeata*, for making papers and ropes.

- **Common plants**

Bauhinia purpurea

Bauhinia vahlii

Caesalpinia pulcherrima

Cassia fistula

Cassia occidentalis

Cassia tora

Haematoxylum campechianum

Parkinsonia aculeata

Saraca indica

Tamarindus indica

MYRTACEAE

- *Myrtle* family of shrubs and trees.
- About 150 genera and 3300 species, widely distributed in the tropics.
- They have rather leathery evergreen leaves with oil glands.

- **Diagnostic features**

1. Vegetative parts, especially the leaves, are aromatic due to lysigenously formed oil cavities.
2. Leaves are simple, opposite, exstipulate, recticulate, evergreen and aromatic.
3. Inflorescence is solitary racemose, cymose clusters or panicle.
4. Flowers are regular, bisexual or unisexual, perigynous or epigynous and pentamerous disc below the calyx tube.
5. Epicalyx is rarely present.
6. Thalamus forms a deep cup which is adnate to the ovary.
7. Calyx is conspicuous, sepals are 4-5 and gamosepalous and polysepalous.
8. Petals are 4-5, free, orbicular, imbricate or united and they form a cap in the bud which comes off as the stamens expand.
9. Stamens are numerous, bent in the bud condition and free or polyadelphous.
10. Ovary is 2-5, muticarpellary and syncarpous, with axile placentation and multilocular ovules.
11. Fruit is a berry, capsule or drupe.

12. Seeds are non- endospermic.

- **Vegetative and reproductive characters.**
  1. **Habit**- Mostly shrubs and trees; rarely herbs and climbers also.
  2. **Root**-Tap root.
     Stem- Erect, branched.
     Leaves- Simple, exstipulate, alternate or opposite, coriaceous and pinnately reticulate. Leaf shape varies, even in a single genus also. Margin entire with a prominent intramarginal vein.
  3. **Inflorescence**-Axillary and solitary cyme (Guava, *Myrtus*) or generally in short cymes (*Rhodomyrtus*), rarely racemose (E*ucalyptus*), or much branched cyme (*Eugenia jambolana*).
  4. **Flowers**-Bracteate, bracteolate or ebracteolate, actinomorphic, bisexual, and usually epigynous, but may be rarely perigynous when ovary is free from the receptacle.
  5. **Calyx**- 4 or 5 free sepals and aestivation is quincuncial. Sepals are valvate and connate in the bud (Guava) and they may separate when the flower opens. Calyx is adnate to the ovary and closed in the bud condition.
  6. **Corolla**- 4-5 petals, free, imbricate and inserted on the top of the deep cuplike receptacle. Petals are orbicular form a cap in the bud condition and they fall off as a calyptra due to the pressure of the growing stamens. Petals alternate with sepals.
  7. **Androecium**- Stamens are numerous, free and arranged on the rim of the receptacle in several whorls. They occur rarely in bundles. Filaments bent inwards in the bud condition. Anthers are dithecous, versatile, introrse and are gland tipped, and they dehisce by longitudinal slits.
  8. **Gynoecium**-Tertra or pentacarpellary and syncarpous. Style is terminal and simple. Stigma capitate. Ovary inferior or half inferior in *Callistemon*. Ovary has many chambers as are the carpels. There is 1-many anatropous ovules, arranged in a horizontal or pendant manner on axile placentae. Unilocular ovary with parietal placentation (*Rhodamnia*)
  9. **Fruit**- Berry (Guava, Gooseberry), or loculicidal capsule (*Eucalyptus*) and rarely drupe or nut (*Darwinia*). Pollination entomophillous. Seed non-endospermic. In some species of *Eucalyptus* with winged seeds.
- **Economic importance**.
  Edible fruits from *Syzygium jambolanum, Psidium guajava*
  Oil obtainted by the steam distillation of leaves and branches of *Eucalyptus* species.

- **Common plants**
  Pimenta dioica (All spice)

  Callistemon lanceolatus (Bottle brush)

  Syzygium aromaticum (Clove)

  Eucalyptus regnans

  Psidium guajava

Syzygium jambolanum

Eucalyptus citriodora

Syzygium malaccense

CUCURBITACEAE

- A large group of plants are commercially important with 130 genera and 800 species.
- Also known to be gourd family.
- **Diagnostic characters**
  1. Large, weak, juicy herbs, climbing by means of tendrils.
  2. Bicollateral vascular bundles in the stem.
  3. Leaves are simple, cordate, alternate, exstipulate and alternate, palmately lobed, with coarse hairs. Oil glands are absent. Leaves are provided with tendrils in extra- axillary position.
  4. Flowers are usually regular, unisexual, monoecious. Female flowers are solitary, while male flowers occur in racemes or corymbs.
  5. Corolla 5, free or fused.
  6. Stamens 5, mostly in 2+2+1 condition and normally synandrous. Anthers extrorse, sinuous.
  7. Ovary is tricarpellary, syncarpous, inferior and trilocular, with ovules on parietal placentation. Styles are terminal and branched with trifid stigma.
  8. Fruit is pepo.
  9. Seed is non-endospermic.
- **Vegetative and reproductive characters.**
  1. **Habit**- Mostly climbing or prostrate annual herb, rarely perennial herbs, shrubs and trees.
  2. **Root**- Tap root.
     Leaves-Simple, alternate, uaually palmately lobed, but show considerable variation in form; plants climb up by means of simple and branched tendrils. Tendrils are sensitive to contact.
  3. **Inflorescence**-Axillary and usually a solitary female flower and several male flowers in various cymose types or racemes.
  4. **Flowers**-Unisexual or rarely bisexual, actinomorphic and epigynous. Thalamus forms a cup above the thalamus.
  5. **Calyx**-5 sepals, free, valvate or imbricate aestivation, sepals are usually narrow.
  6. **Corolla**- 5 petals, usually united, rarely free as in *Luffa* and *Fevillea*. Valvate or imbricate. Petals are white or yellow.

7. **Male flower**- Androecium with 5 stamens, alternating with petals. This group shows a drastic change in the union of the stamens. In *sicydium* the stamens are paired, but show union among the filaments at the base, anthers remaining free. In *Citrullus* filaments and anthers are united, forming synandrous. In *Sicyos* the filaments are united and anthers are curved. In *Cyclanthera* stamens are completely united to form a central column with two rings of pollen containing chambers at the top. Anthers are monothecous, sinuous and extrorse. In *Sechium*, one stamen bears monothecous anther and the others bear dithecous anthers. Staminodes are seen in female flowers.
8. **Female flower**- Gynoecium is syncarpous with tricarpellary ovary. Ovary inferior, either unilocular with parietal placentation, or trilocular with axile placentation. The number of ovules varies varies from one to indefinite in each placenta. In *Sechium* ovary unilocular with single seed. Single style ending in stigma.
9. **Fruit**- Pepo.

- **Economic importance.**

  Vegetable: *Benincasa hispida, Momordica charantia, Trichosanthes anguina, T. dioica, Cephalandra indica, Luffa cylindrica, Cucumis pepo*.

  Fruit: *Citrullus vulgaris*.

- **Common plants**

  Benincasa hispida (Ash gourd)

  Cephalandra indica

  Citrullus colocynthis

  Citrullus colocynthis

  Cucumis melo

  Cucumis pepo.

  Cucumis sativus

  Cucurbita andreana

  Cucurbita maxima

  Lagenaria siceraria

  Luffa cylindrica

  Luffa echinata

  Momordica charantia (Bitter gourd)

  Mukia scabrella

Trichosanthes anguina

Trichosanthes dioica

ASTERACEAE

- Sunflower family comprises of 950 genera and 20,000species.
- Most plants are herbs and cosmopolitan distribution.
- Commonly known as sunflower family.
- **Diagnostic characters**
  1. Most plants show herbaceous habit.
  2. Flowers are aggregated together in dense heads surrounded by the involucral bract, which make them very conspicuous and attractive.
  3. Floral parts are completely whorled and typically pentamerous. Sepals gt reduced into pappus.
  4. Carpel is inferior.
  5. Flower buds are well protected by involucral bract.
  6. Corolla tube is short enough to enable the necter to be reached by insects.
  7. Fruits are very light due to the presence of hairy pappus.

- **Vegetative and reproductive characters.**
  1. **Habit**- Large number of plants are cultivated garden plants such as *Helianthus annuus, Chrysanthemum sp., Tagetes erecta, Calendula officinalis, Gaillardia sp., Lactuca sativa, Centaurea cyanus, C. moschata* etc are annual herbs. *Vernonia* and *Catamixis* are undershrubs. *Sonchus, Launaea, Ageratum* are either annual or perennial herbs.
  2. **Root**-Tap root.
     Stem- Usually stem is slender and covered by different types of trichomes. Stem tubers are produced in *Helianthus tuberosus* and *Crepis bulbosa*. Stem is leaf like in *Baccharis*.
     Leaves- Radical or cauline, simple , opposite or alternate; succulent leaves in *Notonia*, scaly in Haplophyllum, exstipulate, venation pinnately reticulate.
  3. **Inflorescence**-Head or capitulum with distinct involucral cup formed of bracts. Capitulum may be solitary (*Tridax*) or on profusely branched paniculate cyme (*Blumea*).
     The marginal sterile or female flowers called ray floret and central bisexual flowers are disc floret.

Ray floret: Zygomorphic, pistilate or neutral, ligulate and epigynous. Each floret arise from the axil of the bracteoles

Calyx-Usually represented by a ring of small teeth of numerous hairs or scales, called pappus.

Corolla-Petals 5, gamopetalous, strap shaped or ligulate.

Gynoecium – Bicarpellary, syncarpous, inferior ovary with basal placentation.

Disc floret: Actinomorphic, bisexual, tubular and epigynous.

Calyx- Pappus.

Corolla-Petals 5, gamopetalous and tubular.

Androecium- Stamens 5, epipetalous, syngenecious.

Gynoecium – Bicarpellary, syncarpous, inferior ovary with basal placentation, style simple and stigma bifid.

4. **Fruit**- Cypsela with persistent pappus. Seeds non-endospermic.

- **Economic importance**.

  Seed oil extracted from *Helianthus annuus*.

  Insecticide pyrethrin obtained from dried leaves of *Chrysanthemum cinerariifolium*, *Wedelia calendulacea* used as hair tonic.

- **Common plants**

  Tridax procumbens

  Helianthus annuus

  Vernonia abbreviata

  Chrysanthemum cinerariifolium

  Wedelia calendulacea

  Tagetes erecta

  Dahlia arborea

  Haplopappus aberrans

RUBIACEAE

- Known as madder family
- About 450 genera and 6500 species.
- Most of the plants are distributed in tropics, some plants in temperate regions.
- **Diagnostic characters**
  1. Leaves simple, opposite or whorled with inter-petiolar or intrapetiolar stipules.
  2. Inflorescence usually in cyme or cymose panicles.
  3. Flowers tetramerous or pentamerous, bisexual, regular and epigynous.

4. Corolla tubular, rotate or funnel- shaped, lobes sometimes valvate.
5. Stamens 4-5, inserted on the corolla tube and alternating with the corolla lobes.
6. Carpels usually 2, syncarpous, inferior with 1 or many ovules on axile placentation.
7. Fruit a capsule or berry.

- **Vegetative and reproductive characters.**

1. **Habit**- Herbs, shrubs and trees. *Geophila* is a creeping herb, *Rubia* is climbing herb, *Ixora, Mussaenda, Pavetta* are shrubs while *Hedyotis, Dentella* and *Spermacoce* are herbs. *Morinda, Neolamarckia* are trees.
2. **Root**-Normal taproot, Myrmecophily seen in *Myrmecodia.*

   Stem-Erect or twinning (*Rubia*) with or without spines. Rarely truly prickly in *Canthium.*

   Leaves- Simple, oppositely decussate or whorled and stipulate. Leaves margin entire or toothed with reticulate venation. Stipules may be interpetiolar (between petioles) or intrapetiolar (between the petiole and axis). Sometimes stipules may united with the petiole and forms a sheath like structure and round the stem (*Mitracarpus*) or they divided into bristle like structure (*Hedyotis*).
3. **Inflorescence**-Varies according to genus. Dichasial cyme or panicled cyme. It may be terminal (*Mussaenda*) or axiilary (*Coffea arabica*). In *Neolamarckia cadamba* it is a globose head (condensed dichasial cyme).
4. **Flowers**- Mostly bisexual or rarely unisexual (*Coprosma*), epigynous, tetramerous or pentamerous. Actinomorphic or rarely zygomorphic (*Henriquezia*). Pollination entemophilous.
5. **Calyx**-Sepals 4-5, gamosepalous, valvate aestivation. In *Mussaenda* a petalloid sepal is seen, to attract insects. In *Rubia* calyx may be inconspicuous or entirely absent. Or calyx reduced in a ring in *Morinda*.
6. **Corolla**-Petals 4-5, gamopetalous. Petals united into a tubular funnel shaped structure. The aestivation may be valvate (*Hedyotis, Mussaenda*), twisted (*Ixora*). Or corolla may be bilabiate with imbricate aestivation as in *Henriquezia.*
7. **Androecium**- Stamens 4-5, as number of corolla lobes, epipetalous. Anthers dithecous and introrse and they dehisces longitudinally.
8. **Gynoecium**- Usually bicarpellary, syncarpous with inferior ovary. But sometimes it may be 2 or more carpels. Ovules are one to many on axile placentation. Style single with bifid stigma.
9. **Fruit**-Berry in *Coffea*, *Mussaenda* and *Ixora*, capsule in *Hedyotis* and *Mitracarpus*, and multiple fruit in *Morinda*. In *Galium* the fruit separate into one seeded segments that are indehiscent.

- **Economic importance.**

  Coffee powder from *Coffea arabica*.

  Quinine is an alkaloid produced from *Cinchona officinalis*- remedy for malaria.

  Ornamentals- different species of *Ixora, Mussaenda, Hamelia, Pentas, Rondeletia, Neolamarckia* are used as garden plants.

  Many plants of this family used for making furniture, sticks, agricultural implements and building materials.

- **Common plants**

  Chassalia curviflora

Coffea arabica

Hamelia patens

Hedyotis auricularia

Hedyotis corymbosa

Hedyotis herbacea

Ixora acuminata

Ixora coccinea

Ixora javanica

Mitracarpus villosus

Mussaenda frondosa

Neolamarckia cadamba

Ophiorrhiza prostrata

Pavetta indica

Spermacoce mauritiana

APOCYNACEAE

- About 400 genera and about 4,555 species of trees, shrubs, woody vines, and herbs.
- Members of the family are distributed primarily in tropical and subtropical areas of the world.
- Plant parts produce milky latex.
- **Diagnostic characters**
  1. Plants usually with milky latex.
  2. Leaves simple, opposite and mostly exstipulate.
  3. Flowers bisexual, actinomorphic and hypogynous.
  4. Presence of coronary outgrowth on corolla.
  5. Sagittate anthers.
  6. Bicarpellary, apocarpous or syncarpous stigma.
  7. Dumb-bell shaped stigma.
  8. Fruit is follicle.
  9. Seeds with crown of long silky hairs.
- **Vegetative and reproductive characters.**
  1. **Habit**- Herbs, shrubs and trees. Herb- *Vinca rosea*, shrub-*Tabernaemontana*, *Nerium*, woody climbers like *Allamanda* and large and medium sized tree like *Alstonia scholaris*.
  2. **Root**-Taproot.
     Stem- Erect and woody.

Leaves-Simple, mostly oppositely decussate. Sometimes they may be alternate or even whorled. Most plants are exstipulate with entire margins.

3. **Inflorescence**-Terminal or axillary cyme. Flowers are solitary or in axillary pairs in *Vinca*. In *Allamanda* the flowers arranged in axillary paniculate cymes. In *Carissa* , corymbose cyme; in *Plumeria* terminal cymes are present. In *Rauvolfia* , in corymbose or umbellate cymes and *Alstonia* with branched panicle.
4. **Flowers**- Bracteate, bisexual, actinomorphic, hypogynous and pentamerous.
5. **Calyx**- Sepals 5, free or united, imbricate aestivation.
6. **Corolla**- Petals 5, united. Shape may vary with different genus. Bell shaped in *Allamanda*, hypocrateriform in *Vinca* and funnel shaped in *Nerium*. Coronary outgrowths are often present on the corolla tube or at its mouth. Aestivation is twisted.
7. **Androecium**-Stamens 5, epipetalous, often inserted at the throat of the corolla tube. Anthers are usually connivent around the stigma. Anthers are two lobed, linear and sagittate.
8. **Gynoecium**- Gynoecium is bicarpellary, superior and seated on a honey secreting disc. It is partially inferior in *Plumeria*. It is either apocarpous or syncarpous with a common style and stigma. In *Plumeria* and *Carissa*, the syncarpous ovary with axile placentation or unilocular with parietal placentation in *Allamanda.* In apocarpous, each carpel is single celled with many ovules on marginal placentation as in *Vinca*. Most of the plants with single style; stigma is either hour- glass shaped or dumb-bell shaped.
9. **Fruit**-Drupe (*Rauvolfia*), berry (*Carissa*) and pair of follicle (*Vinca*).

- **Economic importance.**

  Fruit- Raw and ripe fruit of *Carissa carandas*.

  Ornamental- *Allamanda cathartica, Vinca rosea, Nerium odorum, Plumeria rubra, Cascabela thevetia.*

  Timber-Wood of *Alstonia scholaris* is light and used for carvings, make tea boxes and black boards.

- **Common plants**

  Allamanda cathartica

  Alstonia scholaris (Ezhilam pala)

  Carissa carandas (cheri)

  Cascabela thevetia

  Ichnocarpus frutescens (Palvalli)

  Nerium indicum(Arali)

  Nerium odorum

  Plumeria rubra

  Rauvolfia serpantina (Sarpaghandi)

Tabernaemontana alternifolia

Vinca rosea (Nithyakalyani)

ASCLEPIADACEAE

- Presence of laticiferous tissue containing milky latex.
- About 320 genera and 2000 species. Distributed in tropical regions of the World.
- **Important characters**
    1. Plants are mostly woody or herbaceous; generally mesophytes while some are xerophytes.
    2. Latex present in leaves and stem.
    3. Leaves are simple, opposite, decussate, exstipulate or stipules are minute, leaves sometimes modified into pitcher or reduced in to scales.
    4. Inflorescence extra axillary umbellate cyme of several flowers.
    5. Flowers are actinomorphic, pentamerous, bisexual, complete and hypogynous. Zygomorphic in *Ceropegia*.
    6. Corolla rotate or companulate, valvate or twisted; 5 lobed or 5 parted calyx and corolla: sepals 5, polysepalous, quincuncial.
    7. Stamens 5, epipetalous, united with the stigma forming gynostegium: pollinia and translators invariably present.
    8. Stamina corona (*Calotropis*) or coralline corona (*Cryptostegia*) is present.
    9. I –shaped translators are present; each translators carries 2 waxy pollinial masses.
    10. Carpels are with separate ovaries; styles joined together towards the tip ending in a large stigma of variable shape.
    11. Gynoecium bicarpellary, apocarpous, each carpel has several ovules along the ventral suture; marginal placentation; stigma is 5 angled disc, united with the anthers to form gynostegium.
    12. Fruit is a pair of follicle; seeds are with comose hairs and endospermic.

- **Vegetative and reproductive characters**
    1. Habit – Mostly mesophytes. Some xerophytes like *Caralluma*, *Stepalia* etc with thick succulent stems and leaves are reduced into spines. Species of *Dischidia* are epiphytes and the adventitious roots help in climbing. *Calotropis* is a large erect shrub. Leaves are pitcher like in *D. rafflesiana*, *Cryptostegia grandiflora* is a stout climbing stout shrub.

Oxystelma, Hemidesmus, Leptadenia are twinning herbs. In *Ceropegia* like herbs the perrenate by means of a fascicles of thick fleshy roots.

2. Leaves- Simple, short petioled, opposite and decussate, rarely alternate or whorled; broad (*Calotropis*); narrow (*Oxystelma*) and reduced (*Caralluma*). Stipules are entirely absent or very minute. Leaves are succulent in Hoya. In *Dischidia*, leaves modified into pitcher.
3. Inflorescence – Extra axillary, short or long peduncled umbellate cyme, basically dichasial but ending in monochasial cymes.
4. Flower- Complete, bisexual, actinomporphic and hypogynous, rarely zygomorphic (*Ceropegia*).
5. Calyx- Sepals 5, free, imbricate aestivation.
6. Corolla- Petals 5, gamopetalous, tubular, hairy outgrowth either inside or at the mouth forming corona known as coralline corona (*Cryptostegia*).
7. Androecium- 5 stamens, which are united in a hollow, horn like appendages known as the staminal corona. Epipetalous, anthers are united to the margins of the pentangular stigma forming a gynostegium. Pollen cohering into 2 pollen masses (sac-like structure) known as pollinia; one lying in each lateral anther lobe. The pollinia of 2 anther lobes are united by a structure called a translator. The translator is made of 2 parts-
    a. Corpusculum- gland like structure, attached to margins of the stigma.
    b. Retinaculi- by means of which the pollinia of adjascent anther lobes are attached to corpusculum.
8. Gynoecium- Bicarpellary, apocarpous. Ovaries remain separate from each other and terminate above 2 distinct styles which unite to form a common style; styles end in a dilated pentagular stigmatic head, with which are united the anthers of 5 epipetalous stamens. The ovary is with marginal placentation.
9. Fruit- Paired follicle. Seeds are flat, compressed and covered with hairs.

- **Family divided into two tribes based on the nature of pollen grains and shape of translator.**

1. *Periplocoideae*- Pollen grains in tetrad; translator spoon or funnel shaped. Eg. *Cryptostegia.*

   The pollen grain tetrad with a sticky disc at the top. As the pollen grains in the form of pollen tetrads are matured, they are shed into the spoon or the funnel- shaped body with the sticky disc projecting towards the outside. As the insect visit the flower, the pollen grains get attached to the stigmatic surface.
2. *Cynanchoideae*- Pollen grains in pollinia, translator made up of corpusculum and retinaculi.

At the time of pollination, insect sit on the stigmatic head to draw the honey, the legs gets entangled into the slit or the space between the anthers. As it tries to release itself, the corpusculum gets attached to its legs and with it the pollinia are drawn out of the anthers and carried away by insects. As it visits another flower, the pollinia are transferred to the stigmatic surface, and the pollination thus effected.

- **Economic importance**

Medicinal- Leaves of *Tylophora asthmatica*, powdered roots of *Calotropis gigantea* and *C. procera* used as native medicine. Roots of *Oxystelma secamone* used to treat jaundice. Roots of *Hemidesmus indicus* are highly aromatic and medicinal for rheumatism, scorpion and snake bite. *Asclepias curassavica* roots are used as the remedy for piles and gonorrhea.

Ornamentals- *Asclepias* and *Ceropegia* are cultivated as ornamentals.

Daemia extensa- stem yield a very strong fibred which is substitute for flax.

- **Common plants**

Asclepias curassavica
Calotropis procera
Calotropis gigantea
Ceropegia aberrans
Cryptostegia grandiflora
Daemia extensa
Hemidesmus indicus
Tylophora asthmatica

SOLANACEAE

- Commonly known as potato family
- Plants distributed in the tropical and sub-tropical regions of the world.
- About 102 genera and 2500 species are distributed worldwide.

- **Diagnostic characters**
  1. Herbs, shrubs or small trees.
  2. Leaves simple, alternate, exstipulate, entire and pinnatified.
  3. Inflorescence cyme or cymose panicle.
  4. Flowers bisexual, regular, hypogynous, rarely zygomorphic.
  5. Sepls 5, persistent, become enlarged in fruits.
  6. Petals 5, gamopetalous, funnel shaped or bell shaped corolla, imbricate sometimes plicate or convolute.
  7. Stamens 5, alternate with thw corolla lobes, free, epipetalous, anther with apical porous or longitudinal dehiscence.
  8. Bicarpellary, syncarpous, obliquely placed, ovary 2- chambered or more.
  9. Stigma capitate or slightly bilobed.
  10. Fruit many seeded berry; sometimes capsule.
  11. Seeds albuminous, flat, compressed.
- **Vegetative and reproductive characters**
  1. Habit – Annual or perennial herb, sometimes small shrub or trees. Climbing shrub like *Solanum trilobatum*.
  2. Root – Tap root, branched.

     Stem- Herbaceous erect, branched, hairy or prickly, underground in potato forming tubers.

     Leaves- Simple, alternate in vegetative region and opposite in the floral region, exstipulate.
  3. Inflorescence- Usually terminal, sometimes axillary or extra-axillary cymose. In *Nicotiana* it is panicle.
  4. Flower – Bisexual, hypogynous, pentamerous with the reduction in two members in the innermost whorl. Flowers are almost regular but for the oblique position of the ovary. Hence it is obliquely zygomorphic. In *Schizanthus*, flowers are extremely zygomorphic because of the presence of irregular bilobed corolla.
  5. Corolla- petals 5, united, twisted. Corolla is rotate, infundibuliform (*Datura*) or campanulate (*Atropa*). Usually regular but it is two lipped in *Schizanthus.*
  6. Androecium- 5 free stamens, epipetalous and alternating with lobes of corolla. In *Schizanthus*, only 2 stamens are fertile others reduced as staminodes. The filaments bear large dithecous anthers which usually liberate pollen by apical pores (porus dehiscence). In Datura dehiscence is longitudinal.
  7. Gynoecium- Bicarpellary, syncarpous, superior ovary with terminal style ends in capitate stigma. The arrangement of the carpels is peculiar. The posterior carpel is tilted towards the

right and the anterior one is tilted to the other end and so the septum occupies an oblique position, whereas normal condition, it occupies the horizontal position. So it described as obliquely zygomorphic flower.

8. Fruit- Berry (Tomato) or capsule (*Datura*). Sepals may be inflated and persistent, helping in dispersal (*Physalis, Solanum*). Seeds are flattend, endospermic.

- **Economic importance**

  Vegetable- tubers of *Solanum tuberosum*, fruit of *Lycopersicum esculentum* and *Solanum melengena*. Fruit of *Physalis minima* are edible. Fruits of *Solanum nigrum, S. indicum and S. xanthocarpum* are eaten by natives.

  Ornamentals- petunia, Cestrum nocturnum, C. diurnum are cultivated as garden plants.

  Commercial- *Nicotiana tabacum* cultivated for the commercial tobacco. Tobacco leaf contains nicotine. Stramonine is a poisonous alkaloid produced from *Datura stramonium*. Atropine produced from the leaves and roots of *Atropa belladonna*.

- **Common plants**

  Atropa belladona
  Capsicum annum
  Capsicum frutescens
  Datura stramonium
  Lycopersicum esculentum
  Nicotiana tabacum
  Petunia axillaris
  Physalis minima
  Solanum indicum
  Solanum melengena
  Solanum nigrum
  Solanum torvum
  Solanum tuberosum

ACANTHACEAE

- Commonly called Acanthus family.
- Most plants are distributed in warmer parts and subtropics of the world.

- Around 240 genera and 3000 species are distributed.

- **Diagnostic characters**
  1. Mostly herbs or shrubs with usually cylindrical stem and swollen nodes, plant parts non-aromatic.
  2. Leaves are simple, opposite, decussate and exstipulate.
  3. Inflorescence is spike with well- developed bracts and bracteoles, or dichasial cymes with monochasial tendency.
  4. Flowers are hypogynous, zygomorphic and often bilabiate.
  5. Sepals 5, gamosepalous, unequal or reduced.
  6. Petals 5, gamopetalous, bilabiate, 5- lobed, oblique.
  7. Stamens 4, didynomous, hairy, epipetalous, alternipetalous, with spurred anthers, 5^{th} stamen is always suppressed.
  8. Gynoecium bicarpellary, syncarpous, superior, with 2 to many anatropus ovules in each locules. Disc is present beneath the ovary. Style simple and terminal, in ovary ovules are in axile placentation.
  9. Fruit is loculicidal capsule.

- **Vegetative and reproductive characters**
  1. Habit – In different habit like
     Herb- *Justicia, Andrographis*
     Undershrub- *Strobilanthus, Adhathoda, Barleria*.
     Climber- *Thunbergia, Mendonica*.
     Mangrove plants- *Acanthus ilicifolius*.
  2. Root- Tap root, tuberous in *Ruellia*.
     Stem- Erect, nodes are swollen and internodes elongated.
     Leaves- Simple, oppositely decussate, rarely whorled, anisophyllous in *Strobilanthus anisophyllus*, exstipulate, leaves are entire.
  3. Inflorescence- Axillary or terminal. Flowers are densely crowded at the base of the plant in *Lepidagathis*; Panicle in *Andrographis*; spike in Rungia and cyme in *Ruellia*. Bracteoles sometimes encloses the flower.
  4. Flower- Small, bracteate, bracteolate, complete, bisexual, hypogynous, zygomorphic and pentamerous with reduction in the number of stamens and carpels. Bracts and bracteoles are conspicuously large and colured (*Thunbergia*).

5. Calyx- Sepals 4 or 5, free, irregular in size. Reduced as ring like structure in *Thunbergia*. Valvate or imbricate aestivation.
6. Corolla- Petals 5, gamopetalous, and personate or bilabiate (upper lip 2+ lower lips 3). Aestivation is valvate or imbricate.
7. Androecium- Stamens 4, didynomous, epipetalous, posterior 5 stamen suppressed or represented by a staminode in *Barleria cristata*. Anthers are dithecous, basifixed, introses and spurred or beareded. Anther lobes may be equal or unequal, separated by a connective.
8. Gynoecium- Bicarpellary, syncarpous. Terminal style and stigma with elongated superior ovary.
9. Fruit- Loculicidal capsule, rarely drupe in *Mendonica*. Capsule splits into two valves carrying 2 to 10 seeds, arranged in a double row. Seeds non-endospermpus, with ejaculator mechanism of dispersal.

- **Economic importance**

Ornamentals- All species of *Barleria* used as ornamentals. *Thunbergia alata, T. coccinea, T. fragrans* and *T. grandiflora, Crosandra infundibuliformis, Pachystachis coccinea* and *Ruellia prostrata.*

Medicinal- *Adhathoda vasica,* leaf powder for rheumatism, skin troubles and chronic bronchitis. Leaf juice for diarrhoea. Leaves and roots of *Barleria* used for haemoptysis and menorrhagia. *Andrographis paniculata* used for fever, dysentery, cholera, diabetes, itches and piles.A. echioides for fever. *Asystasia gangetica* for rheumatism and swellings. Some species of *Justicia* also a medicinaly important plant.

- **Common plants**

Adhathoda vasica (Malabar nut plant or adalodakam)

Andrographis paniculata (kiriyaatha)

Asystasia gangetica

Barleria cristata

Crosandra infundibuliformis

Crosandra infundibuliformis (Kanakambaram)

Justicia procumbens

Pachystachis coccinea

Ruellia prostrata

Ruellia suffrutticosa

Thunbergia alata

Thunbergia coccinea

Thunbergia fragrans

Thunbergia grandiflora

LAMIACEAE

- Commonly known as mint family.
- Most of the plants are highly aromatic and pubescent.
- About 200 genera and 3200 species are distributed in tropical and temperate regions of the World. Wild species occur in hills.

- **Diagnostic characters**
  1. Aromatic herbs or undershrubs
  2. Stem quandrangular and plant parts are hairy.
  3. Leaves are simple, opposite, decussate and exstipulate.
  4. Inflorescence is verticillaster or thyrsus.
  5. Flowers are bisexual, hypogynous, zygomorphic, often bilabiate.
  6. Sepals 5, fused, bilabiate, persistent and tubular.
  7. Petals 5, gamopetalous and bilabiate.
  8. Stamens 4, didynomous, epipetalous.
  9. Gynoecium is bicarpellary, syncarpous, superior and bilocular, but the ovary becomes tetralocular by the formation of false septum. Ovary is often placed on a nectariferous disc. Ovules are anatropous, with one ovule in each locule.
  10. Style is gynobasic.
  11. Fruit is schizocarpic carcerulus, breaking into 4 nutlets or achenes.
  12. Seeds are non-endospermic.
- **Vegetative and reproductive characters**
  1. Habit- Herbs, shrubs, undersrubs and tree.

     Herb- *Ocimum, Leucas, Lavandula, Pogostemon*.

     Undershrub- *Salvia*

     Shrubs- *Ocimum gratissimum*

     Tree-*Leucosceptrum*
  2. Stem- Aerial, erect, quadrangular, aromatic and hairy.

     Leaves- simple, opposite, decussate and sometimes whorled and exstipulate.

3. Inflorescence- Condenced verticillaster, located in the axils of opposite leaves (*Leucas*). Simple, three flowered cyme in Salvia. Thyrsus in Ocimum, spike in *Anisochilus* or panicle in *Hyptis*.
4. Flowers- Bisexual, zygomorphic, hypogynous, bracteate and bracteolate. Slightly zygomorphic in Mentha.
5. Calyx- sepals 5, valvate or imbricate aestivation.
6. Corolla- Petals 5, gamopetalous, irregular and bilabiate (2/3 or 4/1). Posterior petal forms the upper lip which is concave (*Salvia*) or hood like (*Leucas*). Lower lip formed by 3 petals of which the middle one is larger. Corolla show 4/1 arrangement in *Ocimum*, *Plectranthus.*
7. Androecium- Stamens 4, didynomous, epipetalous. The 5^{th} posterior stamen is suppressed or sometimes represented by a staminode. Stamens 2 in Salvia. In Coleus, monadelphous condition is seen.
8. Gynoecium- Bicarpellary , syncarpous. Superior ovary, gynobasic style and stigma. Ovules are seen in axile placentation.
9. Fruit- Single seeded schizocarp- breaking into 4 nutlets. Fruits are dispersed through wind.

- **Pollination mechanism**

In the flowers, the lower lip of corolla act as a landing place for insects. There are 2 stamens, placed at the throat of the corolla. The inner ends of the connectives of stamens block the entry of insects towards the nectar. While trying to gets towards the nectar, the insect pushes the inner ends of the connectives. Since the connective can swing as a lever on the tip of the filament, its long upper half, together with the fertile anther lobe, descends on the back of the insect dusting it with pollen. In the next stage, the style of the ovary bends down, keeping the stigmatic lobes open to receive foreign pollen from the body of the insect.

- **Economic importance**

Medicinal- *Ocimum sanctum*, different species of *Leucas*. *Anisomeles malabarica* leaf infusion used for dyspepsia, teething troubles etc.

Camphor – *Ocimum kilimandscharicum* (Karpura tulasi) used to prepare camphor.

Lavender oil- extracted from *Lavandula augustifolia*. Rosemary oil extracted from *Rosmarinus officinalis* and used in perfumes and soap.

Ornamentals- some species of *Ocimum*

Menthol obtained from *Mentha piperita* (menthol is a derivative of peppermint).

Food- *Mentha aruensis* leaves are used as food additives.

- **Common plants**

  Anisomeles malabarica

  Hyptis saveolens

  Lavandula augustifolia

  Leucas aspera

  Leucas lavandulifolia

  Mentha aruensis

  Mentha piperita

  Ocimum gratissimum

  Ocimum kilimandscharicum (Karpura tulasi)

  Ocimum sanctum

  Plectranthus sp.

  Pogostemon

  Rosmarinus officinalis

EUPHORBIACEAE

- One of the largest and genetically diverse plant families.
- Around 322 genera and 8910 species are primarly distributed in tropics.
- Commonly known as Spurge family. Many species contains milky latex.
- A characteristic inflorescence cyathium present in *Euphorbia*.
- **Diagnostic characters**
  1. Presence of milky or watery latex.
  2. Leaves simple or compound, usually alternate and stipulate.
  3. Flowers unisexual and monochlamydeous.
  4. Inflorescence of various types: raceme, cyme and cyathium.
  5. Tricarpellary, syncarpous, trilocular superior ovary with axile placentation.
  6. Fruit regma or berry.
  7. Seeds are carunculate.
- **Vegetative and reproductive characters**
  1. Habit – Herbs, shrubs and trees. *Euphorbia hirta, E. heterophylla*, *Phyllanthus amarus* are herbs. *Ricinus* is shrub and *Hevea , Macaranga* are trees. *Euphorbia tirucalli* is xerophyte with fleshy stem and small caduceus leaves. *Excoecaria* is mangrove and *Tragia* is a climber.
  2. Root- Normal tap root. Tuberous root in *Manihot esculenta*.

Stem- Herbaceous or woody, erect or prostrate. Stem modified into cladodes or phylloclades for photosynthesis in *Euphorbia tirucalli*.

Leaves-Simple, alternate and stipulate. Palmately lobed in *Manihot, Jatropha, Ricinus* etc. leaves are oppositely arranged in *Euphorbia hirta*. The leaves are nearer to the inflorescence are coloured in *Euphorbia pulcherrima*.

3. Inflorescence-Highly variable in family. Cymes (*Jatropha*), panicle (*Ricinus*), axillary clusters (*Phyllanthus*), drooping catkin(*Acalypha*) and cyathium (*Euphorbia*).
4. Flowers -Small, bracteates, unisexual, monoecious or dioecious, hypogynous, monochlamydeous and actinomorphic or rarely slightly zygomorphic.

   Male and female flowers of euphorbia are achlamydeous, while male flowers of *Croton* are dichlamydeous.
5. Perianth- 5 sepalloid and much reduced tepals. In *Jatropha* and *Croton*, perianth differentiated into calyx and corolla. While tepals are absent in Euphorbia with cyathium inflorescence. Tepals are free and partially imbricate or valvate.
6. Male flower or androecium- Stamens vary from one to numerous, free or united into one bundle (*Phyllanthus*) or into several bundles (*Ricinus*). Anthrs 2- celled. Dehiscences longitudinal, transverse or by apical pores. Intrastaminal disc and pistillode usually present.
7. Female flowers or gynoecium- tricarpellary, syncarpous, trilocular and superior ovary, with one or two pendulous ovules on axile placenta. Style three, basally connate or distinct. Stigma 3 or 6, papillate or dissected into filiform segments.
8. Fruit- Schizocarpic capsule, drupe, berry. Regma in *Hevea*. Seeds carunculate.

- **Economic importance**

  Biofuel- produced from seeds of *Jatropha curcas*.

  Castor oil from seeds of Ricinus.

  Vegetable- tubers of *Manihot esculenta*

  Natural rubber – produced from milky latex of *Hevea braziliensis*.

  Ornamental- *Euphorbia pulcherrima, E. tirucalli, Codiaeum variegatum*

  Medicinal- *Phyllanthus emblica* (Triphala) is medicinally important plant, *P. amarus*.

- **Common plants**

  Acalypha indica (Poochaval)

  Euphorbia heterophylla

Euphorbia hirta

Euphorbia pulcherrima

Euphorbia tirucalli

Excoecaria agallocha

Hevea braziliensis (Rubber plant)

Jatropha curcas (Physic nut)

Macaranga pelatata

Manihot esculenta (Cassava Or Tapioca)

Phyllanthus amarus (Keezharnelli)

Phyllanthus emblica (Nelli)

Ricinus communis (Castor bean)

LILIACEAE

- Commonly known as Lilly family.
- Cosmopolitan distribution. Primarily to temperate and subtropical regions.
- About 300 genera and 3700 species are present.

- **Diagnostic features**
    1. Plants are herbs, shrubs, trees and climbers.
    2. Leaves radical or cauline, exstipulate.
    3. Inflorescence usually a spike.
    4. Flowers hypogynous, trimerous and actinomorphic.
    5. Perianth lobes are petalloid; 6 in number, 2 whorls of 3 each.
    6. Stamens 6, free in 2 whorls, epipetalous.
    7. Ovary single, stigma three lobed.
    8. Fruit loculicidal or septicidal capsule.

- **Vegetative and reproductive characters**
    1. Habit – Herbs with fibrous root persisting from season to season by means of rhizome, bulb, corn and bulbils from leaf axils. Xerophytic *Aloe* with succulent leaves. Asparagus and Smilax are climbing plants. Asparagus and Ruuscus with phylloclade.

2. Stem- Underground bulb or rhizome.

   Leaves- Radical or cauline, alternate, fleshy (*Dracaena*) or reduced to scales (*Asparagus*), usually with parallel venation (not- veined in *Smilax, Trillium*).
3. Inflorescence- Terminal or axillary scape; solitary (*Tulip*), panicled raceme (*Asphodelus*), cymose umbel (*Allium, Smilax*) and solitary, axillary in *Gloriosa.*
4. Flower- Pedicellate, bisexual, actinomorphic or zygomorphic, hypogynous, complete, trimerous rarely 2 or tetramerous.
5. Perianth- Petalloid, polyphyllous or gamophyllous, 6 in number, 2 whorls of 3 each.
6. Androecium- Stamens 6, epiphyllous, arranged in 2 whorls or 3 each. In Ruscus only 3 stamens seen and they united to form a stamina column in the outerwhorl. Whereas in Paris quadrifolia, 8 stamens two whorls. Anthers are dithecous with longitudinal dehiscence.
7. Gynoecium-Superior, tricarpellary and syncarpous. Trilocular with one or 2 ovules in each locule on axile placentatation. Style is entire or divided into 3 branches ending in separate stigmas.
8. Fruit- Loculicidal capsule or a berry (*Asparagus*). Seeds endospermous.

- **Economic importance**

  Underground bulbs of *Allium cepa* (Onion), *Allium sativum* (Garlic).

  Medicinal- Rhizome of *Gloriosa superba*. Aloni drug prepared from *Aloe*.

  Ornamental- *Tulipa, Asparagus*, Lillies and *Yucca.*

- **Common plants**

  Allium cepa (Onion)

  Allium sativum (Garlic)

  Aloe vera

  Asparagus adscendens

  Asparagus officinalis (Asparagus)

  Asparagus racemosa

  Dracaena

  Gloriosa superba (Menthonni)

  Smilax officinalis

  Tulipa

POACEAE

- One of the largest families of angiosperms.
- Commonly known as grass family. It consists of 10,000 species.
- Cosmopolitan distribution. They grow on all continents, in desert to fresh water and marine habitats, and all but the highest elevations.
- The poaceae family is the world's single most important source of food.
- Grassess is occupied about 24 percent of the earth's vegetation.

- **Diagnostic characters**
  1. Mostly annual herbs with fistular (hollow) stem.
  2. Leaves distichous with sheathing bases and ligule.
  3. Inflorescence unit is a spikelet.
  4. Perianth is reduced to lodicules or even absent.
  5. Anthers are versatile.
  6. Stigma is feathery.
  7. Fruit is caryopsis.

- **Vegetative and reproductive characters**
  1. Habit- Mostly annual or perennial herbs. Woody and large size herb (*Bambusa*) is present.
  2. Root- Fibrous and many plants possess rhizomes. The perennial grasses persist by means of rhizome formed by the lower internodes of the stem.

     Stem- Erect, prostrate or creeping. It is divided into nodes and internodes. Stem of grasses is called a culm, which is usually fistular or hollow (*Bambusa*). Rarely solid as in *Saccharum officinale*. Some plants produced by runners and suckers.

     Leaves- Simple, alternate, exstipulate, distichous and ligulate. Leaves possess sheathing bases and venation is parallel. Ligule is represented by hairs at the juncture of sheathing base and lamina.
  3. Inflorescence- Spikelet arranged in racemes, panicle or spike. Spikelet is the ultimate unit of the inflorescence in grasses, which is arranged variously on the rachis. Spikelet may have only bisexual flowers, or may have bisexual and male flowers or may have male and female flowers. Each spikelet has a very short or minute axis called rachilla, on which bracts or glumes are arranged in two vertical rows. The lowest 2 glumes are sterile and bear nothing in their axils. The upper ones are fertile and each of them subtends a simple flower in its axil. This fertile bract or glumes, which subtends the flower called lemma. The flower is enclosed by another membraneous structure from above, the palea (considered as bracteole). The flower is enclosed

by the lemma from below and by the palea from above. Fertile glume (lemma) are closely similar to the sterile glumes or differs from them in shape, size and texture. Each floret is typically trimerous with great variation in the reduction of its parts.

4. Flower- Small, bracteates, bracteolate, sessile, bisexual (*Oryza*) or unisexual (*Zea*), hypogynous and zygomorphic.
5. Perianth- perianth totally absent or represented by membranous scales called lodicules. Lodicules are situated above and opposite the palea. 2 in *Oryza*, 3 in *Bambusa*, and absent in *Anthoxanthum*.
6. Androecium- stamens 3, seen as outer whorl. In *Oryza* and *Bambusa*, there are 6 stamens arranged in 2 whorls. Stamens are numerous in *Pariana*. Anthers are dithecous, versatile and introrse, open by a longitudinal slit.
7. Gynoecium- monocarpellary or bicarpellary or tricarpellary, syncarpous and superior. But it is always unilocular with a single ovule on basal placenta. Style usually 2, rarely 1 or 3 (*Bambusa*) or absent. Stigmas are 2 and feathery.
8. Fruit- caryopsis, nut in *Dendrocalamus*, berry in *Bambusa*, utricle in *Eleusine*.

- **Economic importance**

Grains are used as food – *Oryza sativa, Zea mays, Triticum vulgare, Elusine coracana, Setaria italica, Andropogon sorghum, Avena sativa, Hordeum vulgare*.

Intoxicating drinks are obtainted on fermentation of certain grains like- Arrack from rice, Whisky from rye and barley, rum from the molasses of sugarcane.

Sugar obtainted from- *Saccharum officinale*

Lemon grass oil from *Cymbopogon citratus* leaves.

For construction – *Bambusa arundinacea* stem is used.

Sand binder in sea shore made up of *Spinifex squarrosus.*

Many grasses are cultivated as ornamentals and for lawns.

- **Common plants**

Andropogon sorghum (Cholam)

Avena sativa (Oats)

Bambusa arundinacea (Bamboo)

Cymbopogon citratus (Lemon grass)

Elusine coracana (Ragi)

Hordeum vulgare (Barley)

Oryza sativa (Rice)

Pennisetum polystachion

Saccharun officinale (Sugarcane)

Setaria italica (Thina)

Triticum vulgare (Wheat)

Zea mays (Maize)

MODULE 3

Taxonomic structure

- The taxonomic system in which different taxonomic groups are assigned to specific categories, based on the different levels of the diversity of organism, is known as taxonomic structure.
- Taxonomic hierarchy is the orderly arrangement of organisms in a graded series of progressively higher and complex categories. Or it the arrangement of categories in an ascending scale, ranging from the lowest to the highest category.
- The different levels in taxonomic hierarchy are called ranks.
- The different plant groups of a particular rank are called taxa or taxonomic groups. Taxonomic group of the same rank thus belongs to the same category
- Features of taxonomic hierarchy
    1. A plant may be a member of several taxonomic groups each of which is assigned to a taxonomic category, but not a member of any specific taxonomic category. This means, a particular plant species belongs to all the taxonomic groups, but does not belongs to any particular category.
    2. The character, shared by the members of a taxon of a lower category, constitutes the characters of a taxon of a taxon of the next higher category.
    3. The lower the rank of the taxon in the taxonomic hierarchy, the fewer would be its members and the higher would be the number of common characters
- Significance of taxonomic hierarchy
    1. Enables the grouping of organisms into different categories on the basis of their degree of their diversity.
    2. Helps the assignment of an appropriate category for a particular group of plants.

Nested box system

- In heirarchial taxonomic structure, species is the smallest and the lowest category. So it is the basic unit of biological classification. A species is a group of genetically similar and potentially inbreeding individuals, which share a common ancestry.

- Several similar species for a large category, called genus. Several similar genera form a still larger group, called family. Several similar families form an order, and so on.
- Every individual organism is a part of a series of progressively higher categories and each lower category is a subordinate to and included under higher categories. This can be illustrated by nested box system or box-within-box arrangement.

Major and minor categories

1. **Major category**

- Highest categories in the hierarchical system.
- It includes the division, sub-divisions, classes, order and families.
- The number of diverse types of plants in the major categories will be larger than in the minor categories.
- Each major category will have its own common characters shared by its constituent minor categories.
- The higher the major category, the lesser will be number of shared common characters.
- Each category may be divided into intermediate subordinate categories between itself and the next lower rank. This is done by adding the prefix 'sub' to the name of the higher categories.
- Major categories

Category	ending with
Class	- eae
Order	-ales
Sub-order	-nieae
Family	-aceae

2. **Minor categories**

- Lower categories in the hierarchical system.
- It includes genera, species and variety.
- The number of taxa under each minor categories are lower than higher categories.
- Genus may be divided into sub-genera, which further divided into sections, sub-sections, series and sub series, or a genus may include a homogenous group of plants of the category species.
- Any category below the rank of species in an infraspecific or sub-specific category. The commonest infraspecific categories are sub-species, varieties and forms.

Different opinion about the definition of the categories.

Species concept

- Species is the basic unit of biological classification and the fundamental category of taxonomic hierarchy.
- Species are never static; they constantly undergo slow and steady changes, eventually leading to their transformation to new species.
- Present day species can be considered as the transient stages or products of the continuous and never ending process of organic evolution.
- Species is a dynamic group of genetically similar and actually or potentially interbreeding natural populations, which share a common gene pool and a close common ancestry and are reproductively isolated from other such groups.
- The members of a species can be freely interbreed and produce fertile offspring, but are reproductively isolated from the members of all other species.
- Species are discrete genetically closed systems. So each species forms a gene pool which is accessible only to its own members and is isolated from the gene pool of other species.
- In rare instances, members of closely related animals species do interbreed in captivity or domestication and produce only sterile offspring. The product of infraspecific and intergeneric breeding called hybrids. Eg. Mule, hinny, liger, zorse.
- The concepts of species fall under four main categories, namely
    1. Typological or essentialistic species concept
        - Also known as essentialism.
        - This concept was proposed by Linnaeus and his followers.
        - Species are static, immutable, eternal and ideal and also that individual organisms are copies or representation of ideal types.
        - Variation among the members of a species result from the imperfections in the copying of the ideal types. So in typological concept , individual organisms have no special significance, since they are only the copies of a basic types.
        - Tis concept upholds the morphological species or morphospecies. They are considered to be established only on the basis of morphological traits.
        - It is now discarded.
    2. Nominalistic species concept
        - According to this concept, only individual do exist and species are man-made abstractions.
        - Nominalists believe that nature produces only individuals, and species are non-existent.
        - The concept was advocated by Occam and his followers in 18^{th} century.
        - Now it is discarded.
    3. Biological or genetical species concept.

- According to this concept, species are groups of interbreeding natural populations, reproductively isolated from other such groups.
- According to it, species are absolute realities, typified by individuals, and are not mere man-made abstractions.
- It contains essential aspects of both typological and nominalistic species concept.
- A biological species forms
  1. Reproductive community
  2. An ecological unit
  3. Genetic unit
- A species may be regarded as a reproductive community since its members recognize each other as potential mates for reproduction and propagation.
- So species regarded as an ecological unit since it forms a constituent of a biological community and interacts with the other species of the community.
- Species forms a genetic unit in that it consists of a closed and protected gene pool, which is prevented from genetic exchange with other species.
- Short comings of biological species concept.
  i. The concept holds good only for sexually reproducing organisms.
  ii. It does not take into account the evolutionary history of sexuality starting from primitive ancestors to the present day forms. It is true that the present day sexually reproducing organisms are linked to their totally different primitive ancestors of the distant past through a continuous evolutionary chain of a countless series of intermediate ancestors. Biological species concept does not consider this evolutionary continuity.

4. Evolutionary or phylogenetic species concept
   - Species is a monophyletic group of organisms with a parental pattern of an ancestry and descent.
   - Species is an evolutionary lineage, evolving separately from others and maintaining its own evolutionary tendencies.

Genus concept

- Taxonomic category that consist of one or more species of monophyletic origin.
- It is separated from other genera by some distinctive features.
- some genera are definitely natural. Yet, they cannot be diagnosed unequivocally by a single character. This is because every character, even though diagnostic for the majority of the species of a genus, is modified or absent in one or more species of a genus.
- General features of a genus;
  1. A genus should be phylogenetic unit. This means that the constituent species of a genus must be monophyletic in origin, descended from a common ancestor. In modern taxonomy, monophyly is established on the basis of cytogenetic and geographical evidences in relation to morphology. It is very useful in deciding the line of demarcation between two genera.
  2. A genus must be an ecological unit. This means that all the species of a genus should exhibit similar adaptations for a particular mode of life. For examples, the genus *Utricularia* includes nearly 250 species all of which are insectivores, and grow in N2 deficient soil.

3. A genus should have a distinctive niche or adaptive zone of its own.
4. A genus must be sufficiently different from other genera and could be separated from them by distinct discontinuous varaitions.
5. An ideal genus is the one in which the constituent species show more similarities than differences. Sometimes a genus may include only one species. Such a genus is called monotypic genus.

Family concept

- Family is a taxonomic category which contains either a single genus or a group of monophyletic genera and is separable from other families by distinct discontinuous features.
- Family has single genera called monotypic family eg. Illiaceae, Leitneriaceae etc.
- A family should be a phylogenetic unit so that its constituent genera must be of monophyletic origin.
- Family should be an ecological unit and its genera should be similarly adapted for a particular mode of life. For example, the members of orchidaceae are mostly epiphytic and show mycorrhizal association with fungi. Similarly, members of Cactaceae are adapted for a xerophytic mode of life.
- A family must be sufficiently different and separable from other families by discontinuous variations.
- Families are definable and non-definable.
- Definable families possesses distinct and markedly different from each other. Such families possess a large number of genera which are difficult to identify because of many common and overlapping characters. So they have more similarities than differences. Eg. Asteraceae, Poaceae
- Non-definable families show overlapping character and not markedly distinct from each other. Genera are less in number and are not easily identifiable.

Taxonomic character

- Biological character is an expressed quantitative or qualitative attribute in the form, structure, functions and behaviour of organisms which can be measured, counted or evaluated.
- Character state is the pattern of expression of a character.

Character	Character states
1. Leaf arrangement	-alternate, opposite, whorled
2. Leaf venation	-recticulate, parallel
3. Floral symmetry	-regular, zygomorphic& asymmetric

- Characteristic is the condition in which a particular character state is exclusive to a specific taxon.
  Eg. Head inflorescence- Family Asteraceae
  Pappilionaceous corolla –family Leguminosae
- Analytic character-Character used in the analytical studies. They are of limited occurrence and useful in plant identification so it is the diagnostic characters or key characters.
- Synthetic character- Character used in the synthetic studies. They are of wide occurrence and they are useful in the placement of plants in higher taxa.

- Analytical character of a particular group may turn to be the synthetic character of another group.
- Quantitative character-character can be measured or counted eg. Leaf size, length, number of stamen and carpel etc.
- Qualitative character-character cannot be measured or counted, but can be assessed or evaluated. Eg. Flower colour, leaf arrangement.
- Good character-characters are most reliable in taxonomy. They do not usually exhibit wide variations and are highly correlated within the group.
- Bad character-those characters not much reliable in taxonomy. They exhibit wide variability and high inconsistency.
- Characters are not universally good or bad. Some good character of a particular group may be the bad characters of another group.
- Unit character-it is one of the two or more states of a character which cannot be subdivided. Used in numerical taxonomy. Eg. Leaf length, seed number etc
- Multiple character-complex characters which can be broken down to unit characters. Eg. Leaf arrangement.
- Correlation of characters- characters remain in close association and are transmitted together as a single unit.
- Correlated characters have a significant bearing on our understanding of evolution and phylogeny and also on the formulation of systems of classification.
- Morphological characters in taxonomy- the characters are easily observable. Extensively used in the formulation of classification systems, diagnostic keys.
- Morphological characters are necessary for taxonomical studies. Due to the;
    - Morphological characters are easily observable.
    - For the analysis of morphological characters sophisticate laboratory systems and advanced techniques are not necessary.
    - The time and effort needed for collecting information from other areas of study, such as phytochemistry, molecular biology etc. can be saved.
- Vegetative and reproductive characters- external morphological characters like vegetative and reproductive characters are used for taxonomy as well as classification.
- Equal emphasis has to be given to the vegetative and reproductive character.
- Growth habit, phenological characters, underground organs, stem, leaves petiole, stipule etc. are vegetative characters.
- Type and position of inflorescence, flower symmetry, position of ovary, the number and shape of floral leaves in each whorl, etc.
- Types of fruit and seeds are also important diagnostic characters in plant classification. And fruit morphology is constant within genus. But seed structure different for different species in a genus. In several species both fruit character and seed characters may be constant.
- At normal taxonomic procedure macro-morphological characters are employed for identification of taxa. Micro-morphological features like hairs, trichome, cell type etc. are often neglected. But these micro charaters are employed as a supplementary measure.
- Scanning Electron Microscopy (SEM) has been useful in the comparative studies of a large number of micro-morphological features like studies on the spore and pollengrains, details of leaf surface, stomatal architechture, fruit and seed surface.

- Some micro-morphological characters are used for distinguishing genus and species in a family.
  1. Various species of *Cassia* can be identified on the basis stomatal types and cell wall.
  2. Unusual development of anther wall was noticed in *Myosotis*, member of Boraginaceae.
  3. The stomatal types of each and every members of Commelinaceae is distinguishable.
  4. Extra floral necteries of various species of the genus *Polygonum* and observed peculiar features which help in the identification of species.
  5. Glandular and non-glandular trichomes are present on the surface of anther lobes in *Tecoma stans* of the family Bignoniaceae.

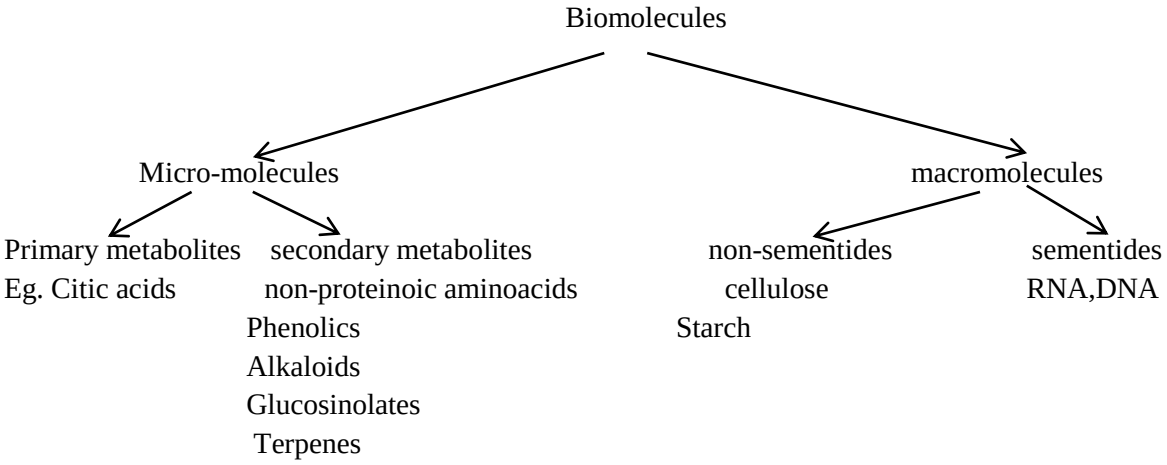
  Modern trends in taxonomy

- Taxonomy was initially based on anatomical and morphological characters. Eg.,Linnaeus systems of classification.
- Later on taxonomy adopted a synthetic approach based on the data and information provided by other branches such as cytology, genetics, molecular biology and biochemistry also.
- After effect all biologist or taxonomist add different data gained from different field of biology for systematics. Which cause for the emergence of different branches of taxonomy like,
  1. Chemotaxonomy
  2. Cytotaxonomy
  3. Numerical taxonomy
  4. Molecular taxonomy

Chemotaxonomy

- Chemical information can be used for solving taxonomic problems simply known to be chemotaxonomy.
- The presence or absence biomolecules or how much present in each taxa will used for the identification of taxonomic group or taxa.
- It has been used since man first began to classify plants as edible and non-edible based on the chemical differences.
- There are large variety of chemical compounds are found among plants.
- Here the taxonomic problems of genus and families can be solved.
- Biochemical can be classified broadly into

  Micro-molecules and macromolecules



Micro-molecules-low molecular weight compounds, with a molecular weight of less than 1000.

1. Primary metabolites
   - Biomolecules are present in most of the plant groups. So it has little taxonomic importance than others.
   - Biomolecules involved in the vital metabolism pathway. Eg., citric acid and aconitic acids.
   - Their quantitative variations may however, be the taxonomic significance sometimes. Eg. Family Rosaceae is rich in Arginine
2. Secondary metabolites
   - They are the byproduct of primary metabolism, have non-vital function.
   - Earlier this biomolecules are considered as waste products. But recently it is realized that these molecules have certain role in chemical defense mechanisms against pathogen, allolepathic agents etc.
     Eg., Morphine in Papaver.
     a. Non-proteinoic amino acids
        - ✓ A large number of amino acids not associated with proteins are known.
        - ✓ Their distribution not universal but specific to certain groups.
        - ✓ These non-proteinoic amino acids have taxonomic significance.
          Eg.., Lathyrine present only in *Lathyrus* genus. Canavanine in Fabaceae.

     b. Phenolics
        - ✓ Single ring benzene with OH group in different portions. They are widely distributed in plant kingdom.
          Eg., Catechol, Hydroquinone, Pyrogallol
        - ✓ Taxonomic significance
          - ❖ Coumarin is a group of Phenolics found in *Anthoxanthum odoratum* crushed leaves of this species have characteristic smell due to this phenolic compound.
        - ✓ Flavonoids-consists of 2 benzene ring joined by C3 open or closed structure. Eg., Falvanols, Anthocyanidine, Malvadins.

- ✓ Anthocyanin and Anthoxanthin (together known to be Anthocyanidine) are important pigment in the cell sap of petals providing red, blue and yellow colors.
- ✓ Betalains- These pigments like anthocyanidine are absent in some families and replaced by Betaxanthin or Betacyanin (Betalains).
- ✓ Betalains are mutually exclusive with anthocyanins, and concentrated in the traditional group Centrospermae of Engler and Prantl's, now recognized as Caryophyllales, of the 9 families contain betalains, 7 were included in centrospermae, cactaceae placed in cactales and didiceraceae in sapindales.

c. Alkaloids
- ✓ Basic nitrogen containing organic compounds, usually with a heterocyclic ring.
- ✓ Alkaloids show significant effects on the central nervous systems of animals.
- ✓ Alkaloids are well- known for their medicinal, chemical and poisonous properties.

  Eg., Quinine- *Cinchona*
  Nicotine- *Nicotiana*
  Ephedrine- *Ephedra*
  Morphine- *Papaver*
- ✓ Families papavaraceae and fumariaceae are closely related. Their affinity is supported by the occurrence of protopine in both.
- ✓ Family solanaceae and convolvulaceae are closely related and their affinity supported by the occurrence of tropine in both.
- ✓ Nymphaceae and nelumbonaceae differs in that, former lack benzylisoquinoline alkaloids.

d. Glucosinolates
- ✓ Group of about 85 thioglucosides which on hydrolysis form glucose and a corresponding isothiocyanate.
- ✓ This biomolecules are called mustard oil glucosides because they are confined to the taxa of the mustard family (Cruciferae) and some related families of Capparales.
- ✓ Taxonomic significance

  Originally, cruciferae, capparaceae and fumariaceae were placed in order Rhoedales. Later the chemical evidences show that placement of capparceae and cruciferae in the order Capparales contain glucosinolates. And fumariaceae and papavaraceae in the order papavarales lacks glucosinolates.

e. Terpenes
- ✓ It's a large group of chemical compound derived from mevalonic acid precursors.
- ✓ Most of them are polymerized.
- ✓ They are isoprene derivatives.

Eg., Camphor- *Cinnamomum*
Menthol- *Mentha*
Carotenoids

- ✓ Terpenoids is atype of terpene.
- ✓ Presence of sesqueterpene lactone in compositae and tribe Genisteae of is used to recognize different tribes.

Macromolecules --high molecular weight compounds, with a molecular weight of higher than 1000.

1. Sementides
   Biomolecules that involved in information transfer. Eg., DNA, RNA and proteins
2. Non-sementides
   Biomolecules that not-involved in information transfer. Eg., Cellulose and Starch.

Cytotaxonomy

- Cytology has made an outstanding contribution to taxonomy during the last few decades, in the elucidation of many taxonomic problems.
- Cytology which includes the study of the cell, or more appropriately karyology, the study of chromosome has made a significant contribution in taxonomy.
- Cytotaxonomy is the utilization of the cytological characters in the elucidation of taxonomic problems.
- The chromosome characteristics used in most cytotaxonomic studies include:
  1. Chromosome number
  2. Chromosome size
  3. Chromosome morphology
  4. Chromosome behavior at meiosis

1. Chromosome number
   - ✓ All individuals of angiosperms within a species possess the same chromosome number.
   - ✓ Thus the haploid number varies between n=2 (Haplopappus) and n=132(Poa).
   - ✓ The majority of them show arrange between n=7 and n=12.
   - ✓ Variation or constancy in the chromosome number within the taxa of different categories is an important character for taxonomic groupings.
   - ✓ In Quercus and Pinus with n=12 chromosome number, this remain constant in all species of these two taxa. So this constant chromosome numbers shows a taxonomic significance for the identification.
2. Chromosome size
   - ✓ Thus chromosome size also very useful in understanding relationship in several taxa of angiosperms.
   - ✓ In most of the plants, the length of a chromosome varies from 0.5 to 0.3µm.
   - ✓ The chromosome size within a particular families shows significance taxonomic importance.
   - ✓ Among monocots, the members of Zingiberaceae possess small chromosomes, the members of Iradiaceae have small to medium sized chromosomes, the

members of Amaryllidaceae have large sized chromasomes, and those of Liliaceae have chromosomes of varying size.

3. Chromosome morphology
    - ✓ Based on the morphology or their length and position of the centromere, chromosomes are characterized as medium, sub-median, sub-terminal or terminal.
    - ✓ Based on the position of primary constriction (centromere) and secondary constrictions chromosome are asymmetrical and symmetrical.
    - ✓ Symmetrical chromosomes with two equal arms and median centromere. Whereas asymmetrical with unequal arms and sub-terminal centromere.
    - ✓ Thus the length of the arms of chromosomes, position of centromere and presence of satellites shows some taxonomical significance also.
4. Chromosome behaviour at meiosis
    - ✓ The fertility of a plant is highly dependent on the ability of meiotic chromosomes to pair (synapsis) and their subsequent separation.
    - ✓ It also enables comparison between genomes to detect the degree of homology, especially when they are result of hybridization.
    - ✓ Degree of sterility and occurance of hybridization are determined by the behaviour of chromosomes during meiosis.
    - ✓ And greater degree of non-homology results in either failure of pairing or loose pairing.

- Systematic values of cytotaxonomy
    - Some cytological evidence show taxonomic significance in certain family, genus and species. These inferences are added to the modern taxonomic studies for the further analysis and identification of taxa.

A. Cytological variation at family level
    - ✓ Cytological data provide a logical basis for the appropriate arrangement of tribes and genera in some families, such as Ranunculaceae, Brassicaceae and Poaceae.
    - ✓ In Ranunculaceae, all the genera n=7,8,9, and those genera differs from some character placed under another family. Those genera with long chromosomes and short chromossomes have been placed under Anemoneae and Helleboreae.
    - ✓ Two genera of Helleboreae (*Coptis* and *Zanthorhiza*) with very small chromosome and n=9 have been placed under an additional tribe Coptideae.
    - ✓ Based on the number and size of chromosome family Poaceae divided into different subdivisions.
    - ✓ Based on the cytological inference *Yucca* and *Agave* possess 5 long and 25 short chromosomes, so it replaced from Liliaceae and Amaryllidaceae into single family Agavaceae.
    - ✓ Delimitations of the tribes in Asteraceae have been done on the basis of chromosome numbers.

B. Cytological variation at generic level

- ✓ There several examples for generic level identifications.
- ✓ The genus *Cistus* (family- Cistaceae) was formerly included under *Helianthemum.* However, is n=8 and *Helianthemum* with n=9. So this evidence replaces this *Cistus* into separate genus.

C. Cytological variation at specific and intra-specific levels

- ✓ All species of the genus *Tephrosia* are with 2n=22, except *T. constricta* in which 2n=16, so. *T. constricta* is treated as distinct genus from others named as *Sphinctospermum constricta*.
- ✓ Karyotype analysis of *Aegilops sitopsis,* suggests that it should be shifted to *Triticum* and *Aegilops,* or it should be given the rank of separate genus.
- ✓ Cytological studies have recognized 2 races in *Veronica prostrata* of the family Scrphulariaceae. It has been suggested that they should be treated as two sub-species namely *prostrata* (n=8) and *scheereri* (n=16).

NUMERICAL TAXONOMY

- It is also called Taximetrics or phonetics
- It is a new methodology in classification proposed by Michael Adanson in families des plantes in 1763.
- He is known as the father of numerical taxonomy who first proposed this idea.
- The method involves thye use of great range of characters with equal weightage to every character (apriori weightage).
- Numerical taxonomy does not produce new data and is not a new system of classification.
- It is a method of organizing data on the basis of similarity for the purpose of obtaining classification.
- The supporters of phonetics stress the importance of using more number of characters, at least 60, but preferably so or more, that can be correlated on the basis of similarity.
- In 1957, Sneath and Sokal published the revised version of principles of numerical taxonomy.
- 7 principles of numerical taxonomy
  1. A classification based on more number of characters carry great content of information and has more predictive value.
  2. A priori weighting; every character is of equal weightage in creating natural taxa.
  3. Overall similarity between 2 entities is a function of their individual similarities in each of many characters in which they are being compared.
  4. Correlation of characters differs in distinct group of organisms or taxa and the same can be used to recognize various taxa.
  5. Phylogenetic interference can be made from taxonomic structure and character correlation, which give indications about evolutionary pathways and mechanisms.
  6. Taxonomy is viewed and practiced as an empirical science.
  7. Classification is based on phonetic similarity.
- Most of these principles except 5 are similar to the ideas conceived by Adanson and are therefore called Neo adansonian Principles.

- In numerical taxonomy wise classification. The referring taxa by specific or generic name are avoided.
- Instead these grouping are replaced with OUT's (operational taxonomic unit), the term given to represent lowest ranking taxon studied in the investigation. In this character states of each selected character has to be determined for each OUT's.
- The data obtained from the character analysis were used to study the total similarity of taxon.
- A data matrix is then prepared and the data are codified for computer processing.
- There are several steps in numerical taxonomy. First step of numerical taxonomy is the selection of unit characters. Unit character may be defined as a taxonomic character of two or more character states, which cannot be sub divided logically.
- In numerical taxonomy, the data coded in numerical form can be integrated with existing electronic data processing systems in taxonomic institutions and can be used for the creation of descriptions, keys, catalogues, maps and other documents.
- This is a quantitative methods, can give better systems of classification and keys that can be obtained by conventional methods.
- Numerical taxonomy helps the re-interpretation of a number of biological concepts, posing new biological and evolutionary questions.

MOLECULAR TAXONOMY

- Recently emerged branch of taxonomy.
- Based on molecular similarity between organisms.
- The core concepts of molecular taxonomy.
    - ✓ At molecular level, members of the same species may be identical, members of closely related species may be less similar, members of distantly related species may be less similar, and members of unrelated species may be totally different.
    - ✓ The amino acid sequence of protein and the nucleotide sequence of the genes which govern the synthesis of these protein may be the same or very much similar in closely related organisms, and different in unrelated organisms.
- Molecular taxonomy utilizes data from nuclear DNA, chloroplast DNA or mitochondrial DNA to elucidate phylogenetic relationship between plants.
- Phylogeny is the course of evolution of a taxonomic group from a simple to a complex and advanced state of organization.
- Phylogenetic evolution or cladogenesis or branching evolution , involves the evolutionary changes that cause the splitting and divergence of an ancestral lineage into two or more lineages. And the schematic, branching tree like diagram which represents phylogenetic evolution is called cladogram or phylogenetic tree.

MODULE 4

: Plant Nomenclature

- Biological nomenclature is the scientific system of naming the taxonomic groups or taxa that are recognized in classification or it is the formal naming of taxa in a scheme of classification.
- Significance of plant nomenclature
    - It provides a universally acceptable name for each species and thereby avoids the confusions, problems and difficulties caused by the vernacular or local names of organisms.
- Biological nomenclature follows some internationally accepted criteria, principles and Codes of law, the scientific name of a species, or that of higher taxon, would be same all over the world.
- The rules of nomenclature are not directly based on phylogenetic considerations or the principles of classification.
- Linnaeus denoted the plant nomenclature in his treatises like *Fundamenta Botanica*(1736) and *Critica Botanica* (1737). In *Philosophica Botanica* (1751) he elaborated his view and thereby formulated a sound and valid system of plant nomenclature, called binomial system, for naming, ordering and ranking plants.
- A binomial system or two part names, is unique to each species. Each taxon has a genus and species name. So according to Linnanean principles, no two genera can have the same generic name, and no two species can have the same specific epithet. If a genus is divided into two or more genera, the original generic name would be given to any one of them.
- The binomial system was consistently used by Carl Linnaeus in his *Species Plantarum*. He employed it for avoiding the assignment of different names for the same species or assignment of the same name to different species.
- Augustin de Candolle (1813) published *Theories Elementaire dela Botanique*, with instruction on various nomenclatural procedures.
- Steudel (1821) published *Nomenclator Botanique*, indexing the names of flowering plants with their synonyms.

Systems of nomenclature

- Four different biological system of nomenclature has been derived.

1. Uninomial nomenclature
    - This system gives one word names for designating taxa that are above the rank of a species.
    - There are different standard endings for different taxa in uninomial nomenclature.
    - Eg. In Fungi

      Division -mycota
      Subdivision -mycotina
      Class - mycetes
      Sub-class -mycetidae
      Order -ales
      Family -aceae
2. Binomial nomenclature
    - Naming of species by giving two- part names (binomial).

- Name of a species is a binary combination of two different names. First name generic name, it has an initial capital letter. The second name is the specific name or specific epithet (a trivial name) and it has an initial small letter.
- Eg. *Mangifera indica*, *Cocos nucifera*.
- In binomial nomenclature, the specific name is followed by the name of the author, who validly published the name. The authors name would be in abbreviated form.
- Binomial nomenclature was first formulated by Bauhin (1623). And applied by Linnaeus in *Species plantarum* (1753).
- This system was internationally adopted in botany since 1753.
- Generic name

  It is usually a singular noun.

  A genus may be named in honor of a scientist or a renowned person. Eg. Linnaea is used to in honor of Linnaeus.

  Some names have a mythological origin. Eg. Nymphaea denotes the lovely water-nymphs.

  Some names denote some characteristic features of a the plant. Eg. Liniodendron or lily tree is based on the shape of the flowers of the Tulip tree.

  Some generic names are aboriginal in origin. i.e ., the names existed in the lands where the plants were discovered, but later they were given latin names. Eg.,Betula is an old Greek name for Birch.
- Specific name

  It may be in honor of a person.

  It may be derived from a special characteristic of the plant.

  May derive from a geographical location where the plant grows.

  It may originate from an old common name.

  It may be named arbitrarily.

3. Trinomial nomenclature
   - It is the system of naming infra-specific taxa, such as sub-species, by giving three-word (trinomials).
   - The first word represent the generic name, the second word represents the specific name, and the third word represents the infra- specific or sub-specific name. Thus it is extention of binominalism.

     Eg. *Crotalaria retusa* var, *indica*. Nampy & Sibi
4. Polynomial nomenclature
   - This is the system of designating a species by a many- word name (polynomial).
   - It was prevalent before the middle of 18th century for naming for plant species.
   - Polynomial system was found extremely difficult for remembering and indexing plant names.

     Eg. *Sida cordifolia- Althea maderspanthana subrotundo folio molli*

- Peculiarities or requirements of biological nomenclature
  1. Stability
     - It is the constancy of the names, free from frequent changes and substitutions in time and space.

- Frequent change of names would cause great deal of confusion with the result that the usefulness or applicability of names as specific recognition symbols would get lost and the very purpose of nomenclature would be defeated.

2. Uniqueness
   - It is the extreme specificity of a scientific name in the sense that it is related only to a specific taxon, and no other taxon can have it.
   - Each taxon is known only by a specific name, and different taxa are never known by the same name.
3. Universality
   - It means that a particular species or any other taxon is known only by the same scientific name all the world over. This implies that scientific names must be universally acceptable.

INTERNATIONAL CODE OF BOTANICAL NOMENCLATURE

- The International Code of Nomenclature for algae, fungi and plants (ICN), formerly called International Code of Botanical Nomenclature (ICBN), and abbreviated as *Code*.
- Code is a set of rules and recommendations set forth for naming plants. Its former name was changed at the international botanical congress, held in Melbourne (Australia) on 23rd July, 2011 as a part of *Melbourne Code*, which replaced *Vienna Code* of 2005.
- The *Code* is approved by the international botanical congress (IBC) and published by the international association of plant taxonomy (IAPT).
- The *Code* can be changed only by the IBC.
- At every congress, it would be subjected to revisions and amendments, involving additions, deletions and modifications.
- The current *Code* has been adopted by the XVIII IBC, held in Melbourne in 2011.
- Each new edition of the Code supersedes the previous ones and is retroactive back to 1753. For naming cultivars there is a separate *Code*, called International Code of Nomenclature for Cultivate Plants. Its rules and recommendations supplement the ICN.
- History of ICN
  - ICBN was first framed by Linnaeus. In 1737 he framed some elementary rules for botanical nomenclature.
  - In 1813, A.P.de Candolle set forth a detailed set of rules regarding plant nomenclature.
  - The first botanical congress held in Paris (1886), entrusted Alphonse de Candolle, son of A.P. de Candolle.
  - He convened an assembly of botanists from different countries and prepared a provisional draft Code. It was accepted with necessary modifications by the next congress, held in Paris (1867). It was called as Paris Code or Candollean Code.
  - Important Codes adopted by IBC
    Paris Code (1867), Vienna Code (1902), America Code (1907), Cambridge Code (1935), Amsterdam Code (1947), Paris Code (1956), Vienna Code (2005) etc.
- A Code contain Division I. Principles (I-IV)

Division II. Rules and Recommendations (Art. 1-62)
Division III. Provisions for the Governance of the Code
Appendix I. Names of Hybrids
Glossary: Glossary of terms used in this Code

- Aims of ICN
  - The Code aims at the provision of a stable method of naming taxonomic groups, avoiding and rejecting the use of names that may cause error or ambiguity or throw science to confusion. Botany requires a precise and simple system of nomenclature used by botanists in all countries. The purpose of giving names to taxonomic groups is not to indicate its character or history but to supply a means of referring to it, and to indicate its taxonomic rank.
  - The Code is utilized in two basic activities;
    1. Naming of new taxa (which were previously unnamed and often not described).
    2. Determining the correct name for previously named taxa (which may have been divided, united, transferred or changed in rank).
- The detailed provisions of the Code are divided into rules, set out in articles and recommendations- examples are added to illustrate them. The objectives of the rules are to put the nomenclature of the past in order and to provide guidelines for the future.
- The recommendations of the ICN Code are aimed to bring uniformity and clarity especially in future nomenclature.
- Principles of ICN (Melbourne Code, 2012)
  1. Nomenclature of algae, fungi and plants is independent of zoological and bacteriological nomenclature. The Code applies equally to names of taxonomic groups treated as algae, fungi, or plants whether or not these groups were originally so treated.
  2. The application names of taxonomic group are determined by means of nomenclatural types.
  3. The nomenclature of taxonomic is based upon priority of publication.
  4. Each taxonomic group with a particular circumscription, position and rank can bear only one correct name, the earliest that is in accordance with the rules, except in specialized cases.
  5. Scientific names of taxonomic groups are treated as Latin regardless of their derivation.
  6. The rules of nomenclature are retroactive unless expressly limited.
- Rule of Priority. Why certain names are conserved against priority?
  - The rule of priority though originally intended to bring nomenclatural stability, its strict application has created a lot of instability in botanical nomenclature.
  - The third principle of the ICBN is priority of publication. When a particular plant is known by more than one botanical name, it can bear only one correct name- the earliest legitimate one, validly published in accordance with the rules of nomenclature (except conserved names).

    Eg. Thus *Adhathoda zeylanica* medic, (1790) is the correct name for the plant commonly known as *Adhathoda vasica* nees (1832). The rule of priority only applies to taxa of the rank of family and below also do not apply outside a particular rank (with a transfer in rank). Eg. *Sida rhombifolia* subsp. *retusa* (I.) Borss. (1966). When this subspecies is elevated to the rank of a species it should be called *Sida alnifolia* I. (1753), not as *Sida retusa* I. (1763)). The subspecific epithet has no priority as it is outside the rank of a

species. The principle of priority for vascular plants starts from 1 may 1753 with the publication of *Species Plantarum* by Linnaeus.

- A scientific name that is well known and frequently used may have to be replaced for some other name if the latter was discovered to have been published earlier. This lends a degree of instability to Botanical Nomenclature. However, in such a case, a petition may be presented and voted upon at the international Botanical Congress to conserve one name over another that actually has priority.
- Such procedure is outlined as three amendments to the ICBN:
  Nomina familiarum Conservanda
  Nomina generica Conservanda et rejicienda and
  Nomina specifica conservanda et rejicienda
- The rationale for conservation of names is to provide greater stability in Nomenclature by permitting names that are well known and widely used to persist, even upon discovery of an earlier, but more obscure name.
  Eg. The generic name *Naregamia* Wight & Arn. (1834) is conserved against the earliest name *Nilanaregam* Adans. (1763).
  Such conservation puts an end to changes in generic names due to nomenclatural conventions such as rule of priority but does not rule out changes due to taxonomic reasons such as an amended circumscription.

- Type method or Typification
  - When a species is described new to science, the author must indicate which is the specimen on which the new species is based.
  - In the case of species or names below the rank of a species (subspecies, variety etc.)
    The type is an individual herbarium specimen on which the name of a new taxon is based. If the specimen is too small or unpreservable, then all illustration, photograph, permanent slide, pure culture may be the type.
  - The type specimens or types are among the most valuable possessions in any herbarium. A deal of care is taken to preserve the type specimens. They are the records for the future and they alone can solve taxonomic riddles. A name of taxon is valid only if the nomenclatural type is indicated.
  - It is not enough to mention in the original description (protologue) that the specimen was collected by Robert Wight from Sispara in Silent Valley on 15/01/1825, and that the specimens is deposited at Central National Herbarium, Culcutta. It should categorically state the type is Wight 1864.2.
  - If the type is not indicated, publication of the new taxon, even if it meets other requirements of the Code, is not valid. The type of a genus is a species; that of a family is a genus. Eg. The type of the order Malvales is Malvaceae; the type of the family Malvaceae is a genus *Malva* L.; the type species of the genus is *Malva sylvestris* L.; the type of the species *Malva sylvestris* is an herbarium specimen, LINN 870.22 in the Linnanean herbarium, London. Thus nomenclaturally, the name of a taxon is permanently attached to its type.
  - The type does not need to represent the average or most typical representative of a population.
  - There are different types of types.

1. Holotype
   It is one specimen or illustration used by the author, or designated by the author as the nomenclatural types.
2. Isotype
   An isotype is any duplicate of the holotype and is always a specimen. If the holotype is an illustration there cannot be any isotypes.
3. Syntype
   It is always a specimen. It is any specimens cited in the protologue when there is no holotype, or any one of two or more specimens simultaneously designated as types.
4. Paratype
   A paratype is any specimen cited in the protologue that is neither the holotype nor an isotype, nor one of the syntypes if in the protologue two or more specimens are simultaneously designated as types.
5. Lectotype
   It is a specimen or illustration designated from the original material as the nomenclatural type if no holotype was indicated at the time of publication, or if the holotype is missing, or if the type is found to belong to more than one taxon.
6. Neotype
   It is a specimen or illustration selected to serve as a nomenclatural type if no original material is extant, or as long as it is missing.
7. Epitype
   An epitype is a specimen or illustration selected to serve as an interpretive type when the holotype, lectotype or previously designated neotype or all original material associated with a validly published name, is demonstrably ambiguous and cannot be critically identified for purposes of the precise application of the name to a taxon. The epitype concept was new to the Code in the Tokyo Code.

- Original Material: original material is defined by the Code as the holotype, isotypes, syntypes, isosyntypes, and paratypes of a name, as well as any other specimens and illustration upon which it can be shown that the description or diagnosis validating the name was based.

- Effective publication (Article 29-31)
  - Publication is effective only when the printed matter is distributed to the general public, or at least to the botanical institutions with libraries that are accessible to botanists.
  - Any mode of publication like announcement of names at public meeting, displaying of new names in collections or gardens, distribution of typescripts and microfilms, etc. will not be considered as effective publication.
  - Publication of a new name on or after 1st January, 1953 of in trade'smen catalogue or in non-scientific newspapers, even if accompanied by a Latin diagnosis, will not constitute effective publication.
  - The date of effective publication of a journal is the date on which the printed matter becomes available.
- Valid publication
  - A name published as per the provisions of the Code (Articles 32-45) are considered as valid publication.

- The following condition are to be followed for valid publication:
    1. The name of the taxon must be effectively published (all conditions for effective publication should be fulfilled)
    2. A name of a new taxon published on or after 1.1.2012 must be accompanied by a description or diagnosis or by a previously and effectively published description or diagnosis of the taxon.
    3. For all new combinations published on or after 1.1.1953, basionym should be clearly indicated with full and direct reference to the author and protologue.
    4. The rank must be indicated (gen. nov., spec. nov., var. nov., etc.) in all new taxa, and new combinations (comb. Nov; nom. Nov., stat. nov.)
    5. Publication of the name of a new taxon of the rank of a family or below on or after 1.1.1958 is valid only when nomenclatural type is indicated. For the name of a new taxon of the rank of the genus or below published on or after 1st Jan 1990, indication of the type must include one of the words "typus" or "holotypus" or its abbreviation. The institution where the type specimen is permanently conserved also should be indicated.

- Author citation
    - The name of a plant to be accurate and complete, it should be followed by the name of the publishing author. This enables one to trace the original description and to ascertain its type and date of publication.
    - There are several rules for author citation as follows;
        1. Usually, the names are cited in abbreviated forms but never underlined or printed in italics. Eg., *Vitex* Linn; *V. trifolia* Linn, etc.
        2. These citations can indicate bibliographic references, which are especially helpful in the recognition of homonyms. For example, *Utricularia caerulea* Linn. And *Utricularia caerulea* Clarice, are two names referring to two different taxa. But it would have been impossible for us to recognize this, if the citation of author's names appended to the respective plant names were not given.
        3. If the name of the plant is jointly published by two authors, their names should be linked by means of an ampersand e.g. Nampy & Sibi.
        4. When more than three authors are involved, citation is normally restricted to the first author and followed by et al.
        5. If an author validly publishes a name but ascribes it to another person, for example to the author who suggested the name but failed to publish it validly, then the name of the latter should be connected to the name of the person who validly publishes the name by an ex. Eg. *Acalypha racemosa* Wall ex Baill.
        6. If a genus or taxon of lower rank is altered in rank or position, but retains its name or epithet, the name of the author who first published the name or epithet (basionym) must be cited in parenthesis followed by the name of the author who effected the change. This is called double citation. E.g. *Leucaena latisiliqua* (Linn) Gillis (1914) Basionym: *Mimosa latisiliqua* Linn (1753).
        7. If a taxon is of garden origin, then while citing the name it should be ascribed to hort. (hortulanorum) and connected by an ex to the name of the author who published it e.g., Geaneria dwklarii hort, ex Hook.

- Choice of names
  - There are several criteria for choosing the name of a taxon. Some of them are the following;
    1. When the taxon rank is changed, the earliest legitimate name is its new rank and its correct name.
    2. When two or more taxa of the same rank are united into one, the oldest legitimate name of these taxa should be retained as the name of the united taxon.
    3. When a genus or species is divided into two or more genera or species, the original name of the genus or species must be retained.
    4. When a species is transferred to another genus without the change of rank, the original name must be retained.
- Rejection of names
  - A legitimate name or epithet must not be rejected merely because it is inappropriate or disagreeable, or because another one is prefereable or better known, or because it has lost its original meaning.
  - A name must be rejected if it is nomenclaturally superfluous when published.
  - The following names can be considered illegitimate or unusable
    - ✓ Synonyms – there are the different names used for the same taxon.
    - ✓ Tautonyms- these are the names where the specific epithet exactly repeats the generic name with or without transcribed symbol.
    - ✓ Typonym-a name is rejected if there is an older valid name based on the same type.
    - ✓ Homonym- a name that is shared by two or more different taxa.
    - ✓ Autonym- automatically created tautonym for intergeneric or intraspecific taxa.
    - ✓ Nomen nudum- this is a name that does not fulfill the criteria set by the international Code of Botanical Nomenclature. So, it is not a legally described scientific name and cannot be used unless it is subsequently proposed correctly.

Plant identification

- Plant identification is the basic activity and one of the primary objectives of systematics.
- It involves the recognition of the characteristics of organisms and the naming of organisms on the basis of their characters.
- Identification is simply the determination of the similarities and differences between two factors- whether the two are the same or they are different.
- Or simply identification is the determination of the exact taxonomic identity of an individual organism.
- Some of the characters commonly considered for plant identification are the following.
  - ✓ Whether a plant is herbaceous or woody, and annual or perennial in nature.
  - ✓ Whether milky or colored sap is present in the leaf, stem or other plant.
  - ✓ Leaf type, phyllotaxy and venation.
  - ✓ Presence or absence of stipule, and the type of stipule on young shoots.
  - ✓ The distribution and the types of hairs, trichomes, spines etc. on the plant surface.

- ✓ The part of the flower, the number and arrangement of sepals and petals (aestivation), and whether they are fused or free.
- ✓ Whether perianth is present in one or more series, or is absent.
- ✓ Whether pappus, epicalyx, or similar structures are present.
- ✓ Whether a nectar-secreting disc is present in the flowers.
- ✓ Whether the flowers are actinomorphic or zygomorphic.
- ✓ The number and attachment of stamens and whether there is any fusion of anthers or filaments.
- ✓ The number of pistils, styles and stigmas in the gynoecium, the numbers of locules, the number of ovules per locule, and the type of placentation.
- ✓ Position of the ovary and fusion of the perianth.

- There are several methods used for plant identification they are:
  - ✓ Using taxonomic literature
  - ✓ Using taxonomic keys
  - ✓ Direct comparison method and combination of different methods.

Taxonomic literature

- It is the basic and preliminary method for plant identification.
- Here the taxonomist compares the specimens with the published descriptions of the species in various literatures.
- The taxonomists consider illustrations, articles, research papers, monographs, floras, manuals, revision, synopsis, conspectus etc. for the identification.

Taxonomic keys

- A taxonomic key enables the taxonomist to easily and quickly identify the species to which a hitherto unknown plant belongs.
- The ultimate goal of taxonomic key is the identification of taxa.
- Taxonomic keys are a tabulation of the diagnostic characters of a taxonomic group like species, genus and family etc. which facilitate rapid identification and classifications.
- Taxonomic key consists of a series of contrasting and contradictory statements or propositions based on which the user can make comparisons and take decisions.
- The main objectives of the keys are to separate and segregate diagnostic characters in such a way as to provide a series of alternative choices for identification.
- Taxonomical keys are commonly used in floras and taxonomic revisions as a mere aid for identification. And the final identification depends on a comparison of the characters of the sample specimens with detailed descriptions and also on matching of the specimen with previously identified specimens.
- Taxonomic key preparation involves different steps like selection, evaluation and arrangement of taxonomically important diagnostic characters.

- An ideal key character is applicable equally to all the individuals of a species. They must be absolute, external and relatively constant so that they can be observed directly. The conspicuous characters used in diagnostic key are called key characters.
    - **Rules for constructing keys**
        - Only contradictory statement should be taken into an account so that one of them is accepted and the other one is rejected.
        - Morphological characters considered must be visible to naked eye or at the best with the hand lens.
        - The smaller group should be dealt with first, followed by the larger group.
        - Avoid the repeating statements.
        - Negative statements should not be chosen. For example, stamens free should be used instead of stamens not diadelphous.
        - Both the leads of couplet must start with the same word.
        - Use of discontinuous characters is better than the use of continuous or overlapping characters eg. leaves 4-9cm broad, leaves with white margin and long petiole.
        - For making a key for dioecious plants, characters of both male and female plants must be incorporated.

    - **Types of keys**

        - Generally there are two types of taxonomic keys are used of taxonomic identification.

        A. Dichotomous key or sequential key or diagnostic key
            - ✓ It is plant identification key constructed in the form of a sequence of alternative choices. This alternatives used are precise and the statements presented are sufficiently definite so that identification is easy.
            - ✓ The key have two contrasting characters at each step. And these paired choices are called character couplets. And the two contrasting or contradictory statements of a couplet are called leads.
            - ✓ Normally a key may be very simple with a single couplet or pair of lead or it can be complex with several pairs of leads.
            - ✓ The first contrasting character in each step is called primary key character or lead character. The characters following the lead character are called secondary key character.
            - ✓ Based on the utility dichotomous key can be classified into two.
                - ❖ Used for general purposes
                    1. Indented key
                    2. Simple bracket key
                    3. Simple non-bracket key
                    4. Grouped type key
                    5. Combination key
                - ❖ Used for special purposes
                    1. Branching key

2. Circular key
3. Pictorial key
4. Box-type key

- ✓ Generally indented key and bracketed key are used in taxonomic literature for plant identification.

1. Indented key (Yoked key)
    - Here the first part of a contrasting couplet is followed by the subsequent couplets.
    - Each two couplet leads or the alternatives of a character are separated by subsequent and subordinate alternatives.
    - And each of the first couplet are indented from the left hand of the page in such a way that each subordinate couplet is indented on step further to the right.
    - In long indented keys, the alternatives get widely separated and take more space. So it is much difficult to identify the higher order taxa.

2. Bracketed key or parallel key
    - Here two contrasting alternatives leads of a couplet are numbered and presented together, without intervening couplets.
    - Each alternative are presented side by side, ready comparison is possible.
    - This key best in serving the diagnostic purposes.
    - The main advantage is easy to prepare.
    - The main disadvantages is that the relationship of the divisions is not quite apparent as in indented key.

B. Multi-access key or multi entry keys

- ✓ Multi-access keys are usually produced in the form of punched cards.
- ✓ Punched card keys consists of cards of suitable size, with the names of the taxa (families, genera or species for which the key is used) printed on them.
- ✓ Each card has a number and any one character is printed near one of its corners. All the taxa having this character are indicated by perforation in front of their names, while those lacking it are without any perforation.
- ✓ There are some disadvantages regarding the preparation of multi-access key like; it require plenty of space for storage and the use of card is relatively time consuming, heavy work and expensive also.
- ✓ There are two types of such perforated or punched keys.

1. Edge punched key
    - In this type of punched key, there is one card for each taxon showing the combination of characters of that particular taxon.

- Each attribute is represented by punched hole around the perimeter of the card.
- When taxa possess a particular attribute, the hole clipped or punched to form an open notch.
- Here the key preparation and plant identification done through certain steps. Each one of the steps is listed below.
- A list of attributes of the unknown specimen is prepared and for each attribute the specimen possesses, the hole is punched.
- All the appropriate cards are stacked together and a needle is inserted through one of the holes representing one of the attributes possessed by the taxon.
- The needle is then lifted horizontally and shaken gently so that all those taxa possessing the attributes fall away from the whole stack. The cards that fall remain on the needle are the taxa which do not possesses the attributes and kept aside.
- The cards that fall down are gathered again and the process is repeated several times so that ultimately one card will fall from the stack.
- And the taxon represented on the card is the correct identification of the unknown taxa.

2. Body-punched key
    - The holes are punched in rows on the main body of the card.
    - Here each card represents one character state or attribute.
    - Numbers are printed on the card to point out the standard position of each taxon; if the taxon possesses that particular attribute, its position is punched out.
    - Here a lisr of attributes possessed by the unidentified taxon is prepared and appropriate cards are selected.
    - When all the cards of the attributes possessed by the unknown taxon have been placed one above the other, after punching of the holes, the taxon which possesses all the attributes will show a hole running through all these cards.
    - Position of the hole on the card will give the correct identification of the taxon.

Taxonomic information resources

- There are different variety of information resources of plant taxonomy are available in this scenario.
- The major information resources of plant taxonomy include herbaria, taxonomic literature, online resources, data bases etc.

HERBARIUM

- Herbarium is the store house of dried and pressed plant specimens, collected from different places, mounded on appropriate sheets, arranged according to an accepted system of classification, and kept in pigeon holes of sheet or in wooden cupboards for the future references an study.
- Herbarium preparation is an art, it was initiated by an Italian taxonomist from Bologna, named *Luca Ghini* who collected plants, dried and affixed them on paper with gum in the form of herbaria specimens.
- Word herbarium was first applied by *Pitton de Tournefort* in the book *Elements*.
- Linnaeus stored millions of dried specimens as herbaria.
- Some plants like *Cactaceae* are preserved in liquid preservatives without pressing and drying.
- Most herbaria include plants from different part of world and are the centres of advanced research in the field of taxonomy.
- Each specimen in the herbarium should be properly labelled and the label must bear details, such as scientific name of the species and family, and date and place of the collection, name of collector, notes etc.
- Each specimen in herbariums is systematically arranged.
- Herbariums are associated with botanical gardens, universities and colleges.
- Kinds of herbarium
    1. General or international herbaria-Specimens from different countries.
    2. National herbaria- Specimens from particular country.
    3. Local herbaria-Specimens from locality or region within a country.
    4. Special herbaria-Small herbaria with a limited or specific purpose.

    It is based the interest of organization or institution and the contents of the holdings, various kinds of herbaria can be recognized.
        a. Herbaria of organization like Botanical Survey of India contain collections from many parts of the world.
        b. The institutions, which are interested in drugs and medicine, herbaria with plants of known medicinal properties.
        c. Herbaria of universities or colleges generally contain specimens which are necessary for teaching, or are included in the syllabus and research.
        d. The herbarium of Agricultural Colleges and Universities includes specimens of crop plants and weeds of cultivated fields.
- Herbarium techniques

  The major steps in preparation of herbarium specimens are the following:
  1. Collection of specimens
      - Specimens were collected from different localities and habitats.
      - The selected plant should have all plant parts (bud, flower and fruit), including the root system for herbaceous plants.
      - The plant collection tools include collection pick, strong knife, pruning shears, plant press, hand lens, field book, tags, blotting papers etc.

- The plants collected may be pressed on the spot, or can be stored temporarily in a vasculum (a metal box used for plant collection) or in a ruck sacks and pressed after reaching the camp site.
- Now, polythene bags are used for plant collection.
- Soon after collection, collector must be tagged and the details regarding locality and the field characters must be recorded in the field book.

2. Poisoning of specimens
   - In order to avoid any chance of infection, the specimens must be poisoned immediately after collection.
   - For poisoning the specimens, 1% mercuric chloride. Lauryl Penta Chloro Phenate (LPCP), 4% formalin etc. are used.
3. Pressing and Drying of specimens
   - After poisoning the collection plant specimen are pressed in between sheets of blotting paper or newspaper.
   - The plants are arranged in such a way that there should be one specimen on each sheet, without overlapping of plant parts.
   - The folded sheet or blotting sheet with the plant specimens are then kept tightly pressed in the press for 24 to 48 hours.
   - The press then opened, papers are changed and the plants are properly arranged on new sheets. Change the paper on different interval up to the proper drying of specimens.
4. Mounting and labeling of specimens
   - After complete drying the specimens are mounted on herbarium sheets of standard size (16.5×11.5 inch or 41.9×29.5cm).
   - The plant specimens were mounted on the sheet using paste or glue or adhesive or gummed strips can be used. Stiff parts of woody plants are usually stitched to the sheet.
   - The mounted specimens should properly labelled.
   - A label is pasted on the lower right- hand corner of the sheet. Herbarium labels constitute an important part of finished specimens.
   - A label should contain the following information

     Collection number :
     Plant name (scientific name) :
     Common or local name :
     Locality and altitude :
     Habit :
     Date of collection :
     Ecological notes :
     Notes :
     Name of collector :
5. Storage of specimens
   - Mounted plant specimens are to be stored in specially constructed herbarium cases or in herbarium cabinets.

- Specimens should be arranged according to a well -known system of classification like Bentham and Hooker's system.
- The different genera of a family, and the different species of a genus should be arranged in alphabetic order.
- To avoid fungal infection, 1% Mercuric chloride may be sprayed.
- We use repellants like naphthalene balls and Para Dichloro Benzene (PDB) to avoid insect attack.

- **SIGNIFICANCE OF HERBARIA**
  1. They serve as a repository of plant specimens as they store dried plant specimens for future study.
  2. They act as a taxonomic aid which provides information for the identification of specimens. Each herbarium possesses a collection of properly identified specimens. One can identify the specimens by comparing them with the duly identified herbarium specimens.
  3. It is the primary source of information for floristic diversity assessment.
  4. Herbaria are comprehensive data-banks, which provide information about the diversity and distribution of species. It provide the basic material for the study of the flora and vegetation of different places or regions. Since it serves as a permanent record of flora, collection in the herbarium provide evidence of the vegetation of a region.
  5. Herbaria also provide details of fruit, external features, internal structures, pollengrains, carpology, etc.
  6. Herbaria facilitate the exchange and loan of materials for various research purposes.
  7. Herbaria form a very valuable source of information for ethano-botanical researches and phytogeographical studies.
- World famous herbaria – Royal Botanic Garden Kew, London, Uk.
  Missouri Botanic Garden-USA, Royal Botanic Garden Edinburgh-Uk. Etc.
- Major Indian Herbaria- Central National Herbarium-Shibpur, BSI-South Circle-Coimbathore, Forest Research Institute Herbarium- Dahradun Etc.

BOTANICAL GARDEN

- Ex-situ conservation of plants
- It is the collection of
  - Different varieties of cultivated plants, especially ornamentals.
  - Medicinal plants, economically valuable plants, plants of special interest.
  - Plants of certain geographic formations, such as desert plants, alpine plants, marsh plants, aquatic plants, etc.
  - Weeds and method of their control.
  - Plants mentioned in classical and religious literature, state flowers, national flowers and favourite flowers of the locality.
  - It is mainly for scientific studies of plants.

- Well planned botanical gardens serve as the centres of aesthetic attraction.

- Role of botanical garden
  - It is the unique collections of highly diverse living plants provide the basis for taxonomic studies, and also for academic studies on cytology, anatomy, phytochemistry etc.
  - Botanical gardens serve as acclimatization areas where exotic plants from all regions of the world live together.
  - It provides information on food plants, ornamental plants and medicinal plants.
  - Botanical gardens provide germplasm for hybridization.
  - Botanical garden provide protection to many endangered plants and economically important plants in glass-houses, green houses, etc.
  - It provides seeds and saplings of important plants on exchange basis to encourage thee introduction of exotic and useful economic plants.
  - Botanical gardens provide training in horticulture landscaping and gardening.
  - They are the centres of recreation and aesthetic beauty.
- Special types of botanical gardens
  a) Arboreta-botanical garden or parts of botanical gardens only trees or woody species are grown.
  b) Orchidaria-gardens only orchids are grown. eg. National Orchidarium at Botanical Survey of India, Shillong.
  c) Pineta-like arboreta, coniferous trees are grown.
  d) Bambuseta-main collection is Bamboo. Eg. Indian Botanical Garden, Kolkata.
- World famous and indian herbaria
  1. Royal Botanical Garden, Kew (1760) - World's largest botanical garden.
  2. Indian Botanical Garden, Kolkata (1787)- with giant banyan tree.
  3. National Botanical Garden(1789), Lacknow
  4. Lalbagh or The Mysore State Botanical Garden (1760), Banglore
  5. Botanical Garden Forest Research institute (1934), Dahradun
  6. Jawaharlal Nehru Tropical Botanical Garden and Research Institute (JNTBGRI) (1979), Palode, Thiruvanthapuram
  7. Malabar Botanical Garden & Institute for plant sciences.

BOTANICAL SURVEY OF INDIA (BSI)

- Government organization. Established in 1890 and recognized in 1954.
- It secures accurate and detailed information regarding the occurrence, distribution, ecology and economic uses of the plants in India.
- So, its main function is the exploration of the vegetable resources of India.
- And it also collects, identifies and distributes plant materials to support educational and research activities in Universities and academic institutions. Which implies it coordinates all the botanical studies and works all over India.
- For the purpose of Botanical survey, the country divided into 4 botanical regions,
  East-Calcutta (Sibpur)
  North- Bombay
  West- Pune
  South- Madras

- Calcutta was the centre of the Botanical survey of India.
- BSI was recognized in 1954 and sanction was accorded to it for the formation of the following organizations.
    1. A headquarters established under a chief botanist at Calcutta. This was meant for controlling and coordinating the activities of the various units of the BSI and also for implementing the policy laid down by the Government of India.
    2. Four regional circles based on phytogeographical affinities. They are the
       Eastern- Shillong
       Western-Pune
       Northern- Dehradun
       Southern- Coimbatore, each under a regional botanists. Each regional botanist will be responsible for the survey of the area of his jurisdiction and will utilize the facilities provided by the State and Universities.
    3. A central Botanical Laboratory under a Director at a suitable place in Uttar Pradesh. Here living plants will be studied in relation to their biology and economic utility.
    4. A national herbarium which will house the type specimens and fully representative collections of the plants of India.
    5. Maintenances of a Botanical museum on modern lines at Calcutta.
- BSI , nine regional stations
    1. Northern circle- Dehradun
    2. Eastern circle- Shillong
    3. Southern circle- Coimbatore
    4. Western circle- Pune
    5. Central circle- Allahabad
    6. Arid zone circle- Jodhpur
    7. Andaman and Nicobar circle- Port Blair
    8. Sikkim- Himalaya circle- Gangtok
    9. Arunachal field station- Itanagar
- Publications of BSI
    - FLORA OF INDIA-
      Series 1: National Flora in the form of fascicles.
      Series 2: State flora analysis- flora of Tamil Nadu, Himachal Pradesh, Karnataka.
      Series 3: District flora- flora of Jawai (Vol.1 & 2), Flora of Tonk District, Flora of Banswara.
    - Records
      Bulletin of BSI (a quarterly journal)
      The Flora of Khandla on the Western Ghats of India.

TAXONOMIC INFORMATION RESOURCES

- Taxonomical literature is a botanical work associated with the identification, classification and the determination and use of the correct name of a plant taxon.
- Taxonomic literature can be classified into the following categories.
    1. General taxonomic indices.
    2. World floras and manuals

3. Monographs and revisions
4. Bibliographic catalogues and reviews.
5. Periodicals
6. Online resources and databases.

- General taxonomic indices
  - ✓ Indices of plant names and they help in locating the original publication of a name, valid name, synonyms and to which family, subfamily or tribe the plant belongs.
  - ✓ Taxonomic indices- Index Kewensis, Index Londinensis, Gray Herbarium Card Index, Index Filicum, Index Muscorum, etc.

1. Index kewensis plantarum phenerogamarum
   - Index of all angiosperms in the world.
   - An alphabetical index of the generic name and binomials is used for the new and changed names of seed bearing plants of worldwide distribution.
   - All known specific epithets published for a particular genus are in alphabetical order under each generic name. Each name or binomial names is followed by author's name, geographical origin of plants and brief literature citation.
   - The original work was compiled into two volume by B. D Jackson(1893-1895), under the supervision of J. D. Hooker, and then supplement was added once in every five year.
   - Synonyms are mentioned in italics in the first volume. Recent supplements donot include synonyms, instead references to illustrations have been added.
   - Almost 968000 records are included. Approximately every year 6000 entries are added.
   - For the easy availability of data, the index published as CD-ROM.
2. Index londinensis to illustrations of flowering plants, ferns and fern allies
   - It was prepared under the auspices of the Royal Horticultural Society of London at the Royal Botanic Gardens, Kew.
   - Alphabetical register or index of representations or illustrations of flowering plants and ferns compiled from botanical and horticultural publications of the XVIIIth and XIXth centuries
   - These illustrations are arranged alphabetically by genus and species.
3. Gray Herbarium Card Index
   - It covers the flowering plants and ferns of the Western hemisphere and has index cards for all the new names and new combinations.
   - It was compiled at gray herbarium (1873) and was published from Harvard University, Cambridge, USA.
   - It was published in 10 volumes between 1893-1967, later G.K Hall gave a supplement to it, it covers 1967 to 1977.
4. Index Filicum
   - Listing of filicinae or true ferns.
   - Puvlished in 1906 by a Danish botanist C.F. A. Christensen from Denmark.
   - The work is completed in year 1905- 1975, the supplements enlisted the names which is considered as fern.

- Other supplements include *Index Lycopodiorum* for earlier *Lycopodiales*.
- *Index Isoetales* for *Isoetales, Index Psilotales* for *Psilotales, Index Selaginellarum* for *Selaginellales* and *Index Equisetophyta* for *Equisetales*.

5. Index Muscorum
    - Index for bryophytes.
    - An alphabetical list of all species and intraspecific taxa of mosses, published up to the end of 1962. It is 5 volume work.
    - C.F. B. Bonner (1962-1973), prepared the *Index Hepaticarum*, pertaining to *Anthocerotales*.

6. Index Nominum Genericorum
    - List of all generic names of plants of all groups, both fossils and extant.
    - Published in 3 volume work in 1979. Type specimens have been indicated along with bibliographic and nomenclatural details of about 63,500 entries.
    - The first supplement, *Regnum Vegetabile*, vol.11 (1986), listed another 2500 generic names and correct names of the previous publications.
7. Indices of Algae
    - An index of all known algae, with their names, classes, families and synonyms appeared in volume 103 of *Regnum Vegetabile* in 1980.
    - Diatoms have been recorded in *Catalogue of the Fossil and Recent Genera and Species of Diatoms* in 7 parts (1967-1978).

- Floras
    - Detailed and systematic enumeration of a major group of plants of a particular region.
    - It will provide full account of vascular plants and all data regarding the plants. Including complete botanical name, author's name, original name with date and page number of the book, synonyms etc.
    - Each flora consists of identification keys with small description.
    - Two books of *Genera plantarum* 1862- 1883 (7 volume work, consist of 200 families and 7569 genera and their species) with its herbarium specimens and accurate descriptions by Bentham and Hooker and *De Naturalichen Pflazenfamilien* 1887-1915 (entire plant kingdom –14 divisions, from algae to flowering plants) with illustrations and brief descriptions by Engler and Prantl respectively are the books considered as world floras.
    - Based on the area covered floras are classified into
        1. Continental flora
            - Covers the whole continent.
              Examples: Flora of Europea by Tulin et al (1964-80)
              Flora of Australiensis by Sentham (1863-78)
        2. Regional flora
            - It covers the information of plants of a vast geographical area, usually a large country, a floristic region, etc.
              Examples: Flora of British India (7 volume)- Dalton Hooker (1827-1897)
              British flowering plants- Hutchinson (1948)
              Palms of British India and Ceylon- Blatter (1926)
              Handbook of British flora- Bentham (1930)
        3. Local flora
            - Flora which covers only a much limited geographical area, such as a village, district, a mountain range, a state etc.

Examples: flora of Presidency of Madras (3 volume, Polypetalae Gamopetalae and Monochlamydeae)- J.S. Gamble (1915-1936)
Flora of Nilgiri and Pulney Hilltops – F.F. Fyson (1915)
Flora of Assam- U.N. Kunjilal et al (1934-40)
Flora of Nilambur
Flora of Calicut
Flora of Agasthyamala

- Based on the content, floras may be classified into:
  1. Research floras
     - Floras are regional revisions and self-contained.
     - Provide excellent data for taxonomic research.
  2. Concise or field floras
     - Shorter than research floras.
     - Description of each taxon is either very brief or lacking altogether.
     - It only includes minimum number of synonyms and type specimens are not mentioned in this flora.
  3. Excursion floras
     - Shortest version of flora.
     - Mainly used for the identification of plant from field itself.
     - It includes the identification keys and descriptions.

➢ Manuals
- It covers the data of a specialized group of plants. It emphasizes mainly on providing keys for identification and description.
- It includes the information about the area of coverage and keys and descriptions of families, genera and species.
- Additional information also provided for each species. Eg., species name, followed by authors names, synonyms, common or local names, ecological and distributional data, illustrations and distribution maps.

Examples : *Manuals of botany* by A. gray (1950)
Manuals of Cultivated Plants by L. h. Bailey (1949)
Manuals of Aquatic Plants by N.C. Fossel
Manuals of Cultivated Trees and Shrubs in Northern America by A. Reholer

➢ Monographs
- It is a taxonomic treatise and synthesis of all known information about the taxon.
- It is complete and comprehensive account of a taxon of any rank like family, genus or species of a given time.
- It includes the existing taxonomic knowledge as well as the results of any original research work carried out by the author.
- It covers some introductory chapters in which presentation and discussion of the original research work done by the author. This is followed by descriptive systematic treatment in which morphological, anatomical, embryological, palynological, cytological, genetic and ecological data are included.
- All species and infra specific taxa under a genus, and all the genera in a family must be included in a monograph.
- Many informations, such as extensive literature reviews and nomenclatural information, designated type specimens, identification keys for all the taxa, full synonyms, citations of the specimens examined, distribution maps, classification by the author for all the taxa included and their phylogenetic relationship, etc. also included in a monograph.

- Monograph differs from manuals in that it contains a detailed taxonomic treatment of a taxonomic group.
  Examples: *The genus Nicotiana* by T. H. Goodspeed. (1955)
  The genus Datura by A. F. Blakslee, et al (1959)
  The genus Pinus by Mirov (1967)
  A monograph of genus Avena by B.R. Baum (1977)

➢ Revisions
- Less comprehensive systematic treatment of any particular taxon occupying a smaller geographical region.
- It may include an entire family also.
- Revision incorporates a complete synonymy, keys to identify the included taxa, short description of mostly diagnostic features, distribution maps, a classification and a brief discussion on supporting data, illustrations in the form of line drawings.
- Revision is based on the herbarium specimens.
- A taxonomic revision usually incorporates much lesser details of introductory material and synoptic literature review.
- Each revision based on primarily on original research work, form the core of systematic botany.
- If there is inconsistency in the characters of a taxon of a particular geographic range and if there are difficulties in identifying the members of a taxon , such taxon needs a revision.

➢ Conspectus
- It is an outline of a revision.
- A conspectus includes listing of all taxa with all or only the major synonyms and often with a brief mention of the geographical range of each taxon.

➢ Synopsis
- It is a list of taxa with abridged diagnostic features to distinguish them from each other.
- Synopsis mostly occupies a few front pages of a revision in the form of a summary of the contents.

➢ Journals and periodicals
- Journals are the publication brought out at regular intervals carrying original research papers.
- Journals are published by a scientific organization or society or by an educational or non-profit research institution. Titles of some journals are very long and it is customary to abbreviate them. Eg., Pl. Syst. Evol. Stands for *Plant Systematics and Evolution* (Denmark).
- Periodicals are usually entitled as annals, bulletins or proceedings.
- Whenever a monumental work is published by a single author, it is treated as a *Memoir* or *Transaction*. eg., *Memoirs of Torrey Botanical Society*.
- Some of the periodicals and journals are listed below
  - ✓ *Botanical Journal Of Linnanean Society New Bulletin* (Royal Botanical Garden, Kew, London)
  - ✓ *Rheedea* (IAAT, Calicut university)
  - ✓ *Botanical Magazine* (Tokyo)
  - ✓ *Journal of Indian Botanical* Society (JIBS , Bangalore)
  - ✓ *Blumea*

- ✓ *Edinburgh journal of Botany*
- ✓ *New Zealand Journal of botany*
- ✓ *Botanical Journal of the Linnaean Society* (London)
- ✓ *Taxon*