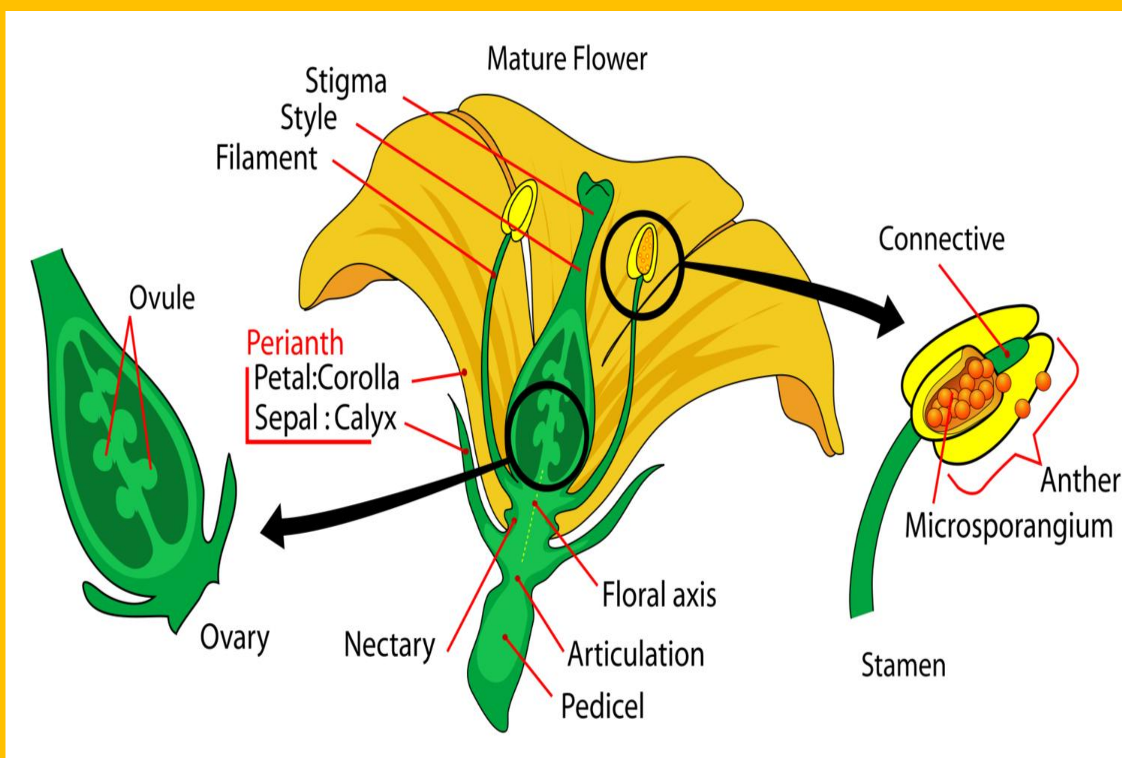
MSCBOT-504

M. Sc. I Semester

TAXONOMY OF FLOWERING PLANTS (ANGIOSPERMS)



DEPARTMENT OF BOTANY
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UTTARAKHAND OPEN UNIVERSITY

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CONTENTS

BLOCK-1 CLASSIFICATION AND PHYTOGEOGRAPHY

UNIT-1 PRINCIPLES, HISTORY AND PHASES OF TAXONOMY

1.1 OBJECTIVES

After reading this unit students will be able to-

- Understand the taxonomic principles.
- Know the history of taxonomy.
- Learn the different phases of taxonomy.
- Know the philosophy of classification.
- Understand the different types of classifications.

1.2 INTRODUCTION

Taxonomy is an old science among almost all sciences which developed with civilization of humans. Taxonomy is a science that includes identification, nomenclature, and classification. Greek meaning of taxonomy is rendering in order and systematic to put together. Taxonomy was not invented in a laboratory by any scientist, inventor or in any school by scholars, or by any philosopher in particular country or geographical area, rather it is everywhere and as old as civilization. Taxonomy is science of disciplined and civilized persons which needs enthusiasm, passion, sensibility, unplumbed knowledge and endurance. Taxonomy is not a branch of biological science but it is a complete science in itself which comprises all branches of biology such as morphology, reproductive biology, phenology, embryology, biochemistry, ecology, cytology, genetics as well as other branches of science like geology, geography, mathematics, statistics, information technology etc.

Taxonomy in relation to plants is called plant taxonomy which gives emphasis on identification and naming of plants. The identification, correct naming and classifying according to any accepted system is called systematics. Some botanists assume that taxonomy and systematics are interchangeable words. According to Solberg (1966) taxonomy includes classification and nomenclature but leans heavily on sytematics for its concept. As per Lam (1959) and Turril (1964) taxonomy and sytematics are synonymous words.

The objectives of plant taxonomy are to gather knowledge of plants of earth and their systematic grouping. It is not possible to gather knowledge without arranging them in systematic way due to the large size of flora of earth. The first aim requires us to make a complete inventory of all the plants of an area and subsequently all parts of the globe. The collection and preparation of herbarium for further study is first step in taxonomy. The second step is identification, which is accomplished by description, making illustrations and formation of identification keys. The primary aim of taxonomy is to identify all kinds of plants and the secondary aim is to arrange according to accepted system of classification.

Identification involves the determination of taxon (Plural taxa) as being similar or identically equal to a known taxon. This identification implies assigning a plant to a particular taxonomic group and ultimately to the species. This may be achieved either by the help of available literature like Flora, monographs and herbaria. In the case when all possibilities to matching a plant to any identified and known plant are failed it becomes a new species (*sp.nov*.).

Classification is the arrangement of plants in taxonomic groups (division, class, order, family, genus and species) according to their observed similarities. It is the production of a logical system of categories, each containing any number of organisms. The principles underlying any modern system of classification are based on the genetical relationship among them thus closely related groups are brought together. Classification may be based on natural characters (natural classification) or on any convenient/artificial relationship (artificial classification) or based on evolutionary relationship (phylogenetic classification).

1.3 PRINCIPLES OF TAXONOMY

Present day taxonomy is based on the primary importance of morphological distinctness and affinity but is also influenced appreciably by the findings of the cytologists, geneticists, anatomists etc. Taxonomy is a functional science. The direction, character and extent of its function are guided by principles that have developed with the increase of plants themselves, which begins with the period of descriptive taxonomy in the nineteenth century. Tournfort, De Jussieu and Linnaeus were the beginners of descriptive taxonomy and during descriptive period most of taxonomic work was usually based on gross morphological characters.

Based on primitive and advanced characters several systematists (Swingle, Bessey, Sporne, Hutchinson, Heywood, Takhtajan, Thorne etc.) proposed and established different principles in plant taxonomy. All these principles are helping us to understand the phylogeny of angiosperms.

Swingle's Principles

Swingle has proposed 36 principles in evolutionary taxonomy which have been uniformly accepted by the plant taxonomists.

1. Plant relationships are up and down genetic lines and these must constitute the framework of phylogenetic taxonomy. This will naturally form a branching but not reticulate structure.
2. Evolution does not necessarily involve all organs of the plant at one time or in the same direction. One organ may be advancing while another is stationary or retrogressing.
3. Some evolutionary processes are progressive while others are regressive.
4. Evolution has generally been consistent and when a particular progression or regression has set in, it is persisted into the end of the phylum.
5. Generally the structures with many similar parts are more primitive, and those with fewer and dissimilar parts are more advanced.
6. The chlorophyllous plants precede the non-chlorophyllous plants in any phylum. Usually saprophytes are derived from independent forms and parasites generally from the saprophytes among the lower plants and from independent forms among the flowering plants.

7. Perennials are more primitive than biennials and biennials are usually more primitive than annuals.
8. In most groups of seed plants woody members have preceded the herbaceous ones.
9. In most groups of seed plants erect members have preceded the vines.
10. In seed plants the stem structure with collateral bundles arranged in a cylinder is more primitive than that of the scattered bundles.
11. In plants scalariform vessels are more primitive than vessels with round pits.
12. The spiral arrangement of leaves on the stem and of the floral leaves precedes that of opposite and whorled type.
13. Simple leaves are more primitive than compound leaves.
14. In the seed plants the netted venation of leaves is more primitive than parallel venation.
15. Historically leaves were first persistent (evergreen) and later deciduous. This way deciduous leaves show advanced character.
16. The solitary flower is more primitive than the inflorescence.
17. Bisexual flowers preceded unisexual flowers.
18. The monoecious is primitive than dioecious.
19. The many parted flower is more primitive, the type with few parts being derived from it, and the change is accompanied by a progressive sterilization of sporophylls.
20. Regular flowers are more primitive than irregular ones.
21. Spirally imbricate floral parts are more primitive than those that are whorled and valvate.
22. Hypogyny is the primitive structure and from it perigyny and epigyny have been derivied.
23. Polypetalous flowers are more primitive than gamopetalous ones, the latter being derived from the former by symphysis.
24. Flowers with petals preceded apetalous ones, the latter being derived by reduction.
25. Perianth consisting of like segments is more primitive than one in which sepals and petals are unlike each other.
26. Numerous carpels are more primitive condition than less carpels.
27. Separate carpels are more primitive condition than united carpels.
28. Axile placentation preceded parietal and free central placentation of ovaries.
29. The presence of numerous stamens is more primitive condition than that of a fewer stamens.
30. Separate stamens preceded united stamens.
31. Simple and aggregate fruits preceded multiple fruits.
32. Evolution in angiosperms is believed to have proceeded from seeds with two seed coats to those with only one.
33. The primitive seed contains endosperm and a small embryo, the advanced type has little or no endosperm, with the food stored in a large embryo.
34. A straight embryo is usually more primitive than a curved one.
35. The same evolutionary phenomena have often been repeated as separate occurrences in different parts of the plant kingdom *i.e.* loss of chlorophyll, loss of petals, stamens and carpels; acquisition of fleshy texture in fruits and of various types of thorns, change from

simple to compound leaves, from erect to prostrate habit and from hypogynous to perigynous insertion of floral parts, and lateral union (symphysis) of petals, stamens and carpels.

36. In determining the closeness of relationship between two families or other groups, it is usually best to compare with each other the most primitive, or basal members of each group, rather than those that are simplified by reduction or those that are most highly specialized.

Bessey's Dicta

Charles E. Bessey (1915) evolved a system based on a series of statements of guiding principles called dicta, he used these in determining the degree of primitiveness or evolutionary advancement of a plant groups. Bessey published his ideas on flowering plants titled "The phylogenetic taxonomy of flowering plants".

General dicta

1. Evolution is not always upward, but often it involves degradation and degeneration.
2. In general, homogeneous structures (with many and similar parts) are lower, and heterogeneous structures (with fewer and dissimilar parts) are higher.
3. Evolution does not necessarily involve all organs of the plant equally in any particular period, and one organ may be advancing while another is retrograding.
4. Upward development is sometimes through an increase in complexity, and sometimes by a simplification of an organ or a set of organs.
5. Evolution has generally been consistent, and when a particular progression or retrogression has set in, it is persisted in to the end of the phylum.
6. In any phylum the holophytic (green) plants precede the colourless (hysterophytic) plants, and the latter are derived from the former.
7. Plant relationships are **up and down** the genetic lines, and must constitute the framework of phylogenetic taxonomy.

Dicta having special reference to the general structure of the flowering plants

8. The stem structure with collateral vascular bundles arranged in a cylinder is more primitive than that with scattered bundles, and the latter are to be regarded as derived from the former.
9. Woody stems are more primitive than herbaceous stems, and herbs are held to have been derived from trees.
10. The simple, unbranched stem is an earlier type, from which branching stems have been derived.
11. Historically the arrangement of leaves in pairs on the stem is held to have preceded the spiral arrangement in which the leaves are solitary at the nodes.
12. Simple leaves preceded compound leaves.
13. Persistent leaves are older than deciduous.
14. The reticulated venation of leaves is the normal structure, and the parallel venation of some leaves is derived from it.

Dicta having reference to the flowers

15. The polymerous flower structure preceeds, and the oligomerous structure follows from it, and this is accompanied by a progressive sterilization of sporophylls.
16. Petaly is the normal perianth structure, and apetaly is the result of perianth reduction.
17. The apochlamydeous perianth is earlier and the gamochlamydeous perianth is derived from it by symphysis of the members of perianth whorls.
18. Actinomorphy is an earlier structure than zygomorphy, and the latter results from a change from similar to dissimilar growth of the members of the perianth whorls.
19. Hypogyny is the more primitive structure and from it epigyny was derived later.
20. Apocarpy is the primitive structure and from it syncarpy was derived later.
21. Polycarpy is the earlier condition and oligocarpy was derived from it later.
22. The endospermous seed is primitive and lower while the seed without endosperm is derived and higher.
23. Consequently, the seed with a small embryo (in endosperm) is more primitive than the seed with a large embryo (in scanty or no endosperm).
24. In earlier (primitive) flowers, there are many stamens (polystemonous), while in later flowers there are fewer stamens (oligostemenous).
25. The stamens of primitive flowers are separate (apostemonous), while those of derived flowers are often united (synstemonous).
26. The condition of powdery pollen is more primitive than that with coherent or massed pollen.
27. Flowers with both stamens and carpels (monoclinous) precede those in which these occur in separate flowers (diclinous).
28. In diclinous plants the monoecious condition is the earlier and the dioecious later.

Hutchinson's Principles

Hutchinson's classification is based on following principles which has been supported by others. Hutchinson's principles are outlined under 24 points which are as follows:

1. The evolution is both upward and downward, the former tending towards preservation and the later to their reduction and degeneration of characters.
2. Evolution does not necessarily involve all organs at one time or simultaneously.
3. Aquatic plants are derived from terrestrial and saprophytes, parasites and epiphytes are more recent.
4. Trees and shrubs are more primitive than herbs.
5. Perennials are more primitive than biennials and annuals.
6. Plants with vascular bundles arranged in a ring are more primitive than those in which vascular bundlers are scattered.
7. Spiral phyllotaxy is primitive than whorled and opposite phyllotaxy.
8. Dioecious plants are more advanced than monocious ones.
9. Unisexual flowers are more advanced than bisexual flowers.
10. Petaloid flowers are more primitive than apetalous flowers.

11. Gamopetally is advanced than polypetalae.
12. Zygomorphic flowers are advanced than actinomorphic flowers.
13. Hypogyny is more primitive than perigyny and epigyny.
14. Simple leaves are more primitive than compound leaves.
15. Solitary flower is more primitive than inflorescenced flowers.
16. Spirally imbricate floral parts are more primitive than whorled and valvate arrangement.
17. Apocarpy is more primitive than syncarpy.
18. Polycarpy preceedes oligocarpy.
19. Endospermic seeds with small embryo are more primitive than non endospermic seeds with large embryo.
20. Flowers with numerous stamens are more primitive than those with fewer stamens.
21. Free stamens precede the fused ones.
22. Aggregate fruits are more evolved than single fruit and capsule preceedes berry or drupe.
23. Parietal placentation is more primitive than axile and free central placentation.
24. Trees or arboreal habit are more primitive than climbers and twiners in any one family or genus.

Thorne's Principles (1958) of Plant Classification

1. Existing species have descended with change from pre-existing species and are therefore, the products of evolutionary forces.
2. Ancestral conditions and trends of specialisation are often recognisable in the organs, tissues and cells of living and fossil angiosperms.
3. The primitive, ancestral condition of any given characteristic can be no more specialised than its condition in derived, existing species most primitive for that characteristic.
4. The presence of vestigial rudiments of organs, or sometimes the presence of vestigial vascular supply to greatly modified or missing organs, often furnishes evidence of evolutionary reduction, loss, fusion or other major modification of structures.
5. The prevalence of parallel and convergent evolution in habit, function and structure is a predictable consequence of the relatively limited means, angiosperms have for effective reproduction and for adaptation to available environmental niches.
6. All parts of plants at all stages of their development may produce evidence that is valuable in establishing relationships.
7. Evolution may tend towards elaboration and diversity or towards reduction and simplicity.
8. The role and direction of evolution may vary in different organs and tissues of plants.
9. Most existing angiosperms are highly specialised and greatly modified from their primitive, generalised ancestors.
10. Evolutionary trends are sometimes reversible under the influence of change in environmental factors.
11. Once lost, organs usually are not regained.

12. New angiospermous structures have arisen as modifications of or as outgrowths from the pre-existing structures.
13. The sporadic or restricted occurrence of unusual or uncommon characteristics lacking apparent evolutionary significance is often an indication of relationship when correlated with other characteristics.
14. The occasional attainment of certain characteristics of certain levels of evolutionary development is frequently valuable in determining the affinities of families and orders.
15. Embryos and seedlings of related though dissimilar plants often resemble each other more than do the adult plants because of their apparent retention of primitive characteristics.

Evolutionary Trends in Angiosperms

The following trends are, in general, agreed upon by those who practice this method of classification.

S. No.	Primitiveness	Advance
1.	Tropical	Temperate
2.	Woody	Climbing or herbaceous
3.	Vessel less	With vessels
4.	Perennial	Biennial or annual
5.	Ring arrangement of vascular bundles	Scattered
6.	Chlorophyllous	Non chlorophyllous
7.	Evergreen	Deciduous
8.	Stipules present	Absent
9.	Leaves simple	Compound
10.	Flowers bisexual	Unisexual
11.	Flowers entomophilous	Flowers anemophilous
12.	Flowers solitary	Inflorescences
13.	Floral parts spirally arranged	Whorled
14.	Perianth undifferentiated	Calyx and/or corolla reduced
15.	Flowers with petals	Flowers apetalous
16.	Petals free	Connate
17.	Actinomorphic flowers	Zygomorphic flowers
18.	Hypogynous condition	Epigynous, perigynous condition
19.	Stamens many	Few
20.	Stamens separate	Connate
21.	Carpels many	Few
22.	Carpels free	Connate
23.	Fruits solitary	Aggregate fruits
24.	Fruit a follicle	Capsule, berry, drupe, *etc.*

1.4 HISTORY

Plant taxonomy is one of the oldest branches of Botany, started as **“Folk Taxonomy”** before fifteenth century but after mid fifteenth century it has grown and gone very long way. History of taxonomy begins with the categorization of useful plants of folk taxonomy; herbalists differentiated them as of economic value. This paved the way for herbal taxonomy. The primitive taxonomy based on interest of medicinal uses rather than systematic interest. Then the plants are divided in different categories according to external appearance *i.e.* herbs, shrubs, under shrubs, trees, annuals, biennials and perennials.

Western scientific taxonomy started in Greek some hundred years BC and was in its peak in 18-19 AD. The most important works are cited and the progress of plant taxonomy is described up to the era of the Swedish botanist Carl Linnaeus, who is considered founder of modern taxonomy and father of binomial nomenclature. The development after Linnaeus is characterized by a taxonomy that increasingly has come to reflect the paradigm of evolution. The used characters have extended from morphological to molecular. The Nomenclatural rules have developed during the 19th and 20th century by International Botanical Congress organized by taxonomists from all over globe, and during the last decade traditional nomenclature has been challenged by advocates of the Phylocode and BioCode. The history of taxonomy can be divided into pre Linnaean and post Linnaean taxonomy.

1.4.1 Pre Linnaean taxonomy

Taxonomy is as old as the human civilization and development of communication skill. It has always been essential to know the names of useful plants in order to communicate acquired experiences to other members of the communities. When we speak about ancient taxonomy it usually mean the history in the Western world, starting with Romans and Greeks. However, the earliest traces are not from the West, but from the East. Eastern taxonomic works were not known to the Western world until the middle ages and could thus not influence the progress of Western sciences.

The pharmacopoeia *Divine Husbandman's Materia Medica* included medicines derived from minerals, plants, and animals. Around 1500 BC medicinal plants were illustrated on wall paintings in Egypt.

1.4.1.1 The Greeks and Romans

Aristotle (384–322 BC) was the first to classify all living things and some of his groups are still used today, like animals with blood and without blood which are now called the vertebrates and invertebrates. He further divided the animals with blood into live bearing and egg bearing and formed groups within the animals without blood that are today’s, insecta, crustacea and testacea.

Theophrastus (370–285 BC), a student of Aristotle, classified 480 species of plants in his book *De Historia Plantarum*, and is called 'father of botany'. His classification was based on growth form like herbs, shrubs and trees *etc.*

Pliny (23–79 AD) was involved in the Roman army and wrote *Naturalis Historia*, in which he described several plants and gave those Latin names. Many of these name we still in practice, like *Populus alba* and *Populus nigra*.

Dioscorides (40–90 AD), a Greek physician, explored the Roman and Greek world to gather knowledge about medicinal plants and wrote *De Materia Medica*, which contained around 600 plant species. The genus *Dioscorea* which includes the yam was named after him by Linnaeus.

1.4.1.2 The Herbalists

With the discovery of art printing books, new books could be made in large numbers. This was the time of the different herbals written by herbalists like **Otto Brunfels**, **Jerome Bock**, **Fuchs**, **Mattioli**, **Turner**, **L'Obel**, **and Gerard**. Some of these authors were honoured by Linnaeus with generic names: *Brunfelsia*, *Mattiolia*, *Turnera*, *Lobelia*, *Gerardia* and *Fuchsia*. The earliest herbalists were merely copying Theophrastus and Dioscorides but later became more and more original with more elaborate woodcuts as illustrations.

1.4.1.3 Early taxonomists

At the end of 16th century the taxonomic works became original enough to replace the ancient Greek works. The reason behind this was the development of lenses, which made it possible to detailed study in specific structures of plants and helpful in comparative study. Collection of specimens became part of the taxonomy, thus emphasis turned from medical aspects to taxonomic aspects.

Andrea Caesalpini (1519–1603), who is sometimes called "the first taxonomist", wrote *De Plantis*, a work that contained 1500 species based on growth habit together with fruit and seed form, as was that of Theophrastus. Some groups that he recognized we still acknowledge, like the plant families Brassicaceae and Asteraceae.

Two Swiss brothers Jean **Bauhin** (1541–1631) and **Gaspard Bauhin** (1560–1624) wrote the work *Pinax Theatri Botanici* in 1623. The word *Pinax* means register, and the work is a listing of 6,000 species. The Bauhin brothers recognized genera and species as major taxonomic levels.

The English naturalist and philosopher **John Ray** (1627–1705) wrote several important works through his life. His most significant contribution was the establishment of species as the basic taxonomic unit and published *Methodus Plantarum Nova* (1682), which contained around 18,000 plant species, a result of a relatively narrow species concept.

J. P. de Tournefort (1656–1708) a French botanist, founder of modern concept of genus published his work *Eléments de botaniqu* (1694), and constructed a botanical classification that came to rule in botanical taxonomy until the time of Linnaeus. He put primary emphasis on the classification of genera, and many genera were accepted by Linnaeus and still in use today like *Betula, Castanea, Fagus, Quercus, Ulmus, Salix, Lathyrus* and *Populus etc.*

1.4.1.4 Linnaean era or Modern Period

For nomenclatural reasons two works of **Carl Linnaeus** (1707–1778) are regarded as the starting points of modern taxonomy: the *Species plantarum* (1753) and *Systema Naturae* (1758) and introduced binomial system of classification. There is no doubt Linnaeus had laid out the foundation for taxonomy and it was now time for subsequent taxonomists to improve this newborn science. Terms like *corolla*, *stamen, filament* and *anther* were created by him.

2.4.3. Post Linnaean taxonomy

One of the few countries in which the Linnaean systematics did not make success was France. The French stuck to Tournefourt and continued to work on a development of the natural system.

Georges L.L. de Buffon (1707–1788) criticizes Linnaeus work. He emphasizes description rather than to classification. His theories touched upon development of species, infraspecific variety and acquired inherited characters in species, which opened up a pathway for an evolutionary theory.

Michel Adanson (1727–1806) launched his idea that in classification one should not put greater emphasis on some characters than on others, but uses a great range of characters. He wrote *Familles des Plantes* (1763) and criticizes Linnaeus' works, and fund Tournefort's classification far superior.

Antoine L. de Jussieu (1748–1836) published his book *Genera Plantarum* in 1789 contained complete system of classification, in which he launched a natural system based on many characters that came to be a foundation of modern classification. He divided the plants into acotyledons, monocotyledons and dicotyledons on their natural characters and established the family rank between class and genus.

Lamarck (1744–1829) put forward an evolutionary theory including inheritance of acquired characters called Lamarckism. This was foreboding the theory of evolution proposed by Charles Darwin and Alfred Russel Wallace (1858). The French scientific work, the development of anatomy and physiology and improved optical instruments founded new era of taxonomy, which was trying to cope with an increasing number of species in a rapidly expanding floristic world.

Augustin Pyramus de Candolle (1778-1841) a Swiss botanist published *Historia Plantarum Succulentarum*, established a new genus *Senebiera*, and he went on to document hundreds of plant families and create a new natural plant classification system.

Most recently **De Queiroz and Gauthier** (2000) developed the theoretical foundation of the phylo-Code in a serial publication of papers in 1990, 1992 and 1994. This is published in version form first time in 2000.

The history of taxonomy can be divided in following four phases:

I. Exploratory phase
II. Consolidation phase
III. Biosystematic phase and
IV. Encyclopaedic or Holotaxonomic phase

2.5 EXPLORATORY PHASE

In exploratory phase Taxonomy was merely exploration and naming of species.

i. Theophrastus (370-285 BC) published *Historia Plantarum,* the first scientific inquiry into plants and one of the first systems of plant classification, Linnaeus called Theophrastus "the father of botany". He uses the names *Crataegus, Daucus, Asparagus, Narcissus, etc.* in his work.

ii. Pliny (23-29 AD) wrote Natural History in 37 volumes, in which he collected much of the knowledge of his time.

iii. Andrea Caesalpini (1519–1603), who is sometimes called "the first taxonomist", wrote De Plantis, a work that contained 1500 species.

iv. The first herbarium of the world was established in Padua, Italy in 1545 and the same year first Botanic Garden was also established. After in the middle of seventeenth century, several herbaria were established in different parts of the world.

v. The important taxonomists of this phase are Jean Bauhin (1541–1631), Gaspard Bauhin (1560–1624), John Ray (1627-1705), Tournefort (1656-1708) *etc.* Within their existing limits and knowledge they gave concept of species, synonym, classification and nomenclature. They defined species as a natural group of organisms with invariant generalized or idealized pattern shared by all members of the group.

vi. Linnaeus (1753) founder of binomial nomenclature, published *Species Plantarum* is a legendry work of plant taxonomy. Linnaeus system of classification is sexual system and was an artificial system on few characters.

1.6 CONSOLIDATION PHASE

The consolidation phase has significant history and is marked by a number of legendry works on plant taxonomy

i. De Candolle (1778-1841) documented hundreds of plant families and created a new natural plant classification system with modification of Linnaeus system.

ii. Bentham and Hooker (1864) published a monumental work *The Genera Plantarum* in which they have given natural system of classification of great practical use.

iii. Charles Darwin (1859) published *On the Origin of Species,* based on natural selection and evolutionary concept.

iv. The evolutionary concept is basis of Phylogenetic classification and started by Endichler (1804-1849) and Eichler (1837-1887).

v. Engler and Prantl (1887-1915) proposed phylogenetic system of classification in the book *Die Naturlichen Pfalenzen Familien*.

vi. The first purely phylogenetic system of classification was given by Bessey (1845-1915) on the basis of Dictas or guiding principles of phylogeny later improved by Hallier (1868-1938).

vii. John Hutchinson (1955) put forth 24 principles for determining primitiveness and advance characters and suggested value of phylogenetic classification in his book "*The Families of Flowering Plants*".

viii. The phylogenetic system was later improved by contemporary Botanists like Takhtajan, Cronquist, Stebbins, Throne *etc.*

1.7 BIOSYSTEMATIC PHASE

In the recent past, unprecedented change has been seen in the field of taxonomy with the advancement in fields of microscopy, cytology and molecular tools and application by advancement of Biosystematics. It is a concept of systematics that considers a species to the product of evolution. It takes into consideration all the known characteristics of organisms and all the known evidences from different fields of biology. The concept of new systematics was developed by Sir Julian Huxley in 1940. Biosystematics is the science through which life forms are discovered, identified, described, named, classified and catalogued with their diversity, life histories, living habitats, roles in an ecosystem, and spatial and geographical distributions recorded.

i. Huxley (1940) proposed the term "New systematics" and Camp and Gilly (1943) proposed the term "Biosystematics" to new systematics.

ii. The chromosomes were considered by cytotaxonomists as very reliable tool.

v. The development of sophisticated techniques like chromatography, extraction and identification of secondary metabolites led to the development of "Chemotaxonomy".

vi. The molecular techniques can give information of proteins (amino acid sequencing) and DNA and RNA (nucleotide sequence).

1.8 ENCYCLOPAEDIC OR HOLOTAXONOMIC PHASE

Information is gathered, analysed, and a meaningful inference is drawn for understanding phylogeny. The "New systematics" is aimed at achieving the goal of "holotaxonomy".

i. Collection of data, analysis and synthesis are the jobs of an independent discipline of taxonomy, i.e., Numerical Taxonomy.

ii. Numerical Taxonomy or quantitative taxonomy is based on numerical evaluation of the similarity between groups of organisms and the ordering of these groups into higher ranking taxa on the basis of these similarities.

Exploratory and Consolidation phase are considered as **Alpha Taxonomy** while Biosystematic and Encyclopaedic phase are considered as **Omega Taxonomy**. Turril (1938) used the term Omega (ω) taxonomy for biosystematics or new systematics. His Alpha (α) taxonomy deals with collection and identification of organisms on the basis of gross morphology, a compilation of flora and monographs.

2.9 TYPES OF CLASSIFICATION SYSTEMS

Classification is the arrangement of a plant or group of plants in orderly ways in distinct categories following a system of nomenclature, and in accordance with a particular and well established plan. Depending upon their objectives, classification may be artificial, natural, or phylogenetic (phyletic), which includes phenetic and cladistic.

Types of Classifications

1. Empirical classification

In this classification plants are arranged in alphabetical (ABC…) order likewise the alphabetical arrangement of words in dictionary. There was no character into consideration.

2. Reasonable classification

In this classification the plants were placed together on the basis of some natural characters which may link them. This type of classification may further be divided into following types:

(a) Artificial classification: This is more or less arbitrary as the plants are classified on the basis of one or at the most few characters, which, however, do not throw any light on the affinities or relationship of the plants with one another. The earliest systems of classification which remained dominant from 300 B.C. up to about 1830 were artificial systems.

(b) Natural system of classification: This system is based not only on the characters of reproductive organs and structural relationship but all the other important characters are also taken into consideration and the plants are classified according to their related character. It helps us not only to ascertain the name of a plant but also its relationship and affinities with other plants. All the modern systems of classification are natural.

(c) Phylogenetic system of classification: This type of system classifies plants according to their evolutionary and genetic relationships. It enables us to find out the ancestors or derivatives of any taxon. These are expressed in the form of phylogenetic trees or shrubs showing presumed evolution of the groups.

1.9.1 Linnaeus Classification

Carolus Linnaeus (1707-1778), a great Swedish naturalist, is rightly known as the 'father of modern botany'. In 1730 he published *Hortus Uplandicus* wherein he enumerated the plants of the Uppsala Botanical Garden growing at that time. Later, in 1737, he published his famous *Hortus Cliffortianus*, based on the collection of plants in the garden of George Clifford at Hartecamp. His *Genera Plantarum* and *Classes Plantarum* appeared in 1737 and 1738 respectively. Linnaeus' *Philosophia Botanica* appeared in 1751 which contained a revised version of his system published previously in his *Classes Plantarum* (1738) and *Systema Naturae* (1735). His *Species Plantarum* was published in 1753, a work where some 7,300 species are described and arranged according to his sexual system of classification. In this book Linnaeus introduced the consistent use of the binomial system of plant names.

Linnaeus' system of classification is though artificial, he was the first to recognize the significance of flower and fruit structure. He recognized 24 classes determined on the basis of the number, size and union of stamens. The classes were subdivided into orders based, not on character, but on his idea of their relationships.

Twenty four classes of Linnaeus are as follows:

S. No.	Class	Number of stamens/type	Example
1.	Monandria	Stamens one	*Lemna, Scirpus*
2.	Diandria	Stamens two	*Salvia, Veronica*
3.	Triandria	Stamens three	*Iris*
4.	Tetrandria	Stamens four	*Mentha, Cornus*
5	Pentandria	Stamens five	*Primula, Solanum*
6.	Hexandria	Stamens six	*Asparagus, Asphodelus*
7.	Heptandria	Stamens seven	*Aesculus*
8.	Octandria	Stamens eight	*Fagopyrum*
9.	Enneandria	Stamens nine	*Rheum*
10	Decandria	Stamens ten	*Acer, Kalmia*
11.	Dodecandria	Stamens eleven to nineteen	*Calla*
12.	Icosandria	Stamens twenty	*Rosa, Rubus*
13.	Polyandria	Stamens twenty or more, attached to the receptacle	*Tilia, Papaver*
14.	Didynamia	Stamens didynamous	*Ocimum, Linaria*
15.	Tetradynamia	Stamens tetradynamous	*Brassica, Rhaphanus*
16.	Monadelphia	Stamens monadelphous	*Malva, Althaea*
17	Diadelphia	Stamens diadelphous	*Pisum, Lathyrus*
18.	Polyadelphia	Stamens polyadelphous	*Citrus*

19.	Syngenesia	Stamens syngenesious	*Viola*, *Tagetus*
20.	Gynandria	Stamens adnate to the gynoecium	*Calotropis*, *Vanda*
21.	Monoecia	Plants monoecious *i.e.* male and female sexes on same plant.	*Typha.*
22.	Dioecia	Plants dioecious	*Salix, Urtica.*
23.	Polygamia	Plants polygamous	*Empetrum.*
24.	Cryptogamia	Flowers concealed	Algae, fungi, mosses, ferns.

The system of Linnaeus which largely depended on the number of stamens and carpels in the flower was very simple and convenient and became very popular. It remained dominant for over 75 years until it was replaced by the systems of de Jussieu and de Candolle.

1.9.2 Bentham and Hooker's system of classification

George Bentham (1800-1884) and **Joseph Dalton Hooker** (1817-1911), the two British botanists who were associated with the Royal Botanic Gardens, Kew, England, jointly published a monumental work ***Genera Plantarum*** (1862-1883) in 3 Vols. This was the greatest taxonomic work ever produced in the United Kingdom and has "ever since been an inspiration to generations of Kew botanists". This three-volume monumental work which required quarter of a century, comprised description of all genera of seed plants known to science at that time and they were classified according to the system proposed by them. The first part of ***Genera Plantarum*** appeared in July 1862 and the last part in April 1883. They have provided first rate descriptions of the families and genera of seed plants then known.

Bentham and Hooker divided the seed plants into Dicotyledons, Gymnosperms and Monocotyledons. They placed Ranales in the beginning and grasses at the end. Their treatment is in consistent with our present day understanding of these groups. The gymnosperms are a distinct group from the angiosperms and their placement between the Dicotyledons and Monocotyledons is inconsistent with our current understanding of this group. The position of Apocarpeae among Monocotyledons is incorrect and they should have been placed at the first place in the Monocotyledons.

Bentham and Hooker divided seed plants into three classes (Dicotyledons, Gymnosperms and Monocotyledons), three sub-classes, 21 series, 25 cohorts and 202 orders (initially 200 orders). Orders Vochysiaceae and Cyrillae were incorporated later.

Outline of Classificaion System of Bentham and Hooker, 1862-1883

CLASS I.: DICOTYLEDONS (two cotyledones, exogenous growth)

Sub class 1. POLYPETALAE (petals separate)

Series I. Thalamiflorae (Petals and stamens hypogynous and usually many)

Cohort 1. Ranales (Gynoecium apocarpus)

Orders: 1, Ranunculaceae; 2, Dilleniaceae; 3, Calycanthaceae; 4, Magnoliaceae; 5, Annonaceae; 6, Menispermaceae; 7, Berberidaceae; 8, Nymphaeaceae

Cohort 2. Parietales (Parietal placentation)

Orders: 9, Sarraceniaceae; 10, Papavaraceae; 11, Cruciferae; 12, Capparideae; 13, Resedaceae; 14, Cistineae; 15, Violarieae; 16, Canellaceae; 17, Bixineae

Cohort 3. Polygalineae (Calyx and corolla 5, ovary 2 locular)

Orders: 18, Pittosporaceae; 19, Tremendreae; 20, Polygaleae; 20a, Vochysiaceae

Cohort 4. Caryophyllinae (Free central placentation, ovary 1-locular)

Orders: 21, Frankeniaceae; 22, Caryophyllae; 23, Portulaceae; 24, Tamarascineae

Cohort 5. Guttiferales (Stamens numerous, calyx imbricate)

Orders: 25, Elatineae; 26, Hypericineae; 27, Guttiferae; 28, Ternstroemiaceae; 29, Dipterocarpeae; 30, Chlaenaceae

Cohort 6. Malveles (Stamens numerous, calyx valvate)

Orders: 31, Malvaceae; 32, Sterculiaceae; 33; Tiliaceae

Series II. DISCIFLORAE (Ovary superior, immersed in the disc of flower)

Cohort 7. Geraniales (Ovules pendulous, raphe ventral)

Orders: 34, Lineae; 35, Humiriaceae; 36, Malpighiaceae; 37, Zygophylleae; 38, Geraniaceae; 39, Rutaceae; 40, Simarubeae; 41, Ochnaceae; 42, Burseraceae; 43, Meliaceae; 44, Chailletiaceae

Cohort 8. Olacales (Ovules pendulous, raphe dorsal)

Orders: 45, Olacineae; 46, Ilicineae; 46a, Cyrilleae

Cohort 9. Celastrales (Ovules erect, raphe ventral)

Orders: 47, Celastrineae; 48, Stackhousieae; 49, Rhamneae; 50, Ampelideae

Cohort 10. Sapindales (Ovules ascending, raphe ventral or inverted)

Orders: 51, Sapindaceae; 52, Sabiaceae; 53, Anacardiaceae

Anomalous Orders: 54, Coriareae; 55, Moringeae

Series III. CALYCIFLORAE (Sepals united, often adnate to ovary; stamens peri- or, epigynous, ovary often inferior)

Cohort 11. Rosales (Flowers usually bisexual, regular or irregular; stamens indefinite, often twice or more than number of petals, styles distinct)

Orders: 56, Connaraceae; 57, Leguminosae, 58, Rosaceae; 59, Saxifragaceae; 60, Crassulaceae; 61, Droseraceae; 62, Hamamelideae; 63, Bruniaceae; 64, Halorageae

Cohort 12. Myrtales (Flowers regular or irregular, stamens definite, rarely indefinite, Floewers peri-or epigynous

Orders: 65, Rhizophoreae; 66, Combretaceae; 67, Myrtaceae; 68, Melastomaceae; 69, Lythraceae; 70, Onagraceae

Cohort 13. Passiflorales (Ovary syncarpous, parietal placentation)

Orders: 71, Samydaceae; 72, Loaseae; 72, Turneraceae; 74, Passifloreae; 75, Cucurbitaceae; 76, Begoniaceae; 77, Datisceae

Cohort 14. Ficoidales (Flowers regular or irregular, ovary syncarpous, inferior to superior, parietal, basal or axile placentation)

Orders: 78, Cacteae; 79, Ficoideae

Cohort 15. Umbellales (Flowers regular, usually bisexual, ovary inferior, umbel inflorescence)

Orders: 80**,** Umbellifereae; 81, Araliaceae; 82, Cornaceae

Sub Class 2. GAMOPETALAE (Petals fused)

Series IV. Inferae (Ovary inferior, stamens no. = petal no. and alternating with them)

Cohort 16. Rubiales (Stamens epipetalous, anthers distinct, ovary 2- many locular, ovules 1- many)

Orders: 83, Caprifoliaceae; 84, Rubiaceae

Cohort 17. Asterales (Stamens epipetalous, ovary 1- locular, 1-ovuled)

Orders: 85, Valerianeae; 86, Dipsaceae; 87, Calycereae; 88, Compositae;

Cohort 18. Campanales (Stamens free, ovary 2-6 locular, ovules many)

Orders: 89, Stylideae; 90, Goodenovieae; 91, Campanulaceae

Series V. Heteromerae (Ovary superior, stamen as many or double the number of petals, carpels more than 2)

Cohort 19. Ericales (stamens double or as many as corolla lobes and alternating with them, ovary 2-many locular)

Orders: 92, Vacciniaceae; 93, Ericaceae; 94, Monotropeae; 95, Epacrideae; 96, Diapensiaceae; 97, Lennoaceae

Cohort 20. Primulales (Stamens as many as petals and opposite to them, ovary 1-locular)

Orders: 98, Plumbagineae; 99, Primulaceae; 100, Myrsineae

Cohort 21. Ebenales (Stamens as many as petals and opposite to them, ovary 2-many locular)

Orders: 101, Sapotaceae; 102, Ebenaceae; 103, Styraceae

Series VI. **Bicarpellatae** (Stamens as many as petals and alternating with them, ovary bicarpellay and superior)

Cohort 22. Gentianales (Corolla regular, leaves opposite)

Orders: 104, Oleaceae; 105, Salvadoraceae; 106, Apocynaceae; 107, Asclepiadaceae; 108, Loganiaceae; 109, Gentianaceae

Cohort 23. Polemoniales (Corolla actinomorphic, leaves alternate)

Orders: 110, Polemoniaceae; 111, Hydrophyllaceae; 112, Boraginaceae; 113, Convolvulaceae; 114, Solanaceae

Cohort 24. Personales (Corolla zygomorphic, ovules many)

Orders: 115, Scrophulariaceae; 116, Orobanchaceae; 117, Lentibulariaceae; 118, Columelliaceae; 119, Gesneriaceae; 120, Bignoniaceae; 121, Pedaliaceae; 122, Acanthaceae

Cohort 25. Lamiales (Corolla zygomorphic, ovules 4)

Orders: 123, Myoporineae; 124, Selagineae; 125, Verbenaceae; 126, Labiatae
Anomalous Order 127, Plantagineae

Sub Class 3. MONOCHLAMYDEAE (Perianth 1 two seriate, mostly sepaloid)

Series VII. Curvembryeae (Endosperm mealy, embryo curved, ovary one ovuled)

Orders: 128, Nyctagineae; 129, Illecebraceae; 130, Amaranthaceae; 131, Chenopodiaceae; 132, Phytolaccaceae; 133, Batideae; 134, Polygonaceae

Series VIII. Multiovulatae aquaticae (Many ovuled aquatic herbs)

Order: 135, Podostemaceae

Series IX. **Multiovulatae terrestris** (Many ovuled terrestrial herbs)

Orders: 136, Nepanthaceae; 137, Cytineae; 138, Aristolochiaceae

Series X. Micrembryeae (Carpel 1-2 ovuled, seed endospermic, ebryo minute)

Orders: 139, Piperaceae; 140, Chloranthaceae; 141, Myristiceae; 142, Monimiaceae

Series XI. **Daphnales** (Ovary usually monocarpellary, ovules 1-few, stamens perigynous, perianth usually sepaloid)

Orders: 143, Laurineae; 144, Proteaceae; 145, Thymeliaceae; 146, Penaeceae; 147, Elaeagnaceae

Series XII. **Achlamydosporea**e (Ovary 1 locular, 1-3 ovuled, seeds without testa)

Orders: 148, Loranthaceae; 149, Santalaceae; 150, Balanophoreae

Series XIII. Unisexuales (Flowers unisexual)

Orders: 151, Euphorbiaceae; 152, Balanopseae; 153, Urticaceae; 154, Platanaceae; 155, Leitnerieae; 156, Juglandeae; 157, Myricaceae; 158, Casuarinaceae; 159, Cupuliferae

Series XIV. **Anomalous families** (Ordines anomali)

Orders: 160, Salicineae; 161, Lacistemaceae; 162, Empeteraceae; 165, Ceratophylleae

CLASS II. : GYMNOSPERMAE

Orders: 164, Gnetales; 165, Coniferae; 166, Cycadaceae

CLASS III- MONOCOTYLEDONS (One cotyledon, endogenous growth)

Series XV. Microspermae (Inner perianth petaloid, ovary inferior, seeds minute)

Orders: 167, Hydrocharideae; 168, Murmanniaceae; 169, Orchidaceae;

Series XVI. Epigynae (Inner perianth petaloid, ovary inferior, endosperm plenty)

Orders: 170, Scitamineae; 171, Bromeliaceae; 172, Haemodoraceae; 173, Irideae; 174, Amaryllideae; 175, Taccaceae; 176, Dioscoreaceae

Series XVII. **Coronarieae** (Inner perianth petaloid, ovary free and superior)

Orders: 177, Roxburghiaceae; 178, Liliaceae; 179, Pontederiaceae; 180, Philydraceae; 181, Xyridaceae; 182, Mayaceae; 183, Commelinaceae; 184, Rapateaceae

Series XVIII. **Calycinae** (Inner perianth sepaloid, ovary free)

Orders: 185, Flagellariaceae; 186, Juncaceae; 187, Palmae

Series XIX. **Nudiflorae** (Perianth absent or represented by hairs or scales)

Orders: 188, Pandaneae; 189, Cyclanthaceae; 190, Typhaceae; 191, Aroideae; 194, Lemnaceae

Series XX. **Apocarpae** (Perianth in 1 or 2 whorls, or absent; ovary superior, apocarpous, no endosperm)

Orders: 193, Triurideae; 194, Alismaceae; 195, Najadaceae

Series XXI. **Glumaceae** (Flowers solitary, sessil in the axils of bracts and arranged in heads or spikelets with bracts; perianth of scales or none, ovary 1- locular, 1- ovuled)

Orders: 196, Eriocauleae; 197, Centrolepideae; 198, Restiaceae; 199, Cyperaceae; 200, Gramineae

Merits of Bentham and Hooker's System of Classification

1. It is a natural system of classification with immense practical utility. It is very popular in many countries and used for arrangement of plant species in Kew Herbarium, and in many countries including India.
2. The descriptions of the taxa are based on an actual study, thus making the system detailed, authentic and highly practical. The accuracy of Latin descriptions is unparalleled.
3. The larger genera are divided into subgenera with definite number of species which helps in easy identification of plants.
4. The keys for the identification of genera and families are precise and useful.
5. It includes geographical distribution of genera and species.
6. Dicots start with Ranales which is considered as most primitive amongst the angiosperms by many taxonomists.
7. The gymnosperms are placed as a separate independent group and not along with dicots as had been done by de Candolle.
8. The monocots are placed after dicots which are accepted by present day taxonomists.
9. The position of gamopetalae after polypetalae is accepted as fused petals are considered an advanced character over free petals.
10. The sequence adopted in the classification suggests an evolutionary pattern.

Demerits of Bentham and Hooker's System of Classification

1. The classification does not include any information about the origin of angiosperms even when it was published after Darwin's theory of evolution.

2. The position of gymnosperms between dicots and monocots is inappropriate according to the accepted evolutionary sequence.

3. The grouping of Monochlamydeae is artificial as it is based on single character and has separated some closely related families. For example:
(i) Chenopodiaceae, Illecebraceae (placed in Monochlamydeae) are related to Caryophyllaceae (placed in Polypetalae), and placed in same order by modern taxonomists.
(ii) Podestemaceae (belonging to Multiovulatae aquaticae, Monochlamydeae) is regarded closely related to Saxifragaceae or Crassulaceae of Rosales (placed in Polypetalae).
(iii) Lauraceae (belonging to Daphnales, Monochlamydeae) is considered related to Magnoliaceae of Ranales (belonging to Polypetalae).
(iv) Nepenthacaeae (belonging to Multiovulatae terrestris, Monochlamydeae) is related to Saracenniaceae (placed in Parietales, Polypetalae).
4. Advanced family like Orchidaceae with inferior ovary and zygomorphic flowers has been considered primitive by placing it in the beginning of Monocots.
5. The arrangement of Monocots is unnatural and unphylogenetic.
6. Compositae or Asteraceae has been placed in the beginning of Gamopetalae which is unnatural.
7. Families Liliaceae (placed in Coronarieae) and Amaryllidaceae (placed in Epigynae) are closely related but have been separated on the basis of ovary characteristics.
8. The position of Series Inferae with inferior ovary before the series Heteromerae and Bicarpellatae with superior ovaries is not accepted as the inferior ovary is derived from the superior ovary.

1.9.3 Hutchinson's system of Classification

John Hutchinson (1884-1972), a British botanist proposed a phylogenetic system in his two volume work *The Families of Flowering Plants* (1926, 1934), the 3rd edition of which was published in 1973. The final edition appeared in 1973 after several revisions. His classification was based on 24 principles that are similar to Bessey's dicta. He recognized 418 families of flowering plants belonging to 112 orders. Hutchinson's system is basically in the Bentham-Bessey tradition. He considered the angiosperm to be monophyletic possibly from an ancestral group of gymnosperms related to the Cycadeoids. He divided the angiosperms into two subphyla Dicotyledons and Monocotyledons. The Dicotyledons were divided into those considered fundamentally and predominantlly woody (Lignosae) and those considered fundamentally and predominantlly herbaceous (Herbaceae). The division Lignosae started with Magnoliales and ended with Verbenales while Herbaceae started with Ranales and ended with Lamiales. The apocarpous monocotyledons-Alismataceae and Butomaceae were considered to be the most primitive members of the group because of their close resemblance to Ranales. There are three lines of monocot evolution which are Calyciflorae, Corolliflorae and Glumiflorae.

Although Hutchinson's system has not been followed widely, it has provided a sound basis for the later phylogenetic systems by Oswald Tippo, Cronquist, Takhtajan and others. The arrangement of families within the Monocotyledons has been appreciated all over the world.

Hutchinson's Classification in his *Families of Flowering Plants*

HUTCHINSON'S SYSTEM OF CLASSIFICTION

Phylum - Angiospermae

Sub – Phylum -Dicotyledons

Division I - Lignosae

Order 1. **Magnoliales**

Families- 1.Magnoliaceae, 2. Illiciaceae, 3. Winteraceae, 4. Canellaceae, 5. Schisandraceae,

6. Himantandraceae, 7. Lactoridaceae, 8. Trochodendraceae, 9. Cercidiphyllaceace.

Order 2. **Annonales**

Families- 10. Annonaceae, 11. Eupomatiaceae.

Order 3. **Laurales**

Families- 12. Monimiaceae, 13. Austrobaileyaceae, 14. Trimeniaceae, 15. Lauraceae,

16.Gomortegaceae, 17. Hernandiaceae, 18. Myristicaceae.

Order 4. **Dilleniales**

Families- 19. Dilleniaceae, 20. Connaraceae, 21. Crossosomataceae. 22. Brunelliaceae.

Order 5. **Coriariales**

Family- 23. Coriariaceae.

Order 6. **Rosales**

Families-24. Rosaceae, 25. Dichapetalaceae, 26.Calycanthaceae.

Order 7. **Leguminales**

Families- 27. Caesalpiniaceae, 28. Mimosaceae, 29. Papilionaceae.

Order 8. **Cunoniales**

Families- 30. Pterostemonaceae, 31. Cunoniaceae, 32. Philadelphaceae, 33. Hydrangeaceae, 34. Grossulariaceae, 35. Oliniaceae, 36. Greyiaceae, 37. Escalloniaceae, 38. Baueraceae,

39. Crypteroniaceae.

Order 9. **Styracales**

Families- 40. Lissocarpaceae, 41. Styracaceae, 42. Symplocaceae.

Order 10. **Araliales**

Families- 43. Cornaceae, 44. Alangiaccae, 45. Garryaceae, 46. Nyssaceae, 47. Araliaceae, 48. Caprifoliaceae

Order 11. **Hamamelidales**

Families- 49. Tetracentraceae, 50. Hamamelidaceae, 51. Myrothamnaceae, 52. Platanaccae, 53. Stachyuraceae, 54. Buxaceae, 55. Daphniphyllaceac, 56. Bruniaceae.

Order 12. **Salicales**

Family- 57. Salicaceae.

Order 13. **Leitneriales**

Family- 58. Leitneriaceae

Order 14. **Myricales**

Family- 59. Myricaceae.

Order 15. **Balanopsidales**

Family- 60. Balanopsidaceae.

Order 16. **Fagales**

Families- 61. Betulaceae, 62. Fagaceae, 63. Corylaceae.

Order 17. **Juglandales**

Family- 64. Rhoiptelcaceae, 65. Juglandaceae, 66. Pictrodendraceae.

Order 18. **Casuarinales**

Family- 67. Casuarinaceae.

Order 19. **Urticales**

Families- 68. Ulmaceae, 69. Cannabiaceae, 70. Moraceae, 71. Urticaceae, 72. Barbeyaceae, 73. Eucommiaceae.

Order 20. **Bixales**

Families- 74. Bixaceae, 75. Cistaceae, 76. Flacourtiaceae, 77. Cochlospermaceae, 78. Hoplestigmataceae, 79. Achatocarpaceac, 80. Lacistemaceae.

Order 21. **Thymelacales**

Families- 81. Gonystylaceae, 82. Aquilariaceae, 83. Geissolomataceae, 84. Penaeaceae,

85. Thymelacaceae, 86. Nyctaginaccac.

Order 22. **Proteales**

Family-87. Proteaceae

Order 23. **Pittosporales**

Families-88. Pittosoporaceae, 89. Byblidaceae, 90. Stegnospermaceae, 91. Vivianiaceae.

92. Tremandraceae

Order 24. **Capparidales**

Families-93. Capparidaceae, 94. Moringaceae, 95. Tovariaceae.

Order 25.**Tamaricales**

Families - 96. Frankeniaceae, 97. Tamaricaceae, 98. Fouquieriaccac.

Order 26.**Violales**

Family- 99.Violaceae.

Order 27. **Polygalales**

Families- 100. Polygalaceae, 101. Krameriaceae, 102. Trigoniaceae, 103.Vochysiaceae.

Order 28. **Loasales**

Families- 104.Turncraceae, 105. Loasaceae.

Order 29. **Passiflorales**

Families-106. Malesherbiaceae, 107. Passifloraceae, 108. Achariaceae.

Order 30. **Cucurbitales**

Families- 109. Cucurbitaceae, 110. Begoniaceae, 111. Datiscaceae, 112. Caricaceae.

Order 31. **Cactales**

Family-113. Cactaceae.

Order 32.**Tiliales**

Families-114. Dirachmaceae, 115. Scytopetalaceae, 116.Tiliaceae, 117. Sterculiaceae, 118.

Peridiscaceae, 119. Bombacaceae.

Order 33. **Malvales**

Family-120. Malvaceae.

Order 34. **Malpighiales**

Families- 121. Ixonanthaceae, 122. Malpighiaceae. 123. Humiriaceae, 124. Linaceae, 125.

Irvingiaceae, 126. Huaceae, 127. Ledocarpaceae, 128. Erythroxylaccae, 129. Ctenolophonaceae, 130. Lepidobotryaceae, 131. Balanitaceae, 132. Zygophyllaceae.

Order 35. **Euphorbiales**

Family-133. Euphorbiaceae.

Order 36. **Theales**

Families- 134. Bonnetiaceae, 135. Theaceae, 136. Sauraniaceae, 137. Actinidiaceae, 138. Pellicieraceae, 139. Pentaphylacaceae, 140. Tetrameristaceae, 141. Marcgraviaceae, 142. Caryocaraceae, 143. Medusagynaceae.

Order 37. **Ochnales**

Families- 144. Strasburgeriaceae, 145. Ochnaceae, 146. Rhodolaenaceae,

147. Sphaerosepalaceae, 148. Dipterocarpaceae, 149. Ancistrocladaceae,

Order 38. **Ericales**

Families-150. Clethraceae, 151. Pyrolaceae, 152. Ericaceae, 153. Epacridaceae, 154. Diapensiaceae, 155. Monatropaceae, 156. Lennoaceae, 157. Vacciniaceae.

Order 39. **Guttiferales**

Families-158. Hypericaceae, 159. Clusiaceae; 160. Eucryphiaceae, 161. Quiinaceae.

Order 40. **Myrtales**

Families- 162. Myrtaceae, 163. Lecythidaceae, 164. Rhizophoraceae, 165. Sonneratiaceae, 166.

Punicaceae, 167. Combretaceae, 168. Melastomataceae.

Order 41. **Celastrales**

Families- 169. Pandaceae, 170. Aquifoliaceae, 171. Salvadoraceae, 172. Koeberliniaceae, 173.

Cneoraceae, 174. Cardiopteridaceae, 175. Cyrillaceae, 176. Icacinaceae, 177. Empetraceae, 178.

Aextoxicaceae, 179. Pentadiplandraceae, 180. Celastraceae, 181. Corynocarpaceae, 182. Stackhousiaceae, 183. Goupiaceae, 184. Hippocrateaceae, 185. Erythropalaceae, 186. Capusiaceae, 187. Scyphostegiaceae.

Order 42. **Olacales**

Family-188. Olacaceae, 189. Opiliaceae, 190. Octoknemaceae, 191. Aptandraceae, 192. Dipentodontaceae 193. Medusandraceae.

Order 43.**Santalales**

Families-194. Loranthaceae, 195. Grubbiaceae, 196. Santalaceae, 197. Myzodendraceae, 198. Balanophoraceae.

Order 44. **Rhamnales**

Families-199. Heteropyxidaceae, 200. Elaeagnaceae, 201. Rhamnaceae, 202.Vitaceae.

Order 45. **Myrsinales**

Families-203. Myrsinaceae, 204. Theophrastaceae, 203. Aegicerataceae.

Order 46. **Ebenales**

Families- 206. Ebenaceae, 207. Sapotaceae, 208. Sarcospermaceae.

Order 47. **Rutales**

Families- 209. Rutaceae, 210. Simaroubaceae, 211. Burseraceae, 212. Averhoaceae.

Order 48. **Meliales**

Family-213. Meliaceae.

Order 49. **Sapindales**

Families- 214. Melianthaceae, 215. Sapindaceae, 216. Podoaceae, 217. Sabiaceae, 218. Anacardiaceae, 219. Aceraceae, 220. Hippocastanaceae, 221. Staphyleaceae, 222. Akaniaceae, 223. Julianiaceae, 224. Didiereaceae.

Order 50. **Loganiales**

Families-225. Potaliaceae, 226. Loganiaceae, 227. Buddleiaceae, 228. Antoniaceae, 229. Spigeliaceae, 230. Strychnaceae, 231. Oleaceae.

Order 51. **Apocynales**

Families- 232. Plocospermaceae, 233. Apocynaceae, 234. Periplocaceae, 235. Asclepiadaceae.

Order 52. **Rubiales**

Families-236. Dialypetalanthaceae, 237. Rubiaceae.

Order 53. **Bignoniales**

Families- 238. Cobacaceae, 239. Bignoniaceae, 240. Pedaliaceae, 241. Martyniaceae.

Order 54.**Verbenales**

Families- 242. Ehretiaceae, 243.Verbenaceae, 244. Stillbeaceae, 245. Chloanthaceae, 246. Phrymaceae.

Subphylum Dicotyledones

Division II Herbaceae

Order 55. **Ranales**

Families-247. Paeoniaceae, 248. Helleboraceae, 249. Ranunculaceae, 250. Nymphaeaceae, 251.

Podophyllaceae, 252. Ceratophyllaceae, 253. Cabombaceae.

Order 56. **Berbcridales**

Families-254. Sargentodoxaceae, 255. Lardizabalaceae, 256. Menispermaceae, 257. Nandinaceae, 258. Circaeasteraceae, 259. Berberidaceae.

Order 57. **Aristolochiales**

Families-260. Aristolochiaceae, 261. Hydnoraccace, 262. Cytinaceac, 263. Nepenthaccac.

Order 58. **Piperales**

Families--264. Piperaceae, 265. Saururaceae, 266. Chloranthaceae.

Order 59. **Rhocadales**

Families-267. Papaveraceae, 268. Fumariaceae, Order 60. **Cruciales** (Brassicales).

Family- 269. Cruciferae (Brassicaceae).

Order 61. **Resedales**

Family- 270. Resedaceae

Order 62. **Caryophyllales**

Families- 271. Elatinaceae, 272. Molluginaceae, 273. Caryophyllaceae, 274. Ficoidaceae, 275. Portulacaceae.

Order 63. **Polygonales**

Families- 276. Polygonaceae, 277. Illecebraceae,

Order 64. **Chenopodiales.**

Families- 278. Barbeniaceac. 279. Phytolaccaceae, 280. Gyrostemonaceae, 281. Agdestidaceae,

282. Petiveriaccac, 283. Chenopodiaccac, 284. Amaranthaceae, 285. Cynocrambaceae, 286. Batidaceae, 287. Basellaceae.

Order 65. **Lythrales**

Families- 288. Lythraceae, 289. Onagraceae, 290. Trapaceae, 291. Haloragidaceae, 292. Callitrichaceae.

Order 66. **Gentianales**

Family- 293. Gentianaceae, 294. Menyanthaceae.

Order 67. **Primulales**

Families- 295. Primulaceae, 296. Plumbaginaceae.

Order 68. **Plantaginales**

Family- 297. Plantaginaceae.

Order 69. **Saxifragales**

Families-298. Crassulaceae, 299. Cephalotaceae, 300. Saxifragaceae, 301. Eremosynaceae, 302. Vahliaceae, 303. Francoaceae, 304. Donatiaceae, 305. Parnassiaceae, 306. Adoxaceae,

Order 70. **Sarraceniales**

Families-307. Droseraceae, 308. Sarraceniaceae.

Order 71. **Podostemales**

Families-309. Podostemaceae, 310. Hydrostachyaceae.

Order 72. **Umbellales**

Family-311. Umbelliferae (Apiaceae).

Order 73.**Valerianales**

Families- 312. Valerianaceae, 313. Dipsacaceae, 314. Calyceraceae.

Order 74. **Campanales**

Families-315. Campanulaceae, 316. Lobeliaceae,

Order 75. **Goodeniales**

Families-317. Goodeniaceae, 318. Brunoniaceae, 319. Stylidiaceae.

Order 76. **Asterales**

Family-320. Compositae (Asteraceae).

Order 77. **Solanales**

Families- 321. Solanaceae, 322. Convolvulaceae, 323. Nolanaceae.

Order 78. **Personales**

Families- 324. Scrophulariaceae, 325. Acanthaceae, 326. Gesneriaceae, 327. Orobanchaceae,

328. Lentibulariaceae, 329. Columelliaceae.

Order 79. **Geraniales**

Families-330. Geraniaceae, 331. Limnanthaceae, 332. Oxalidaceae, 333. Trapaeolaceae, 324. Balsaminaceae.

Order 80. **Polemoniales**

Families-335. Polemoniaceae, 336. Hydrophyllaceae, 337. Cuscutaceae.

Order 81. **Boraginales**

Family-338. Boraginaceae.

Order 82. **Lamiales**

Families-339. Myoporaceae, 340. Selaginaceae, 341. Globuriaceae, 342. Labiatae (Lamiaceae).

Subphylum - Monocotyledones

Division 1 - Calyciferae

Order 83. **Butomales**

Families- 343. Butomaceae, 344. Hydrocharitaceae.

Order 84. **Alismatales**

Family- 345. Alismataceae, 346. Scheuchzeriaceae, 347. Petrosaviaceae.

Order 85.**Triuridales**

Family- 348.Triuridaceae.

Order 86. **Juncaginales**

Families- 349. Juncaginaceae, 350. Lilaeaceae (Heterostylaceae), 351. Posidoniaceae.

Order 87. **Aponogetonales**

Families- 352. Aponogetonaceae, 353. Zosteraceae.

Order 88. **Potamogetonales**

Families- 354. Potamogetonaceae, 355. Ruppiaceae.

Order 89. **Najadales**

Families- 356. Zannichelliaceae, 357. Najadaceae.

Order 90. **Commelinales**

Families- 358. Commelinaceae, 359. Cartonemataceae, 360. Flagellariaceae, 361. Mayacaceae.

Order 91. **Xyridales**

Families- 362. Xyridaceae, 363. Rapatcaceae

Order 92. **Eriocaulales**

Family- 364. Eriocaulaceae.

Order 93. **Bromeliales**

Family- 365. Bromeliaceae,

Order 94. **Zingiberales**

Families- 366. Musaceae, 367. Sterlitziaceae, 368. Lowiaceae, 369. Zingiberaceae, 370. Cannaceae, 371. Marantaceae.

Division II - Corolliferae

Order 95. **Liliales**

Families- 372. Liliaceae, 373. Tecophilaceae, 374.Triliaceae, 375. Pontederiaceae, 376. Smilacaceae, 377. Ruscaceae.

Order 96. **Alstroemeriales**

Families- 378. Alstroemeriaceae, 379. Petermanniaceae, 380. Philesiaccae.

Order 97. **Arales**

Families- 381. Araceae, 382. Lemnaceae.

Order 98.**Typhales**

Family- 383. Sparganiaceae, 384. Typhaceae.

Order 99. **Amaryllidales**

Families- 385. Amaryllidaceae.

Order 100. **Iridales**

Family- 386. Iridaceae.

Order 101. **Dioscoreales**

Families- 387. Stenomeridaceae, 388. Trichopodaceae, 389. Roxburghiaceae, 390. Dioscoreaceae.

Order 102. **Agavales**

Family-391. Xanthorrhoeaceae, 392. Agavaceae.

Order 103. **Palmales**

Family- 393. Palmae (Palmaceae, Arecaceae).

Order 104. **Pandanales**

Family- 394. Pandanaceae.

Order 105. **Cyclanthales**

Family- 395. Cyclanthaceae.

Order 106. **Haemodorales**

Families- 396. Haemodoraceae, 397. Hypoxidaceae, 398. Velloziaceae, 399. Apostasiaceae,

400. Taccaceae, 401. Philydraceae.

Order 107. **Burmanniales**

Families- 402. Burmanniaccae, 403. Thismiaceae, 404. Corsiaceae.

Order 108. **Orchidales**

Family- 405. Orchidaceae.

Division III -Glumiflorae

Order 109. **Juncales**

Families- 406. Juncaceae, 407. Thurniaceae, 408. Centrolepidaceae, 409. Restionaceae.

Order 110. **Cyperales**

Family-410. Cyperaceae.

Order 111. **Graminales**

Family-411. Gramineae (Poaceae)

Merits and Demerits of Hutchinson's System.

Merits:

1. Most taxonomists are of opinion that this system has given a much better idea of phylogenetic conception and has stimulated phyletic rethinking to a greater extent.

2. Primitive or basic orders are Magnoliales representing arborescent families and Ranales representing herbaceous families, giving rise to woody and herbaceous forms respectively on parallel lines.

3. Bisexual and polypetalous flowers precede unisexual and gamopetalous flowers.

4. Amentiferae (catkin-bearingfamilies with unisexual, apetalous flowers), e.g., Fagaceae-oak, Betulaceae-birch, Juglandaceae walnut, Salicaceae-willow and poplar, etc., is regarded as advanced (and not primitive as consideredby Engler) and thus transferred (including Urticales) to

a new phyletic position close to Rosales and Leguminales; their apparent simplicity represents reduction and specialization (and not primitiveness).

5. Casuarinaceae has been assigned an advanced position and placed at the top of the Amentiferae.

6. Several big orders have been split up into distinct small families, thus simplifying matters, e.g., Rosales, Perietales, Malvales etc.

7. Many families have been raised to the rank of orders e.g., Leguminosae to Leguminales, Saxifragaceae to Saxifragales, Podostemaceae to Podostemales etc.

8. Reshuffling of several orders and families, e.g. Cactales (Opuntiales of Engler) placed close to Cucurbitales and Passiflorales.

9. Origin of monocotyledons from dicotyledons at an early stage of evolution, the point of origin being the Ranales.

10. Splitting up of Helobiae (of Engler) into separate orders and considering the order Butomales (Butomaceae and Hydrocharitaceae) as the starting point of monocotyledons.

11. Reshuffling of genera of Liliaceae and Amaryllidaceae on the basis of inflorescence characters.

12. Rearrangement of several orders, finally ending in Cyperales and Graminales.

Demerits:

1. Many taxonomists do not agree with his rigid bifurcation of dicotyledons into Lignosae (woody plants) and Herbaceae (herbaceous types).

2. Many taxonomists hold different views regarding the relationship between various orders and families.

3. Monophyletic view regarding the origin of angiosperms is not universally accepted.

4. Monophyletic origin of Monocotyledons from the Ranales, as against the polyphyletic (diphyletic) views of Lotsty (1911) and Hallier (1912).

5. Urticales, Umbellales, Euphorbiales etc., as originating from different ancestors.

1.9.4 Cronquist's Classification

Arthur Cronquist was the senior Curator of New York Botanic Garden and adjunct professor of Columbia University. He presented an elaborate interpretation of his concept of classification in "The Evolution and Classification of Flowering Plants" (1968). The further edition of his classification was published in "An Integrated System of Classification of Flowering Plants" (1981).

The latest revision was published in the 2nd edition in 1988 in "The Evolution and Classification of Flowering Plants". He discussed a wide range of characteristics important to phylogenetic system. He also provided synoptic keys designed to bring the taxa in an appropriate alignment.

He also represented his classification in charts to show the relationships of the orders within the various subclasses. His system is more or less parallel to Takhtajan's system, but differs in details.

Class Magnoliopsida (dicotyledons)

1. **Subclass Magnoliidae (mostly basal dicots)**
    1. Order Magnoliales
    2. Order Laurales
    3. Order Piperales
    4. Order Aristolochiales
    5. Order Illiciales
    6. Order Nymphaeales
    7. Order Ranunculales
    8. Order Papaverales
2. **Subclass Hamamelidae**
    1. Order Trochodendrales
    2. Order Hamamelidales
    3. Order Daphniphyllales
    4. Order Didymelales
    5. Order Eucommiales
    6. Order Urticales
    7. Order Leitneriales
    8. Order Juglandales
    9. Order Fagales
    10. Order Myricales
    11. Order Casuarinales
3. **Subclass Caryophyllidae**
    1. Order Caryophyllales
    2. Order Polygonales
    3. Order Plumbaginales
4. **Subclass Dilleniidae**
    1. Order Dilleniales
    2. Order Theales
    3. Order Malvales
    4. Order Lecythidales
    5. Order Nepenthales
    6. Order Violales
    7. Order Salicales
    8. Order Capparales
    9. Order Batales
    10. Order Ericales
    11. Order Diapensiales
    12. Order Ebenales
    13. Order Primulales
5. **Subclass Rosidae**
6. **Subclass Asteridae**

1. Order Rosales
2. Order Fabales
3. Order Proteales
4. Order Podostemales
5. Order Haloragales
6. Order Myrtales
7. Order Rhizophorales
8. Order Cornales
9. Order Santalales
10. Order Rafflesiales
11. Order Celastrales
12. Order Euphorbiales
13. Order Rhamnales
14. Order Linales
15. Order Polygalales
16. Order Sapindales
17. Order Geraniales
18. Order Apiales

1. Order Gentianales
2. Order Solanales
3. Order Lamiales
4. Order Callitrichales
5. Order Plantaginales
6. Order Scrophulariales
7. Order Campanulales
8. Order Rubiales
9. Order Dipsacales
10. Order Calycerales
11. Order Asterales

Class Liliopsida (monocotyledons)

1. **Subclass Alismatidae**
    1. Order Alismatales
    2. Order Hydrocharitales
    3. Order Najadales
    4. Order Triuridales
2. **Subclass Arecidae**
    1. Order Arecales
    2. Order Cyclanthales
    3. Order Pandanales
    4. Order Arales
3. **Subclass Commelinidae**
    1. Order Commelinales
    2. Order Eriocaulales
    3. Order Restionales
    4. Order Juncales
    5. Order Cyperales
    6. Order Hydatellales
    7. Order Typhales
4. **Subclass Zingiberidae**
    1. Order Bromeliales
    2. Order Zingiberales
5. **Subclass Liliidae**
    1. Order Liliales
    2. Order Orchidales

1.10 SUMMARY

1. Taxonomy is an oldest science among almost all sciences which developed with civilization of human that includes identification, nomenclature and classification.
2. Taxonomy with relation to plants is called plant taxonomy which emphasises on identification and naming of plants.
3. The objectives of plant taxonomy are to gather knowledge on plants of earth and their systematic grouping.
4. Identification involves the determination of taxon (Plural taxa) as being similar or identically equal to a known taxon.
5. Classification is the arrangement of plants in taxonomic groups (division, class, order, family, genus, and species) according to their observed similarities.
6. Present day taxonomy is based on the primary importance of morphological distinctness and affinity but is influenced appreciably by the findings of the cytologists, geneticists, anatomists etc.
7. Swingle has proposed 36 principles in evolutionary taxonomy which have been uniformly accepted by the plant taxonomists.
8. Charles E. Bessey (1915) evolved a system based on a series of statements of guiding principles called **dicta**, he used these in determining the degree of primitiveness or evolutionary advancement of a plant group.
9. For nomenclatural reasons two works of Carl Linnaeus (1707–1778) are regarded as the starting points of modern taxonomy: the ***Species Plantarum*** (1753) and ***Systema Naturae*** (1758).
10. Classification is the arrangement of a plant or group of plants in orderly ways in distinct categories following a system of nomenclature, and in accordance with a particular and well established plan.
11. Depending upon their objectives, classification may be artificial, natural, or phylogenetic (phyletic), which includes phenetic and cladistic.
12. Linnaeus system of classification is though artificial, he was the first to recognize the significance of flower and fruit structure.
13. Linnaeus recognized 24 classes determined on the basis of the number, size and union of stamens.
14. George Bentham (1800-1884) and Joseph Dalton Hooker (1817-1911), the two British botanists who were associated with the Royal Botanic Gardens, Kew, England, jointly published a monumental work ***Genera Plantarum*** (1862-1883) in 3 Vols.
15. Bentham and Hooker divided seed plants into three classes (Dicotyledons, Gymnosperms and Monocotyledons), three sub-classes, 21 series, 25 cohorts and 202 orders (initially 200 orders).

16. It is a natural system of classification with immense practical utility. It is very popular in many countries and used for arrangement of plant species in Kew Herbarium, and in many countries including India.
17. The position of gymnosperms between dicots and monocots is inappropriate according to the accepted evolutionary sequence.
18. John Hutchinson (1884-1972), a British botanist proposed a phylogenetic system in his two volume work ***The Families of Flowering Plants*** (1926, 1934).
19. Hutchinson recognised 418 families of flowering plants belonging to 112 orders.
20. Arthur Cronquist was the Senior Curator of New York Botanic Garden, presented an elaborate interpretation of his concept of classification in ***"The Evolution and Classification of Flowering Plants"*** (1968).

1.11 GLOSSARY

Actinomorphy: Being radially symmetrical and capable of division by any longitudinal plane into essentially symmetrical halves.

Angiosperm: Plant group that comprises those that have flowers and produce seeds enclosed within a vessel (carpel).

Carpel: The female reproductive organ of a flower, consisting of an ovary, a stigma, and usually a style, may occur singly or in group.

Dicta: Guiding principles.

Dioecious: Having the male and female reproductive organs in separate individuals.

Epigyny: A floral arrangement in which the ovary is completely enclosed by the receptacle so that the stamens and perianth arise above it, from the top of the receptacle.

Evolution: Descent with modifications.

Gymnosperm: A plant group that comprises those that have seeds unprotected by an ovary or fruit, *i.e.* conifers, cycads, *etc.*

Hypogyny: A floral arrangement in which the ovary is superior, *i.e.* it arises from the receptacle above the sepals, petals, and stamens.

Monoecious: Having both the male and female reproductive organs in the same individual.

Monophyletic: A group that includes an ancestral species and all of its descendants.

Natural classification: Classification based on the natural characters.

Perianth: Collective term for the outer part of a flower, consisting of the calyx (sepals) and corolla (petals).

Perigyny: Having sepals, petals, and stamens around the edge of a cuplike receptacle containing the ovary, as in flowers of the rose or cherry.

Phanerogams/ Spermatophytes: A plant division that comprises those that bear seeds, including the gymnosperms and angiosperms.

Phylogenetic classification: Classification based on the evolutionary relationships between the entities to be classified.

Polypetalous: Having separate petals, as in the corolla of a rose or carnation.

Priority: A principle in the ICBN stating that the earliest validly published name is the proper name assigned to a species.

Taxon: A systematic group of plants in a hierarchical system.

Taxonomy: Arrangement according to rules.

Type/Nomenclatural type: That element to which the name of a taxon is permanently attached, whether as a correct name or as a synonym.

Variety: A variety is a rank in the taxonomic hierarchy below the rank of species and subspecies and above the rank of form.

Zygomorphy: Bilaterally symmetrical; that can be divided in two identical halves by a single plane passing through the axis.

1.12 SELF ASSESSMENT QUESTIONS

1.12.1 Multiple Choice Questions:

1. Father of modern taxonomy is called:

(a) Huchinson (b) Linnaeus

(c) De Candolle (d) Hooker

2. Bentam and Hooker's Sysytem of classification is:

(a) Natural (b) Artificial

(c) Phylogenetic (d) Sexual

3. Binomial system of nomenclature was given by:

(a) Huchinson (b) Linnaeus

(c) De Candole (d) Darwin

4. Author(s) of *Genera Plantarum*:

(a) Benthum and Hooker (b) Linnaeus

(c) De Candolle (d) Huchinson

5. *Genera Plantarum* was written in ……. volumes:

(a) 3 (b) 4

(c) 2 (d) 7

6. Hutchinson's system of classification is:

(a) Natural (b) Phylogenetic

(c) Artificial (d) Sexual

7. The starting family in Bentham and Hooker's sytem of classification:

(a) Ranunnculaceae (b) Poaceae

(c) Magnoliaceae (d) Liliaceae

8. According to Bentham and Hooker the most advance family is:

(a) Ranunnculaceae (b) Poaceae

(c) Magnoliaceae (d) Liliaceae

9. Linnaeus divided plants in …….. classes:

(a) 24 (b) 3

(c) 34 (d) 36

10. *The Families of Flowering Plants* was written by:

(a) Benthum and Hooker (b) Linnaeus

(c) Cronquist (d) Huchinson

11. Swingle has proposed …… principles in evolutionary taxonomy:

(a) 36 (b) 24

(c) 27 (d) 15

12. The last class of Linnaeus system of classification:

(a) Polydelphia (b) Didynamia

(c) Icosandria (d) Cryptogamia

13. *De Historia Plantarum* was compiled by:

(a) Theophrastus (b) Linnaeus

(c) Cronquist (d) Hutchinson

14. Term "New Systematics" was coined by:

(a) Huxley (b) Darwin

(c) Bessey (d) Candolle

15. Bentham and Hooker divided plants in their classification into:

(a) 202 orders (b) 205 orders

(c) 186 orders (d) 206 orders

1.12.2 Fill in the blanks:

(1) The term taxonomy was coined by _______________.

(2) There are a total __________orders in Benthum and Hooker's system of classification.

(3) Author of *The Historia Platarum* was__________.

(4) Bentham and Hooker classified phanerogams primarily in _________ divisions.
(5) The starting family is ________________in Bentham and Hooker system of classification.
(6) John Hutchinson recognised _______________families of flowering plants.
(7) *The Evolution and Classification of Flowering Plants* (1968) was published by___________.
(8) Linnaeus divided all plants in __________ Classes.
(9) A systematic group of plants in a hierarchical system is called_____________.
(10) _______________condition is, being radially symmetrical and capable of division by any longitudinal plane into essentially symmetrical halves.

1.12.3 True or False

(1) Bentham and Hooker's system of classification is natural one.
(2) Linnaeus proposed 24 classes of plants in his classification.
(3) Linnaeus's system of classification is phylogenetic.
(4) The last class of Linnaeus is Cryptogamia.
(5) Linnaeus's system of classification is also called sexual sysystem of classification.
(6) *Genera Plantarum* is compiled by Linnauus.
(7) Bentham and Hooker divided phanerogams in 3 groups.
(8) Cronquist proposed phylogenetic system of classification.
(9) *The Families of Flowering Plants* book was written by John Hutchinson.
(10) Gamopetally is advanced than polypetalae.

1.12.4 Very short answer questions:

(1) What is outline of Bentham and Hooker's system of classification?
(2) Give the different phases of taxonomy.
(3) What is binomial system of classification?
(4) Why Htchinson System of classification called phylogenetic?
(5) What is taxonomy?

1.12.1 Answer key: 1-(b), 2-(a), 3-(b), 4-(a), 5-(a), 6-(b), 7-(a), 8-(b), 9-(a), 10-(d), 11-(a), 12-(d), 13-(a), 14-(a), 15-(a).

1.12.2 Answer key: 1- De Candolle, 2-202, 3- Theophrastus, 4- three, 5- Rannunculacaeae, 6- 418, 7- Cronquist, 8- twenty four, 9- Classification, 10- Actinomorphic.

1.12.3 Answer key: 1- True, 2- True, 3-False, 4- True, 5-True, 6-False, 7-True, 8-True, 9-True, 10-True.

1.13 SUGGESTED READINGS

- Bhattacharya, B. 2005. *Systematic Botany*. Narosa Publishing House, New Delhi.

- Davis, P.H. and V.H. Heywood. 1973. *Principles of Angiosperm Taxonomy*. Kreiger, New York.
- Jeffrey, C. 1982. *An Introduction to Plant Taxonomy*. University Press, Cambridge.
- Judd, W.S., C.S. Campbell, E.A. Kellogg and P.F. Stevens. 1999. *Plant Systematics: A Phylogenetic Approach*. Sinaeur Associate, Inc., Sunderland, MA, USA.
- Lawrence, G.H.M. 1951. *Taxonomy of Vascular Plants*. Macmillan, New York.
- Naik, V.N. 1984. *Taxonomy of Angiosperms*. Tata McGraw-Hill, New Delhi.
- Stace, C.A. 1989. *Plant Taxonomy and Biosystematics*. Edward Arnold, London.
- Stuessy, T.F. 1990. *Plant Taxonomy*. Columbia Univ. Press, New York.

1.14 REFERENCES

- Bentham, G.and Hooker, J.D. 1862-1883. *Genera plantarum ad exemplaria imprimis in herbariis kewensibus servata definite*. (3 vols.). London.
- Camp, W.H. and Gilly, C.L.1943. The structure and origin of species. *Brittonia* 4: 323-385.
- Charles E. Bessey. (1915). The phylogenetic taxonomy of flowering plants. *Annals of the Missouri Botanical Garden.* Missouri Botanical Garden Press. **2** (1/2): 109–164.
- Cronquist, A. 1988. *The evolution and classification of flowering plants.* New York Botanical Garden.
- Hutchinson, J. 1973. *The Families of Flowering Plants* (3rd ed). Oxford.
- Huxley, J. 1940. *The New Systematics.* Oxford
- Lam H.J. 1959. Taxonomy: General principles and Angiosperms. In W.B. Turrill (ed.) *Vistas in Botany*. 4: 3-75. Pergamon Press, London.
- Thorne, R.F. 1958. Some guiding principles of angiosperm phylogeny. *Brittonia*. 10: 72–77.
- Turrill, W. B. 1938. The expansion of taxonomy with special reference to spermatophyta. Biological Reviews.13: 342-373.
- Turrill, W.B. 1964. Plant Taxonomy, Phytogeography and Ecology. In W.B. Turrill (ed.) *Vistas in Botany*. 4: 187-224. Pergamon Press, London.

1.15 TERMINAL QUESTIONS

1.15.1 Short Answer Questions:

(1) Briefly explain about systems of classification.

(2) Describe about phylogenetic classification.

(3) Give an account of contribution of Linnaeus in field of taxonomy.

(4) Explain about practical system of classification.

(5) Differentiate between phylogenetic and natural system of classification.

(6) What is Taxon?

(7) Why Bentham and Hooker’s sysytem of classification is called natural one?

(8) What is classification?

(9) What do you understand by New Systematics?

(10) Why Linnaeus's classification called sexual system of classification?

1.15.2 Long Answer Questions:

(1) Give a broad ouline of Bentham and Hooker's system of Classification.

(2) Describe merits and demerits of Bentham and Hooker's system of classification.

(3) Give a broad ouline of Hutchinson's system of classification.

(4) Describe history of plant classification.

(5) What is phylogenetic system of classification and describe any phylogenetic system of classification studied by you.

UNIT-2 PHYTOGEOGRAPHICAL REGIONS OF INDIA, ENDEMISM, HOTSPOTS

2.1 OBJECTIVES

After reading this unit students will be able to-

- Understand the concept of phytogeography.
- Know the phytogeographical regions of India.
- Learn the vegetation types found in different phytogeographical regions of India.
- Understand the concept of Endemism and Hotspots.
- Know the major hotspots of world.
- Understand the biodiversity hotspots of India.

2.2 INTRODUCTION

Phytogeography also called geobotany, is the branch of biogeography that is concerned with the geographic distribution pattern of plant species or more generally plants on earth. Phytogeography is a branch of science which deals with spatial relationship of plants both in the present and in the past and their influence on the earth's surface. The basic data elements of phytogeography are occurrence records (presence or absence of a species) with operational geographic units such as political units or geographical coordinates. Phytogeography is concerned with all aspects of plant distribution, from the controls on the distribution of individual species ranges at both large and small scales, to the factors that govern the composition of entire communities and floras. The aim of phytogegraphy is to record the plant species and if possible, to explain the distribution of plants in the region. This data is often used to construct phytogeographic provinces or floristic provinces and elements. In contrast zoogeography is concerned with animal distribution rather than plant distribution. The term phytogeography itself suggests a broad meaning. Phytogeography section includes phytogeography, distribution of genetic variation, historical biogeography and general plant species distribution patterns. Biodiversity patterns are not heavily covered. The study of nativity, distribution, adaptation, association of plants is some of the important aspects in the comprehensive field of plant geography. The phytochoria or bio-geographical regions, the biomes and the flora provinces indicate the different types of plant association in different perspective. As the climatic condition and the edaphic factors are the chief criteria for plant migration, the study on phytogeography of the region understudy may throw some light on the present day ecological condition of the region.

The questions and approaches in phytogeography are largely shared with zoogeography, except zoogeography is concerned with animal distribution rather than plant distribution. How the term is actually applied by practicing scientists is apparent from periodicals using the term. Biodiversity patterns are not heavily covered.

Several attempts have been made from time to time for a suitable classification of the phytogeographical regions of the world, out of these the classification of Schouw (1923) and

Good (1964) are important. Schouw (1923) divided the entire world into 25 kingdoms. Kingdoms were again subdivided into provinces which were named after the characteristic plants of respective provinces. On the basis of the floristic pattern, Good (1964) divided the world into 6 kingdoms. The kingdoms were sub-divided into subkingdoms, regions and ultimately into provinces.

There are two major divisions of Phytogeography: (i) **Descriptive (or Static Phytogeography)** and (ii) **Interpretive (or Dynamic Phytogeography)**. **Descriptive Phytogeography** deals with the actual description of floristic or vegetational groups found in different parts of the world. Early plant geographers described floras and attempted to divide earth into floristic and botanical zones. **Interpretive** deals with the dynamics of migration and evolution of plants and floras. It explains the reasons for varied distribution of plant species in different parts of the world. It is a borderline science involving synthesis and integration of data and concepts from several specialized disciplines like ecology, physiology, genetics, taxonomy, evolution, palaeontology and geology.

Good (1931), Mason (1936) and Cain (1944) have pointed out the factors involved in the distribution of plants. The distribution of plants is primarily controlled by climatic conditions. There has been variation in climate during geological history in the past which affected migration of plants. On the basis of area of the earth surface occupied by the plants, the various taxa are categorized as under: 1. **Wides, 2. Endemics and 3. Discontinuous species**. Plants widely distributed over the earth in definite climatic zones and the different continents are referred to as wides. A taxon whose distribution is confined to a given area is said to be endemic to that area. When plants occur at two or more distant places of the world which are separated by overlands or oceans hundreds or thousands of kilometres apart such a distribution is called discontinuous or disjunct distribution.

Gross patterns of the distribution of plants became apparent early in the study of plant geography. Biologists have sought to explain the uneven distribution of organisms across the globe for over two centuries, a field of enquiry called biogeography. It is still a vital research area in a time when we need to be able to predict how organisms will react to anthropogenic environmental change. However, because of the complex interplay of contemporary ecology, earth history, organismal extinction and evolution, universal biogeographic explanations are still elusive. Phytogeography has a long history. One of the subject’s earliest proponents was Prussian naturalist Alexander von Humboldt, who is often referred to as the "father of phytogeography". Von Humboldt advocated a quantitative approach to phytogeography that has characterized modern plant geography.

According to Campbell (1926), the main theme of plant geography is to discover the similarities and diversities in the plants and floras of the present and past found in widely separated parts of the earth.

Wulff (1943) states that phytogeography is the study of distribution of plant species in their habitats and elucidation of origin and history of development of floras.

According to Croizat (1952), Phytogeography is the study of migration and evolution of plants in time and space.

2.3 PHYTOGEOGRAPHICAL REGIONS OF INDIA

Vegetation of any place is modified by the environmental factors; climate, geology and biotic factors. The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation.

India has been divided into the following botanical zones by D. Chatterjee (1962):

(1) Western Himalaya
(2) Eastern Himalaya
(3) Indus plain
(4) Gangetic plain
(5) Central India
(6) Deccan
(7) Western coasts of Malabar
(8) Assam and
(9) Bay Islands of Andaman and Nicobar.

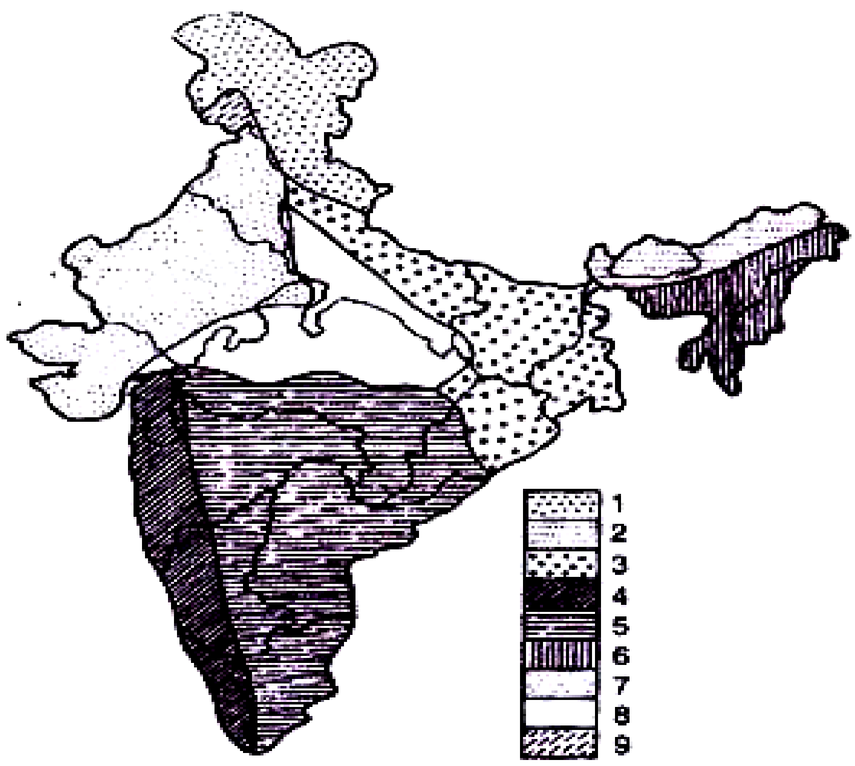

Fig. 2.1: Botanical Zones of India

1. Western Himalaya

The northern part of India is bounded by highest ranges of Himalaya. Himalaya is store house of plant wealth and comprises enormous plant diversity and thus forms important botanical regions of the world. Thus on the basis of physiography and vegetation, Indian Himalayan Region (IHR) can be divided in two major contrasting regions: Western Himalaya and Eastern Himalaya. The Western Himalaya region extends from Jammu and Kashmir to Uttarakhand. The vegetation of the area ranges from truly tropical near the low altitudes to temperate arctic types at the high altitudes. Western Himalayan Region (WHR) again phytogeographically can be divided into western, central and eastern phyto zones.

Western Himalaya consists of Kashmir, a part of Punjab, Himachal Pradesh, Garhwal and Kumaon region of Uttarakhand. This zone is wet in outer southern ranges and dries in inner northern zone and forms cold desert. The average rainfall in Western Himalayan zone ranges from 100 to 200 cm annually. The Western Himalayan range is much wider and colder characterised by less precipitation, dry and arid climatic conditions in contrast with eastern counterpart. Snowfall occurs in this region during winter season. The Western Himalayan range represents drought resistant and cold tolerant vegetation. There are dominant forests of conifers like pine, deodar, fir, spruce and junipers.

The region may be divided into three subzones altitudinally:

(i) **Submontane zone** or lower region or tropical and subtropical belt ranges up to ca. 1500m asl. (meters above sea level).

(ii) **Temperate zone** ranges from 1500 m to 3000 m asl, and

(iii) **Alpine zone** ranges above 3000 m asl and up to the snowline characterized by permanent snow capped region.

(i) Submontane zone

The submontane or lower region or tropical and subtropical belt includes outer Himalayas, particularly region of Siwaliks and adjoining areas where annual average rainfall is over 100 cm. This zone ranges between 300 and 1500 metres above sea level (m asl). In this zone, forests dominated by timber trees of *Shorea robusta* are common. Other important tree species are *Bombax malabaricum, Butea monosperma* and *Acacia catechu* etc.

In the swampy areas, *Dalbergia sisso* (Shisham), *Ficus glomerata* and *Syzygium cumini* are of common occurrence. In west dry regions sal trees are replaced by xeric plants particularly *Zizyphus, Carissa, Acacia,* and thorny Euphorbias. At higher elevation, around 1000 to 1500 metre altitude, pine (Chir) forests are also found at certain places. The common species of pine is *Pinus roxburghii*. Ground vegetation is scanty.

(ii) Temperate zone

It commonly ranges at the altitudes from 1500 to 3000 m asl. Oaks (*Quercus* spp.) are dominant along with *Populus, Rhododendron, Betula and Pyrus. Pinus excelsa, Cedrus deodara, Picea, Abies, Cupressus* and *Taxus baccata* subsp. *wallichiana* are found in the heavy rainfall region (between 1600 and 1800 m). Herbs are also common in this region. Common herbs are

Ranunculus sceleratus, *Polygonum*, *Pedicularis*, *Potentilla argyrophylla*, *Primula, Delphinium, Clematis*, crucifers and many members of family Asteraceae.

In cultivated drylands of Punjab, wheat and barley are main crops. In Kashmir, *Betula* (birch), *Salix* (willow), *Populus* (poplar) are of common occurrence. Besides these, *Quercus semecarpifolia, Q. dilatata, Aesculus indica* (chestnut) and many conifers are commonly met within this region. In west Kashmir, rice cultivation is common. Sar or saffron (*Crocus sativus*), apples, peaches, walnut, almonds and other fruits are important economic plants of Kashmir region.

(iii) Alpine zone

Above the altitude of 3000 m asl and up to snowline (about 5000 m asl) is alpine zone. The vegetation consists of evergreen conifers and some low and broad leaved trees. The vegetation of this region is characterized by cushion habit, dwarf nature and gregarious habit. In lower alpine region, shrubby forests are common which may be (a) Birch-fir forests which are fairly dense and is mixed with evergreen shrubby *Rhododendron* at higher level and (b) Birch-*Rhododendron* forests in which *Abies, Betula, Rhododendron* and *Juniperus* are common. In the upper alpine region, prominent herbaceous plants are the species of *Primula, Polygonum, Gentiana, Cassiope, Meconopsis, Saxifraga, Potentilla, Geranium, Aster, Astragalus,* etc. which form alpine meadows. At about 5000 metre altitude and above snow perpetuates round the year and plant growth is almost zero. This altitude is called snow line or ice line.

Populations of *Draba, Braya, Cortia, Leontopodium* go on increasing with the increase in altitude. Species *of Ephedra, Juniperus, Berberis* are also found scattered. *Poa, Stipa* and *Fectuca* are common grasses of alpine zone.

2. Eastern Himalaya

Eastern Himalaya extends from Sikkim to upper Assam, Darjeeling and NEFA (North-East Frontier Agency now Arunachal Pradesh). Vegetation of this region differs from that of Western Himalaya. In contrast to Western Himalaya, Eastern Himalaya is dominated by broad leaf evergreen and semi-deciduous forests, and is reservoir of vast diversity. The chief differences are due to changed environmental factors as heavy monsoon rainfall, less snowfall and high temperature and humid condition. Eastern Himalayan vegetation is considered to be one of the richest vegetation units in the world and consists of several species of plants which are native of foreign countries, such as, China, Japan, Myanmar, Malaya and European countries.

This region is also divided into three altitudinal zones likewise western Himalaya:

(i) **Tropical or sub-montane zone,** ranges up to ca. 1800m asl.

(ii) **Temperate or Montane zone**, ranges between 1800 and 4000 m asl.

(iii) **Alpine zone,** ranges above 4000 m asl and up to the snowline.

Main types of vegetation at different altitudes in the Western and Eastern Himalaya are:

(i) **Tropical or Submontane Zone:**

The tropical subzone characterized by warm and humid conditions extends from plain up to the altitude of about 1800 m asl. In this zone mostly saal forests, and mixed deciduous forests consisting of important plants, such as *Anthocephalus cadamba* (Kadamb) *Sterculia* (Udala), *Terminalia* spp. (Harad, Baheda, etc.) and *Bauhinia* are common. In the savannah forests, common plants are *Albizia procera, Bischofia, Bombax, Dendrocalamus*. Evergreen forests of *Dillenia indica, Michelia champaca, Echinocarpus, Cinnamon,* etc. are common.

(ii) **Temperate or Montane Zone:**

Temperate or Montane Zone may be further divided into two zones *viz.* upper and lower zones, lower temperate zone ranges between 1800 and 3000 m. asl. The lower temperate zone dominated by Oaks (*Quercus*), *Cedrela, Echinocarpus, Eugenia, Michelia, Pyrus* are common plants and upper temperate zone (3000-4000 m asl) dominated by conifers and *Rhododendrons.* Important conifers of this region are *Picea, Abies, Larix, Juniperus, Tsuga,* etc.

(iii) **Alpine Zone**:

Alpine Zone of Eastern Himalaya is characterized by humid and extremely cold climatic conditions. Complete absence of trees and predominance of shrubs and meadows is characteristic feature of this zone. Shrubs of *Rhododendron* and *Juniperus* are commonly found in this zone.

3. Indus Plains

Indus Plains includes part of Punjab, Rajasthan, a part of Gujarat, Delhi. Some part of this plain is now in Pakistan. This region usually receives less than 70 cm annual precipitation, but in certain regions it is as low as 10-15 cms only. The climatic conditions of this region are characterised by dry hot summer, and dry cold winter. The soil of a wide area except cultivated land is saline. Much of the land has become desert due to excessive dryness.

It includes sandy areas of Rajasthan and Punjab mainly. The land is not irrigated. Vegetation of this region is mainly xerophytic in the form of bushy, spiny and thorny plants e.g. *Argemone, Tephrosia, Acacia, Prosopis, Salvadora, Butea, Opuntia, Agave, Calotropis, Tamarix, Suaeda, Salsola, Solanun surattense, Tribulus, Capparis, Boerhaavia, Echinops,* etc. *Salsola phoetida* and Lunakh grass are found commonly in saline soils. *Saccharum munja, Cenchrus ciliaris, Prosopis spicigera, Acacia leucophloea, A. senegal* are grown for afforestation purpose in this region.

4. Gangetic Plains

Gangetic Plains are one of the richest and fertile vegetational zones in India. This zone extends from Delhi to Sundarbans of Bengal passing through Bihar, Orissa and Uttar Pradesh. The annual rainfall in this zone ranges from 50 cm to 150 cm. Vegetation of this region is characterized by dry deciduous (Scrub), moist deciduous vegetation and swampy mangroves in sunderbans. Sometimes the Indus region and Gangetic region, because of similar type of vegetation, is called as Indo-Gangetic plain. The Gangetic plain is divided into upper Gangetic plain, Lower Gangetic plain and Sundarbans. A large part of the land of this region is known for cultivation due to its fertility. The common cultivated crop plants of this zone are varieties of wheat (*Triticum* spp.), barley (*Hordeum*), maize (*Zea mays*), jowar (*Sorghum*), bajra (*Pennisetum glaucum*), urad (*Vigna mungo*), moong (*Vigna radiata*), arhar (*Cajanus cajan*), til (*Sesamum indicum*), sugarcane (*Saccharum officinarum*), pea (*Pisum* sp.), gram (*Cicer arietinum*), potato (*Solanum tuberosum*), sarson (*Brassica*), rice (*Oryza sativ*a) etc.

In western part of Uttar Pradesh annual rainfall ranges from 50 cm to 110 cm. Dry deciduous and shrubby vegetation is common feature of this part. *Acacia, Arabica, Capparis, Saccharum munja,* etc. are common plants. In foothills, common plants are *Dalbergia sisso, Tectona grandis, Acacia arabica, Holoptelea integrifolia* and *Ficus* spp., etc.

In eastern gangetic plain, cold and wet conditions prevail and annual rainfall is about 150 cm in West Bengal area. Commonly evergreen and deciduous forests are found in this region. The vegetation is dominated by *Shorea robusta* (Saal), *Artocarpus, Lagerstroemia, Ptersopermum, Bombax, Ehertia, Aegle marmelos* (Bel), *Holoptelea, Areca, Borassus, Pogostemon, Adhatoda, Murraya koenigii*, etc. Other common trees are *Terminalia tomentosa, T. bellirica, Acacia* sp., *Bauhinia, Diospyros, Eugenia* sp., *Madhuca indica* (Mahua), *Cordia* (Lasora), *Tamarindus* (Imli), *Mangifera indica* (Mango), *Ficus* spp. etc.

Mangrove vegetation is common in tidal regions in West Bengal near Sunder-ban, and Orissa (now Odisha). The largest mangrove forest of the world is of Sunderbans covering an area of over 15,000 sq. km. The area has sea creepers and swampy islands. *Rhizophora mucronata, R. conjugata, Sonneratia, Ceriops roxburghiana, Acanthus ilicifolius, Kandelia rheedii* and *Bruguiera gymnorhiza* are common mangrove plants in those regions. The main vegetation includes *Typha elephantina* (elephant grass), *Pharagmites karka* (reed), *Pandanus, Ipomoea, Bruguiera, Kandelia, Heritiera, Ceriops, Aviecnnia officinalis, Aegiceras, Sonneratia, Nipa fruiticons, Phoenix paludosa, Cocos nucifera, Acanthus illicifolius, Panicum repens, Salicornia, Allophylus, Tamarix, Hygrophila, Derris* etc.

5. Central India

Central India extends from hilly part of Madhya Pradesh, part of Orissa/Odisha, Gujarat and Vindhya. This part represents hilly topography and some places are at the altitudes of 500-1050 m asl. The average annual rainfall ranges between 100-170 cm. Pachmarhi, a hill station widely known as Satpura ki Rani ("Queen of Satpura") is situated at a height of 1067 m in a valley of the Satpura Range in Hoshangabad district. The UNESCO has designated it a biosphere reserve in 2009 including Bori Sanctuary and Satpura National Park. This region is commonly dominated by teak (*Tectona grandis*) and sal (*Shorea robusta*) forests of great economic value, thus biotic disturbances are very common in this botanical province. Other associated trees are *Terminalia, Bauhinia, Mangifera, Phyllanthus, Ficus, etc.* common with shrubs like *Mimosa, Desmodium, Acacia sp., Zizyphus, Pyrus, Berberis, Rubus,* etc. Thorny vegetation is commonly found in open areas.

The forests of central India may be divided into:

(i) Sal forests
(ii) Mixed deciduous forests, and
(iii) Thorny forests

6. Deccan

Deccan phytogeographic region comprises whole of the southern peninsular India including Satpura, southern part of Godawari River and east of Malabar. The Deccan highlands constitute the principal catchment for a number of south India's main river system (Narmada, Tapti, Mahanadi, Godawari). Average annual rainfall in this region is about 100 cm. it is the home of the deciduous forests, thorny and degraded shrub lands. Evergreen forest occurs in small areas. Teak (*Tectona grandis*) and saal (*Shorea robusta*), the precious timber yielding species occur in northern half of the zone along with other associated trees. The southern region is generally drier and dominated by thorny forests with *Acacia, Albizia, Hardwickia* associations. The commonly found shrubs in this region are *Zizyphus, Bauhinia, Woodfordia, Capparis, Lagerstroemia,* etc. This region may be divided into the following two subdivisions:
(i) **Deccan plateau**
(ii) **Coromandel coast**

Deccan is characterized by presence of "black cotton soil". Common plants of this soil are *Hibiscus*, *Cassia, Acacia arabica, Parkinsonia, Calotropis, Zizyphus, Jatropha grandiflora,* etc. In Deccan plateau teak forests containing *Diospyros* (Tendu), *Acacia, Prosopis. Santalum* (chandan/sandalwood tree) and *Cedrela toona* are common. *Capparis, Euphorbia, Phyllanthus* are common lithophytes. *Tectona*, *Pterocarpus, Borassus, Phoenix sylvestris* are also common in this area. In Chhota Nagpur plateau, important species are *Clematis, Berberis, Thalictrum* and Orchids with common ferns.

In Coromandel coast vegetation consists largely of some halophytic species. The vegetation of this subregion is same as in Deccan except some estuarial and mangrove plants such as *Brugiera, Ceriops, Avicinnia,* etc. Other plants are *Mimusops, Garciia, Chloroxylon swietenia, Strychnos nux-vomica* (Kuchala) *etc*.

7. Western Coast of Malabar

This is small botanical province covering Cape Comorin to Gujarat and Western Ghats. Area of Malabar includes Kerala, Maharashtra, Gujarat and Karnataka. Hill areas of Western Ghats are also included in this zone which forms a biodiversity **hotspot in India**. This region receives heavy precipitation thus harbors enormous plant diversity and varied woods.
In this zone, four types of forests are common:
(i) **Tropical forests** (occur at 700 m asl).
(ii) **Mixed deciduous forests** (found up to 1600 m asl).
(iii) **Temperate evergreen forests** (occur above 1200 m asl), and
(iv) **Mangrove vegetation.**

The area includes Mysore plateau, western side of Western Ghats, Coorg and Annamalai hills, etc. Evergreen dense vegetation is dominated by *Dillenia pentagyna, Terminalia bellirica, Artocarpus peltata, Cinnamomum zeylanicum, Dipterocarpus, Areca, Calamus, Croton, Ixora,* etc. In tropical evergreen forests the trees are tall and have root buttresses.

In the mixed deciduous forests, wet and dry types of vegetation are found. Wet type is common in Cochin, west coast of Karnataka and Travencore, where rainfall is more. Dominant vegetation is of *Tectona grandis, Grewia tiliaefolia, Butea monosperma, Dalbergia latifolia, Mitragyna parviflora, Bombax malabaricum, Adina cordifolia, Xylia xylocarpa, Anogeissus latifolia, Santalum album, Erythrina variegata, Lantana, Clerodendrum, Woodfordia, Kydia calycina, Bambusa arundinacea, Terminalia tomntosa, Gardinia latifolia,* etc. On the Nilgiri hills sub-tropic and temperate conditions exist. Important plants of Nilgiri vegetation are *Rubus, Rhododendron, Berberis, Thalictrum, Ranunculus, Fragaria, Potentilla*, etc.

The temperate forest area includes Nilgri hills, Palni, Annamalai and Tirunevelly hills etc. The vegetation shows red tinged leaves of the trees, e.g., *Meliosma wightii, Michelia nilagirica, Rhododendron nilagiricum, Gardenia obtusa, Toddalia, Clematis, Impatiens, Arisaema, Cymbopogon, etc.* In Malabar, plants belonging to family Dipterocarpaceae, Anacardiaceae, Meliaceae, Myrtaceae, Piperaceae, Orchidaceae and many ferns are common.

The west coast of Malabar region receives very high rainfall. In the coastal region mangrove plants grow luxuriantly. The Mangrove vegetation is found in Elora, Elephanta, Bombay suburbs, Mudh Island, Arabian sea shore, etc. the common plants are *Rhizophora, Bruguiera parviflora, Ceriops tagal, Kandelia candel, Xylocarpus grantum, Acanthus illicifolius, Sonneratia, etc.*

8. Assam

This phytogeographical zone is very rich in plant wealth and covers valley of of Brahmputra, Jaintia, Khasi and Garo hills, Mishmi hills, part of Himalayas, Santosh River, Naga, Cachar and Mizo hills, Mizoram, Meghalaya, Nagaland, Manipur, Tripura and Assam region. This is the region which receives maximum annual precipitation in India. Cherapunji is one of the rainiest places in the world where annual rainfall often exceeds 1000 cm. Excessive wetness and high temperature are factors responsible for the development of dense forests and luxuriance of pteridophytic flora in this zone. Evergreen broad leaved tall vegetation of angiosperms and some conifers are very common in this zone.

Common plants occurring in this region are Ficus, *Artocarpus, Michelia, Sterculia, Morus* species. Besides these bamboos canes, climbers, and green bushes are also common. Prominent plants in the northern forests of this zone are *Alnus*, *Betula. Rhododendron, Magnolia*, *Michelia* and *Prunus*. Saal (*Shorea robusta*) also occurs in Garo hills. Orchids and fern species are very rich in this zone. *Nepenthes khasiana* is an endangered and endemic tropical insectivorous pitcher plant of the genus *Nepenthes* found in this region. It is the only *Nepenthes* species native to India. This species has a very localised distribution and is rare in the wild and isolated populations are known to occur in the Jarain area of the Jaintia Hills, the Baghmara area of the Garo Hills, adjacent to the Khasi Hills region of Meghalaya.

9. Bay Islands of Andaman and Nicobar

This zone represented by two different groups of islands (i) the Andaman and Nicobar islands in the east, located in Bay of Bengal, thinly populated and dominated by tropical rainforests and (ii) Lakshadweep islands in the west located in Arabian sea. The Andaman and Nicobar islands are a group of 348 islands, which support many characteristic plants and animals. Biogeographically Andaman has affinity with Myanmar and islands are separated by shallow waters from the Myanmar- India coasts. The vegetation ranges from tropical evergreen to moist deciduous and mangrove. The Lakshadweep group of islands comprises 36 major Islands, which together from an area of 32 sq km. Beautiful coral reefs are also present in this part of India. This zone is also one of the hotspots of India. Some 2200 species of higher plants are found in the Island which makes the 10% species of India growing in only 8000 sq. km with over 200 as strict endemics. About 1300 species are restricted to the area but found in Myanmar, Malaysia, Indonesia and Polynesia.

These bay islands represent elevated portions of submarine mountains. Climate is humid in the coastal region. In Andaman, beech forests, evergreen forests, semi-evergreen forests deciduous forests and mangrove vegetation are of common occurrence. *Rhizophora, Mimusops, Calophyllum, etc.* are common plants in mangrove vegetation. In the interior evergreen forests tall trees are common. *Dipterocarpus* is most characteristic of the most evergreen forest. Important species of trees are *Calophyllum, Dipterocarpus, Lagerstroermia and Terminalia, etc.* Some part is also under cultivation. The important crops are paddy and sugarcane.

2.4 ENDEMISM

Every natural taxon has its own natural place of origin from where it migrated to other places, this place is known as native place regarding to that taxon and if taxa are found outside their native places by anthropogenic and other activities, then they are referred as an introduced species. The distribution of plants is primarily controlled by climatic conditions. There has been variation in climate during geological history in the past which affected migration of plants. On the basis of area of the earth surface occupied by the plants, the various taxa are categorized as under: 1. **Wides,** 2**. Endemics** and 3. **Discontinuous species**. Endemism is the ecological state of a species, which is only found in a defined region, location or habitat type and nowhere else in the world. Species are endemic to an area if they occur within it and nowhere else. According to Samant *et al.,* (1998) nativity is original place of a species and endemism is the restricted distribution of a species in a particular biogeographic province or a single Island or mountain top or even in a single rock outcrop. A native species is not necessarily endemic and may occur in areas other than the one under consideration. From ecological point of view, endemic means exclusively native to the biota of a specific place. The high nativity and endemism of particular biogeographic province denotes the high conservation value of that area. These two attributes help in tracing the evolution and play an important role in assessing the conservation value of any habitat and ecosystem. Endemics are highly sensitive species and can easily become endangered or extinct if their distribution is disturbed.

The term 'endemism' was coined by A.P. de Candolle (1855) for the distribution of an organism in a limited geographical area. According to Engler (1882) there are two kinds of endemisms, one based on the preservation of ancient forms, which may have originated in entirely different regions and the other based on the development of new, entirely autochthonous forms. Based on the theory of age and area, Willis (1922) quantified the youthful endemics with his J-shaped or "hollow" (hyperbolic) curves. Cain (1944) put forth the following three dicta on endemics: a) Endemism includes two types of plants that are confined to single regions-endemics, *sensu stricto,* which are relatively youthful species, and epibiotics which are relatively old relict species, b) Youthful endemics may or may not have attained their complete areas by having migrated to their natural barriers. Epibiotics may, but frequently do not contain the biotype richness that will allow or has allowed them an expansion of area, following their historical contraction of area and c) A high degree of endemism is usually correlated with age and isolation of an area, and with the diversification of its habitats, as these factors influence both evolution and survival. Stebbins and Major (1965) modified Cain's observations and divided in two major subcategories of endemics (i) Neo-endemic or newly evolved or youthful species and (ii) Palaeoendemic or relict species. Paleo-endemism refers to species that were widespread in past or remote past but now restricted to a smaller area or habitat. Neo-endemics are those species that have recently arisen through divergence and reproductive isolation, or through hybridization and alteration in ploidy level. Depending on pattern of confinement of taxa, endemism is defined in several ways. According to Krukeberg and Rabinowitz (1985) the confined occurrences of a taxon in a few localities with one or few populations referred to as narrow endemics; and species with specialized habitats distributed in small geographic locations without clear endemicity, referred to as microarealophytes by Dickore and Nusser (2000).

However, it is difficult to explain the origin of endemic species on the basis of ecology, past history and genetics only. As stated earlier, high degree of endemism is usually correlated with age and isolation of an area and with the diversification of its habitats as these factors influence both evolution (formation of new endemics) and survival or production of relic endemics. Endemics with more than one disjunctive population are most likely relict while endemics confined to a single population can be either paleao- or neo-endemics. The floristic account of particular geographic area could be a key source for determining status of nativity and endemism, but insufficient and illusive field records and taxonomic biases impart major problems. Wherry (1944) classified endemic plants into Primary and Secondary endemics. The latter has been further classified into: a) environmentally repressed, b) genetically repressed and c) senescent, based on the reasons for their restricted distribution. According to Stebbins and Major (1965) some species might have lost aggressiveness because, the changing environment restricts them only to a specialised niche.

Moreover, the genetic knowledge lends support to the idea that a small population could have lost its genetic variability (Stebbins, 1942) leading to genetically suppressed endemics. Stebbins (1965) observed that the mode of origin of relicts and newly formed had remained mostly unclarified. He also noted that the use of cytological data might determine the direction and relative ages of origin of taxa. Favarger and Contandriopoulos (1961) proposed a classification of endemics based on cytological data. They are 1) Paleoendemics, which are isolated systematically, old, with little variation and not necessarily having arisen in their area of present survival. 2) Schizo endemics, produced by gradual speciation having a common origin and identical chromosome numbers. 3) Patroendemics, which are narrow diploids and have given rise to widely distributed polyploids and 4) Apoendemics, which are narrow polyploids arisen from widely distributed diploids. They also discussed the historical and phytogeographical significance of the various kinds of endemics they have differentiated. However, Drury (1974; 1980) argued that neither genetics, ecology nor history alone would suffice to explain the origin of endemic taxa. Richardson (1978) concluded that the nature of plant distribution varied with time and all species start as neoendemics and end as paleoendemics. Between these events some species will loose their endemic status and occupy larger areas and some remain as endemics. He called this intermediate form of endemics as Holoendemics.

2.5 HOTSPOTS

A biodiversity hotspot is an area which harbors maximum biodiversity with unusual concentration of species, many of which are endemic. It is marked by serious threat to its diversity by humans. Biodiversity hotspots are a method to identify those regions of the world where attention is needed to address biodiversity loss and to guide investments in conservation. The concept biodiversity hotspot was developed by British biologist Norman Myers in 1988 who coined the term "biodiversity hotspot" for a biogeographic region characterized both by exceptional levels of plant endemism and serious habitat loss, which he then expanded to a more global scope. Conservation International (CI) adopted Myers' hotspots as its institutional blueprint in 1989, and in 1999, the organization undertook an extensive global review which introduced quantitative thresholds for the designation of biodiversity hotspots.

According to Conservation International (CI), to qualify as a hotspot a region must meet two strict criteria: (i) **Endemism:** it must contain at least 1,500 species of vascular plants (> 0.5 % of the world's total) as endemics, and (ii) **Loss of Habitat:** it has to have lost at least 70 % of its original habitat.

Currently, 35 biodiversity hotspots have been so far identified, most of which occur in tropical belt of globe. They represent just 2.3-2.5% of Earth's land surface, but between them they contain around 50% of the world's endemic plant species and 42% of all terrestrial vertebrates. Five Overall, Hotspots have lost around 86% of their original habitat and additionally are considered to be significantly threatened by extinctions induced by climate change.

World's 35 Biodiversity Hotspots:

I. Africa

1. Cape Floristic Region
2. Coastal Forests of Eastern Africa
3. Eastern Afromontane
4. Guinean Forests of West Africa
5. Horn of Africa
6. Madagascar and the Indian Ocean Islands
7. Maputaland-Pondoland-Albany
8. Succulent Karoo

II. Asia-Pacific

9. East Melanesian Islands
10. Himalaya
11. Indo-Burma
12. Japan
13. Mountains of Southwest China
14. New Caledonia
15. New Zealand
16. Philippines
17. Polynesia-Micronesia
18. Southwest Australia
19. Forests of Eastern Australia (new)
20. Sundaland
21. Wallacea
22. Western Ghats and Sri Lanka

III. Europe and Central Asia

23. Caucasus
24. Irano-Anatolian
25. Mediterranean Basin
26. Mountains of Central Asia

IV. North and Central America

27. California Floristic Province
28. Caribbean Islands
29. Madrean Pine-Oak Woodlands
30. Mesoamerica

V. South America

31. Atlantic Forest
32. Cerrado
33. Chilean Winter Rainfall-Valdivian Forests
34. Tumbes-Choco-Magdalena
35. Tropical Andes (Most recent)

The biodiversity importance of hotspots is due to the high vulnerability of habitats and high irreplaceability of species found within large geographic regions. This means that these areas and the species present within them are both under high levels of threat and of significant global value based on their uniqueness. Therefore, operations that occur within global biodiversity hotspots should follow rigorous biodiversity assessments to prevent further biodiversity loss within these areas. This is a global scale approach based on coarse scale eco-regions that therefore, has limited use for site-scale assessment and decision making. Biodiversity hotspots will include areas of high biodiversity importance as well as degraded land and urban areas and therefore more detailed assessments are needed to locate the actual distribution of biodiversity within these areas.

Hotspots are areas which offer essential ecosystem services. It is estimated that biodiversity hotspots, despite comprising 2.3% of the Earth's surface, account for 35% of the global ecosystem services. Furthermore, hotspots are home to 2.08 billion people which play a significant role to the ecosystem services. Biodiversity hotspots can include a variety of human land-uses, rural and urban, as well as protected areas under a range of possible governance types therefore many social and/or cultural values are likely to be present in some parts. This however is irrespective of the identification of the area as a biodiversity hotspot.

New biodiversity hotspots are periodically added based on scientific assessments of new regions. For example, the Forests of East Australia are the latest hotspot to have been added after research showed that the area fulfilled all criteria of Conservation International (CI). Changing circumstances such as sustained habitat degradation, fragmentation or the discovery of new species may mean that areas previously not considered biodiversity hotspots could qualify in a future reassessment.

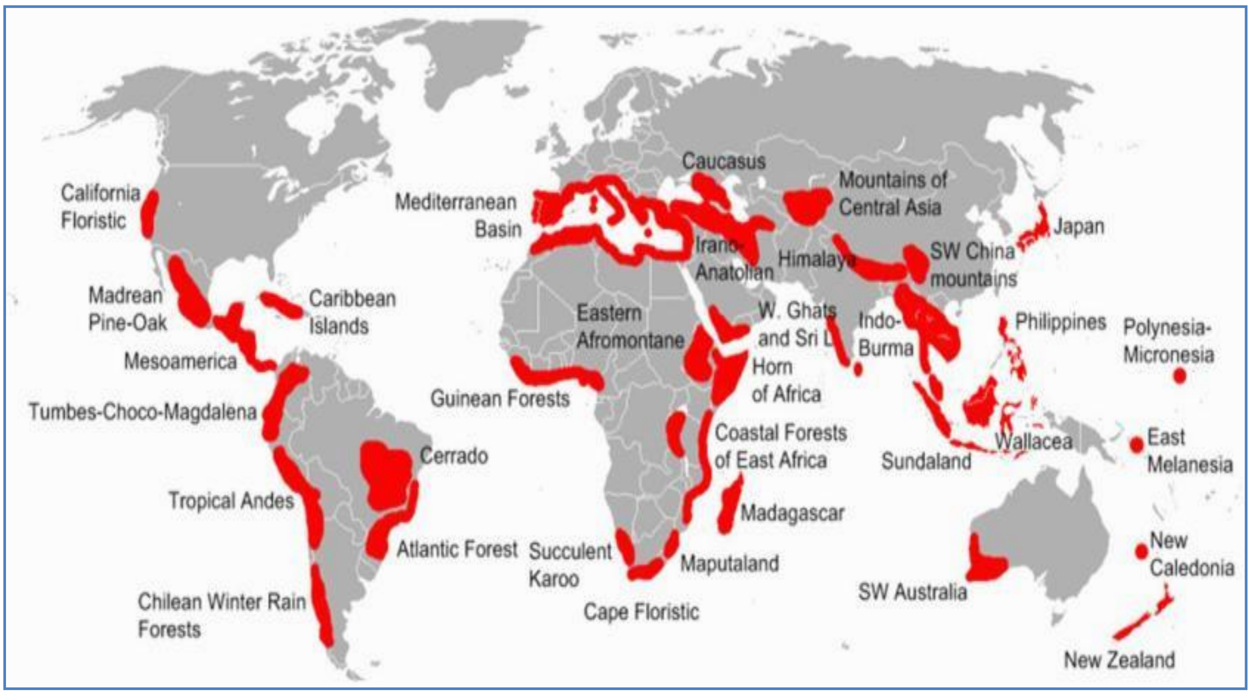

Fig. 2.2: Biodiversity Hotspots on map (Courtesy: Conservation International)

Biodiversity hotspots in India

India covers 2.4% of the world's total geographical area, and harbors over 8% of the total global biodiversity, making it one of the 12 mega-diversity countries in the world. This status is based on the species richness and levels of endemism recorded in a wide range of taxa of both plants and animals. The enormous diversity of India is due to variety of landforms and climatic conditions, resulting in diverse habitats ranging from tropical to temperate and from alpine to desert. Adding to this is a very high diversity of human-influenced ecosystems, including agricultural and pasture lands, and a diversity of domesticated plants and animals, one of the world's largest. India is also considered one of the world's eight centres of origin of cultivated plants indicated by Nikolai Vavilov. Being a predominantly agricultural country, India also has a mixture of wild and cultivated habitats, giving rise to very much specialised biodiversity, which is specific to the confluence of two or more habitats.

India shares its territories into four biodiversity hotspots *viz*:

1. Himalaya: Includes the entire Indian Himalayan region (and that falling in Pakistan, Tibet, Nepal, Bhutan, China and Myanmar).

2. Indo-Burma: Includes entire North-Eastern India, except Assam and Andaman group of Islands (and Myanmar, Thailand, Vietnam, Laos, Cambodia and southern China).

3. Sundalands: Includes Nicobar group of Islands (and Indonesia, Malaysia, Singapore, Brunei, Philippines).

4. Western Ghats and Sri Lanka: Includes entire Western Ghats (and Sri Lanka).

Out of them, **Eastern Himalaya and Western Ghats** are mostly located within Indian Territory. In the Sundalands and Indo-Burma Biodiversity hotspots, India shares only a small part in Andaman Nicobar region and North East India.

Biodiversity Hotspots also work as **funding regions** for Conservation International for its **Critical Ecosystem Partnership Fund (CEPF).** The Northeastern India is included in a separate CEPF funding region (Eastern Himalayas Biodiversity Hotspot), while Bangladesh and Malaysia only extend marginally into the Indo-Burma hotspot. For this purpose, officially, the Indo-Burma Hotspot is defined as all non-marine parts of Cambodia, Laos PDR, Myanmar, Thailand, Vietnam plus some parts of southern China. This is the reason that India has only two biodiversity hotspots *viz*. **Eastern Himalayas and Western Ghats.**

The floristic richness has rendered the North-East region and Western Ghats to be recognized as two hot spots among 35 hotspots identified throughout the world. In addition to these two, there are about 40 other sites in different biogeographic zones of India which have high degree of endemism and genetic diversity. These are as follows:

1) Andaman group of islands

2) Nicobar group of islands

3) Agasthyamalai Hills

4) Anamalai and High Ranges (Cardamon Hills)

5) Palni and Highway Mountains

6) Nilgiris, Silent Valley – Wyanaad – Kodagu

7) Shimoga - Kanara

8) Mahabaleshwar – Khandala Ranges

9) Konkan – Raigad

10) Marathwada – Satpura Ranges

11) Tirupati – Cuddappa – Nallamalai Hills

12) Vizagapatnam – Ganjam – Jeypore Hills

13) Southern Deccan (Leeward side)

14) Chotanagar Plateau

15) Kathiawar – Kutch

16) Rajasthan – Aravalli

17) Khasia – Jainitia Hills

18) Patoki – Manipur – Lushai Hills

19) Assam

20) Arunachal Pradesh Himalaya

21) Sikkim Himalaya

22) Garhwal – Kumaon Himalaya

23) Lahul – Himachal Pradesh Himalaya

24) Kashmir – Ladakh Himalaya

25) Nepal (interface of E. Himalaya and W. Himalaya)

26) Eastern Himalaya

27) Khasi - Jaintia – Lushai

28) Central India

29) Eastern Ghats

30) Southern Eastern Western Ghats

31) Northern Western Ghats

32) Western Himalayas

33) Sandstone Flora of Dun and Mussorie

34) Myristica Swamps of Kerala

35) Sea grasses of Coromandel Coast

36) Mangroves of Sunderbans

37) Mangroves and coral reefs of Andamans

38) Wetland of Chilka Lake

39) Cold Desert of Ladakh

40) Lakshadeep coral reef and algal flora.

2.6 SUMMARY

1. Phytogeography, also called geobotany, is the branch of biogeography that is concerned with the geographic distribution pattern of plant species or more generally plants on earth.
2. Phytogeography is concerned with all aspects of plant distribution, from the controls on the distribution of individual species ranges at both large and small scales, to the factors that govern the composition of entire communities and floras.
3. The aim of phytogegraphy is to record the plant species and if possible, to explain the distribution of plants in the region.
4. Phytogeography section includes phylogeography, distribution of genetic variation and, historical biogeography, and general plant species distribution patterns.
5. The phytochoria or bio-geographical regions, the biomes and the flora provinces indicate the different types of plant association in different perspectives.
6. There are two major divisions of Phytogeography: (i) Descriptive (or Static Phytogeography) and (ii) Interpretive (or Dynamic Phytogeography).
7. Gross patterns of the distribution of plants became apparent early on in the study of plant geography.
8. One of the subject's earliest proponents was Prussian naturalist Alexander von Humboldt, who is often referred to as the "father of phytogeography".
9. According to Campbell (1926), the main theme of plant geography is to discover the similarities and diversities in the plants and floras of the present and past found in widely separated parts of the earth.
10. Wulff (1943) states that Phytogeography is the study of distribution of plant species in their habitats and elucidation of origin and history of development of floras.
11. According to Croizat (1952), Phytogeography is the study of migration and evolution of plants in time and space
12. Vegetation of any place is modified by the environmental factors; climate, geology and biotic factors. The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation.
13. India has been divided into the following botanical zones by D. Chatterjee (1962): (1) Western Himalaya, (2) Eastern Himalaya, (3) Indus plain, (4) Gangetic plain, (5) Central India, (6) Deccan, (7) Western coasts of Malabar, (8) Assam, and (9) Bay Islands of Andaman and Nicobar.
14. Every natural taxon has its own natural place of origin from where it migrated to other places, this place is known as native place regarding to that taxon and if taxa are found

outside their native places by anthropogenic and other activities then they are referred as introduced species.

15. The term 'endemism' was coined by A.P. de Candolle (1855) for the distribution of an organism in a limited geographical area.
16. According to Engler (1882) there are two kinds of endemisms, one based on the preservation of ancient forms, which may have originated in entirely different regions and the other based on the development of new, entirely autochthonous forms.
17. It is difficult to explain the origin of endemic species on the basis of ecology, past history and genetics only.
18. A biodiversity hotspot is an area which harbors maximum biodiversity with unusual concentration of species, many of which are endemic.
19. Currently, 35 biodiversity hotspots have been so far identified, most of which occur in tropical belt of globe.
20. India covers 2.4% of the world's total geographical area, and harbors over 8% of the total global biodiversity, making it one of the 12 mega-diversity countries in the world.
21. Biodiversity Hotspots also work as funding regions for Conservation International for its Critical Ecosystem Partnership Fund (CEPF).

2.7 GLOSSARY

Autochthonous: (auto = self, + chthon, = earth.) Originated in that part of the body where found indigenous or endemic to a region

Biodiversity: Variety and varieability among organism of a particular geographic region.

Biogeography: Study of the distribution of species and ecosystems in geographic space and through geological time.

Buttresses: Extended roots of trees that extend above ground as a platelike outgrowth of the trunk supporting the tree, mainly found in trees of tropical rain forests

Coral reefs: A ridge of rock in the sea formed by the growth and deposit of corals.

Deciduous forest: A type of forest characterized by trees that seasonally shed their leaves.

Endangered: Seriously at risk of extinction.

Endemic/ Endemism: Confined distribution of taxa in particular geographic region.

Evolution: Descent with modifications/ the way by which living things (Taxa) change and develop over lapse of time.

Flora: The plant list of a particular region, habitat, or geological period.

Hotspot: A biogeographic region that is both a significant reservoir of biodiversity with endemism and is threatened with destruction.

Luxuriance: Vegetation with rich and profuse in growth; lush.

m asl: Abbreviation of meter above sea level.

Mangrove: A tree or shrub which grows in tidal, chiefly tropical, coastal swamps, having numerous tangled roots that grow above ground and form dense thickets.
Niche: A comfortable or suitable position in life of organisms.
Phytogeography: Branch of biogeography that is concerned with the geographic distribution of plant species and their influence on the earth's surface.
Plateau: An area of fairly level high ground.
Precipitation: Rain, snow, sleet, or hail that falls to or condenses on the ground.
Relict: Taxon survived from an earlier period or in a primitive form.
Sholas: Patches of stunted tropical montane forest found in valleys amid rolling grassland in the higher montane regions of South India.
Taxon: A systematic group of plants in a hierarchical system.
Tropical: The region on either side of the equator.
Vegetation: Plants considered collectively, especially those found in a particular area or habitat.
Xerophytes: Plant that is adapted to an arid environment.

2.8 SELF ASESSMENT QUESTIONS

2.8.1 Multiple choice questions (MCQs):

1. The term 'endemism' was coined by:
(a) De Candolle (b) Norman Mayer
(c) Linnaeus (d) J. D. Hooker

2. Father of phytogeography:
(a) Norman Mayer (b) De Candolle
(c) Alexander von Humboldt (d) N. Vavilow

3. India is divided in ….. Phytogeographical regions by Chatterji:
(a) 12 (b) 8
(c) 10 (d) 9

4. Shola forests are characterisitic feature of:
(a) Gangetic Plains (b) Western Himalaya
(c) Assam (d) Coast of Malabar

5. Two biodiversity hotspots in India are:
(a) Western Himalaya and Eastern Ghats (b) Eastern Himalaya and Western Ghats
(c) Western Himalaya and Western Ghats (d) Eastern Himalaya and Eastern Ghats

6. Xerophytic vegetation is characteristic feature of:
(a) Gangetic Plains (b) Eastern Himalaya

(c) Indus Plain (d) All of these

7. Endemism refers to:
(a) Origin place of plants (b) Wide distribution range
(c) Confined distribution (d) Rare occurrence of plants

8. Patches of stunted tropical montane forest found in valleys amid rolling grassland in the higher montane regions of South India called:
(a) Sholas (b) Xerophytes
(c) Mangroves (d) Steppes

9. Total number of hotspots over world is:
(a) 35 (b) 25
(c) 34 (d) 12

10. Mangrove vegetation found in:
(a) Himalaya (b) Rajasthan
(c) Punjab Plains (d) Sundarbans

11. *Nepenthes khasiana* is:
(a) An endemic to Assam (b) Endemic to Western Ghats
(c) An Insectivorous plant (d) Both (a) and (c)

12. Maximum biodiversity hotspots of world are found in:
(a) Tropical belt (b) Temperate belt
(c) In Himalaya (d) Subtropical region

13. Concept of hotspot was given by:
(a) Norman Mayer (b) Chatterji
(c) De Candolle (d) Humboldt

14. Most recently identified and 35 hotspot of world is:
(a) Tropical Andes (b) Western Ghats
(c) Sundand (d) Indo- Burma

15. India covers ……… of the world's total geographical area, and harbors over ……… of the total global biodiversity:
(a) 2.4%, 8.0% (b) 24%, 8.0%
(c) 8.0%, 2.4% (d) 0.24%, 0.80%

16. *Rhizophora* and *Sonneratia* are:

(a) Mangroves (b) Xerophytes

(c) Epiphytes (d) Lithophytes

17. "Phytogeography is the study of migration and evolution of plants in time and space." Defined by:

(a) Croizat (1952) (b) Campbell (1926)

(c) Wulff (1943) (d) Good (1964)

18. A Phytogeographical region also known for its fertility and cultivation of crop plants:

(a) Indus Plains (b) Gangetic Plains

(c) Western Himalaya (d) Coasts of Malabar

19. Uttarakhand state falls in:

(a) Western Himalaya (b) Gangetic Plains

(c) Eastern Himalaya (d) Indus Plains

20. Endemics, produced by gradual speciation having a common origin and identical chromosome numbers:

(a) Schizoendemics (b) Holoendemics

(c) Neoendemics (d) Relics

2.8.2 Fill in the Blanks:

(1) India is divided into ______________ Phytogeographical regions by Chatterji.

(2) There are total ______________ numbers of hotspots over world.

(3) The concept of hotspot was given by__________________ .

(4) The father of phytogeography is called_________________ .

(5) ____________________ and ______________ are two hotspots of India.

(6) India covers ___________% of the world's total geographical area, and harbors over __________ % of the total global biodiversity.

(7) Maximum number of biodiversity hotspots found in _______________ belt of globe.

(8) A plant species having confined distribution is called ______________ species.

(9) *Nepenthes khasiana* is endemic to _________________ .

(10) Sholas found in ___________________ geographical region of India.

2.8.3 True and False:

(1) Term endemism coined by A.P. De Candolle.

(2) *Rhizophora* is found growing in Indus Plains.

(3) Endemic Plants have wide range of distribution.

(4) Western Himalaya is a biodiversity hotspot in Indian sub-continent.

(5) Eastern Himalaya represents biodiversity hotspots of India.
(6) Mangrove vegetation is found in Sundebans.
(7) *Nepenthes khasiana* is a Mangrove Plant.
(8) There are more than 40 hotspots over world.
(9) Most of the biodiversity hotspots of the world are near tropics.
(10) The phytogeographical region, Gangetic plains of India also known for its fertility and cultivation of crop plants.

2.8.4 Very short answer questions:

(1) What is Phytogeography?
(2) What means the endemics?
(3) Describe Nativity.
(4) Differentiate between flora and Vegetation.
(5) Differentiate between paleoendemics and neoendemics.
(6) Define the mangrove vegetation.
(7) What do you mean by biodiversity hotspot?
(8) Describe biodiversity hotspots of India.
(9) What do you mean by Sholas?
(10) What are the criteria for determining biodiversity hotspots?

2.8.1 Answer Keys: 1-(a), 2-(c), 3-(d), 4-(d), 5-(b), 6-(c), 7-(c), 8-(a), 9-(a), 10-(d), 11-(d), 12-(a), 13-(a), 14-(a), 15-(a), 16-(a), 17-(a), 18-(b), 19-(a), 20-(a).

2.8.2 Answer Keys: 1-9, 2-35, 3-Mayer, 4-Alexender V. Humboldt, 5- Eastern Himalaya, Western Ghats, 6- 2.4, 8 7-Tropical, 8- Endemic, 9-Assam, 10- Western Coast of Malabar.

2.8.3 Answer Keys: 1-True, 2-Fase, 3-False, 4-False, 5-True, 6-true, 7-False, 8-False, 9-True, 10-True.

2.9 REFERENCES

- Cain, S.A. 1944. *Foundations of Plant Geography*. New York, London.
- Campbell, D.H .1926. *An outline of plant geography*. Macmillan, New York.
- Chatterjee, D.1962. Floristic patterns of Indian Vegetation. *Proceedings of Summer School of Botany*. Darjeeling. 32-42.
- Croizat, L. 1952. *Manual of Phytogeography: An Account of Plant-Dispersal throughout the World.* Springer-Science+Business Media, B.V.
- de Candolle, A.P. 1855. *Géographie botanique raisonnée.* Paris, V. Masson.
- Dickore, W.B. and Nusser, M. 2000. *Flora of Nanga Parbat (NW Himalaya, Pakistan): An annotated inventory of vascular plants with remarks on vegetation dynamics.* Englera, 19.
- Drury, W.H. 1974. Rare Species. *Biological Conservation*. 6:162-169.

- Favarger, C. and Contandriopoulos, J. 1961: Essai sur l'endémisme.-Ber. Schweiz. *Bot. Ges.*71:384-408.
- Good, 1964. *A Geography of flowering plants*. 3rd ed. John Wiley & Sons, New York.
- Good, R. 1931. *A Theory of Plant Geography*. *The New Phytologist*. 30(3): 149.
- Kruckerberg, A.R. and D. Rabinowitz. 1985. Biological aspects of endemism in higher plants. *Annual Review of Ecology and Systematics*, 16:447-479.
- Mason H.L.1936. The principles of geographic distribution as applied to floral analysis. *Madroño*, California Botanical Society. 3(5): 181-190.
- Myers, N. 1988. Threatened biotas: "hot spots" in tropical forests. *Environmentalist.* 8: 187-208.
- Samant, S.S., Dhar, U. and L.M.S. Palni. 1998. *Medicinal plants of Indian Himalaya: Diversity Distribution Potential Values.* Gyanodaya Prakashan, Nainital.
- Schouw, J. F. 1823. *Grundzüge einer Allgemeinen Pflanzengeographie*, Berlin, Reimer.
- Stebbins, G.L. and J. Major. 1965. Endemism and speciation in the California flora. *Ecological Manographs,* 35:1-36.
- Wherry, E.T. 1944. A Classification of Endemic Plants. *Ecology*. 25(2): 247-248.
- Willis, J.C. 1922. *Age and area; a study in geographical distribution and origin of species*. Cambridge University Press.
- Wulff, E.V. 1943. *An Introduction to Historical Plant Geography*. Chronica Botanica Co., Waltham, Mass.

2.10 SUGGESTED READINGS

- Bhattacharya, B. 2005. *Systematic Botany*. Narosa Publishing House, New Delhi.
- Croizat, L. 1952. *Manual of Phytogeography: An Account of Plant-Dispersal throughout the World.* Springer-Science+Business Media, B.V.
- De-Yuan, H. 2010. *Peonies of the World Taxonomy and Phytogeography*. Royal Botanic Gardens, Kew.
- Kumaresan, V. and Arumugam, N. 2016. *Plant Ecology and Phytogeography.* Saras Publication. India.
- Lawrence, G.H.M. 1951. *Taxonomy of Vascular Plants*. Macmillan, New York.
- Naik, V.N. 1984. *Taxonomy of Angiosperms*. Tata McGraw-Hill, New Delhi.
- Santra, S.C. 2010. *Fundamentals of Ecology and Environmental Biology.* New Central Book Agency, India.

2.11 TERMINAL QUESTIONS

2.11.1 Short answer questions:

(1) What is Phtogeography? Explain in brief.

(2) Describe the hotspots of India.
(3) Describe Gangetic Plains and its dominant vegetation.
(4) Describe Indus Plains and its dominant vegetation.
(5) What do you understand by endemism, describe different types of endemics?
(6) What are narrow endemics? Describe briefly.
(7) Describe the vegetation of Western Himalayan phytogeographical region of India.
(8) What are hotspots? Mention criteria used for determining hotspots.
(9) What do you understand by relics, explain in brief?
(10) How many phytogeographical regions are in India? Give a list.

2.11.2 Long answer questions:

(1) What do you understand by phytogeography? Give an account of phytogegraphy of India.
(2) Describe phytogeographical regions of India with their dominant vegetation in detail.
(3) Explain modern concept of endemism in detail and different types of endemics.
(4) Citing suitable examples, explain about biodiversity hotspots?
(5) Compare the vegetation zonations of Western and Eastern Himalayan Phytogeographic Regions of India.

UNIT-3 PLANT EXPLORATION, INVASION AND INTRODUCTION, HERBARIA AND BOTANICAL GARDENS

3.1 OBJECTIVES

After reading this unit you will be able to learn:

- What is the need of plant exploration and how it started in India?
- What is plant invasion and what is its process and effect.
- Types and methods of plant introduction.
- Merits and demerits of plant introduction.
- The concept and importance of herbaria.
- Techniques used to prepare herbaria.
- What are botanical gardens and their significance?

3.2 INTRODUCTION

Exploration is the act of searching for the purpose of discovery of resources. In human history, its most dramatic rise was during the age of discovery when European explorers sailed and charted much of the rest of the world for a variety of reasons. The systematic plant exploration in India was initiated in early of 1940s with the establishment of the plant introduction unit in the division of Botany, Indian Agriculture Research Institute (IARI), New Delhi. This ultimately developed into the National Bureau of Plant Genetic Resources (NBPGR) which helps to preserve the germplasm collection of different crops.

Humans are dependent upon plants directly or indirectly. They provide food, clothing, fuel, shelter, and many other necessities of life. To share his knowledge and experience about the utility of plants with next generation, the practice of collection and preservation was started. For this purpose the concept of herbarium was started. The word herbarium was originally coined from a book about dried medicinal plants and they called herbaria; a collection of herbs. A modern herbarium is a modern filing system for information about plants primarily in the form of actual specimens and secondarily in terms of recorded notes, information and pictures.

3.3 PLANT EXPLORATION

Plant exploration is one of the oldest activities of mankind. Since the dawn of civilization, individuals have gathered new and useful plants from far away places. Seeds and seedlings were routinely included as part of the household as people explored new territories and settled in new lands.

While the early colonists subsisted on corn, squash, peas, wild fruits and game, the native Americans, seed-carrying travelers, immigrants, explorers, and missionaries enhanced the colonists' diet with imported grains and plants, transported from great distances.

India with its highly diverse geology, topography and climate is endowed with a very rich heritage of biological diversity flourishing in every conceivable ecosystem. From the ancient time the importance of plants was known to people and the plants were explored and classified on the basis of their utility e.g., as medicinal, food, fibre, etc. *Ayureveda* is one of the alternative medical sciences and mainly depends upon herbs. *Charak Samhita* and *Sushrut Samhita* are our oldest documents which deal with medicine and surgery.

Later Portuguese were the first who explored plants from India. Garcia de Orta was the first Portugese explorer who first published a book in 1563 on Indian flora named *Colóquios dos simples e drogas.* In this book he described a large number of drug plants. Hendrick van Rheede who was the governor of Malabar in 1976 also explored Indian plants and published his work in *Hortus Indicus Malabaricus* in 13 volumes.

William Roxburgh toured India extensively for plant exploration. He was known as the 'Linnaeus of India'. His collections were published in 1825 by D. Don in "Prodromus Florae Napalensis".

Joseph Dalton Hooker wrote *Flora of British India* on the basis of Griffith and Thomson's collections. Hooker along with Thomson made extensive exploration in the Himalayas discovering many new species of *Rhododendron* and published a monograph also in 1949.

3.4 INVASION AND INTRODUCTION

3.4.1 Plant Invasion

Plant invasion is the second most severe threat to biodiversity after habitat fragmentation. An invasive species may be any plant, fungus or animal species which is not native to a specific location (an introduced species). It can damage to local environment by dominating a region, wilderness areas, particular habitats or wild-urban interface land from loss of natural controls (such as predators or herbivores).

3.4.1.1 Method

The process of invasion of an unoccupied region by new taxa is completed in three phases:

A. Introduction: As a result of dispersal, propagules arrive at a site beyond their previous geographical range and establish populations of adult plants.

B. Colonization: The plants in the founding population reproduce and increase in number to form a colony that is self-perpetuating.

C. Naturalization: The species establishes new self-perpetuating populations, undergoes widespread dispersal and becomes incorporated within the resident flora.

3.4.1.2 Effect of Invasion

3.4.1.2.1 Ecological

Various anthropogenic activities put significant pressure on local species and cause habitat disturbance and change in the functions of ecosystems. Invasive species cause competition for native species. Species that are closely related to rare native species have the potential to hybridize with the native species. Harmful effects of hybridization have led to decline and even extinction of native species.

3.4.1.2.2 Individual Effects

Invaders can have a variety of effects on individual's performance. For example, invasive plants can compete with native plants and reduce their growth and change their structure. Such changes in individual growth and life cycles can translate into changes in population size and fate. Population models built around a simple description of the life cycle can be used to link the individual and the population (Caswell, 2000).

3.4.1.2.3 Biodiversity

Invasive species can cause reduction in the biological diversity of native species and the size of populations. Next to land transformation, they are the most important cause of extinction. Invasive species may drive local native species to extinction via competitive exclusion, niche displacement, or hybridization with related native species. Therefore, besides their economic ramifications, alien invasions may result in extensive changes in the structure, composition and global distribution of the biota of sites of introduction, leading ultimately to the homogenization of the world's fauna and flora and the loss of biodiversity. Invaders can also interact with habitat transformation and thus exacerbate the threat to biodiversity.

3.4.1.2.4 Population and Community Effects

After habitat destruction, introduced species are second most reason for loss of native plant species. Replacement of natives with non-indigenous species is immediate, readily measurable evidence of the impact of invasions. Extinction could be the most dramatic impact of invasive species. Small populations of natives suffer the highest risk of extinction from various genetic and demographic causes. Invaders pose a major risk to threatened and endangered species.

3.4.2 Plant Introduction

Plant introduction is one of the oldest and very effective tools for crop improvement. It is defined as the orderly transfer of a cultivated species or variety to a new habitat following the usual procedures of quarantine, evaluation, multiplication and distribution. It is also the adaptation of plant in a new environment.

3.4.2.1 TYPES

Introduction may be categorized into two types: (a) Primary Introduction (b) Secondary Introduction

3.4.2.1.1 Primary Introduction

If any plant variety is directly introduced without any alteration in its genotype and well adapted and released for the commercial cultivation, then it is known as primary introduction. For example, the Australian wheat variety *"Ridley"* is now grown commonly in Uttarakhand and Himachal. The dwarf wheat varieties Sonora-64, Lerma rojo and semi-dwarf rice varieties IR-8, IR 2 are introduced varieties in India.

3.4.2.1.2 Secondary Introduction

When introduced variety hybridizes with the indigenous variety to develop a superior variety then it is known as secondary introduction. The examples of secondary introduced varieties are Kalyan sona, Sonalika wheat varieties. Likewise 'Pusa Ruby' and 'Pusa early dwarf' varieties of tomato were bred by hybridizing the local variety 'Meerute' with US variety 'Sioux' and 'Red cloud' respectively.

Both types of introduction activities have run parallel since the beginning of agriculture and horticultural activities.

3.4.2.2 Procedure for Plant Introduction

Plant introduction is one of the most effective tools in for the crop improvement. The procedure consists of following steps: Procurement of germplasm, quarantine, cataloguing, evaluation, multiplication and distribution.

3.4.2.2.1 Procurement of Plants or Germplasm

A request for acquiring the plant material for introduction of plant or new variety is submitted to NBPGR (National Bureau of Plant Genetic Resources) within the country or to IBPGR (International Bureau of Plant Genetic Resources). The material may be obtained on an exchange basis from friendly countries either directly or through F.A.O. or the material can also be purchased or obtained as free gift from individuals or organizations.

The part of the plant for propagation of that species is known as propagule. It may be seeds, tubers, runners, suckers, stolons, bulbs, root cuttings, buds or seedlings depending upon the crop species. Depending on the type of propagule those are cleaned from other weed-seeds and contaminants and treated with fungicides, packed carefully and dispatched so that it can reach the destination in viable condition.

3.4.2.2.2 Quarantine

"*A strict isolation imposed to prevent the spread of disease for ensursing disease and pest-free plants"* is known as plant quarantine. In case of plant introduction all propagules are inspected by the recipient country for any contaminants. The suspected materials are treated with insecticides, fungicides or nematicides and then released to the user. The general objective of the quarantine process is to prevent any pests or diseases to enter in the country.

3.4.2.2.3 Cataloguing

After quarantine the introduced specimen is given a number regarding species, variety, place of origin and the data is recorded. The plant materials are classified into three groups:

a. Exotic collection: prefix 'EC'
b. Indigenous collection: designated as 'TC'
c. Indigenous wild collection: marked as 'TW'.

3.4.2.2.4 Evaluation

To assess the potential of new introductions, these varieties are grown at different substations of the NBPGR to evaluate their performance under different environmental conditions for the study of its resistance to diseases and pests.

3.4.2.2.5 Multiplication and Distribution

Promising introduced materials are propagated and then released as varieties after necessary trials.

3.4.2.3 Merits and Demerits of Plant Introduction

Merits

Plant introduction is oldest method to improve the plant wealth. The merits of it are as follow:

1. It is the easiest method for crop improvement.
2. It helps in obtaining quickly and at low cost the best or elite variety available as it happened in semi dwarf Mexican wheat.
3. It provides superior variety directly after selection.
4. It protects the variability from genetic erosion by collecting germplasm.
5. It is a very quick and economical method of crop improvement.

6. It provides protection to the crop by introducing into new disease free areas.

Demerits

Uncontrolled plant introduction may lead to the introduction of many new problematic varieties, of which are as follow:

1. Introduction of noxious weeds e.g. *Argemone mexicana*, *Parthenium* sp., *Phylaris minor* etc.
2. Introduction of disease e.g. late blight of potato from Europe in 1883, flag smut of wheat from Australia and Bunchy top of Banana from Ceylon.
3. Introduction of pests e.g. Potato tuber moth from Italy. Wooly aphis of apple and fluted scale of *Citrus* also entered in India by plant introduction.
4. Ornamentals turned noxious weeds e.g. Water hyacinth and *Lantana camara*.
5. Threat to Ecological balance, *Eucalyptus* sp. Introduced from Australia.

3.5 HERBARIA AND BOTANICAL GARDENS

3.5.1 Herbaria

3.5.1.1 Introduction

A herbarium is like a depository of information about plant biodiversity. Plant samples are taken from the field by people with special collecting permits, then dried or otherwise preserved. They are then carefully stored in archival conditions to ensure their longevity. These specimens, including information about them, are kept to learn more about the plants and their habitats. So a **herbarium (plural: herbaria)** is a collection of preserved plant specimens and associated data used for scientific study.

The term can also refer to the building or room where the collection of preserved plants stored, catalogued and arranged systematically for study by professional taxonomists (scientists who name plants), botanists and amateurs.

The oldest traditions of making herbarium collection have been traced to Italy by Prof. Luca Ghini and his students created herbaria by pressing plants and mounting them on paper sheet. The oldest herbarium was prepared by Gherardo Cibo from around 1532, a student of Prof. Luca Ghini.

In starting plant specimens were mounted on paper sheet which bound as book like volume. Later Carolus Linnaeus came up with the idea of maintaining them on free sheets that allowed their easy re-ordering within cabinets.

3.5.1.2 The Value of Herbarium Collections

Traditionally, the primary importance of herbarium specimens was related to questions of taxonomy. Ideally, this would be done through the study of live plants but, when this is not practical, referring to a collection of preserved plants is important. The specimens that are stored in the herbarium are a working reference collection used in the identification of plants, the writing of Floras (a description of all the plants in a country or region), monographs (a description of plants within a plant group, such as a family) and the study of plant evolutionary relationships.

Beyond their customary value to taxonomy, herbarium collections have become crucial for a wide array of studies including such things as reconstruction of plant phylogeny, the spread and habitat preferences of invasive species, population trends of rare plants, identifying priority sites for conservation, pollination ecology, education, forensic studies, ethnobotanical studies, and phenology studies to name a few.

A herbarium is like a library or vast catalogue and each plant specimen has its own unique information - where it was found, when it flowers and what it looks like. They can also be used to provide samples of DNA for research, as DNA remains intact for many years. It is usually used for evolutionary studies and is routinely extracted from herbarium specimens.

3.5.1.3 Important International and National Herbaria

There are approximately 3,990 recognized herbaria in the world today, with about 10,000 associated curators and biodiversity specialists. Collectively the world's herbaria contain an estimated 350,000,000 specimens that document the earth's vegetation for the past 400 years. India stands 19th in position among the herbaria of the world for the repository of over 3.5 million specimens representing more than 23 thousand type specimens.

3.5.1.3.1 Important Herbaria of World

The world's largest museum is at Paris with record holding of about 9 million specimens. The second largest is the Royal Botanical Gardens, Kew, London which harbours about 7 million specimen including 3.5 million type specimens.

Table 1: List of major International herbaria

S. No.	**Name**	**Established**	**Location**	**Country**
1.	Natural History Museum (Muséum National d'histoire Naturelle)	1635	Paris	France
2.	Royal Botanical Gardens	1853	Kew, London	United Kingdom
3.	New York botanical Garden	1891	New York	USA
4.	Missouri Botanical Garden	1859	Missourie	USA
5.	British Museum of Natural History	1753	London	United Kingdom
6.	Conservatorie et Jardin botaniques	1817	Geneva	Switzerland

3.5.1.3.2 Important Indian Herbaria

Most of the herbaria in India are managed by Botanical Survey of India. The Central National Herbarium (CNH) is India's oldest herbaria with about 2 million plant species. It is one of the largest herbaria in the world. William Roxburgh established this herbarium in 1795 at his office-cum-residence. This building, located on the bank of the river Hooghly, is now called Roxburgh House. In 1883 the herbarium was shifted to a specially built building. More than 15,000 type specimens are housed in it.

Table 2: List of major Indian herbaria

S. No.	Name	Established	Location
1.	Central National Herbarium	1793	Howrah
2.	Forest Research Institute	1816	Dehradun
3.	Botanical Survey of India, Eastern Circle	1956	Shillong
4.	Botanical Survey of India, Southern Circle	1956	Coimbatore
5.	Botanical Survey of India, Northern Circle	1956	Dehradun
6.	National Botanical Research Institute	1948	Lucknow

3.5.1.4 Preparation and Preservation of Herbaria

The dried, pressed plant specimens and their associated collections data preserved in the herbaria are remarkable and irreplaceable sources of information about plants and the world they inhabit. Since these records provide the comparative material that is essential for various plant studies so the herbarium records should be carefully collected, prepared, preserved and maintained.

3.5.1.4.1 Field Equipments and Collection

Numbers of instruments are required by plant collector, for the excursion. A pair of secateurs for cutting woody twigs, khurpi for digging up roots and underground stems, knife, pair of forceps, vasculum for keeping the collected plants and their twigs, blotting papers and newspapers, a field book and pocket lens.

The entire healthy typical specimens, of almost all natural phases should be collected with all above ground and below ground parts. The single specimen may be collected in the late flowering stage having both flowers and young fruits. Collection should be done from different localities and habitats. Take photograph of rare and only plant species of the locality instead of collection.

In certain cases, the roots and other underground parts of the plant are necessary for identification. For collection of the plants one should go out on excursion several times in a season.

3.5.1.4.2 Pressing and Drying of Specimens

Generally the plants are pressed flat. To get good specimens, the plants must be pressed before their wilting. The plants should be placed in between the sheets of newspaper which are alternated between sheets of blotting paper. Since the wooden presses are too heavy to carry them in the fields, therefore presses with aluminium covers are preferred. The standard size of the press is 12″ x 18″. The blotting sheets or newspaper sheets which have been used for pressing the plant materials must frequently be changed after every 24, 48 or 72 hours. The changing depends very much upon the weather conditions.

Generally the plants are collected in a cork lined tin vasculum, and then they are pressed after the day's trip. To get the finest specimens the plants must be pressed directly in the plant press, then and there, as soon as they are collected in the field.

3.5.1.4.3 Mounting and Labelling of Specimens

After drying, the plant specimens are mounted on herbarium sheets. The sheets must be of heavy white paper to give support to the plants in handling. The standard size of the herbarium sheet is 28 cm X 42 cm (11.5 X 16.5 inches). The specimens are fastened to the sheets by glue or gummed cellophane tape. Usually one specimen, no matter how small it is, should be mounted on one herbarium sheet.

3.5.1.4.4 Storage of Herbarium Sheets

After mounting the plant specimens on herbarium sheets they are usually kept in specially constructed herbarium cases. The wooden or steel cabinets with shelves slightly bigger than the size of the herbarium sheets are used for keeping the mounted plant specimens. The keeping of mounted plant specimen for further record is known as 'filing the specimen.'

3.5.2 Botanical Gardens

A botanical garden is a garden dedicated to the collection, cultivation and display of a wide range of plants labeled with their botanical names. It may contain specialist plant collections such as cacti and other succulent plants, herb gardens, tropical plants, alpine plants or other exotic plants. Thus *"botanical gardens are institutions holding documented collections of living plants for the purpose of scientific research, conservation, display and education."*

The world's first botanical garden was created in Padua in 1545. Botanical gardens are important centers for conserving endemic and endangered plant species. A display garden that concentrates on woody plants (shrubs and trees) is often referred to as an arboretum. It may be a collection in its own right or a part of a botanical garden. A major contemporary objective of botanical gardens is to maintain extensive collections of plants, labeled with common and scientific names and regions of origin.

3.5.2.1 Role and Function

Botanic gardens have collectively accumulated centuries of resources and expertise that now means they play a key role in plant conservation. Many of these activities contribute to *ex situ* conservation, but botanical gardens also play an important role in *in situ* conservation. Following are the main activities that are used for plant conservation:

(a) Cultivation of plants in botanical gardens allows growing plants that might be lost in nature, thus the species diversity can be conserved and restored.

(b) Living collections of plants contain species under various groupings, to maintain a living store of genetic diversity that can support many activities in conservation and research.

(c) Seed banks and collections of living plants allow species to be safeguarded. This is the conservation of plant diversity *in situ,* and botanic gardens are keys to this strategy's capacity and success.

(d) Linking plants with the well-being of people, and also helping conserve indigenous and local knowledge, to encourage the sustainable use of plant resources for the benefit of all, as part of sustainable development.

(e) These gardens help to aware people and spread knowledge about the importance of conserving plants by reaching out to diverse audiences, and also to communicate how this may be achieved.

In recent times, the focus has been on creating an awareness of the threat to the Earth's ecosystems from human overpopulation and its consequent need for biological and physical resources. Botanical gardens provide an excellent medium for communication between the world of botanical science and the general public. Education programs can help the public develop greater environmental awareness by understanding the meaning and importance of ideas like conservation and sustainability.

3.6 SUMMARY

Herbaria are storehouse of plant specimens collected from far and wide. The plants arranged in herbaria are sequenced according to some known system of classification. It serves as a fundamental source in plant identification and helps in teaching and research.

The specimens with a distinctive seal are to be incorporated in the herbarium and accessioned herbarium sheets are sorted out rank wise. Special arrangements should be made with the specimens like type specimens and specimen should be protected from pests and fumigated often for long preservation.

3.7 GLOSSARY

Adaptation: Adjustment of an organism or population for perpetuation in a given environment.

Artificial selection: Selection by humans in domesticate population, *i.e.*, crops favours such features that are desirable to humans.

Biodiversity: Generally refers to the variety and variability of life on Earth.

Biological Invasion: Exotic species introduced in a new area become acclimatized in the area and destroy the native species.

Blotting Paper: It is a highly absorbent type of paper used to absorb an excess of liquid substances from the surface.

Botanical Garden: A garden dedicated to the collection, cultivation and display of a wide range of plants labelled with their botanical names.

Conservation: The protection of plants, animals, natural areas, and interesting and important structures and buildings, especially from the damaging effects of human activity.

Control: Reduce numbers or extent of an invasive species to an acceptably small amount or impact.

Eradicate: Completely eliminate all individuals of a targeted species from an area to which reintroduction will not occur.

Established: Introduced species that are a fixed part of a plant or animal community, reproducing by themselves without support from humans.

Exotic species: Not native species which is introduced from another area.

Exploration: A trip for collection of germplasm of crop species.

Gene bank: A collection of genetic resources maintained, usually as seeds, under suitable storage conditions.

Germplasm: Germplasm is living genetic resource such as seeds or tissues that are maintained for the purpose of breeding, preservation, and other research uses. These resources may take the form of seed collections stored in seed banks, trees growing in nurseries. Germplasm collection is important for the maintenance of biological diversity and food security.

Herbaria: A storehouse of information about plant diversity.

In situ: It means locally, on site, on the premises or in place situated in the original, natural, or existing place or position.

Indigenous: Produced, growing, living, or occurring naturally in a particular region or environment; innate, inborn.

Introduced: Species brought accidentally or on purpose by people to a new location, across a natural geographic boundary, like an ocean or mountain chain that the species would not usually cross naturally.

Invasive species: A species that is non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

Natural selection: Selection by natural forces like temperature, soil moisture, etc. that favors survival in nature.

Plant Introduction: Taking a genotype or a group of genotypes of a crop species into a new area where it/they was/were not being grown before.

Plant quarantine: Plant quarantine is a technique for ensuring disease and pest free plants, whereby a plant is isolated while tests are performed to detect the presence of a problem.

Primary Introduction: Introduced genotype/strain directly released for commercial cultivation after testing its performance.

Selection: A differential reproduction of different genotype present in a population.

Vasculum: A box used by botanists for carrying samples from field to lab as they are collected by maintaining a cool, humid environment.

3.8 SELF ASSESSMENT QUESTIONS

3.8.1 Multiple choice questions:

1 The Indian Botanical Garden is located at:

(a) Delhi (b) Allahabad

(c) Kolkata (d) Lucknow

2 Which one of the following is not used for *in situ* plant conservation?

(a) National Park (b) Wild life sanctuary

(c) Biosphere reserve (d) Botanical Garden

3 Herbarium of Forest Research Institute is situated in

(a) Dehradun (b) Lucknow

(c) Kolkata (d) Chennai

4 National Botanical Research Institute is situated at:

(a) Lucknow (b) Dehradun

(c) Howrah (d) Chennai

5 Quick referral systems in taxonomic studies are:

(a) Botanical gardens (b) Herbaria

(c) Monographs (d) Manuals

6 In a herbarium, sheets are arranged according to:

(a) Regionally accepted system of classification

(b) Universally accepted system of classification

(c) Nationally accepted system of classification

(d) Locally accepted system of classification

7 Information on any one taxon is found in:

(a) Manuals (b) Museums

(c) Herbarium (d) Monographs

8 Botanical gardens have:

(a) Living plants and animals for reference (b) Collection of living plants
(c) Preserved plant specimens (d) Living and preserved plants

9 Herbaria are useful in

(a) Understanding the distribution of plants (b) Observing the habitat of plants
(c) Identification of plants (d) Indicating list of plants in a particular area

10 Standard size of herbarium sheet is:

(a) 25 cm x 41 cm (b) 28 cm x 42 cm
(c) 22.5 cm x43.5 cm (d) 14cm x 18cm

11 Royal Botanical Garden is situated at:

(a) Kew (London) (b) Venice (Italy)
(c) Paris (France) (d) Delhi (India)

12 Which of the following is responsible for the evolution of crop plant under domestication?

(a) Artificial selection (b) Natural selection
(c) Both ‘A’ and ‘B’ (d) None of the above

13 Selection is effective only when……. is present in population:

(a) Genetic variation (b) Genetic selection
(c) Both ‘A’ and ‘B’ (d) None of the above

3.8.1 Answer Keys: 1-(c), 2-(d). 3-(a), 4-(a), 5-(b), 6-(b), 7-(d), 8-(b), 9-(c), 10-(b), 11-(a), 12-(c), 13-(a)

3.9 REFERENCES

- Harlan, J. R. 1956. Dist ribution and utilization of natural variability in cultivated plants. Brookheaven symp. Boil. 9: 191-208.
- Daisey, P. 1996. Promoting interest in plant biology with biographies of plant hunters. *American Biology Teacher*. 58: 396-406.
- Kaplan, Kim, J. 1998. Conserving the world's plants. *Agricultural research. 46*: 4-9.
- Milius, Susan. 1991. Raiders of the lost potato: as genetic diversity dwindles, botanists scour the globe for rare plants. *International Wildlife*. 21: 14-17.
- Ryerson, K. A. 1976. A survey of the introduction of various plants into the United States. *Agricultural History*. 50: 248-257.
- Caswell, H. 2000. Matrix Population Models: Construction, Analysis, and Interpretation. 2nd Ed. Sunderland, MA: Sinauer Associates.

- Rai, P.K. 2015. What makes the plant invasion possible? Paradigm of invasion mechanisms, theories and attributes. *Environmental Skeptics and Critics.* 4(2): 36-66
- Richardson, D.M., Pysek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D. and Carol J. W. 2000. Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions*. 6: 93–107
- Groves, R.H. 1986. Invasion of Mediterranean Ecosystems by Weeds. *Resilience in Mediterranean-Type Ecosystems* (ed. by B. Dell, A.J.M. Hopkins & B.B. Lamont), pp. 129–145, Junk, Dordrecht.

3.10 SUGGESTED READINGS

- Singh B.D. Plant Breeding Principles and Methods. Kalyani Publishers.
- Pandey B.P. College Botany. S. Chand Publication.
- Kochhar, S.L. Economic Botany in the Tropics. Macmillan Publishers India Ltd.
- Saxena and Saxena. Taxonomy of Angiosperm. Pragati Prakashan.
- https://www.bgci.org/resources/bgs_in_conservation/
- http://whc.unesco.org/en/list/824

3.11 TERMINAL QUESTIONS

1. Comment upon following:
    a. Plant invasion
    b. Plant exploration
    c. Plant introduction
2. Write a short note upon:
    a. Procedure for plant introduction.
    b. Merits and demerits of plant introduction.
3. Define herbarium. Write the importance of the herbarium.
4. Write an account on the methodology of collecting plant specimens.
5. Write a note on major international and national herbaria.
6. Write the documentation methods adopted in a herbarium.

BLOCK-2 FUNDAMENTALS OF ANGIOSPERMS

UNIT-4 TAXONOMIC TOOLS AND HIERARCHY

4.1 OBJECTIVES

After reading this unit students will be able to-

- Understand the various types of taxonomic tools used in identification and nomenclature.
- Understand the concept of herbarium and herbarium preparation.
- Define flora and know about world's and Indian flora.
- Compute taxonomic literature for the identification of plants.
- Know the rank or category in systematics and taxonomic hierarchy.

4.2 INTRODUCTION

Taxonomy is a branch of science that encompasses the identification, nomenclature and classification of organisms. Thus the first step of taxonomy is identification and then naming (nomenclature) and classification. Modern classification systems are based on many types of evidences in contrast to classical system which is generally based on morphological evidences. A truly natural classification is obtained from analysis and harmonization of evidences from all organs and parts like habit (herb, shrub, and tree), root types, stem types, leaf types and arrangement, flower arrangement (inflorescence) etc. Gross morphology provides the foundation for taxonomy and it should be supplemented by the information from anatomy, palynology, embryology, cytology, paleobotany, physiology and ecology. In the following sub sections we will discuss each aspect one by one. Morphology is the study of structure and form of plants and animals usually dealing with the organism and its component organs. Morphological evidence provides the basic language for plant characterization, identification, classification and relationship. Morphological data is easily observable and obtainable and thus most frequently used in taxonomic studies and taxonomists depend for this source directly on herbarium. The growth habit of herbaceous or woody plants is useful in classification. The root structural types like tap root system (fusiform, napiform) and adventitious root systems (fascicled, fibrous) classify plants into two major groups namely monocots and dicots. In monocots the number of cotyledons is one (wheat, rice, maize *etc.*) and these are characterized by adventitious roots while in dicots the number of cotyledons is two (gram, pea *etc.*) and these are characterized by tap root system.

Thus taxonomic tools or aids are techniques, procedures and stored information that are useful in identification and classification of organisms. They are required because taxonomic study of plants, animals and other organisms is basic to almost all branches of biological studies for their proper identification and finding their relationship with others. Herbaria, botanical gardens, museums, zoological parks (zoos) and keys are important tools used in identification of plants and animals. Now a days as science and technology achieve advancement in every field taxonomist also merely not depend upon traditional tools but advance and sophisticated tools like phytochemistry, serology, histology, cytology, numerical taxonomy or computerised data analysis and many other techniques boost their work. The most recently included in this list are GIS (Geographical Information System), DNA barcoding and molecular techniques, nucleotide sequencing *etc.*

4.3 HERBARIUM

Herbarium is a store house plant of specimens where plant specimens are collected from far and wide preserved in dried condition and mounted on a standard size of herbarium sheet. The standard herbarium sheets are kept in pigeon holes under separate generic covers and arranged according to any accepted system of classification for future reference and study. Succulent plants like members of Cactaceae and pulpy fruits lose their diagnostic characters on drying and are preserved in some suitable preservatives, such as 4% formalin solution or F.A.A (Formalin-acetic acid-alcohol). Many types of dry fruits like *Lodoicea maldivica* (double coconut), coconut, *Oroxylum,* hard cones of gymnosperms and long, sclerenchymatous inflorescences of palms etc., are dried and are kept in large transparent containers. It is a great filing system for information about plants primarily in the form of actual specimens and secondarily in the form of recorded notes on labels attached on the sheets. The material in the herbarium remains as permanent record of flora of those regions even the natural topography and the vegetation might have changed or became extinct. In these circumstances the herbarium provides evidence of what once existed. The herbarium specimens bear labels with adequate data on habitat, common name, native place, uses, ecological notes like abundance frequency rarity of species, associated plants, habit etc. This data for the particular species may vary from different collections of different regions, but when carefully studied and analysed, provides valuable material for almost complete description of various taxonomic characters such as morphological range of variation, distribution etc. A herbarium receives fresh material by collection of its staff, taxonomists, explorers, gifted by other taxonomist, exchanges etc. So it is a conservatory of material along data.

The attempt of Herbarium preparation was done about 500 years ago by an Italian taxonomist Luca Ghini in late fifteenth century till sixteen century (1490-1556). The oldest herbarium in existence is believed to be the collections of Gherardo Cibo, a student of by Luca Ghini, in Bologna, Italy, dating from around 1532 and is kept in Rome. Luca Ghini conducted many plant explorations and collection trips in Italy. The first herbarium of the world was established in University of Padua, Italy in 1545, where plant specimens were presented in this way by him. In the same year first Botanic Garden was also established.

The word ‘Herbarium’ was originally applied to a book of medicinal herbs, not to collection of plant specimens. Tournefort in about 1700 used the term as an equivalent to *hortus siccus* (Stearn, 1957), and this use was taken up by Linnaeus who also adopted it as a substitute for *hortus siccus, hortus mortus* and others.

Ancient Greek physician Pedanius Dioscorides wrote a book in the 1st century AD, "De Materia medica" (On medical material), which includes an account of the medicinal use of about 100 plants. During Renaissance this field developed in Italy and Italians start teaching botany and developed the first ever botanical garden. They prepared book of mounted, dried plants specimens and called them "Dry gardens" or "Horti Sicci".

In the prior times the dried plant specimens were mounted on sheets and bound in the form of book till the time of Linnaeus. Today the plants are mounted on single sheet of definite size (i.e., 29 x 42cms. ± 1 cm) and arranged according to any accepted system of classification. The commonwealth countries generally adopt Bentham and Hooker's system of classification. The present concept of herbarium collection alongside detailed field data is also due to the experience of botanists over four centuries.

There are around 3,000 herbaria over 165 countries at present time with an estimated 350 million specimens. A world catalogue of public herbaria, Index Herbariorum, is provided on the web at: http://sweetgum.nybg.org/science/ih/. Each herbarium in Index Herbariorum is assigned an official acronym (code) that is used as a standard for referring to the institution and its specimens.

4.3.1 Kinds of Herbaria

The kinds of herbaria depend upon the contents, purpose, region/place, plant groups etc. There are different kinds of herbaria depending upon the type of holder (Government organisations, individuals, institutional, universities *etc.*), interest, particular plant type (fungi, algae, angiosperm, herb, medicinal, woody *etc.)* and uses (medicinal plants, crops, cultivated plants) *etc.* like following:

(i) Herbaria of Organizations e.g. Herbarium of National Botanical Research Institute (NBRI), Lucknow, Herbarum of Botanical Survey of India (BSI) *etc.*

(ii) Regional Herbaria *e.g.* Herbaria of regional circles of BSI (Botanical Survey of India)

(iii) Local Herbaria and

(iv) Herbaria of institutions, universities, colleges *etc.*

(v) Herbaria of medicinal and aromatic plants.

(vi) Herbaria of crop cultivated plants.

(vii) Herbaria of weed flora *etc.*

4.3.2 Functions of Herbarium

The aim of the herbarium is to accumulate all possible information about all the plants with which it may be concern like habit, habitat, phenology, distribution, ecology and uses in one place. A herbarium may be concerned with a specific area, such as a township, commissionery, district, state, country, or it may attempt to cover a nation, a continent. It may attempt to accumulate all information available about a single taxon, such as a species, or about a few taxa, such as those included in a genus or a family, or it may attempt to contain information about all kinds of plants.

The classification of the world flora is primarily based on herbarium material observation and associated information. More recently, the herbaria have gained importance for sources of information on native, endemic, rare and endangered species and are of primary interest to conservation groups.

A herbarium serves valuable functions or utility in various forms as follows:

1. Repository of plant specimens: the first and most important function of a herbarium is to store dried plant specimens and provide safeguard these against destruction, loss and make them ready for study.

2. Safe custody of type specimens: Type specimens are those specimens in which name of taxa is based thus these are proof material for identification, correct naming and principal proof of the existence of a species or an intra-specific taxon. These are kept in safe custody, often in rooms with restricted access, in several recognised herbaria.

3. Identification of specimens: The majorities of herbaria have a wide-range collection of plant specimens and offer facilities for identification at same place and same time. Researchers can personally identify their collected specimens by comparison with the duly identified herbarium specimens.

4. Resources for compilation of Floras, Manuals and Monographs: Herbarium specimens are the 'original documents' along with necessary information, upon which the knowledge of taxonomy, evolution and plant distribution rests. Floras, manuals and monographs are largely based on herbarium resources.

5. Facilitation centre for taxonomic training and herbarium methods: Many herbaria carry facilities for training young taxonomists, botanists, graduates and undergraduate students in identification, classification, herbarium practices, organizing field trips and even expeditions to remote areas.

6. Information on geographical distribution: Major herbaria have collections from different geographical areas of world along with their details thus, scrutiny of the herbarium specimens can provide information of geographical distribution and range of distribution.

7. Preservation of voucher specimens: Voucher specimens are specimens collected by botanist, researcher and naturalist on which any specialized study has been undertaken. These are later preserved in various herbaria and provide material for further future study.

8. Material for teaching and research: Herbarium acts as teaching aid in botany to graduate and post-graduate students. While teaching a teacher can show herbarium specimens if fresh material is not available at the time of giving the course. It is of essential requirement for biosystematic research *i.e.,* for correct identification and nomenclature besides a source of material. It provides research material for anatomical, palynological and chemotaxonomical studies.

According to Davis and Heywood (1961) "in the herbarium we can compare all the related species of a genus in the same place, in the same state and at the same time".

4.3.3 Making of Herbarium

Herbarium preparation is an art rather than a science; it requires skill, dedication, discipline, enthusiasm and love to plant and nature. Before making a herbarium first question in mind should be what to collect, how to collect and where to collect. The collection of plants began in the 16th century. Later, Tourneforte (ca. 1700, France) used the term herbarium for plants (Bridson and Forman 1999). Plant collections are essentials for taxonomic researches because they serve as voucher specimens. They also help to identify the family, genus and species. A voucher herbarium specimen is a pressed plant sample deposited for future reference. It supports research work and may be examined to verify the identity of the specific plant used in a study. A voucher specimen must be deposited in a recognized herbarium committed to long-term maintenance. More information on herbaria may be found in our web document "Herbaria and Herbarium Specimens". Why is voucher material needed? Plant classification is constantly changing. Shifts in species alignments and groupings are made as new evidence comes to light. Identifications are subject to change. Vouchers specimens help cross reference these changes to previous research. So a herbarium is basically a storehouse of botanical specimens, which are arranged in the sequence of an accepted classification system, and available for reference or other scientific study. Once mounted and deposited in the herbarium, the collections are referred to as herbarium specimens. Such herbarium specimens can be stored for many years and as such they serve as: (i) historical collection, (ii) reference collection for checking the identity of newly collected plants, (iii) as an aid in teaching, and as a source of research material. Taxonomic research therefore, relies upon a collection of reserved plants built up over a long period of time; the herbarium.

Thus plant collection and specimen preparation is first step of herbarium preparation and requires some special materials and instruments. The materials and instruments required for plant collection are:

- i) Vasculum: vasculum for keeping the collected plants and their twigs.
- ii) Plant press.
- iii) Digger/Khurpi: for digging up roots and underground parts.
- iv) Knife: For cutting.
- v) Secateurs (Plant cutter): A pair of secateurs for cutting woody twigs.
- vi) Leather/rubber gloves.
- vii) A pocket lens/magnifying glass.
- viii) Digital camera.
- ix) Forceps.
- x) Blotters or newspaper.
- xi) Corrugated plates.
- xii) Collection bags/Plastic (poly) bags.
- xiii) First aid box,
- xiv) Topographic maps,
- xv) Compass.

xvi) Global Positioning System (GPS)
xvii) Field book
xviii) Note book, pencil, pen *etc*.

Fig 4.1: A vasculum

Fig. 4.2: Plant press

Fig. 4.3: Pocket Lens

Fig. 4.4: Knife

Fig.4.5: Khurpi

Fig. 4.6: Secateurs

Fig. 4.7: Compass

Fig. 4.8: GPS

Fig. 4.9: Gloves

4.3.4 Herbarium Technique

The herbarium technique or specimen preparation involves following steps:

1. Collection
2. Pressing
3. Drying
4. Poisoning
5. Mounting and stitching
6. Labeling and
7. Deposition

1. Collection

First step of herbarium preparation is collection. A herbarium specimen to be collected should be complete as possible and represent whole plant. Herbs and small shrubs up to 2-3 ft. tall should be collected in flowering condition, along with leaves and roots. The specimen should represent all parts of the root system as well as rhizomes, stolons, or tubers, if any, basal leaves, cauline leaves, any leaves or bracts in the inflorescence, and of course flowers and/or fruits. Large shrubs and trees should be represented by a twig or small branch bearing three or more adjacent leaves, or at least leaf bases, so as to show their arrangement. It must bear flowers and/or fruits. Material without flowers or fruits should be collected only if it has some unusual value or significance. There are, in general, two techniques of collecting specimens: (i) by use of vasculum, the other uses the so-called field press. Now a day's it is in culture use of polyethylene bags as a substitute for a vasculum. (ii) Field press consists of two lightweight press frames, hinged along one side with two short straps and the straps around the body of the press to keeps it closed and apply pressure on specimens thus specimen becomes flattened.

2. Pressing

Each specimen should be composed of material to fit within the dimensions of a standard herbarium sheet (29 x 42cms). When collecting small herbs, several should be collected, so as to fill a folded sheet of newspaper, and later a standard herbarium sheet. The specimens should be placed in the field press at the first opportunity, either directly after collection, or sometimes after a temporary storage in vasculum or a polythene bag. A larger size specimen of herb or shrub may have its main axis variously bent into a "V", N", or even an "M" to fit a fold of paper. The bulky fruits may be thinly sliced with the help of sharp knife and then pressed. Some special groups of plants such as conifers, aquatic plants, succulents and mucilaginous plants causes problems during collection and need special methods for their pressing. *Aroids* and bulbous plants continue to grow in a press even after they have presumably been properly pressed and dried. These should be killed with ethyl alcohol and formaldehyde or chloroform prior to pressing.

3. Drying: For drying specimens two methods are used:

(a) Natural Drying: Drying of pressed plant specimens is a slow process and it is time consuming and tedious especially in humid and rainy areas. Generally specimens are dried naturally by changing blotting papers continuously but in some cases artificial heat may also be used. Drying may take up to weeks or months for complete drying. The plants, freshly collected, are placed in a press without corrugated sheets and the press is locked for 4 hours. During this sweating period, plants lose some moisture, become flaccid and can be easily rearranged. The folded sheet containing the specimen is lifted and placed in a fresh dry folded blotter. The changing of newspaper is mandatory after intervals; the plant should be carefully transferred from one newspaper to another. The use of a blotter in such a case can be dispensed with, especially after one or two changes. The change of blotters or newspaper sheets is repeated every 4-8 hours initially and few days later, increasing the interval between the changes successively until the specimens are fully dried. The whole process of drying may take about 10 days to one month, depending on the specimens and the climate of the area. All these blotters/newspaper are placed between two wooden frames of plant press and pressed tightly together by two straps.

(b) Drying with Artificial Heat: Drying with the help of artificial heat takes 12 hours to two days. The specimens, after the initial sweating period in the field press, are transferred to a drying press, in the ample number of corrugated sheets, usually one alternating every folded blotter containing one specimen. The press is kept in a drier, a cabinet in which a heat lamp, dry hot air blower or electric bulb warms the air, drying the specimens by movement through corrugates. Use of a hot air blower in the cabinet speeds up circulation of the hot air and, consequently, faster drying is achieved. The rapid drying of specimens using artificial heat has limitations of rendering plants brittle, loss of loom and some colour change in leaves.

4. Poisoning

The specimens need poisoning to keep away insects, paper borer, silver fish and fungus attack. This is normally done when the specimens are partially dehydrated or dried. There are several methods of treating specimens making them either permanently poisonous or unpalatable to herbarium pests. Specimens may be poisoned by dipping or painting them with an alcoholic solution of mercuric chloride ($HgCl_3$). Another method employs lauryl pentachlorphenate (a 3.75% solution of LPCP in pure white kerosene free from high boiling paraffins).

5. Mounting and Stitching

The dried specimens are mounted on herbarium sheets of standard size (42 x 29 cm). Mounting is done with the help of saresh glue, fevicol, fixatives, adhesive or cello-tape. The bulky plant parts like dry fruits seeds, cones, *etc.* are dried without pressing and are put in small envelops called fragment packets. Succulent plants are not mounted on herbarium sheets but are collected in 4% formalin or FAA (Formalin Acetic acid and Alcohol). Most of the contemporary specimens are fixed using liquid paste or glue. Except where strapping is the only process, most specimens, after gluing, are strapped in some manner-linen tape, liquid plastic, white glue, and/or sewing with a heavy linen thread. Sewing is restricted to heavy stems, overlapping leaves, rhizomes, matted bases of grasses, large fruits, cones or heads, or other places where the use of plastic or glue is impossible or impractical. Threads on the back of sheets should be covered with linen or paper tape.

6. Labelling

A label is pasted or printed on the lower right hand corner. The label should indicate necessary information recorded about the flora of, locality, altitude, habit, date of collection, name of collector, common name, complete scientific name, uses and any special note, *etc.* The size of a herbarium label may vary but the recommendation is of 4x6 inches (10-15cms).

7. Deposition of mounted specimens

Mounted, labelled and treated specimens are finally deposited in a herbarium, where they are properly stored and looked after.

8. Storage

Properly dried, pressed and identified plant specimens are placed in thin paper folds (specimen covers) which are kept together in thicker paper folders (genus covers), and finally they are incorporated into the herbarium pigeon-holes in their proper position according to any accepted system of classification. In India Bentham and Hooker's system of classification is followed.

LARGEST HERBARIA IN THE WORLD				
S. No.	**Name**	**Location**	**Year Established**	**Number of Specimens (approximate)**
1.	Museum National d'Histoire Naturelle	Paris, France	1635	8,877,300
2.	Royal Botanic Gardens	Kew, England	1841	6,000,000
3.	New York Botanical Garden	New York, U.S.A.	1891	6,000,000
4.	Komarov Botanical Institute	St. Petersburg, Russia	1823	5,770,000
5.	Swedish Museum of Natural History	Stockholm, Sweden	1739	5,600,000
6.	The Natural History Museum	London, England	1753	5,300,000
7.	Conservatoire et Jardin Botaniques	Geneva, Switzerland	1824	5,200,000
8.	Harvard University	Cambridge, Massachusetts, U.S.A.	1864	5,000,000
9.	Smithsonian Institution	Washington, D.C., U.S.A.	1848	4,858,000
10.	Institut de Botanique	Montpellier, France	1845	4,368,000
Source: Data from P. N. Holmgren, Index Herbariorum, 8th ed. (New York Botanical Garden, 1990), Index.				

4.4 FLORA

Flora is sum totality of plant species, irrespective of number of particular found in a particular geographical area. In general flora is list if total plant species found in particular geographic region and does not depend on the strength of any particular species. In flora description of plants are arranged according to any accepted system of classification. Thus flora is systematic study of plants. Thus in nutshells “Flora is a systematic account of plant species of a defined geographical area at a time period and provides keys and descriptions of plants for identification”. The word "flora" comes from the Latin name means "flower", the Roman goddess of spring and flowering plants, fertility in Roman mythology especially wild flowers and plants not raised for food. The common phrase "flora and fauna" covers just about every visible living thing *i.e.* biota.

Primarily ‘Flora’ helps in identification of species. It also provides other data like local or vernacular name, distribution, botanical name used, description of a particular plant. The flora contains description and other details of the plants of the region, *i.e.*, it is listing of plants of the region or area. Floristics is the descriptive term used to refer to an investigation of the flora. Flora is a book means for identifying the plants using descriptive keys. An identification key, also known as a taxonomic key, is a useful tool for identifying unknown plants. Keys are constructed so that the user is presented with relevant information in a structured form. This allows to skip over the many species that do not possess certain characters and is supposed to lead the user to a correct identification with a minimum number steps. Thus taxonomic keys are useful tools guiding researchers towards the known name of taxon. However, all taxonomic keys are not created equally. They are often created on a regional level or for a particular group of plants.

Steps of Flora Writing

1. First step of flora writing is selection of area, e.g., Continent (Flora Indica), huge area like Himalaya (*Flowers of the Himalaya* by Polunin and Stainton, 1997), District (*Flora Nainitalensis* by R.K. Gupta, 1968) or division/comissionary (*A Forest Flora for Kumaon* by Osmaston, 1927), *etc.*
2. Get all relevant information about the area like topography, environment, and detailed account of ecology of the area (e.g., temperature, rainfall, major habitats, irrigation, soil nature, physiographic regions, *etc.*)
3. Identify climatic zone of selected area e.g. tropical, sub tropical, temperate, alpine *etc.* or micro-habitats within the area.
4. Conduct extensive field survey for study of vegetation and collection trips in all season because plants have different phenology in different seasons.
5. Field book should be maintained for the plants collected including its field number and description, local name, phenology, uses, ecology *etc.*
6. All collected specimens to be identified with the help of experts, identification keys, regional and local flora. The identity of specimens to be confirmed by matching it with authentic sheets in any regional herbarium.
7. Nomenclature of the species with the help of monograph, flora with the names which are confirmed by ICN (Formerly ICBN).
8. Provide identification keys for all families, genera and species.
9. Description of the species should be in accordance with proto-logue and the actual specimen collected from the area.
10. New species found, if any, should be described according to norms of ICN.
11. Arrange families according to an accepted system of classification in the flora. It was Bentham and Hooker’s system in commonwealth countries.

4.5 HISTOLOGICAL TECHNIQUES

Plant histology is the branch of botany (more appropriately Anatomy) concerned with the composition and structure of plant tissues (specially wood and floral anatomy) in relation to their specialized functions. The aim of histology is to determine how tissues are organized at all structural levels, from cells and intercellular substances to organs. It provides a realistic interpretation of morphology, physiology, and **phylogeny** of the structure of cells and tissues. Thus histology provides most critical evidences to solving phylogenetic problems of plant species. The matter was given importance in the VIIIth International Botanical Congress (IBC) held at Paris of France in 1954. A variety of techniques are needed for histological study of plants and their specific tissues. This task is done by using various fixatives, use of microtome for preparing thin sections, staining, microscopy (light, fluorescence and electron microscopy) and X-ray diffraction techniques, *etc.* To study tissues, the specimens are generally sliced into thin sections then dyed with specific stains to contrast within tissues or heavy metals, or fluorochromes. Specific stain has an affinity for a particular cell type or tissue element (for e.g. xylem takes acidic stain like fast green), or by the use of specific probes, such as radio or enzyme-labeled antibodies or RNA or DNA probes (FISH and GISH techniques). The basic equipment required of histological studies is: glass vials, rotator/shaker, hotplate, glass slides, cover slips, and basic reagents are: distilled water, fixatives, stains/dyes, histoclear, ethanol, mounting media *etc.* The main stages in the preparation of histological slides are: (i) fixation (ii) dehydration (iii) clearing (iv) sectioning and (iv) staining.

Many a times use of histological tool in taxonomy is limited but it may be useful in solving phylogenitic problems by using some specific tissues like, vascular bundles arrangement, presence or absence of endosperm, cotyledon count, stomata types, vein arrangement *etc.* For example, formerly it was considered that monocots constitute a monophyletic group derived from Ranalian stock. Alismataceae was thought to be primitive family of monocots but histology proves that Alismataceae bears paracytic type of stomata in contrast to Ranunculaceae having anomocytic type of stomata. The metaxylem of Ranunculaceae has simple pitted vessels while that of Alismataceae have tracheids instead of vessels. The spongy parenchyma in members of aquatic Ranunculaceae made up of loosely arranged cells unlike those of Alismataceae. But on basis of phylogeny tracheids are primitive than vessels, thus theory does not fit on that Alismataceae is derived from Ranunculaceae.

The use of histological tool in taxonomy is tedious, skilled job and time consuming, thus used restrictedly by taxonomists. But advancement of instrumentation like sophisticated microscopy, microtomy, computerised machinery may be boon for phylogenetic classification.

4.6 CYTOLOGICAL TECHNIQUES

Cytology and genetics are related to each other and constitute a branch cytogenetics. Cyto-taxonomy is a branch of systematic botany dealing with the classification and relationships among plants by using detailed studies of chromosomes and their behavior. The properties (number/ploidy level, structure, and behavior) of chromosomes play significant value in taxonomy, because the ploidy level of chromosome being the most widely used and quoted character in botany. Chromosome numbers are mainly determined at metaphase and quoted as the diploid number (2n) for somatic cells and haploid (n) for gametes. Another important taxonomic character is the position of the centromere on chromosomes. Cytological data is significant than other taxonomic evidences.

The application of cytological data in elucidation of taxonomic problems, it is seen that various attributes of chromosomes like ploidy, morphology and behaviour in crosses and aberrations in reproduction are all important. About 35 to 40% per cent of the flowering plants are polyploids.

It is usually seen that closely related plants, like the different species of a genus, show chromosome numbers which reveal an arithmetic relation with one another – often in multiples of base number of characteristics of the genus. For example the different species of *Piper* show chromosome numbers in multiples of 26, like 2n = 52 in *P. nigrum*, 2n = 78 in *P. betle*, and 2n = 104 in wild species of *Piper* according to Mathew (1958). *Solanum nigrum* (Fam. Solanaceae) is a good example of the existence of a species complex, comprising diploid (n = 12), tetraploid (n = 24) and hexaploid (n = 36) forms.

The behaviour of chromosomes in crosses is a reliable factor in assessing relationships. For example karyotype analysis of various species of *Aegilops*, *Secale* and *Triticum*, suggesting that the hexaploid *T. spelta* and *T. vulgare* were probably derived through hybridisation between a tetraploid wheat. Another example of the karyotype analysis is the species of *Aegilops*, Cheenaveeraiah (1960) postulated that the section *Sitopsis* should be shifted from *Aegilops to Triticum* or given the rank of a new genus.

According to Datta (1988) "Despite a healthy scepticism of the value of the chromosomes in easing taxonomic decision- making, the annual outpouring of cytological data continues to illuminate the taxonomic study of many groups. With increasing knowledge the chromosomes will further reflect the manifold ways in which evolution has proceeded and will thus become an increasing refined tool, among the many available to the discriminating taxonomist".

4.7 PHYTOCHEMICAL TECHNIQUES

Phytochemistry is the approach of taxonomy in which chemical characters of plants are used in solving taxonomic problems and classification and called Chemotaxonomy (*sesu lato*) or chemosystematics or chemical plant taxonomy. Chemotaxonomy is based on the assumption that similar or related group of plants have similar chemistry. Thus phyto- chemistry plays a key role in identification and systematic botany. It gives the close relationship between chemical constituents of plants and their taxonomical status.

All the living organisms produce secondary metabolites that are derived from primary metabolites. The chemical structure of the secondary metabolites and their biosynthetic pathways is often specific and restricted to taxonomically related organisms and hence useful in classification. This method of classification is considered better in comparison to traditional method due to the ease of working methodology. According to De Candolle (1816) :1) plant taxonomy will be the most useful guide to man in his search for new industrial and medicinal plants; and 2) Chemical characteristics of plants will be most valuable to plant taxonomy in the future. In Lichen taxonomy chemical methods play a key role and used for identification of taxa at their generic and species level. But there is a controversy among lichenologist as some morphologically similar lichens have chemically different characters and these known as “chemical strains” and not as different species.

Three broad categories of compounds are used in chemotaxonomy: **Primary metabolites; secondary metabolites and semantides.**

Primary metabolites are the compounds that are involved in the fundamental metabolic pathways. These compounds are ubiquitous in nature and hence play minor role in chemotaxonomy as tool. However, these molecules sometimes serve as useful chemotaxonomic tool on the basis of their quantities. For *e.g.* sedoheptulose is present in genus *Sedum*, thus o sedoheptulose serves a identification tool in species of genus *Sedum.*

Secondary metabolites are the compounds that usually perform non-essential functions in the plants. They play protection and defense role against predators and pathogens. These compounds are of restricted occurrence and hence very useful for chemotaxonomic classification. According to smith (1976) phenolics, alkaloids, terpenoids and non-protein amino acids, are the four important and widely exploited groups of compounds utilized for chemotaxonomic classification except these carotenoids, tannins, flavanoids, betalins, anthocyanins, glucosinolates, fatty acids, and oils are basic compounds used in taxonomy. Hegnauer (1986) demonstrated that these groups of compounds exhibit a wide variation in chemical diversity, distribution and function. According to Atal (1982) the system of chemotaxonomic classification relies on the chemical similarity of taxon.

Semantides or semantophoretic molecules are macromolecules that carry phylogenetic information about evolutionary history and classified into three categories: the genes themselves are known as 'primary semantides', the mRNA transcripts 'secondary semantides', and polypeptides 'tertiary semantides'. The macromolecules chosen are usually common to all cells, used in phylogenetic studies and yield different phylogenetic trees, because they change slowly over time. Examples of semantides are: DNA, RNA, nucleases, ATPase, Rec proteins (involved in genetic recombination), Cytochrome-C, Heat shock protein (Hsp) genes, *etc.*

4.8 SEROLOGICAL TECHNIQUES

Serology is the branch of biology, which is concerned with the nature and interactions of antigenic material and antibodies. Smith (1976) defined it as "**the study of the origins and properties of antisera**." When foreign cells or particles (antigens) are introduced into an organism, antibodies are produced in the blood (antiserum). The substance capable of stimulating the formation of an antibody is called antigen and the highly specific protein molecule produced by plasma cells in the immune system in response to the antigen is called antibody.

Proteins most widely used as antigens in sero-taxonomy are those, which carry useful taxonomic information and are easy to handle. Both structural and reserve proteins can be used in the field of systematics, as long as they belong to the same group and the same organs are always compared. Generally, storage proteins are most amenable for taxonomic studies followed by pollen proteins. Stem tubers, algal cells, fern spores, fruits and leaves can also be employed as satisfactory antigenic materials for systematic investigations.

Phyto-serology, which deals with immunochemical reactions, between serum antibodies and antigens, has also established itself as a valid method in systematics, because it helps to detect homologous proteins. It uses the specific properties of antisera produced by animals against plant proteins as characters to assess plant relationships. Sero-taxonomy developed and became popular in Germany, which has been an active center since the long past. Nuttal was the first person to compare the immunochemical specificity of serum proteins for systematic purposes. Kowarski, Bertarelli and Magnus were the other early notable serologists, who compared proteins from various grass and legume species, showing similarities and differences. As a result of this conflict, there was a decline of serology in Germany. Later, Otto Moritz gave a critical new start to phyto-serology in the 1950s, and plant serology has now been established as a valid method in systematics.

In sero-taxonomy method, a crude protein (antigen) extract of a particular plant is injected into the blood stream of an experimental animal, usually a rabbit or a rat, to develop antibodies. In response to the specific antigen injected, a specific antibody is produced in the blood of the animal. The serum now termed the antiserum containing the antibody is then collected and made to react *in vitro* with the antigenic proteins as well as proteins from other related taxa, of which the affinities are in question. Serological reactions between antibody-antigen results in the formation of a precipitate (agglutination). Kraus (1897) showed that this reaction indicates similarity of antigens. The degree of protein homology is determined by the amount of precipitation and hence is taken as a phylogenetic marker/tool and taxonomic character. Serological studies using crude plant protein extracts have been widely used in elucidating the taxonomy of a wide variety of higher-level taxa and in estimating phylogenetic relationships.

Some serological methods which are commonly used are:

(1) Immuno diffusion: Immuno diffusion in gels (Agarose gel) are two types:

(a) Single radial immune-diffusion: In this technique, the antigen is usually allowed to diffuse into the gel containing the antiserum.

(b) Ouchterlony-double immune-diffusion: Both the antigen and antibody are allowed to diffuse into the gel and meet each other.

(2) Rocket Immuno-electrophoresis

(3) Enzyme-Linked Immunosorbant Assay (ELISA): Indirect ELISA, Sandwitch ELISA, competitive ELISA *etc.*

4.9 BIOCHEMICAL TECHNIQUES

Biochemical or biochemistry is the approach of taxonomy in which characteristics of plant biochemical are used in solving taxonomic problems and classification. Bochemistry (*sesu stricto*) is a branch of chemotaxonomy or chemosystematics or even molecular systematics (*sesu lato*). Biochemical techniques are based on assumption that similar or related group of plants have similar biochemistry or similar biochemicals they contain. Thus biochemicals of plants play a key role in identification and systematic botany. Similar biochemicals provide the close relationship (phylogeny) between plants and their taxonomical status. The basic biochemicals used in taxonomy are: (i) micro-molecules and (ii) macro-molecules.

(i) Micro-molecules: Micro-molecules are relatively low molecular weight compounds like alkaloids, phenolics, glucosinolates, glucosides, terpenoids, *etc.* Micro-molecular data provides practical utility in taxonomic problems of taxa at the generic level or below taxa. Micro-molecules have been used to study variations caused by natural hybridization as well as other problems:

(ii) Macro-molecules: Macro-molecules are compounds of high molecular weight (> 1,000) like proteins, DNA, RNA, Cytochrome c, ferridoxin complex, polysachharides, *etc.* Macro-molecular data has been treated as character used in classification. Macro-molecular data is most helpful when applied to solving phylogenic problems of taxa above generic level.

4.10 MOLECULAR TECHNIQUES

Use of molecular techniques as taxonomic tool is a recent advancement in field of taxonomy. Rapid advancement in molecular biology of plants influenced taxonomists in this respect. The considerable change in plant classifications happened since the highly informative results obtained by the molecular taxonomists through DNA sequence analyses of chloroplast rbcL gene and nuclear rRNA gene. Data obtained from these, together with morphological and other data from the other tools of taxonomy have made great change in the field of taxonomy. Before reviewing the most recent works in this field, Rieseberg and Soltis (1991), Doyle (1992) pointed that the gene trees are mostly based on single gene whether of chloroplast or nucleus chromosomes and that most molecular trees based on sequence data, no matter how parsimonious, are single-character trees. This means that the phylogenetic trees derived from molecular data only will be taken with precaution. Only phylogenetic trees derived from molecular data which are congruent with macromolecular ones, we can accept such approach as a significant new tool for phylogeny. The direct application of the molecular parameters as taxonomic feature is relatively less developed. The first generation of DNA markers were the still widely-used restriction fragment length polymorphisms (RFLP), identified by endonuclease restriction and blot hybridization of DNA with single locus probes. Higher heterozygosity levels could be achieved by studying minisatellite (variable number of tandem repeats - VNTRs) and microsatellite (short tandem repeats - STRs) markers through either single locus or multilocus probing of digested and blotted DNA. Hybridization with these latter probes determines a unique pattern, a DNA fingerprint, owing to the virtually innumerable combinations of different allele lengths at each of the different loci sharing sequence homology.

DNA Profiling/Finger Printing

DNA profiles are most widely used in molecular taxonomy in modern days. Intra-specific variation can be detected easily by using DNA sequencing technique. DNA profiling offers the most unambiguous and reliable basis for phylogenetic as well as systematic consideration. Eukaryotic genome has a variety of sequence types including various claims of highly repetitive or satellites, moderately repetitive and non-repetitive types or unique sequences. A microsatellite is a simple DNA sequence which is repeated several times across various points in the DNA of an organism. These repeats are highly variable and these loci can be used as markers. The methods which reveal specific DNA sequence and their distribution patterns over genome are generally known as DNA profile methods. The important DNA profiling methods are DFP (DNA finger printing) and MAAP (Multiple Arbitrary Amplicon Profiling).

DNA finger printing/profiling is a useful molecular technique used for identification of taxon at genetic level and determination its genotype. It is possible to trace gene-flow amongst individuals in the population or gene pool and to establish genetic relationship among individuals. Individual genotype can be identified at molecular level on the basis of an extremely high level of polymorphism in the sequence of its DNA. DNA finger printing adequately describes intra-population genotype distribution. The trials on Internal Transcribed Spacer (ITS) regions of ribosomal DNA (rDNA) have been utilized for the identification of several fungi and plant species in modern days. According to Nybom (2004) it is difficult to analyse inter-population and interspecific genetic variation. DNA based molecular markers are applied in various aspects on taxonomy to analyse genetic identity, genetic relatedness among species of populations, phylogenetic relations.

MAAP (Multiple Arbitrary Amplicon Profiling)

Multiple Arbitrary Amplicon Profiling (MAAP) uses one or more oligonucleotide primers (>or=5nt) of arbitrary sequence to initiate DNA amplification and generate characteristic fingerprints from anonymous genomes or DNA templates. MAAP markers can be used in general fingerprinting as well as in mapping applications, either directly or as Sequence-characterized amplified regions (SCARs). Caetano-Anolles (1994) described MAAP (Multiple Arbitrary Amplicon Profiling) collectively for three versions, *i.e.*, RAPD (Randomly Amplified Polymorphic DNA), Ap-PCR (Arbitrarily-primed PCR) and DAF (DNA Amplification Finger Printing) *etc.* In recent time such molecular markers are identified including hybridization and PCR based markers as: Microsatellites, Minisatellites, MP-PCR, ISSR, STS, STMS, SCAR, DAF, RFLPs AFLP, *etc.*

4.11 COMPUTER AND GIS

A Geographic Information System (GIS), or sometimes referred to as a Geospatial Information System is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. According to Rajat (2013) Geographical Information Technology is the beautiful application of information technology which manages the information about places by mapping and analyzing the earth's feature. It is all about understanding and utilizing the earth by linking databases and maps. Whether it is agriculture, natural resource management, planning and economic development, education, etc., GIS is used everywhere in modern sense. According to Bolstad (2005) GIS is a computer system capable of integrating, storing, editing, analyzing, sharing and displaying geographically referenced information, *i.e.* computer-based tool for mapping and analyzing geographic phenomenon that exists and events that occur on earth. GIS technology coordinates common database operations such as queries and statistical analyses with the unique visualization and geographic analysis benefits offered by maps. These unique abilities distinguish GIS from other information systems and makes it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. Map making and geographic analysis are not new, but a GIS performs these tasks faster and with more sophistication than do traditional manual methods.

Components of a GIS

An operational GIS has a series of components that combine to make the system work. These components are critical to a successful GIS. A working GIS integrates five key components:

1. Hardware
2. Software
3. Data
4. People
5. Methods

The latest technique used as a tool in biosystematics is remote sensing and the use of computer. Remote sensing is carried out by satellites to get an idea of the particular phytogeographical area. It was first used in 19th century by using camera. But now the technology is well developed and pictures are provided by the satellites. Geographical Information System gives the information about an area. Computer and software is required for interpreting results. A Geographic Information System (GIS) captures, stores, analyzes, manages, and presents data, which is linked to a location. It includes mapping software and its application with remote sensing, land surveying, aerial photography mathematics, photogrammetry, geography, and tools that can be implemented with GIS software.

4.12 TAXONOMIC HIERARCHY

Taxonomic hierarchy is the arrangement of various categories in successive levels of the biological classification. Each of this level or hierarchy is called as the taxonomic category or rank. Taxonomic hierarchy categories were introduced by Linnaeus thus also known as Linnaean hierarchy. Linnaeus first used only five categories-class, order, genus, species and variety. These were sufficient to serve the needs of biological diversity in the late 18the century but were quite insufficient to classify the increasing number of species discovered since 1758. As a result, the last one category was discarded and three more categories added so that now there are seven obligate categories *i.e.*, **Kingdom, Division or Phylum, Class, Order, Family, Genus and Species.** The botanists use Division in place of Phylum as a category in the classification of the plant kingdom. Hierarchy is defined as sequence of categories in a decreasing or increasing order from kingdom to species and vice versa. Kingdom is the highest taxonomic rank of classification followed by division, class, order, family, genus and species. Species is the lowest rank in the hierarchy and regarded as the basic unit of classification. The hierarchy has two categories or ranks which are: (i) obligate and (ii) intermediate. Obligate ranks are those followed strictly and range from kingdom to species as described above. Intermediate ranks are not followed strictly and they are described as sub- prefix and intermediate of successive categories such as sub-division, sub-family, sub-class, sub-order, sub-species *etc.* The descending hierarchy of kingdom plantae is as follows:

1. **Kingdom**
2. **Division**
3. **Class**
4. **Order**
5. **Family**
6. **Genus**
7. **Species**

1. Kingdom: The top most taxonomic category is kingdom. For example all plants are included in Kingdom Plantae.

2. Division: It is a term used for plants while its synonym phylum is used for animals. It is a collection of similar classes. Division Angiospermae or Magnoliophyta includes all flowering plants.

3. Class: One or more than one orders which share a few similarities form a Class. Class Ebenaceae Ericaceae, Primulaceae, Theaceae are grouped under same order Ericales.

4. Order: One or more than one similar families constitute order. The classification starting from order has less similarities as a result, they are categories based on aggregates of characteristics. A group of families showing somewhat few similarities forms an order.

5. Family: It is defined as group of similar genera. This category of taxonomy comprises of a number of genera which share some similarity among themselves. However, the number of similarities decreases compared to species and genus. It can be separated from genera by reproductive and vegetative features. For example, *Rhododendron arboreum, R. campanulatum, anthopogon, R. barbatum* are included in the same family Ericaceae.

6. Genus: It is defined as group of similar species. This taxonomic group composes of multiple species which have similar characteristics but different from that of species from other genus. But it is not mandatory that a genus have many species. Some genera have only one species known as Monotypic genus. If there are more than one species it is known as polytypic. For example *Rhododendron arboreum, R campanulatum, R anthopogon, R barbatum* are species of genus *Rhododendron* found in growing Uttarakhand Himalaya.

7. Species: It is the lowest level of classification and shows the high level of similarity among the organisms. Generally one species can be distinguished from other closely related species based on distinct differences in morphology e.g., in *Rhododendron arboreum* is a species of genus *Rhododendron*. Group of similar species forms population.

4.13 SUMMARY

1. Taxonomy is a branch of science that encompasses the identification, nomenclature, and classification of organisms.
2. Taxonomic tools or aids are techniques, procedures and stored information that are useful in identification and classification of organisms.
3. Herbarium, botanical gardens, museum, zoological parks (zoos) and keys are important tools used in identification of plants and animals.
4. Now a days as science and technology achieve advancement in every field, taxonomists also merely not depend upon traditional tools but advance and sophisticated tools like phytochemistry, serology, histology, cytology, numerical taxonomy, or computerised data analysis and many other techniques are boosting their work.
5. The most recently included in this list are GIS (Geographical Information System), DNA barcoding and molecular techniques, nucleotide sequencing *etc*.
6. Herbarium is a store house of plants specimens where plant specimens are collected from far and wide, preserved in dried condition mounted on a standard size of herbarium sheet.
7. The attempt of Herbarium preparation was done about 500 years ago by an Italian taxonomist Luca Ghini in late fifteenth century till sixteen century (1490-1556).

8. Today the plants are mounted on single sheet of definite size (i.e., 29 x 42cms. ± 1 cm) and arranged according to any accepted system of classification.
9. The aim of the herbarium is to accumulate all possible information about all the plants with which it may be concerned like habit, habitat, phenology, distribution, ecology and uses in one place.
10. The classification of the world flora is primarily based on herbarium material observation and associated information.
11. Flora is sum totality of plant species, irrespective of number of particular found in a particular geographical area.
12. Primarily Flora helps in identification of species. It also provides other data like local or vernacular names, distribution, botanical names used, and description of a particular plant.
13. An identification key, also known as a taxonomic key, is a useful tool for identifying unknown plants.
14. Keys are constructed so that the user is presented with relevant information in a structured form.
15. Plant histology is the branch of botany (more appropriately Anatomy) concerned with the composition and structure of plant tissues (specially wood and floral anatomy) in relation to their specialized functions.
16. Many a times use of histological tool in taxonomy is limited but it may be useful in solving phylogenitic problems by using some specific tissues like, vascular bundles arrangement, presence or absence of endosperm, cotyledon count, stomata types, vein arrangement *etc.*
17. Cytology and genetics are related to each other and constitute a branch cytogenetics. Cyto-taxonomy is a branch of systematic botany dealing with the classification and relationship among plants by using detailed studies of chromosomes and their behavior.
18. DNA finger printing is a useful molecular technique used for identification of taxon at genetic level and determination its genotype.
19. A Geographic Information System (GIS), or sometimes referred to as a Geospatial Information System is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth.
20. The latest technique used as a tool in biosystematics is remote sensing and the use of computer.
21. Taxonomic hierarchy is the arrangement of various categories in successive levels of the biological classification.
22. Each of this level or hierarchy is called as the taxonomic category or rank. Taxonomic Hierarchy categories were introduced by Linnaeus thus also known as Linnaean hierarchy.
23. The hierarchy has two categories or ranks which are: (i) obligate and (ii) intermediate. Obligate ranks are those followed strictly and range from kingdom to species.
24. The descending hierarchy of kingdom plantae is as: **Kingdom, Division-Class-Order, Family-Genus-Species.**

25. Intermediate ranks are not followed strictly and they are described as sub- prefix and intermediate of successive categories such as sub-division, sub-family, sub-class, sub-order, sub-species *etc.*

4.14 GLOSSARY

Chemotaxonomy: Solving taxonomic problems and classification on the basis of chemicals found in particular taxon.
Class: A taxonomic rank which comprises one or more than one orders which share a few similarities.
Cytology: Branch of science that deals with cellular structure and behavior.
Division: A taxonomic rank used for plants (synonymous phylum in zoological classification), which comprises a collection of similar classes. Division Angiospermae or Magnoliophyta includes all flowering plants.
Family: A taxonomic rank which comprises group of similar genera.
Flora: Sum totality of plant species of particular geographic region.
Genus: A taxonomic rank which comprises one or more than one of similar species.
Global Positioning System (GPS): A satellite based radio-navigation system that provides location and time information in all weather conditions, anywhere on the earth.
Herbarium: Store house of dried plant specimens for future study.
Inflorescence: Arrangement of flowers on inflorescence axis.
Kingdom: The top most taxonomic category, i.e. Kingdom Plantae includes all plants.
Nomenclature: Science of giving precise name to organisms.
Palynology: Science related to study pollen morphology.
Phenology: The scientific study of periodic biological phenomena, such as flowering, breeding, leaf fall and migration, in relation to climatic conditions.
Phylogeny: Evolutionary history of species or group.
Secateurs: A cutting instrument used during field collection of plant specimens by botanists.
Serology: Branch of biolog related to *in vitro* of antigen-antibody interactions.
Sesu lato: In broad sense.
Sesu stricto: In narrow sense.
Species: Basic rank of classification.
Taxon: A taxonomic group of any rank, such as a species, family, or class.
Taxonomy: Arrangement according to rules.
Vasculum: A container used by botanists during plant collection, typically in the form of a flattened cylindrical metal case, carried by a shoulder strap.
Order: A taxonomic rank which comprises one or more than one similar families.

4.15 SELF ASSESSMENT QUESTIONS

4.15.1 Multiple choice questions (MCQs):

1. The term 'taxonomy' was coined by:

(a) De Candolle (b) Linnaeus
(c) Hooker (d) Theophrastus

2. Taxonomy means:

(a) Giving name (b) Arranging by rules
(c) Identification (d) None of these

3. The term 'taxon' refers to:

(a) Any living organism (b) Species
(c) Genus (d) All of these

4. The term *hortus siccus* is equivalent to:

(a) Herbarium (b) Museum
(c) Garden (d) Arboreum

5. The Kew Herbarium is located in:

(a) England (b) Padua
(c) Paris (d) Kolkata

6. The attempt of Herbarium preparation was done by:

(a) Luca Ghini (b) Linnaeus
(c) Tournfort (d) De Candolle

7. The basic rank of taxonomy:

(a) Genus (b) Species
(c) Phylum (d) Kingdom

8. The arrangement of various categories in successive levels of the biological classification called:

(a) Hierarchy (b) Taximetrics
(c) Systematics (d) Phylogeny

9. If a taxon ends with suffix –aceae it denotes:

(a) Family (b) Class
(c) Order (d) Division

10. Group of similar species forms:

(a) Population (b) Family

(c) Genus (d) Order

11. The top most taxonomic category is:

(a) Division (b) Domain

(c) Kingdom (d) Phylum

12. The sub-family is:

(a) Obligate rank (b) Intermediate rank

(c) Both (a) and (b) (d) None

13. The dimensions of a standard herbarium sheet:

(a) 29 x 42cms (b) 29 x 42 inches

(c) 16 x 11cms (d) 16x11 feet

14. National Botanical Research Institute (NBRI) is situated at:

(a) Lucknow (b) Kolkata

(c) Delhi (d) Dehradun

15. *Rhododendron arboreum* belongs to family:

(a) Ericaceae (b) Fagaceae

(c) Rhamnaceae (d) Ulmaceae

4.15.2 Fill in the blanks:

(1) _________ is a store house of plant specimens, mounted on a standard size of herbarium sheet.

(2) The standard size of herbarium sheet is ______________cm.

(3) Largest herbarium of India is situated at ____________.

(4) The northern regional circle of BSI is situated in _____________ .

(5) _____________is the arrangement of various categories in successive levels of the biological classification.

(6) One or more than one orders which share a few similarities forms a ___________.

(7) ____________ is a vessel used for collection of plant specimens during collection trip.

(8) ___________is sum totality of plant species, irrespective of number of particular found in a particular geographical area.

(9) First herbarium of the world was established in University of ___________in 1545.

(10) _______________is defined as the branch of biology, which is concerned with the nature and interactions of antigen-antibody.

4.15.3 True or False:

(1) Taxonomic Hierarchy is also known as Linnaean hierarchy.

(2) First step of herbarium preparation is mounting.

(3) Flora is sum totality of plant species, irrespective of number of particular found in a particular geographical area.

(4) One or more than one orders which share a few similarities forms a Class.

(5)The hierarchy has two categories or ranks: (i) obligate and (ii) intermediate.

(6) Sub- family is obligate category in taxonomic hierarchy.

(7) A Geographic Information System (GIS) captures, stores, analyzes, manages, and presents data, which is linked to a location.

(8) Herbarium of National Botanical Research Institute (NBRI), situated in Delhi.

(9) In Indian herbaria specimens are arranged according to Bentham and Hooker's system of classification.

(10) Molecular taxonomists use DNA sequence analyses of chloroplast rbcL gene and nuclear rRNA gene as taxonomic tool.

4.15.4: Very short answer questions:

(1) What is herbarium?

(2) What do you understand by taxonomic tools?

(3) Define GIS.

(4) Which is the largest herbarium of India?

(5) What is serotaxonomy?

(6) Define molecular tools.

(7) What is flora?

(8) Define hierarchy.

(9) What is chemotaxonomy?

(10) Define taxon.

4.15.1 Answer Keys: 1-(a), 2-(b), 3-(d), 4-(a), 5-(a), 6-(a), 7-(b), 8-(a), 9-(a), 10-(c), 11-(c), 12-(b), 13-(a), 14-(a), 15-(a).

4.15.2 Answer Keys: 1-Herbarium, 2-42x29, 3-Kolkata, 4-Dehradun, 5- Hierarchy, 6- Class, 7- Vasculum, 8- Flora, 9- Padua, Italy, 10- Serology.

4.15.3 Answer Keys: 1-True, 2-False, 3-True, 4-True, 5-True, 6-False, 7-True, 8-False, 9-True, 10-True.

4.16 REFERENCES

- Atal C. K.1982. *Cultivation and utilization of aromatic plants*, 1st edn. Council of Scientific and Industrial Research, New Delhi, 15-21.

- Bolstad P. (2005) GIS Fundamentals: A first text on Geographic Information Systems. 2nd edn. White Bear Lake.
- Caetano-Anollés G. 1994. MAAP: a versatile and universal tool for genome analysis. *Plant Molecular Biology*. 25(6):1011-26.
- Channaveeraiah MS.1960. Karyomorphologic and cytogaxonomic studies in Aegilops . *Acta Horti. Gotob.* 23*:* 85-178.
- Datta SC. 1988. *Systematic Botany*. New Age International.
- Davis, P.H. and V.H. Heywood. 1973. *Principles of Angiosperm Taxonomy*. Kreiger, New York.
- De Candolle A. P. 1816. *Essaisur les propridtdsmédicales des plantes, cornparees avec leurs forms extérieuresetleur classification naturelle*. 2nd edn, Paris,
- Doyle J. J. 1992. Gene trees and species trees: Molecular systematics as one-character taxonomy. *Systematic Bototany*. 17:144-163.
- Hegnauer R. 1986. Phytochemistry and plant taxonomy-an essay on the chemotaxonomy of higher plants. *Phytochemistry.* 25:1519-1535
- Mathew P. M. 1958. Studies on *Piperaceae*. *Journal of Indian Botanical Society*. **37**: 155–171
- Nybom H. 2004. Comparison of different nuclear DNA markers for estimating intraspecific genetic diversity in plants. *Molecular Ecology.* 13(5): 1143–1155.
- Rajak S. K. 2013. Geographical Information System (GIS). *International Journal of Information And Computation Technology.* 3(10):1079-1082.
- Riesberg, LH and Soltis DE. 1991. Phylogenetic consequences of cytoplasmic gene flow in plants. *Evol. Trends Plant*, 5:65-84.
- Smith P. M. 1976. *The Chemotaxonomy of plants*. London, Edward Arnold.
- Tourneforte J. P. 1700. *Institutiones rei Herbariae*, 3. Vols. Paris.

4.17 SUGGESTED READINGS

- Davis, P.H. and V.H. Heywood. 1973. *Principles of Angiosperm Taxonomy*. Kreiger, New York.
- Grant, W.F. 1984. *Plant Biosystematics*. Academic Press, London.
- Jeffrey, C. 1982. *An Introduction to Plant Taxonomy*. University Press, Cambridge.
- Jones, S.B. Jr. and A.E. Luchsinger. 1986. *Plant Systematics*. McGraw-Hill Book Co., New York.
- Judd, W.S., C.S. Campbell, E.A. Kellogg and P.F. Stevens. 1999. *Plant Systematics: A Phylogenetic Approach*. Sinaeur Associate, Inc., Sunderland, MA, USA.
- Lawrence, G.H.M. 1951. *Taxonomy of Vascular Plants*. Macmillan, New York.
- Naik, V.N. 1984. *Taxonomy of Angiosperms*. Tata McGraw-Hill, New Delhi.
- Porter, C.L.1959. Taxonomy of Flowering Plants. W.H. Freeman and Company, San Francisco.

- Stace, C.A. 1989. *Plant Taxonomy and Biosystematics*. Edward Arnold, London.
- Stuessy, T.F. 1990. *Plant Taxonomy*. Columbia Univ. Press, New York.

4.18 TERMINAL QUESTIONS

4.18.1 Short answer questions

(1) Define taxonomic hierarchy.
(2) Write a short note on herbarium.
(3) What is taxonomic hierarchy?
(4) What is the significance of herbarium preparation?
(5) What do you stand by taxonomic tools?
(6) Give an account of taxonomic tools used in plant taxonomy.
(7) What are serologiacal reactions and their use in taxonomy?
(8) Define molecular taxonomy.
(9) Discuss the role of biochemistry in plant taxonomy.
(10) Write short note on plant collection.

4.18.1 Long answer questions

(1) Explain different taxonomic tools?
(2) Describe the herbaria and uses of herbarium?
(3) Explain modern trends in plant taxonomy in detail?
(4) What are molecular and biochemical tools in taxonomy?
(5) Write a detailed note on herbarium preparation.

UNIT-5 PLANT NOMENCLATURE

5.1 OBJECTIVES

After reading this unit students will be able to-

- Understand the International Code of Botanical Nomenclature (ICBN).
- Understand the Aims and principles of (ICBN).
- Know the rules and recommendations of (ICBN).
- Learn the criteria of naming fossil and cultivated plants.
- Understand the proposed bio- and phylo-codes of nomenclature.

5.2 INTRODUCTION

One of the first impressions that someone introduced to taxonomy gets is that there is an inordinate confusion over the use of scientific names. Why not just use common names? They are easier to pronounce and remember than scientific names. However, scientific names have several major advantages over common names and it should become apparent that common names, at best, will never be more than an unnecessary accessory to the framework provided by the formal system of naming organisms (nomenclature). Name is the means of reference to all living and non-living things. Any object known to human being is given a name to describe and communicate ideas about it. The name may be different in different languages and at different places. The art of naming the object is known as Nomenclature. And when it comes to naming of plants it is called Botanical nomenclature.

Common name is the name of the plant in a particularly area or locality given by the people of that particular area. Such names vary from place to place and language to language. The common namesare simple and hence easy to remember, usually descriptive of the plant, and larger number of people will sometimes know what you are talking about when common names are used than in the case with scientific names. The two major problemswith common names are: (1) there are about more than 250,000 species of vascular plants and only a small percentage has common names; (2) the same name is often used for different plants and the same plant may have different common names in different regions.Incountry like India the name changes even with the dialect.To overcome the problems of common names, scientists suggested name in such a way that it is accepted in the world and is used internationally. But again, the problem remained the same, *i.e.*, the language which is not universal. So the botanists agreed to lay down certain rules and conditions. The main suggestion was that the language of the name should be Latinbecause: (a) The language is not a national language of any country at present (b) European languages derived from Latin only (c) Past European scholars learnt their subjects in Latin. A lot of previous botanical literature is written in Latin only.The ICBN set the formal starting date of plant nomenclature as1 May 1753, the publication of *Species Plantarum* by Linnaeus.

Since the time of Linnaeus, the system of nomenclature has become more formalized and codified. The process of naming plants based on international rules proposed by botanists to ensure stable and universal system is called botanical nomenclature. It is an essential process to overcome the problems of common names. The botanists agreed to lay down certain rules and conditions. The International Code of Botanical Nomenclature (ICBN) has been established to provide a uniform set of rules to be followed in applying names to plants. The rules contained in the ICBN are revised during the International Botanical Congresses (IBC), which are held after every six years. The code of the ICBN is composed of six principles.

The ***International Code of Botanical Nomenclature*** (**ICBN**) which is now called ***International Code of Nomenclature for algae, fungi, and plants*** (**ICN**) is the set of rules and recommendations dealing with the nomenclature of plants, fungi and a few other groups of organisms, all those "traditionally treated as algae, fungi, or plants". The name ***International Code of Botanical Nomenclature*** (**ICBN**) was changed to ***International Code of Nomenclature for algae, fungi, and plants*** (**ICN**) after XVIIIth International Botanical Congress held in Melbourne in July 2011 as part of the *Melbourne Code* which replaces the *Vienna Code* of 2005. The Vienna Code, based on the decisions of the XVII IBC at Vienna was preceded by the St Louis Code (1999) and the Tokyo Code (1993). The name of the *Code* is partly capitalized and partly not. The lower-case for "algae, fungi, and plants" indicates that these terms are not formal names of clades, but indicate groups of organisms that were historically known by these names and traditionally studied by phycologists, mycologists, and botanists. There are special provisions in the *ICN* for some of these groups, as there are for fossils. Its intent is that each taxonomic group ("taxon", plural "taxa") of plants has only one correct name that is accepted worldwide. The value of a scientific name is that it is an identifier; it is not necessarily of descriptive value, or even accurate.

The *ICN* can only be changed by an International Botanical Congress (IBC), with the International Association for Plant Taxonomy providing the supporting infrastructure. Each new edition supersedes the earlier editions and is retroactive back to 1753, except where different starting dates are specified. For the naming of cultivated plants and bacteria there are separate codes, the *International Code of Nomenclature for Cultivated Plants*, (**ICNCP,** also known as the **Cultivated Plant Code**) and **International Code of Nomenclature of Prokaryotes (ICNP, formerly known as International Code of Nomenclature of Bacteria** (**ICNB**) or **Bacteriological Code** (**BC**), which gives rules and recommendations that supplement the *ICN*.

Binomial Nomenclature

Linnaeus for the first time proposed that every living organism should have binomial name, *i.e.*, a name with two epithets, first is generic and other specific epithet followed by authority. Linnaeus proposed some rules for generic names of plants in *Fundamenta Botanica*

(1736) and *Critica Botanica* (1737). A.P.de Candolle for the first time proposed rules for nomenclature of plants which were passed by International Botanical Congress at Paris (1867).

The generic epithet is always a noun showing cooler, name in honour of person or adjective, *e.g., Nicotiana* named after Jean Nicot a French diplomat and scholar had introduced tobacco to France. Species is an adjective*e.g.,* for white color it is *alba*, red-*rubra*, green-*viridis,* black color- *nigrum, etc.* for cultivated one it is *sativa*, edible one *esculenta,etc.*These names are not used always and species may be a pronoun, *e.g., americana, indica, benghalensis, etc.* It may chracterise shape of a leaf (character of plant), *e.g., hastata, cordata, sagitata, etc.* name of other scientisst to whom the plant is dedicated, *e.g., pangteyana, sahnia*, *etc.*

Principle V of ICBN states that a scientific name must be treated as if it were Latin, but the Articles 16-28 of the *Code* also specify what form the name must take in Hierarchy. The rank or category of hierarchy should be as follows:

Taxonomic Rank	**Suffix**	**Examples**
Division (Phylum)	-phyta	Magnoliophyta
Class	-opsida	Magnoliopsida, Liliopsida
Order	-ales	Magnoliales, Liliales
Family	-aceae	Magnoliaceae,Liliaceae
Tribe	-eae	Magnolieae. Lilieae
Genus	A noun	*Magnolia*, *Lilium*
Species	Depends	*Magnolia grandiflora, Lilium grandiflorum*

5.3 HISTORY OF ICBN

Botanical nomenclature has a long history, going back beyond the period when Latin was the scientific language throughout Europe. In ancient time main Latin writer in botany was Pliny the Elder (23–79 AD). From Mediaeval times, Latin became the principal scientific language (lingua franca) in Europe. The purpose of early herbalists was primarily medicinal rather than plant science *per se*. Leonhart Fuchs, a German physician and botanist is often considered the originator of Latin names for the rapidly increasing number of plants known to science,used the name *Digitalis* in his *De Historia Stirpium CommentariiInsignes* (1542).

According to *Barkworth*, (2004) a key event was Linnaeus' adoption of binomial names for naming plant species in his book *Species Plantarum* (1753)for this he is credited as 'father of binomialnomenclature' and also 'Father of modern Taxonomy'.

In the nineteenth century it became increasingly clear that there was a need for rules to govern scientific nomenclature, and initiatives were taken to refine the body of laws initiated by

Linnaeus. These were published in successively more sophisticated editions. For plants, key dates are 1867 (de Candolle) and 1906 (*International Rules of Botanical Nomenclature*, 'Vienna Rules'), *Melbourne Code*, adopted in 2011. The most recent is the Shenzhen China July 2017.

Before the middle of the 18th century, plant names were not scientific usually polynomials *i.e.* made up of several words in a series. It was superseded by the binomial system, proposed by Linnaeus in his book*Species Planetarium* (1753). Linnaeus is the person who proposed the elementary rules for precise naming of plants first time in his book *Critica Botanica* (1737) and then *Philosophia Botanica* (1751). Later A.P. de Candolle (1813) in his *Theorie elementaire de la botanique* gave a detailed set of rules regarding plant nomenclature to serve as a guide to botanists.

As time passed and new plants werediscovered by botanists from later explorations, it caused concern over nomenclature of these species. Thus, with the passage of time, the need for an international system and rules for naming plants became increasingly important. The man was Alphonse de Candolle; son of Augustine P. de Candolle convened an assembly of botanists from different countries to present a new set of rules at Paris in 1867. This assembly was thought to be first International Botanical Congress.

Subsequent meetings of the International Botanical Congress were held in Rochester (1892), Vienna (1905), America (1907) but a general agreement regarding the internationally acceptable rules of plant nomenclature was reached in 1930 at the IBC meeting at Cambridge where for the first time in botanical history, a code of nomenclature came into being that was international in function as well as in name.This code is called the International Code of Botanical Nomenclature (ICBN). The modifications or amendments as suggested by the International Botanical Congress at the subsequent meetings have been incorporated in the ICBN regularly.

(i) Paris Code (1867)

The First International Botanical Congress was organisedin Paris (1867), for proper nomenclature practices. About 150 American and European botanists were invited to attend the congress.

(ii) Rochester Code (1892)

In 1892 congress of botanists was held in Rochester, New York, in the United States headed by N.L. Britton and developed a set of rules to govern nomenclature called as Rochester Code.The importantrecommendations of Rochester Code were:(a) Establishment of the type concept for correct application of names and (b) Strict adherence to the principle of priority,*etc.*

(iii) Vienna Code (1905)

The third International Botanical Congress was held at Vienna in June 1905.The **changes includedin** *Vienna Code* were**:**(a) Establishment of Linnaeus *Species Plantarum* (1753) as the starting-point for naming vascular plants,(b) Nomina generic conservanda by which generic names with wide use would be conserved,(c) Banning of tautonyms, and (d) naming of new taxa be accompanied by a Latin diagnosis.

(iv) American Code (1907)

Being dissatisfied with the results of the Vienna Congress, most proponents of the Rochester Code refused to accept the new rules in 1907, they modified the Rochester Code under the heading of the American Code. The first provision inAmerican Code was that itdidnot subscribe to the principle of *Nominagenerica conservanda* or of the requirement of Latin diagnosis, but accepted the type concept.Another provision of this code was that **'a binomial may not be used again for a plant in any way if it has been employed previously for another plant, even though the previous use may have been illegitimate'**.Thus the Rochester Code and American Code created two opposing schools of thought.

(v) Brussels Code (1912)

The Fourth International Botanical Congress was held at Brussels in 1910. Establishment of different starting points for priority of names of non vascular plants was the significant decision in this Congress.

(vi) Cambridge Code (1935)

The differences between the Vienna Code and American Code were finally resolvedin Fifth International Botanical Congress held in 1930 at Cambridge, England.The *Cambridge Code* was not published until 1935. The suggested and **approved provisions of this code were as:**

(a) The type concept should be pursued.
(b) There should be a list of *Nominagenerica conservanda.*
(c) Tautonyms should be discarded.
(d) Latin diagnosis is necessary after January 1, 1932.

(vii) Amsterdam Code (1947)

At the Sixth International Botanical Congress, Amsterdam (1935).A few major changes were made in rules by Amsterdam Code. It was resolved that "**from January 1, 1935, names of**

new groups of recent plants (except the Bacteria) are considered, as validly published only when they are accompanied by a Latin diagnosis".

(viii) Stockholm Code (1952)

The seventh International Botanical Congress was held at Stockholm in 1950. The word "Taxon" was introduced for the first time to designate any taxonomic group.

(ix) Paris Code (1956)

The Eighth International Botanical Congress was held in Paris in July, 1954. In Paris Code great emphasis was laid on types. But the rule,compulsion ofLatin diagnosis was flushed out. It was decided that the code should be published in English, French and German languages.The separation of the Preamble and Principles from the Rules and Recommendations was the major feature of this code.

(x) Montreal Code (1961)

The Ninth International Botanical Congress was held at Montreal in August, 1959 whre a special committee was appointed to study the question of conservation of family names (*nomina familiarum conservanda for Angiospermae* as Appendix II was introduced). In this code, emphasison the naming of fossil plants was given.

(xi) Edinburgh Code (1966)

The Tenth International Botanical Congress held at Edinburgh in August, 1964. The report of the special committee appointed during the Ninth Congress was submitted at Edinburgh Code. **Some of the important points in the report are as follows:**(a) A.L. de Jussieu's *Genera Plantarum* (1789) is the starting-point for family names. (b) In the list of *nomina familiarum conservanda*, spelling of a few family names were altered with a somewhat different from the long-established names, e.g. Cannabaceae for Cannabinaceae, Capparaceae for Capparidaceae, Haloragaceae for Haloragidaceae, Melastomataceae for Melastomaceae, *etc.* Anew committee was set up for preparation of glossary of the main technical terms occurring in the code called An Annotated Glossary of Botanical Nomenclature.

(xii) Seattle Code (1972)

The Eleventh International Botanical Congress was held at Seattle city of the United Statesin August, 1969. It proposed the Seattle Code, edited by F.A. Stafleu and published in 1972. The main issues of Seattle Code include the tautonymous designations of taxa between genus and species and below species. The word autonym (automatically established names) was introduced in the Seattle Code.

(xiii) Leningrad Code (1978)

The Twelfth International Botanical Congress was held in July, 1975 at Leningrad, Russia and its recommendations published in 1978.**This Code indicates minor differences from the Seattle Code as:**(a) The concept of organ genera is eliminated for fossil plants.(b) The Code does not apply for names of bacteria and does apply to all other organisms treated as plants.(c) The principle of automatic typification is extended to those names of taxa above the family rank. (d) A name or combination published before 1953 without indicating the rank is considered validly published.

(xiv) Sydney Code (1983)

The Thirteenth International Botanical Congress was held in August, 1981 at Sydney, Australia.Official versions of the code are published in English, French, and German in case of any discrepancy the English version to take precedence.

(xv) Berlin Code (1988)

This includes the proposals made at the Fourteenth International Botanical Congress at Berlin, Germany in 1986 and outcomes published in code form in 1988. *Nomina Specifica Conservanda* was for the first time introduced at this Congress. Two species names *viz.*, *Lycopersicon esculentum* P. Miller and *Triticum aestivum* Linn., have been conserved against the rule of priority, as these names are widely used and any change may create confusion. Articles 66 and 67 were removed.

(xvi) Tokyo Code (1994)

The Fifteenth International Botanical Congress met at Yokohama city of Japan in 1993 and outcomes published in 1994. Tokyo Code has been translated into Chinese, French, German, Italian, Japanese, Russian and Slovak. In this code, extensive renumbering has taken place.

(xvii) St. Louis Code (1999)

Sixteenth International Botanical Congress was held at St. Louis, Missouri in July-August, 1999 and supersedes the Tokyo Code. The detailed provision of the Code is divided into Rules, set out in Articles, and Recommendations. Like the Tokyo Code, St. Louis Code, has also been translated in several languages Chinese, French, Japanese, Portuguese, Russian, Slovak, and Spanish.

The object of the "**Rules**" is to put the nomenclature of the past into order and to provide for that of the future. The **Rules and Recommendations** apply to all organisms whether fossil or non-fossil, including fungi but do not including bacteria. A separate code called **International Code of Nomenclature of Bacteria (ICNB)** governs the nomenclature of bacteriawas purposed.

(xviii)Vienna Code (2005)

The Seventeenth International Botanical Congress was held in Vienna in 2005 and supersedes the Saint Louis Code, published six years ago subsequent to the Sixteenth International Botanical Congress in St Louis, Missouri, U.S.A. It is written entirely in (British) English. The *St Louis Code* was translated into Chinese, French, Japanese, Portuguese, Russian, Slovak, and Spanish; it is therefore anticipated that the Vienna Code, too, will become available in several languages in due course. One of the reasons invoked for the choice of Vienna as the site of the seventeenth Congress, was that the second International Botanical Congress had been held there exactly 100 years earlier. The Vienna Code does not differ substantially in overall presentation and arrangement from the St Louis Code, and the numbering of Articles remains the same, although there have been a few additions to, and modifications of, paragraphs, Recommendations, and Examples, often involving changes in their numbering. That for fossil plants was a reversal of one component of the rules on morphotaxa introduced in the *St Louis Code*. At the St Louis Congress it was argued (and accepted) that all fossil taxa should be treated as morphotaxa.

(xix) Melbourne Code (2011)

The Eighteenth International Botanical Congress held in Melbourne, Australia in July 2011 made a number of very significant changes in the rules governing what has long been termed botanical nomenclature, although always covering algae and fungi as well as green plants. This edition of the *Code* embodies these decisions; the first of which that must be noted is the change in its title. Since the VII International Botanical Congress in Stockholm in 1950, successive editions of the *Code* have been published as the ***International Code of Botanical Nomenclature***, abbreviated as ***ICBN***. In Melbourne, reflecting the view, particularly amongst mycologists, that the word "Botanical" was misleading and could imply that the *Code* covered only green plants and excluded fungi and diverse algal lineages, it was agreed that the name be changed to ***International Code of Nomenclature for algae, fungi, and plants***. In referring to the *Code* under its new title, with abbreviation as ***ICN*.**It is currently necessary to provide a description and/or a diagnosis in Latin, in order to validly publish the name of a new taxon, *e.g.*, a species, except for names of fossils. The Nomenclature Section modified this so that, for names published on or after 1 January 2012, the description and/or diagnosis must be in either English or Latin.

(xx) Shenzhen **Code (2018) – Yet to come**

The Nineteenth International Botanical Congress held in Shenzhen, China in July23-29, 2011and the code was published in 2018.

List of botanical congresses and their major actions concerning nomenclature.

S. No.	Year	City/ Country	Code	Major actions concerning nomenclature
I	1900	Paris, France		Decisions on nomenclature deferred.
II	1905	Vienna, Austria	Yes	First binding *Rules of Nomenclature*; French became the official language of the meeting.Requirement for Latin plant descriptions from 1908 onwards (not enforced). End of the Kew Rule.
III	1910	Brussels, Belgium	Yes	Separate starting dates for nomenclature of fungi established.
IV	1926	Ithaca, United States		Decisions on nomenclature deferred.
V	1930	Cambridge, United Kingdom	Yes	The *Cambridge Code* was published in 1935. The type method incorporated, Latin requirement deferred until 1932, homonym became illegitimate (unless conserved), which altered the status of many names, including many that had previously been conserved.
VI	1935	Amsterdam, Netherlands		English became the official language of the Congress, replacing French.
VII	1950	Stockholm, Sweden	Yes	FirstInternational Code of Nomenclature for Cultivated Plants adopted. Decision to hold future congresses every five years (except four years for the next one). Organ genera and form genera were introduced for fossil plants.
VIII	1954	Paris, France	Yes	Two additional principles II and III were added, dealing with types and with priority.
IX	1959	Montreal, Canada	Yes	Starting point for family names to be Antoine Laurent de Jussieu's *Genera Plantarum* 1789. Choice among French, English, and German official codes of English as the standard in case of discrepancy.Presentation of a completely reworked list of *nomina conservenda* and *nomina rejecenda* necessitated by changes made at the 1930 congress, but the list for species was not accepted. Decision that rules of priority do not apply above the rank of family.
X	1964	Edinburgh, United Kingdom	Yes	No major changes to the code.
XI	1969	Seattle, United	Yes	Established the International Association of

		States		Bryologists.
XII	1975	Leningrad, Soviet Union	Yes	Official versions of the code in English, French, and German, the English version to take precedence in case of discrepancy. Rejection of species names allowed in a few special cases. Organ-genera for fossil plants are eliminated, replaced by form-genera.
XIII	1981	Sydney, Australia	Yes	Official version of the code was translated inBritish English, French, and German languages. The English version to take precedence in case of discrepancy.The types of genera and higher categories become the types of species (*i.e.*, the taxa themselves are no longer types, only specimens or illustrations).
XIV	1987	Berlin, Germany	Yes	Official version of the code only in BritishEnglish. Later translated in French, German, and Japanese.Conservation extended to species names that represent the type of a conserved generic name.
XV	1993	Tokyo, Japan	Yes	Official version of the code only in British English.Later translations in Chinese, French, German, Italian, Japanese, Russian, and Slovak.Conservation extended to all species names.Rejection permitted for any name that would cause a disadvantageous nomenclatural change.
XVI	1999	St. Louis, United States	Yes	Refinement of type concept; illustrations as types mostly forbidden from 1958. Morphotaxa for fossils introduced. Proposals defeated included the Bio-Code and registration of plant names.
XVII	2005	Vienna, Austria	Yes	Introduction of Morphotaxa and regular taxa for fossils. Illustrations as types mostly forbidden from 2007and glossary added to the code of nomenclature.
XVIII	2011	Melbourne, Australia	Yes	The Major point was permission of electronic publication and registration of fungal names. English or Latin diagnoses from 2012.The concepts of anamorph and teleomorph for fungi and morphotaxa for fossils were eliminated.
XIX	2018	Shenzhen, China	Yes	This edition of Code embodies the decision of the

				Nomenclature Section of the XIX International Botanical Congress (IBC) which took place in Schenzhen, China in July 2017. It supersedes the Melbourne Code. The Schenzhen Code was published in its final form on 27th June, 2018(printed version). A PDF version was made available to members of the IAPT on 27 June 2018.

5.4 AIMS AND PRINCIPLES

AIMS

The functions of nomenclature are to provide labels/names for all taxa at all levels in the hierarchy of classification. Plant nomenclature is, to some degree, the dialect of systematic botany. It originates from the binomial nomenclature that was originally codified in the legendary works of Linnaeus, *Species Plantarum* (1753). The process of naming of plants is based on international rules proposed by botanists by organizing congress called International Botanical Congress (IBC) and publishingits outcomes in a code form for futureprecise nomenclature of taxa which is recognised and accepted atinternational level. It is an essential process to overcome the problems of common name. Thus first aim of ICBN is to give a proper name to any taxon which is valid at international level. The three major aims of ICBN are:

- To provide stable method of nomenclature.
- To avoid and reject the names which cause confusion.
- To avoid useless creation of names.

The ICBN is divided into three parts (i) Principles, (ii)Rules and Recommendations and (iii) Provisions. The objective of principle is to guide decisions concerning the International Code of Botanical Nomenclature (ICBN).The objective of the rules is to bring past nomenclature into order and to follow rules for future nomenclature. The objective of the recommendations is to bring uniformity and clearness in future nomenclature. The objective of provisions is to provide opportunity for the modification of code and appendices.

PRINCIPLES

There are six principles that guide in correct naming of taxa concerning the International Code of Botanical Nomenclature (ICBN).

Principle I: (Straightforward Principle)

Botanical nomenclature is independent of zoological nomenclature.

The Code applies equally to names of taxonomic groups treated as plants whether or not these groups were originally so treated. If an organism is considered to be a plant, then it must be named in accordance with the *Botanical Code.* If it is considered a animal or bacterium, it must be named according to the zoological, Bacteriological *Code.*

Principle II: (Type Principle)

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

The name of new taxon is valid only when the type of the name is mentioned meaning thereby that all names are permanently attached with specimen designated as type. Single specimen, may be whole plant or a part of it with which the name of taxon is permanently attached, is known as **holotype.**

Principle III: (Principle of Priority)

The nomenclature of a taxonomic group is based upon priority of publication.
This principle states, in essence, that if a taxonomic group has been given two or more names, the correct name is the first name which is published with ICBN *standards (i.e. valid publication).*

Principle IV: (Principle of Uniqueness)

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

The uniqueness principle states that there is only one correct name for a particular taxonomic group within a given taxonomic treatment.

Principle V: (As-it-should-be Principle)

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

Principle V states that scientific names are treated as if they were *Latin*, regardless of their derivation.

Principle VI (Retroactivity Principle)

The Rules of nomenclature are retroactive unless expressly limited.

The Retroactivity Principle means that anyone proposing a change in the *Code*needs to consider the effect that the proposed change will have on names published in a wide range of literature and over a considerable period of time. This is an intimidating requirement. It is why all proposed changes to the Code undergo committee scrutiny before being voted on. If the committee has a problem with a proposed change, one of its members will get in touch with the person proposing the change. The committee member may point out unforeseen consequences of the proposed change. Alternatively, he or she may suggest examples that will make a stronger case for the change, or suggest modifications that will avoid some undesirable consequences.

5.5 RULES AND RECOMMENDATIONS

The rules governing botanical nomenclature have a long and tumultuous history. The personwas Linnaeuswho laid down the foundation of nomenclature in his work *Philoshophia Botanica* (1751). In 1813 A. P. de Candolle proposed elaborated form of the rules regarding plant nomenclature in *Théorie élémentaire de la botanique.*The first set of international rules was the *Lois de la nomenclature botanique* ("Laws of botanical nomenclature") that was adopted as the "best guide to follow for botanical nomenclature"at an "International Botanical Congress" convened in Paris in 1867. It is the product of intensive study by the best brains in the botanical science.

Some Important Rules and Recommendations

1. All those plants which belong to one genus must be designed by the source generic name **(Rule 213).**
2. All those plants which belong to different genera must be designated by different generic names **(Rule 214).**
3. He who establishes a new genus should give it a name **(Rule 218).**
4. Those generic names are best which show essential characters of plants or its appearance **(Rule 240).**
5. Generic names one and a half foot long or difficult to pronounce or unpleasant are to be avoided **(Rule 249).**
6. The specific name must distinguish a plant from all its relatives **(Rule 257).**
7. Size does not distinguish species **(Rule 260).**
8. The original place of plant does not give specific difference **(Rule 264).**
9. A generic name must be applied to each species **(Rule 284).**
10. The specific name should always follow the generic name **(Rule 285).**

5.5.1 Fossil plants

A fossil plant is any preserved part of a plant that has long since died. Thus fossil plants are remnants of plants which are once living in remote past. Plant fossils can be preserved in a variety of ways, each of which can give different types of information about the original parent plant.

Fossil-taxa

According toBriquet (1906) for many years this approach to naming plant fossils was accepted by palaeobotanists but not formalised within the *International Code of Botanical Nomenclature*. *Lanjouwet al., (1952)state that*, Thomas (1935) and Jongmans, Halle &Gothan (1935) proposed a set of formal provisions, the essence of which was introduced into the 1952 International Code of Botanical Nomenclature. These early provisions representing particular plant part fossils in a particularstate of preservation to be referred to **organ-genera.** In addition, a small subset of organ-genera, to be known as form-genera, wererecognised based on the artificial taxa introduced by Brongniart (1822) mainly for foliage fossils. Over the years, the concepts and regulations surrounding organ- and form-genera became modified within successive codes of nomenclature, reflecting a failure of the palaeobotanical community to agree on how this aspect of plant taxonomic nomenclature should work. According to Greuter*et al.*(2000), the use of **organ-** and **fossil-genera** was abandoned with the St Louis Code, replaced by "**morphotaxa".**

The situation in the *Vienna Code* (2005) was that any plant taxon whose type is a fossil, except diatoms, can be described as a **morphotaxon**, a particular part of a plant preserved in a particular way. Morphotaxa were introduced to try to overcome the issue of competing names that represented different plant parts and/or preservation states. Themorphotaxa offer no real advantage to palaeobotanists over normal fossil-taxa and the concept was abandoned with the 2011 botanical congress and the 2012 International Code of Nomenclature for algae, fungi, and plants.

5.5.2 Cultivated plants

Nomenclature of cultivars, cultivar groups and graft-chimaeras are regulated by**The International Code of Nomenclature for Cultivated Plants (ICNCP).**The ICNCP operates within the framework of the International Code of Nomenclature for algae, fungi, and plants which regulates the nomenclature of plants. For example the following names are governed by the ICNCP:

i. *Clematis alpina* 'Ruby' : a cultivar within a species
ii. *Magnolia* 'Elizabeth' : a hybrid between at least two species
iii. *Rhododendron boothii*Mishmiense Group: a Group name
iv. *Paphiopedilum* Sorel grex: a grex name; the name of the grex is capitalized but the word "grex" (or abbreviation "gx") is not, and quotes are not used.
v. Apple 'Jonathan': permitted use of an unambiguous common name with a cultivar epithet.
vi. *+Crataegomespilus* : a graft-chimaera of *Crataegu*s and *Mespilus*.

The first edition of the ICNCP was agreed in 1952 in Wageningen and published in 1953. It was followed by seven subsequent editions in 1958 (Utrecht), 1961 (update of 1958), 1969 (Edinburgh), 1980 (Seattle), 1995 (Edinburgh), 2004 (Toronto) and 2009 (Wageningen), compiled by *Brickell, et al*. (2009). The ninth and most recentedition of ICNCP was published in 2016, compiled by *Brickell, et al*. (2016).

William Stearn (1952) was the person who has outlined the origin of *ICNCP*, tracing it back to the International Horticultural Congress of Brussels (1864). This set out de Candolle's view that Latin names should be reserved for species and varieties found in the wild, with non-Latin or "fancy" names used for garden forms. Supported by Karl Koch at the 1865 International Botanical and Horticultural Congress and at the 1866 International Botanical Congress.

(IBC).The Article 40 of the *Lois de la Nomenclature botanique* dealt with nomenclature of plants of horticultural origin. This Article survived redrafting of the *International Rules of Botanical Nomenclature* until 1935 and its core sentiments remain in the current ICNCP of 2009.

Cultivar names

The full name of a cultivar will always begin with the name of the generic epithet to which the cultivar belongs. Optionally, the species or hybrid epithet may be included as a second element in the entire name but this is not usually necessary; inclusion of such epithets merely provide more information about a cultivar.

5.6 PROPOSED BIO- AND PHYLO-CODES

Bio-Code

As information on the world's biota becomes increasingly integrated across different groups of organisms, from bacteria and fungi to animals and plants, there is concomitant rising need for a consistent and harmonized approach to the regulation of scientific names. The *Bio-Code* initiative represents a concerted effort by biologists intimately involved in the operation of the current system of separate codes, to devise a unified approach to the future naming of organisms of all kinds. This need has become pressing in view of common issues that the separate organismal codes now have to address, consequent on the rapid changes taking place in global informatics, database architecture, molecular systematics and ecology, and electronic publication.

A more radical approach was made in 1997 when the International Committee on Bionomenclature (ICB) presented the long debated Draft Bio-Code, proposed to replace all existing Codes with an harmonization of them. The originally planned implementation date for the BioCode draft was January 1, 2000, but agreement to replace the existing Codes was not reached.

IUBS (International Union of Biological Sciences)/IUMS (International Union of Microbiological Societies) in 2011proposed a revised Bio-Codethat, instead of replacing the existing Codes, would provide a unified context for them, referring to them when necessary. Changes in the existing codes are slowly being made in the proposed directions.

The *Draft Bio-Code* (2011) compiled by Greuter*et al.*(2011) is most appropriately viewed as a framework over-arching the practices of the current series of codes, but which also addresses ways in which some of the key issues of current concern in systematics could be handled by all codes, for example the registration of new names and electronic publication. In addition, it has been drawn up so that its provisions can be adopted at the appropriate time for any particular group of organisms, at any rank or range of ranks. Such adoption is to be determined by the appropriately mandated international body if and when the necessary structures exist and are operational

Phylo-Code

The Linnaean system of binomial nomenclature is landmark for today's taxonomists butnow failed to govern the naming of clade and species. A group of organisms which membersshow a common ancestry called clade. A clade is a group having all the descendants of the last common ancestor of the members of the group. De Queiroz and Gauthier developed the theoretical foundation of the phylo-Code in a serial publication of papers in 1990, 1992 and 1994. In version form phylo-Code first time published in 2000.

According to Cantino and Queiroz (2010) in contrast to the rank-based codes, the PhyloCodewill provide rules for the purpose of naming clades through explicit reference to phylogeny. In doing so, the PhyloCode extends "tree-thinking" to biological nomenclature. This development parallels the extension of tree-thinking into taxonomy, as manifested in the concepts of species as lineage segments and supra specific taxa as clades. The Phylo-Code, however, is designed for the specific purpose of naming clades. The purpose of the Phylo-Code is not to replace existing names but to provide an alternative system or governing the application of both existing and newly proposed names. In developing the Phylo-Code, much thought has been given to minimizing the disruption of the existing nomenclature.

In the pre-existing code the name of a species changes whenever a species is referred to a different genus as a result of phylogenetic or phenetic consideration. In this the supraspecific names are associated with clade as they are operationally defined in terms of ranks and types.

The phyloCode (Phylogenetic code) Botanical nomenclature is proposed to promote clear communication and efficient storage and retrieval of biological information. The code was cited on 1st January 2000. Presently phylo-Code governs only clade names.

The first public draft of the Phylo-Code covered only Clade names.**Then in 2002 it was decided that:**

(i) The rules for clade names and rules for species names would be published in separate documents.

(ii) The timing of implementation of the two documents would be independent.

The rules for clade names are implemented before the names of species. The decision was reconsidered in 2006.

5.7 SUMMARY

1. One of the first impressions that someone introduced to taxonomy gets is that there is an inordinate confusion over the use of scientific names.

2. Name is the means of reference to all living and non-living things. Any object known to human being is given a name to describe and communicate ideas about it.
3. Common name is the same of the plant in a particularly area or locality given by the people of that particular area. Such names vary from place to place and language to language.
4. To overcome the problems of common names, scientists suggested name in such a way that it is accepted in the world and is used internationally.
5. Since the time of Linnaeus, the system of nomenclature has become more formalized and codified.
6. The process of naming plants based on international rules proposed by botanists to ensure stable and universal system is called botanical nomenclature.
7. The botanists agreed to lay down certain rules and conditions. The International Code of Botanical Nomenclature (ICBN) has been established to provide a uniform set of rules to be followed in applying names to plants. The rules contained in the ICBN are revised during the International Botanical Congresses (IBC), which are held after every six years.
8. The International Code of Botanical Nomenclature (ICBN) is the set of rules and recommendations dealing with the nomenclature of plants.
9. The name **International Code of Botanical Nomenclature** (ICBN) was changed to **International Code of Nomenclature for algae, fungi, and plants** (ICN) after XVIIIth International Botanical Congress held in Melbourne in July 2011.
10. The ICN can only be changed by International Botanical Congress (IBC), with the International Association for Plant Taxonomy providing the supporting infrastructure.
11. Linnaeus for the first time proposed that every living organism should have bionomial name, *i.e.*, a name with two epithets, first is generic and other specific epithet followed by authority.
12. The objective of principle is to guide decisions concerning the International Code of Botanical Nomenclature (ICBN).
13. The objective of the rules is to bring past nomenclature into order and to follow rules for future nomenclature.
14. The objective of the recommendations is to bring uniformity and clearness in future nomenclature.
15. The objective of provisions is to provide opportunity for the modification of code and appendices.
16. These early provisions representing particular plant parts fossils in a particular state of preservation to be referred to **organ-genera.**
17. The use of **organ-** and **fossil-genera** was abandoned with the St Louis Code, replaced by "**morphotaxa".**
18. The situation in the *Vienna Code* (2005) was that any plant taxon whose type is a fossil, except diatoms, can be described as a **morphotaxon**.
19. The full name of a cultivar will always begin with the name of the generic epithet to which the cultivar belongs.

20. A more radical approach was made in 1997 when the International Committee on Bionomenclature (ICB) presented the long debated Draft BioCode, proposed to replace all existing Codes with an harmonization of them.
21. The *Draft BioCode* (2011) compiled by Greuter*et al.*, is most appropriately viewed as a framework over-arching the practices of the current series of codes.
22. The Linnaean system of binomial nomenclature is landmark for today's taxonomists but now failed to govern the naming of clade and species.
23. A group of organisms which members show a common ancestry called clade.
24. A clade is a group having all the descendants of the last common ancestor of the members of the group.
25. The Phylo-Code will provide rules for the purpose of naming clades through explicit reference to phylogeny.
26. The Phylo-Code extends "tree-thinking" to biological nomenclature.

5.8 GLOSSARY

Binomial: A two-part naming system, especially the Latin name of a species of living organism consisting of the genus followed by the specific epithet.

Bio-Code: A nomenclatural code drafted by IUBS/IUMS International Committee on Bionomenclature (ICB).

Clade: A clade is a group having all the descendants of the last common ancestor of the members of the group.

Cultivar: A plant variety that has been produced in cultivation by selective breeding.

Fossil: The remains or impression of a prehistoric plant or plant part embedded in rock and preserved in petrified form.

Genus: Taxonomic rank or category that ranks above species and below family, and is denoted by a capitalized Latin name, *e.g. Mangifera*.

Generic epithet: The *genericepithet* of binomial nomenclature refers to the taxonomic hierarchy of organisms, genus, of each organism *i.e.*first part in binomial nomenclature.

Hierarchy: *Taxonomichierarchy* is the system of arranging *taxonomic* categories in a ascending or descending order.

Holotype: A single type specimen upon which the description and name of a species is based.

ICBN: International Code of Botanical Nomenclature.

ICN: International Code of Nomenclature for algae, fungi, and plants.

IUBS: International Union of Biological Sciences

IUMS: International Union of Microbiological Societies

Morphotaxon (pl. ***morphotaxa***)**:** A taxon of a group of organisms classified according to morphology alone used in taxonomy of fossil plants.

Nomenclature : Process of naming of plants.

Palaeobotany: Botany related to fossil plants.

Phylo-code: A formal set of rules governing phylogenetic nomenclature.
Species Planetarum: A book written by Carl Linnaeus, originally published in 1753, which lists every species of plant known at the time, classified into genera.

5.9 SELF ASSESSMENT QUESTION

5.9.1 Multiple choice questions (MCQs):

1. The Binomial system of classification was proposed by:
(a) De Candolle (b) Norman Mayer
(c) Linnaeus (d)Tournefort

2. Father of modern taxonomy:
(a) Hutchinson (b) De Candolle
(c) Tournefort (d) Linnaeus

3.The name of ICBN changed ICN after ….. International Botanical Congress:
(a) XII (b) XVIII
(c) XVI (d) XV

4.The XVIIIInternational Botanical Congress held at:
(a) Melbourne (b) Vienna
(c) St Louis (d) Amsterdam

5.The number of ICBN principles is:
(a) 8 (b) 3
(c) 5 (d) 6

6.The Type principle of ICBN is:
(a) II (b) III
(c) IV (d) V

7. The Morphotaxon is related to:
(a) Fungi (b) Angiosperm
(c) Bacteria (d) Fossil Plant

8. The retroactive principle of ICBN is:
(a) II (b) III
(c) III (d) VI

9. The *Species Plantarum* was written by:

(a) Linnaeus (b) Hutchinson
(c) Takhtajan (d) Darwin

10. The Year of publication Species Plantarum:
(a) 1 May 1753 (b) 1 May 1573
(c) 1 May 1873 (d) 1 May 1973

11. Correct publication order of books *FundamentaBotanica*,*CriticaBotanica* and *Species Plantarum* is:
(a) 1736- 1737-1753 (b) 1836- 1837-1573
(c) 1736-1737-1873 (d) 1726-1733-1573

12. Most recent International Botanical Congress was held at:
(a) China (b) Melbourne
(c) Vienna (d) Paris

13. Botanical nomenclature is …………………… zoological nomenclature:
(a) Independent of (b) Parallel
(c) Dependent on (d) Based on

14. According to ICBN suffix of class should be:
(a) -opsida (b) -aceae
(c) -ales (d) -phyta

15. Theoretical foundation of the Phylo-Code was developed by:
(a) de Queiroz and Gauthier (b) De Candole and Gauthier
(c) Hutchinson and Tournfort (d)Tournfort and De Candole

16. A group of organisms in which every member shares a unique common ancestor called:
(a) Clade (b) Taxon
(c) Phylloclade (d) Rank

17. According to ICBN suffix of division should have:
(a) -ales (b) -aceae
(c) -opsida (d) -phyta

18. *Critica Botanica* was authored by:
(a) Linnaeus (b) Hutchinson
(c) Takhtajan (d) Darwin

19. According to ICBN suffix of family should be:

(a) -opsida (b)-phyta

(c) -ales (d) -aceae

20. Tautonymis having same………………. epithets:

(a) Generic and Specific (b) Sub-specific and varietal

(c) Specific and sub-specific (d) varietal and forma

5.9.2 Fill in the blanks:

(1) ______________ is the author of *Species Plantarum*.

(2) There are ____________ principles of ICBN.

(3) __________________ is process of naming of plants.

(4) ______________ isbotany related to fossil plants.

(5) _______________ is a formal set of rules governing phylogenetic nomenclature.

(6) A single type specimen upon which the description and name of a species is based called___________.

(7) The ICBN is divided into three parts (i) ___________(ii) ___________and (iii)___________.

(8) The Eighteenth International Botanical Congress held in ____________in July 2011.

(9) Botanical nomenclature is independent of ________________nomenclature.

(10) The name of ICBN changed to ICN after ________ International Botanical Congress.

5.9.3True or False:

(1) Botanical nomenclature is dependent on zoological nomenclature.

(2) Clade is group of organisms in which every member shares a unique common ancestor.

(3) A single type specimen upon which the description and name of a species is based called Neotype.

(4) According to ICBN suffix of family should be -opsida.

(5) The Binomial system of classification proposed by De Candolle.

(6) Linnaeus is considered as 'father of modern taxonomy'.

(7)The name of ICBN changed to ICN after XVII International Botanical Congress, held in Vienna.

(8) The XIX International Botanical Congress (IBC) held at Shenzhen, China.

(9) ICN stands for International Code of Nomenclature for algae, fungi, and plants.

(10) A.P.de Candolle for the first time proposed rules for nomenclature of plants which are passed by International Botanical Congress at Paris (1867).

5.9.1 Answer Keys: 1-(c), 2-(d), 3-(b), 4-(a), 5-(d), 6-(a), 7-(d), 8-(d), 9-(a), 10-(a), 11-(a), 12-(a), 13-(a), 14-(a), 15-(a), 16-(a), 17-(d), 18-(a), 19-(d), 20-(a).

5.9.2 Answer Keys: 1- Linnaeus, 2- Six, 3-Nomenclature, 4-Palaeobotany, 5-Phylocode, 6-Holotype, 7- Principles, Rules and Recommendations, Provisions 8- Melbourne, 9-Zoological, 10-XVIII.

5.9.3Answer keys: 1-False, 2-True, 3-False, 4-False, 5-False, 6-true, 7-False, 8-True, 9-True, 10-True.

5.10 REFERENCES

- *Barkworth, M. 2004.* Botanical Nomenclature (Nomenclature, Names, and Taxonomy), *University of Utah, archived from*the original *on 2011-02-20,* retrieved*2011-02-20.*
- *Brickell C.D., Alexander C., Cubey J.J., David J.C, Hoffman M.H.A., Leslie A.C., Malécot V., Jin Xiaobai. 2009."International Code of Nomenclature for Cultivated Plants". ScriptaHorticulturae (8th ed.). International Society of Horticultural Science.* ***10****: 1-184.*
- *Brickell C.D., Alexander C., Cubey J.J., David J.C, Hoffman M.H.A., Leslie A.C., Malécot V., Jin Xiaobai 2016."International Code of Nomenclature for Cultivated Plants". ScriptaHorticulturae (9th ed.). International Society of Horticultural Science.* ***18****.*
- *Briquet, J. (1906), Règlesinternationales de la nomenclature botaniqueadoptées par le Congrès International de Botanique de Vienne 1905, Jena: Fischer.*
- *Brongniart, A. 1822. "Sur la classification et la distribution des végétauxfossiles en général, et surceux des terrains de sediment supérieur en particulier", Mém. Mus. Natl. Hist. Nat.,* ***8****: 203–240, 297-348.*
- Cantino P.D. and Queiroz Kevin de. 2010. International Code of Phylogenetic Nomenclature. Version 4c.
- Davis, P.H. and Heywood, V.H.. 1963. *Principles of angiosperm taxonomy*. London.
- *Greuter W., Garrity G., Hawksworth D.L. et al., .2011. The Draft BioCode (2011). On behalf of the IUBS/IUMS International Committee for Bionomenclature (ICB).*
- Greuter, W., McNeill, J., Barrie, F.R., Burdet, H.-M., Demoulin, V., Filgueiras, T.S., P.M., Nicolson, D.H., Silva, P.C., Skog, J.E., Trehane, P. Turland, N.J. and Hawksworth, D.L., 2000: International Code of Botanical Nomenclature (St. Louis Code). Regnum Vegetabile, 138:474.
- http://home.kpn.nl/klaasvanmanen/icbn/0002Preface.htm
- http://www.iapt-taxon.org/nomen/main.php?page=pf.
- Jongmans, W.J., Halle, T.G. &Gothan, W. 1935. Proposed editions to the International Rules of Botanical Nomenclature adopted by the fifth International Botanical Congress Cambridge 1930. Heer-len: Geologisch Bureau.
- *Lanjouw, J.; Baehni, C.; Merrill, E.D.; Rickett, H.W.; Robyns, W.; Sprague, T.A. &Stafleu, F.A. 1952. International Code of Botanical Nomenclature: Adopted by the Seventh International Botanical Congress; Stockholm, July 1950, Regnum Vegetabile 3, Utrecht:*

International Bureau for Plant Taxonomy of the International Association for Plant Taxonomy.

- *McNeill, J.; Barrie, F.R.; Buck, W.R.; Demoulin, V.; Greuter, W.; Hawksworth, D.L.; Herendeen, P.S.; Knapp, S.; Marhold, K.; Prado, J.; Prud'homme Van Reine, W.F.; Smith, G.F.; Wiersema, J.H.; Turland, N.J. 2012.* International Code of Nomenclature for algae, fungi, and plants (Melbourne Code) adopted by the Eighteenth International Botanical Congress Melbourne, Australia, July 2011. *Regnum Vegetabile 154. A.R.G. GantnerVerlag KG.*
- *Nicolson, D.H. (1991). "A History of Botanical Nomenclature". Annals of the Missouri Botanical Garden.* ***78*** *(1): 33–56.*
- *Spencer, R.D.; Cross, R.G. 2007. "The International Code of Botanical Nomenclature (ICBN), the International Code of Nomenclature for Cultivated Plants (ICNCP), and the cultigen". Taxon.* ***56*** *(3): 938–940.*
- Stearn, William T. (1952). "Proposed International Code of Nomenclature for Cultivated Plants. Historical Introduction". Journal of the Royal Horticultural Society. 77: 157–173.

5.11 SUGGESTED READINGS

- Davis, P.H. and V.H. Heywood. 1973. *Principles of Angiosperm Taxonomy*. Kreiger, New York.
- *Isely D. 2002. "Carl Linnaeus".OneHundred and One Botanists.*Purdue University Press.
- Jeffrey, C. 1982. *An Introduction to Plant Taxonomy*. University Press, Cambridge.
- Jones, S.B. Jr. and A.E. Luchsinger. 1986. *Plant Systematics*. McGraw-Hill Book Co., New York.
- Judd, W.S., C.S. Campbell, E.A. Kellogg and P.F. Stevens. 1999. *Plant Systematics: A Phylogenetic Approach*. Sinaeur Associate, Inc., Sunderland, MA, USA.
- Lawrence, G.H.M. 1951. *Taxonomy of Vascular Plants*. Macmillan, New York.
- Naik, V.N. 1984. *Taxonomy of Angiosperms*. Tata McGraw-Hill, New Delhi.
- Stace, C.A. 1989. *Plant Taxonomy and Biosystematics*. Edward Arnold, London.
- Stuessy, T.F. 1990. *Plant Taxonomy*. Columbia Univ. Press, New York.
- Woodland, D.W. 1991. *Contemporary Plant Systematics*. Prentice Hall, New Jersey.

5.12 TERMINAL QUESTIONS

5.12.1 Short answer questions:

(1)Write short note on ICBN.

(2) Briefly describe Vienna code.

(3) Describe the binomial system of classification in brief.
(4) Differentiate between taxa and morphotaxa.
(5) What is Phylo-Code.
(6) Write short note on typification.

5.12.2 Long answer questions:

(1)Explain about salient features of Melbourne Code, 2011.
(2)Describe about history of ICBN.
(3) Describe BioCode and Phylocode.
(4) What are the principles of ICBN?
(5) What is type specimen and describe different type of type specimens and their significance.

UNIT-6 TAXONOMIC EVIDENCES AND MODERN APPROCHES IN TAXONOMY

6.1 OBJECTIVES

After reading this unit students will be able to-

- Understand the various types of taxonomic evidences used in field of taxonomy.
- Know the concept of embryological, anatomical and palynological evidences in taxonomy.
- Understand palynology.
- Learn modern approaches in taxonomy.
- Explain the numerical and chemotaxonomy.

6.2 INTRODUCTION

Taxonomy is the science of grouping organisms into different categories on the basis of their gross morphological characters. The grouping, or classification, may be based on homology of various organs. The individuals of the same group must share common morphological features that have been inherited from a common ancestor. The earlier taxonomic work was based on gross morphology of organisms, merely descriptive and has limitations and termed as Alpha taxonomy by Turril (1938). Undoubtly gross morphological features have provided the foundation and framework for plant taxonomy as well as other fields of taxonomy.

Morphology has been the most widely used taxonomic tool in the field of plant classification from ancient times. Morphological study deals with external structure and form (Morph) of plants, usually its component organs. Morphological features have been extensively studied by classical taxonomists in various ways to classify plants thus it might be said that there is a little scope to learn. Morphological evidences provide the basic tool for plant characterisation, identification and classification. However, morphological characters are easy to observe and do not need any specific instrumentation, thus it seems most frequently used tool in classical taxonomic studies by traditional taxonomists.

Morphological features are traditionally used taxonomic tool as evidence at all taxonomic levels, particularly at the specific and generic levels. The gross morphological characters are habit of plant, root and stem habit and structural types, structure of bud, leaf and inflorescence, flower, perianth, androecium, stamen, gynoecium, types of carpel and fusion manner, types of ovules, fruit and seed. Flower modifications and alteration of stamens and attachment manner, position, size and shape of anther, ovary, style, stigma, number of carpels and their manner of fusion, perianth number and their attachment manner *etc.* contribute to the reproductive success of the species. The habit of plants (herb, shrub or tree) may be primarily useful in classification. Morphological characters are backbone for natural system of classification. Bailey (1949) has said, if a truly natural classification is to be attained, it must be based upon “the analysis and the harmonization of evidences from all organs, tissues and parts”.

The modern taxonomist has, therefore, must have a broader outlook than his predecessors a few years ago. The validity of relying of such a system of classification which is developed and build up simply on the basis of morphological features only have been criticized and challenged by the thinking botanists. To study the modern trends in taxonomy we must go through the history of classification and how this branch has developed with the development of peoples, instruments and techniques. We must keep in our minds that taxonomy today is a reflection of the past, meanwhile the systems of classification reflect both needs, level of knowledge, philosophical concepts and available technology of each historical period.

Now a day's taxonomy is progressing rapidly and these progresses have been brought about by the research work in various branches of science like optics, microscopy, molecular biology, cytology, cytogenetics, anatomy, embryology, biochemistry, paleobotany, *etc.* Thus we have entered in new era of taxonomy with major developments of tools and techniques. Modern taxonomists consider that the gross morphological characters are not always sufficient to provide means of differentiation in determining the genetically and evolutionary relationship among organisms. To achieve these taxonomical evidences from anatomy, embryology, palynology, cytology, palaeobotany, biochemistry molecular biology *etc.* are used as taxonomic tools. According to Puri (1958) **"One of the most significant modern trends in plant taxonomy is towards a synthesis between the older methods, outlook and more recent developments in our knowledge of plants"**.

6.3 TAXONOMIC EVIDENCES

6.3.1 Embryology

Embryology is the branch of science that deals with the study of sporogenesis, gametogenisis, fertilization, formation of zygote and embryo, development of endosperm finally in the form of seed and its protective covering (seed-coats).

Recognition of the value of embryology in taxonomy as a taxonomic tool for solving taxonomic problems was delayed because of the time and trouble involved in embryological data collection. The role of embryology as taxonomic tool in solving taxonomic problems was first brought into prominence by a German embryologist, Schnarf in 1931. Although the possibility of utilizing embryological characters in taxonomy was indicated by some earlier botanists like Hofmeister and Strasburger.

Embryological characters, have acquired great significance in plant taxonomy, especially when external morphological characters are inconclusive and misleading as a result of convergence. Thus the embryological evidences have been utilized by taxonomist for solving taxonomical problems which are not possible at gross morphological level. Although embryological evidences have its significance almost at all levels, and have helped to resolve the doubtful and disambiguous systematic positions of several taxa. According to Jones and Luchsinger (1987), the embryological characters have proved to be of significant role in determining relationships within families, genera and species, but less useful at the rank of order, subclass, or class.

The embryological characters have been utilized by plant taxonomists in analysis of evolutionary trends, delimitation of taxa and determining of systematic position of taxa, *etc.* Barthlott (1984) has given an account of seeds and fruits morphology as important tool in plant taxonomy, especially after the invention of the transmission microscopes which opened new vistas in field of taxonomy.

There are several embryological characters, which have proved to be of taxonomic significance.

(i) Anther: Number and arrangement of anther lobes (monothecous or bithecous), sporangium (tetra-, bi-, or monosporangiate). Tapetum tissue whether glandular (secreatory) or amoeboid (periplasmoideal), persistant or deciduous, dimorphic or monomorphic (like *Alectera thomsoni*). Type of endothecium *i.e.* structure and thickenings. According to Fossard (1969) endothelial thickenings contain high amount of alpha cellulose, lignin was found to be absent from endothelial walls in *Chenopodium rubrum* but Vasil (1969) confirmed slight lignifications at maturity with small amount of pectin in *Pisum* and *Lens.* Manner of division of microspore mother cell whether simultaneous or successive, and arrangement of microspores *i.e.* tetrahedral, isobilateral, linear, T-shaped or deccusate. Mode of pollen grains development, organization, pollen wall stratification, number of cells at the time of anthesis, number and position of germ pores and NPC (Number Position and Character) system *etc.* Wodehouse (1935) has proposed the classification of plants on the basis of critical studies of pollen grains structure in various groups or taxa and suggested that pollen grains of related family are similar.

(ii) Ovule: Development and structure of ovule, placentation, vasculature of integuments, and orientation of ovule has proved important, orthotropus ovule has been considered as evolutionary older. According to Davis (1966) 82% of angiospermic families show anatropus ovules and circinotropus ovule is characteristic feature of Cactaceae family. Form and extent of the nucleus *i.e.*, whether it is broad and massive (crassinucellate) or ephemeral (tenuinucellate), persistence or gradual disappearance of nucleus. The extent and origin of the sporogenous tissue in ovule *i.e.*, whether single-celled or several-celled, presence or absence of wall layers, type of division of nuclear epidermal cells; mode of mega-sporogenesis, arrangement of megaspores, position of the functional megaspore, and development of embryosac *i.e.*, whether monosporic, bisporic or tetrasporic embryosac and their types; number and distribution of nuclei in embryosac and presence and absence of endosperm; entrance or pathway of pollen tube to the ovule *i.e.*, porogamy, chalazogamy or mesogamy and temporal relationship between pollination and fertilization in addition to formation of seed and seed coat have provided data of taxonomical significance.

(iii) Endosperm: It consisted of presence and absence and mode of formation *i.e.,* whether nuclear, cellular or helobial type, nature of food reserves; persistence or gradual disappearance of endosperm at the time of maturity in seed; some special cases and abnormalities in development such as apogamy, apospory, diplospory, adventive embryony, polyembryony and parthenogenesis, *etc.*

Majority of angiosperms have anatropous ovule and polygonum type of embryo sac. Another characteristic feature of flowering plants is double fertilization and triple fusion, and post-fertilization development of polyploid endosperm, which also support the probable monophyletic origin of angiosperms. Further the classification of the Angiosperms into two groups namely, Monocotyledonae and Dictoyledonae is based on cotyledons present singly or in pairs which is the characteristics of embryo. Certain groups have well marked their characteristic embryological features like endospermic or non endospermic seeds and seeds with small embryo, *etc.* that can be easily used in identification of members of particular taxa. The delimitation of angiosperms in the first instance has been largely based on embryological characters.

Following are some examples of angiospermic orders and families, members of which exhibits uniform embryological features:

1- Caryophyllales: Order Caryophyllales is characterized bitegmic ovules with the inner integument longer than the outer with crassinucellate type of development, which are campylotropous or amphitropous type orientation and tri-nucleate pollen grains. Embryo curved, more or less surrounding the food storage tissue, consists mainly of perisperm, with little or no endosperm.

2. Gentianales: Gentianales is characterized by simple and opposite leaves, absence of integumentary tapetum and endosperm development is nuclear type, these characters help it to be distinguished from other sympetalous orders. Some of the families like Buddlejaceae, Menyanthaceae and Oleaceae, which had been formerly placed under Gentianales, have now been removed from it, on the basis of presence of integumentary tapetum and cellular endosperm.

3. Orchidales: This order is characterized very small seeds without or little endosperm (dust seeds).

4. Onagraceae and Tarpaceae: The family **Onagraceae** is characterized by the presence of peculiar monosporic tetranucleate Onagrad-type of embryo-sac except genus *Trapa*. The genus *Trapa* having an eight nucleate embryo sac which was earlier placed in the family Onagraceae, since have been removed from fomily Onagraceae and assigned to new family Trapaceae. Embryological evidences however strongly support that *Trapa* has a well developed suspensor haustorium and eight-nucleate embryosac, which are absent in members of family Onagraceae, Manasi Ram (1956) confirmed this in *Trapa bispinosa.*

5. Cyperaceae and Poaceae: In majority of angiosperms the pollen mother cell divides by meiosis and forms microspore tetrads all of which remain functional and produce two or three celled pollen grains. In the family Cyperaceae, while all four microspore nuclei are produced after meiosis, three of them are cut off on one side of the pollen grain and only the fourth develops to form the generative cell and then the male gametes.

Earlier systematists considered that Cyperaceae and Poaceae family to be closely associated. However morphological and anatomical features and the structure of the spikelets reveal that the two families are quite distinct. The Cyperaceae-Poaceae is also delimited by embryological evidences.

The micro-sporogenesis is of simultaneous type in Cyperaceae and out of three in tetrad degenerates and only one remains functional, on the other hand in the Poaceae, micro-sporogenesis is of successive type and all the spores in the tetrad remains functional. The parietal cell is present in the archesporium of the Cyperaceae, while lacking in Poaceae. The antipodals are ephemeral in Cyperaceae, while they form a complex or become coenocytic in Poaceae. The embryogeny is of Onagrad type with Juncus variation in Cyperaceae and it is variable in Poaceae. Thus embryological evidence reveals a close relationship of Cyperaceae with Juncaceae.

6. Garryaceae and Amentiferae: The disputed position of Garryaceae and Amentiferae has been resolved by use of embryological evidences. Several taxonomists like Engler and Gilg and Engler and Diels have referred them to Amentiferae, while Bentham and Hooker and Wangerin included them high up in the polypetalous families near Cornaceae. However, the latter placement is more natural, which has been confirmed by morphological and embryological studies of Hallock (1930). Comparative morphological and phylogenetic studies of the family also support the view of their inclusion in the Cornales.

7. Liliaceae and Amaryllidaceae: The family Liliaceae has also been resolved based on embryological evidences. The Liliaceae and Amaryllidaceae family are considered as polyphyletic, and certain taxa of these families are closely related. Based on embryological data certain taxa have been resolved under family Liliaceae, Amaryllidaceae and Agavaceae.

Other systematic cases resolved by embryological evidences are:

Paeonia was previously kept under family Ranunculaceae but based on embryogeny and font size pollen characters, this genus has been shifted from Ranunculaceae to family Paeoniaceae.

Butomus is unique genus having monosporic 8-nucleate embryo sac, while *Butomopsis*, *Limnocharis* and *Hydrocleis* have bisporic, 5-nucleate embryo sacs. Thus *Butomus* retained under Butomaceae while all the others taxa resolved under Alismataceae.

The separation of *Hippocratea* from Celastraceae into a separate family Hippocrateaceae and placing of genus *Sphenoclea* under Campanulaceae is based on embryological studies. The splitting of Gentianaceae into Menyanthaceae and Gentianaceae, Malvaceae in to Bombacaceae and Malvaceae is also based on embryology Embryogeny of *Lemna*, *Wolffia* and *Arisaema* confirms older views of an intimate relationship of the duck weeds with the aroids.

The disputed systematic position of the genus *Parnassia* has been resolved by embryological evidences. Formerly *Parnassia* has been treated as a member of the family Saxifragaceae but dissimilarity of its embryology with the other genera of Saxifragaceae, suggested that it should be removed from Saxifragaceae and resolved under family Parnassiaceae.

6.3.2 ANATOMY

Undoubtly morphology (external features) provides primary taxonomic evidence but internal structure of plants can provide more information in solving taxonomic problems. Anatomy is the study of internal structure, organization of plant cell and tissues. When morphological characters are solely unable to prove or no help in the preliminary identification of taxa, anatomical evidences may be helpful. Anatomical characters of vegetative and floral parts of plants have been successfully employed in solving angiosperm taxonomic problems and for resolving of phylogenetic relationships among them. Anatomical evidences have proved to be very useful in discerning evolutionary trends and interrelationships of taxa at and above the species level and at higher taxonomic categories. The most useful evidence is in determining relationship between different genera, families, orders and other taxonomic categories. Thus anatomical studies of flowering plants can serve as an integral part of taxonomy. The application of anatomical data to phylogenetic problem is of great value in elucidating taxonomic relationships. Vegetative anatomy and floral anatomy have been proved useful in resolving controversial systematic position and classification of several taxa. A fairly long list of correlated characters of vascular tissues is given by Sporne (1956). The vascularization of floral parts, nodes, and integuments of seeds also give the clues of affinities. The vegetative anatomical evidences come from:

i) Cell size, shape and type.
ii) Cell wall structure and sculpture pattern.
iii) Leaf anatomy: Stomatal type, Mesophyll tissue, Trichome type, crystal type (Raphides, sphaeraphides, cystolith, *etc.*), Ventation, Petiole vasculature, *etc.*
iv) Epidermal tissue system.
v) Ground tissue sytem.
vi) Vascular system and stealer system.

vii) Wood anatomy and type (Xylem, wood and ray type).
viii) Nodal anatomy.
ix) Sclerieds types and origin.
x) Periderm anatomy and origin.
xi) Pholem and its components, and
xii) Any specialized cell, its origin and evolution.

Stomata are very useful anatomical tool in the fields of plant taxonomy for resolving the appropriate position of several taxa. Stomata have been classified according to the origin of various stomatal cells, position of subsidiary cells and guard cells in relation to the aperture. Stomata are classified into following types based on their development:

1. **Ranunculaceous or anomocytic/irregular celled:** This type is the feature of Ranunculaceae, Capparidaceae, Malvaceae and some other families.
2. **Cruciferous or anisocytic/unequal celled:** This type of stomata is found in members of Cruciferae (Brassicaceae) and several genera of Solanaceae family.
3. **Rubiaceous or paracytic/parallel celled:** This type of stomata is feature of family Rubiaceae and allies.
4. **Caryophyllaceous or diacytic/cross celled:** Common in members of Caryophyllaceae, Lamiaceae and Acanthaceae.
5. **Gramineous type:** These types of stomata are commonly found in members of family Gramineae (Poaceae) and Cyperaceae.

There are 31 known types of arrangement of subsidiary cells in the stomatal complex of vascular plants. At higher taxonomic levels, these distinct patterns play a big role in classification of several taxa. However, in some plants various types of stomata are present together.

Crystal

Crystals of calcium oxalate are found in many families like Apocynaceae, Begoniaceae, Cactaceae, Caricaceae and Euphorbiaceae. In these families sphaeraphides are common. Raphides are very common in the monocotyledons like Araceae and Musaceae. Crystals of calcium carbonate (Cystoliths) are commonly found in the family Acanthaceae, Boraginaceae and Urticaceae.

Vascular bundles

Scattered vascular bundles are feature of monocot stems, while in dicot stems vascular bundles are arranged in ring. Bicollateral vascular bundles are found in members of family Cucurbitaceae and Gentianaceae.

Generally vascular bundles are found in steler region but some abnormal occurrences of vascular bundels are characteristic to particular taxa *e.g.* cortical bundles are found in a number of families Araliaceae (*Panax*), Bombacaceae (*Bombax*), Cactaceae (*Rhipsalis*), Aizoaceae (*Mesembryanthemum*), Oleaceae (*Nyctanthes*) and Asteraceae (*Vernonia*), and Medullary bundals/phloem are found in *Aralia racemosa* (Araliaceae), Amaranthaceae, Chenopodiaceae, Crassulaceae (*Echevaria*), Euphorbiaceae, *Melastoma* (Melastomaceae), Nyctaginaceae, Polygonaceae, Piperaceae; *Dahlia*, *Lactuca* and *Sonchus* (Asteraceae) *etc.* In members of Salvadoraceae, Apocynaceae (*Lysonia*), Asclepiadaceae (*Leptadenia lancifolia, Asclepias obtusifolia and Ceropegia*), Combretaceae (*Calycopteris*) forminate type interxylary phloem is found. Concentric type inter-xylary phloem is found in members of Chenopodiaceae, Icacinaceae, Loranthaceae Menispermaceae, Onagraceae (*Epilobium* and *Oenothera*), Papilionaceae (*Wistaria*).

Wood Anatomy

Based on wood anatomy, several taxonomic problems have been resolved successfully. Wood anatomy also provides a phylogenetic tool in determining evolutionary relationship among taxa. Wood anatomy has helped to establish the systematic position of primitive vesselless angiosperms. It is believed that there is a progressive evolution in angiosperms from small tracheids to long narrow vessels with lignified thickening of various types. Wood anatomy reveals that Gnetales are not ancestral to angiosperms and Amentiferae constitute a relatively advanced group. Nonporous wood is mainly found in gymnosperms thus it makes the characteristic feature of it while porous wood is found in angiosperms thus characteristics for angiosperms. Anatomical work of taxonomic significance was mainly dealt by Bailey (1940) who suggested that in Gnetales the vessels arose from tracheids with circular pittings while in angiosperms they evolve with scalariform pitting. Members of angiosperm families like Winteraeae, Trochodendraceae, Tetracentraceae, *etc.* show their primitive angiospermic relationship. Magnoliales are considered primitive on the basis of wood anatomy. Wood anatomy provides a strong evidence for separation of genus *Austrobaileya* and *Paeonia* to separate family as Austrobaileyacae and Paeoniaceae respectively; *Amborella*, *Tetracentrom* and *Trochodendron* are resolved as independent families. Family Rapateaceae differs from Xyridiaceae having silica bodies, tannin cells and type of chlorlenchyma.

Bureau, for the first time used anatomical characters in plant classification for the delimitation of taxa of various levels. Bureau's work on the family Bignoniaceae, in which anatomical features were made use of in the diagnosis of the genera. However Radlkofer's monograph of the Sapindaceous genus *Serjauia* is really the flrst important contribution towards systematic anatomy, being based on the anatomical examination of numerous specimens of each species and a careful comparison of the relative value of the different features observed.

Floral Anatomy

Floral anatomy proves to be significant taxonomic evidence in identification and classification of angiospermic plants. The role of floral anatomy has been emphasised in solving taxonomic problems. It is also important in understanding the evolutionary relationship thus tracing the phylogeny of angiosperms. The behavior and numerical strength of vascular bundles in floral parts of plant have been utilized in taxonomic study. Once the vascular bundles are formed they become autonomous with regard to their behavior by virtue of their position. Vascular anatomy of floral organs mostly helps in ranking taxa of higher level such as genera and families in taxonomic hierarchy.

Floral anatomy is used in resolving systematic positions of several taxa like members of Asclepiadaceae, *Opuntia, Cuscuta*, *Evolvulus, etc.* Based on floral anatomy it is believed that, Cactaceae is closely related to Calycanthaceae. Eames (1953) suggested the removal of *Paeonia* from Ranunculaceae and frmation of a new family Paeoniaceae on the basis of floral anatomy. On the basis of floral anatomy Puri (1958), suggested that the gynoecium structure in the Capparidaceae, Cruciferae, Moringaceae and Papaveraceae is essentially alike. Similarly floral anatomy has offered valuable evidence concerning other doubtful genera such as *Trapa*, *Peperomia*, *Centella* and *Hydrocotyl* on the basis of vascular supply in inflorescence and ovule. *Melandrium* is separated from genus *Silene* on the basis of locules in ovary (unilocular).

6.3.3 Palynology

Palynology is deals with the study of pollen grains (modern and fossil) and spores generally focusing on the wall structure rather than on internal or living features and its applications. The term Pollen is derived from Greek word “palynein” meaning to scatter. Since the first use of the term palynology by Hyde and Williams in 1945, it has emerged as an important discipline of fundamental and applied interests. Pollen grains are often easily disseminated by wind, insect, water *etc.* and found in everywhere *e.g.* in rock sediments, glacier ice, air over the poles and oceans. Fossil spores occur in peat and various sediments. Palynology has proved significant in the field of plant taxonomy. The significance of pollen attributes in taxonomy has been realised during the last few decades with the revolutionary changes in field of microscopy. Now a days, palynological investigations have become a popular tool in plant taxonomy, especially with the invention of the high resolution power microscopes such as scanning electron microscope and transmission electron microscopes. The basic of this branch is in work of Erdtman’s (1969) Handbook of Palynology later edited by Nilson and Praglowski (1992). The invention of Scanning Electron microscopy (SEM) and transmission Electron microscopy (TEM), besides light microscopy, helps in revealing ultra-structure of the pollen grains. The angiospermic pollen grains vary in shape and size. The shape of pollen varies from spheroidal to oval, rhomboidal, rectangular and circular to semi-angular, angular or lobate. It varies from 8-10 µm to 350 µm in angiosperms or more even in certain members of families Cucurbitaceae and Nyctaginaceae.

Outer special covering of pollen is called sporoderm, which provides another important character for consideration. Sporoderm or pollen wall is made up of biologically very resistant substance called sporopollenin. Pollen wall comprises of two layers, the outer is the ektexine/sexine and the inner is endexine/nexine. Ektexine presents various structural and sculptural elements which help in identification, classification, *etc*. Endexine does not present such structure and sculpture as the ektexine but its thickness or other irregularity helps in various ways. The use of pollen morphology in the field of angiosperm taxonomy has been dealt with in great deatails by Wodehouse (1935) in the form of book Pollen-Grains and Erdtman (1957) who discussed the taxonomic indications of pollen morphology in angiosperms.

NPC system: The NPC analysis can be applied in systematic investigation in various taxonomic groups like sub-family, genera, species, *etc.* The pollen classification is based on Number (N) Position (P) and Character (C) of aperture, called NPC system. Under this system the usage of term treme has been recommended in place of aperture for purpose of preparing key for the classification of pollen grains. A treme is represented by N_0 for pollen grains without aperture. Depending on number of apertures pollens are called monotreme (N_1), ditreme (N_2), tritreme (N_3), tetratreme (N_4) type, *etc.* For example the number of apertures in the cryptogams is only one in proximal position and gymnosperms whenever the grains are aperturate, the position is distal. The apertures are ill-developed (primorphous) in thallophytes, while in bryophytes, pteridophytes and gymnosperms (archegoniates), pollen-grains are trimorphous and in the angiosperms polymorphous. The apertural conditions of pollen-grains have been utilised in solving taxonomic problems. Taxa with the same general NPC formula should be grouped together and those showing aberrant NPC separately. Nair (1974) classified the plant kingdom into (i) Amorphosporophyta (Primorphosporatae), which includes Thallophyta with no apertural markings (ii) Trimorphosporophyta (Trimorphosporatae) which includes Archegoniatae with monolete, trilete or alete spores and (iii) Polymorphosporophyta (Polymorphosporatae) which includes angiosperms with diverse apertural types on the basis of above morphological situations. This analysis has thrown light on the phylogeny and evolution of the primitive angiosperms.

Stenopalynous and Eurypalynous taxa: There are Stenopalynous (constant range) or Unipalynous and Eurypalynous (Diverse or broad range) or multipalynous two broad categories of angiospermic taxa based on range of pollens found. Stenopalynous taxa are those, which bear constant pollen type *e.g.* Cruciferae, while in others, called Eurypalynous if there are broad range of pollens or different pollen types varying in size, shape, aperture, exine stratification *e.g.* Compositae (Asteraceae), *etc.*

Palynological studies have helped in resolution of doubtful taxa *e.g.* separation of Paeoniaceae from Ranunculaceae, Nelumbaceae from Nymphaeaceae, Fumariaceae from Papavaraceae, Bombacaceae from Malvaceae and Cuscutaceae from Convolvulaceae. According to Bailey and Nast (1943;1944) "There are families of dicotyledons in which the pollen is of very considerable taxonomic significance, not only in the differentiation of subfamilies and tribes, but also of genera and species".

6.4 MODERN APPROACHES IN TAXONOMY

6.4.1 Numerical Taxonomy

Numerical taxonomy (or taxometrics/taximetrics) is a kind of classification based on numerical comparison of large number of equally weighted characters scored consistently for all groups under consideration and in which individuals are grouped solely on the basis of observable similarities without regard to phylogeny. The criteria of taximetrics is overall morphological, anatomical, physiological or biochemical similarities and dissimilarities. Such classifications came to be known as Adansonian classifications. According to Heywood (1967) the numerical taxonomy (or Taxometrics) is defined as a numerical evaluation of the similarity between groups of organisms and the ordering of these groups into higher ranking taxa on the basis of these similarities.

Numerical taxonomy is a classification system deals with the grouping by numerical methods of taxonomic units based on their character states. It aims to create a taxonomy using mathematical or statistical methods like cluster analysis rather than using subjective evaluation of their properties. Numerical taxonomy developed in the late 1950s as part of multivariate analyses and in parallel with the development of computers. Its aim was to devise a consistent set of methods for classification of organisms. Michel Adanson (1727-1806), a French botanist, first time gave views regarding fundamental position of numerical taxonomy. The views were represented by certain principles. He put forward a plan for assigning numerical values to the similarity between organisms and proposed that equal weightage should be given to all the characters while classifying plants. These principles are therefore frequently called neo-Adansonian-principles. The modern concept of Numerical taxonomy was initiated by Robert R. Sokal and Peter H.A. Sneath in 1963 by publication of a book *Principles of Numerical Taxonomy* and later was elaborated in 1773 as *Numerical Taxonomy* by them, which laid down seven principles of numerical taxonomy. They divided the field into phenetics in which classifications are formed based on the patterns of overall similarities and cladistics in which classifications are based on the branching patterns (Cladistics) of the estimated evolutionary history of the taxa. Numerical taxonomy or taxometrics/taximetrics, perhaps more appropriately referred to as phenetics, refers to the application of various mathematical procedures to numerically encoded character. In recent years numerical taxonomy and phenetics are considered as synonyms or interchangeable by many authors despite of the distinctions made by those authors.

Principles of Numerical Taxonomy:

Seven principles of numerical taxonomy laid by by Sneath and Sokal are summarised as follow:

1. The greater the content of information in the taxa of classification and more the characters on which it is based, the better a given classification will be.

2. A priori, every character should be given equal weightage in creating natural taxa.
3. The overall similarity between any two entities is a function of the individual similarities in each of the many characters, which are considered for comparison.
4. Distinct taxa can be recognized because correlation of characters differs in the groups of organisms under study.
5. Phylogenetic inferences can be drawn from the taxonomic structure of a group and from character correlations, given some assumptions about evolutionary mechanisms and pathways.
6. The science of taxonomy is viewed and practiced as an empirical science.
7. Classifications are based on Phenetic similarity.

Merits and Demerits of Numerical Taxonomy

Merits

1. In numerical taxonomy data is collected from diverse sources *e.g.* morphological, anatomical, biochemical, physiological sources *etc.* Thus data of conventional taxonomy is improved by numerical taxonomy as it utilizes better and more number of described characters.
2. As numerical methods are more sensitive in delimiting taxa, the data obtained can be efficiently used in the construction of better identification keys and classification systems, with the help of computational data processing systems.
3. The biological concepts have been reinterpreted in the light of numerical taxonomy.
4. Numerical taxonomy opens door for taxonomic work for less skilled workers while taxonomy is tedious and time consuming science for beginners.

Demerits

1. The Numerical taxonomic system gives weightage to characters thus it proved to be phenetic classification, not phylogenetic classification.
2. The proponents of **biological** species concept may not accept the specific limits bound by these methods.
3. The equally weighted character selection is a disadvantageous approach in numerical taxonomy. In inadequate selection of characters for comparison of taxa, there are full chances of getting unsatisfactory solution by statistical calculations.
4. There are chances of altered result in using different taxometric processes. According to Steam, different taxonometric procedures may yield different results. Selection of number of characters imparts a major difficulty to obtain satisfactory results. It is necessary to ascertain whether a large number of characters would really give satisfactory results than those using a smaller number.

Operational Taxonomic Unit (OTU):

In numerical taxonomy term Operational Taxonomic Unit (OTU) is given to the lowest ranking taxa or taxonomic entities under investigation. Any item, individual or convenient group or basic units used for comparison or analysis in any specific study is called Operational Taxonomic Units (OTU's). The term Operational Taxonomic Unit (OTU) was originally introduced by Sokal and Sneath (1963; 1973) in the context of Numerical taxonomy, where an Operational Taxonomic Unit (OTU) is the group of organisms undergoing in the study. Thus an Operational Taxonomic Unit (OTU) is a practical definition to group individuals on the basis of similarity, equivalent to but not necessarily in line with modern phylogenetic or classical Linnaean taxonomy.

Cluster analysis is a method for arranging OTUs into homogenous group on the basis of their mutual similarities. Clusters are the groups of Operational Taxonomic Units (OTUs). Phenon are the groups of similar organisms recognized by cluster analysis. Phenons may be prefaced by a number of indicating the percentage of similarity at which they are formed *e.g.* 75-phenon indicates a group whose members are affiliated at no lower than 75 percent. In practice phenon defines group by drawing lines horizontally across the dendrogram. Dendrogram is a branching diagram in the form of a tree used to depict degrees of relationship or resemblance. Separate dendograms expressing the average linkage were computed using available computer programs, which produce a phenogram that is a dendrogram of phenatic relations in which less similar OTUs successively linked together (Fig: 6.1).

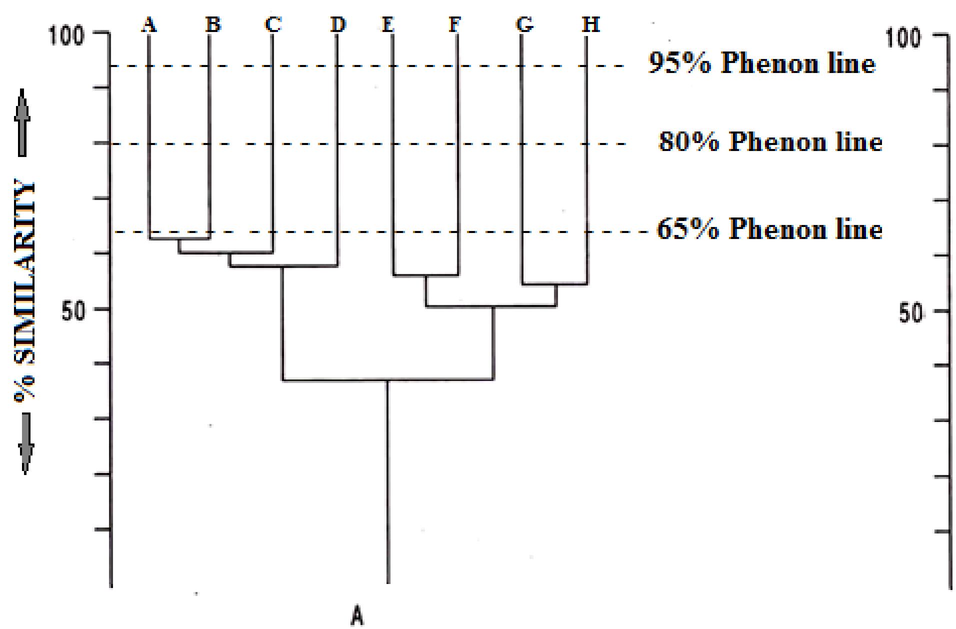

Fig.6.1: Dendrogram representing a hypothetical hierarchy in terms of phenon line or operational taxonomic unit (OTU).

6.4.2 Chemotaxonomy

The use of chemicals found in plants naturally as taxonomic tool in plant classification or for solving taxonomic problems is called chemotaxonomy or chemosystematics. Thus in general chemotaxonomy is use of biochemistry in taxonomic studies. Plants produce several kinds of natural products in varying amounts, and quite often according to their own biosynthetic pathways, these compounds also differ from one taxonomic group to another. The occurrence, distribution and biosynthetic pathways of the various types of chemical compounds present in plants prove to be of taxonomic significance. Chemotaxonomy is the based assumption that similar or related group of plants have similar chemical compounds. Thus plant chemicals play a key role in identification and systematic botany. It gives close relationship between chemical constituents of plants and their taxonomical status. The basic chemical compounds used in chemotaxonomy are phenolics, alkaloids, terpenoids and non-protein amino acids. Except these carotenoids, tannins, flavanoids, betalins, anthocyanins, glucosinolates, fatty acids, and oils are also exploited in chemotaxonomy. However, all kinds of chemical compounds present in plants do not play significant role to provide useful taxonomic information. Mentzer (1966) recognized three principal kinds of chemical constituents helpful in taxanomy: (a) **Basic or primary constituents** *e.g.*, proteins, nucleic acids, chlorophyll and polysaccharides, *etc.*, (b) **Secondary constituents** lacking nitrogen and not involved directly in plant metabolism *i.e.*, simple phenolic compounds like flavonoids, terpenes, coumarines, alkaloids, *etc.* and (c) **Miscellaneous substances**: Their use in taxonomy is not developed so far.

On the basis of their molecular weight, Jones and Luchsinger (1987) have divided the natural chemical plant products useful in taxonomy, into two major groups.

1. Micromolecules: Micromolecules are compounds of relatively low molecular weight (1000 or less) *e.g.,* amino acids, alkaloids, cyanogenic glucosides, fatty acids, terpenoids, flavonoids, anthocyanins, betalins, *etc.*

2. Macromolecules: Macromolecules are high molecular weight compounds (over 1,000) e.g., proteins, DNA, RNA, complex polysaccharides, *etc.*

The sementides (or semantophoretic molecules) are information carrying macromolecules such as DNA, RNA, polypeptides, *etc.* Semantides also carry phylogenetic information about evolutionary history and are classified into three categories: the genes themselves are known as 'primary semantides', the mRNA transcripts 'secondary semantides', and polypeptides 'tertiary semantides'.

The chemical compounds, used in solving taxonomic problems are as follows:

1. **Tannins:** These are amorphous substances with wide distribution pattern in plant kingdom. Tannins are known for their astringent flavor and form cloured solution with iron and other metals. Anacardiaceae, Lauraceae, Punicaceae, Magnoliacae, Meliaceae, Moraceae, Sapindaceae, Sapotaceae, Rosaceae, Urticaceae, Theacae *etc.* are tanniniferous families. Acanthaceae, Amaranthaceae, Campanulaceae, Chenopodiaceae, Cucurbitaceae, Lamiaceae, Solanceae *etc.* are non-tanniniferous families.
2. **Steroids:** Steroids may be considered as derivatives of a fused and fully saturated ring system called cyclopentanoperhydrophenanthrene or sterane. These are Cardinolites or cardiotonic glucosides, found in family Apocynaceae, Asclepiadaceae, Celastraceae

(Euonymus), Euphorbiacaea (Mallotus), Scrophulariaceae (Digitalis), Ranunculaceae (*Isoplexis*), Rosaceae *(Malus*= Sex hormone steroids) Salicaeae (*Salix*= Estradiol) *etc.*

3. **Alkaloids:** Alkaloids are heterogenous group of nitrogen containing organic compounds with nitrogen containing heterocyclic nucleus derivative from a biogenic amine structurally related to parent base such as pyridine, piperidine, isoquinoline, and tropane. Alkaloid distribution has been proved usefull taxonomic tool in plant systematics. For example, alkaloid protopine is found in all species of family Papavaraceae and Fumariacae thus tracing close relationship of family Papavaraceae and Fumariaceae. But members of family Fumariaceae have a combination of isoquinine derivative while these are absent in members family of Papvaraceae. Berberidaceae Fabaceae, Ranunculaceae, and Solanaceae are rich in alkaloid containing families.
4. **Phenolics/Flavanoids:** Flavanoids are largest group of naturally occurring phenols, mostly found in vacuoles of plant cells. Phenols contain hydroxyl group directly attached to aromatic nucleus. Flavanoids include flavones, flavonones, isoflavones, anthocynidins, *etc.*
5. **Terpenoids:** these are volatile compounds responsible for essence in plants like Mints, Citrus, Umbellifers, gymnosperms, *etc.* Terpenoids are mostly polymerized isoprene isoprene units (C_5). On the basis of isoprene units present in a terpenoid molecule, they are categorized as follows:
   1. Monoterpenoids (two isoprene units) — *e.g.,* menthol
   2. Sesquiterpenoids (three isoprene units) — *e.g.,* farnesol
   3. Diterpenoids (four isoprene units) — *e.g.,* phytol
   4. Triterpenoids (six isoprene units) — *e.g.,* squalene
   5. Tetraterpenoids (eight isoprene units) — *e.g.,* β-carotene
   6. Polyterpenoids (multiple isoprene units-$(C_5)_n$) – *e.g.* Latex, rubber

Terpenoids are almost universal, though not as widespread as flavonoids and have been used extensively in the chemotaxonomy of mints, umbellifers, *Citrus* plants, and gymnosperms. Some specific terpenoids are characteristic to particular families, *e.g.,* lactones in family Asteraceae, cucurbitacins in Cucurbitaceae and asperuloside in Rubiaceae.

6. **Betalins:** Betalins are pigments, different from flavonoids and other phenolic compounds due to presence of nitrogen in them. However, they are functionally equivalent to phenolics, popularly known as nitrogenous anthocyanins. Red to violet betacyanins and yellow betaxanthins are confined to ten families of angiosperms (which contain only betalin but no anthocyanin):- Chenopodiaceae, Portulacaceae, Aizoaceae, Cactaceae, Nyctaginaceae, Phytolaccaceae, Stegnospermaceae, Basellaceae, Amaranthaceae and Didieraceae, which have been included under a single, order Centrospermae.

7. **Iridoids:** Iridoids are separate class of monoterpenoid cyclopentanoid lactones, which also represent a separate class of taxonomically significant compounds. The distribution of iridoid compounds has been proved helpful in tracing phylogenetic ancestry. Several iridoid compounds like asperuloside are particularly common in family Rubiaceae. Aucubin is frequently found in

family Cornaceae, Scrophulariaceae, Orobanchaceae, *etc.* The aucubin-containing genus Buddleja transferred from the Loganiaceae to the Buddleiaceae, with a position near the Scrophulariaceae.

8. Cyanogenic Compounds: The poisonous compounds produced by plants after injury to their cells are called cyanogenic compounds and such plants are called cyanophoric plants. Examples of such compounds are hydrocyanic acid, amygdalin, etc. Cyanophoric plants usually contain one or several cyanogenic glycosides. The taxa belonging to family Araceae, Poaceae, Juncaceae, Juncaginaceae and Scheuchzeriaceae are common cyanogenic plants. Several dicotyledonous families belonging to Asteridae, Rosidae and Dilleniidae are also cyanogenic.

Thus the use of chemical criteria proves to be an efficient taxonomic tool in the field of plant taxonomy or systematics.

6.5 SUMMARY

1. Taxonomy is the science of grouping organisms into different categories on the basis of their gross morphological characters.
2. The earlier taxonomic work was based on gross morphology of organisms, merely descriptive and had limitations and termed as “Alpha” taxonomy by Turril (1938).
3. Morphology has been the most widely used taxonomic tool in the field of plant classification from ancient times.
4. Morphological evidences provide the basic tool for plant characterisation, identification and classification.
5. The modern taxonomist has, therefore, to have a broader outlook than his predecessor a few years ago.
6. Now a day’s taxonomy is progressing rapidly and these progresses have been brought about by the research work in various branches of science like optics, microscopy, molecular biology, cytology, cytogenetics, anatomy, embryology, biochemistry, paleobotany, etc.
7. Embryology is the branch of science that deals with the study of sporogenesis, gametogenisis, fertilization, formation of zygote and embryo, development of endosperm finally in the form of seed and its protective covering (seed-coats).
8. The role of embryology as taxonomic tool in solving taxonomic problems was first brought into prominence by a German embryologist, Schnarf in 1931.
9. Morphological features are traditionally used taxonomic tool as evidence at all taxonomic levels, particularly at the specific and generic level.
10. Embryological characters, have acquired great significance in plant taxonomy, especially when external morphological characters are inconclusive and misleading as a result of convergence.

11. The embryological characters have been utilized by plant taxonomists in analysis of evolutionary trends, delimitation of taxa and determining of systematic position of taxa, *etc.*
12. Majority of angiosperms have anatropous ovule and *Polygonum* type of embryo sac. Another characteristic feature of flowering plants is double fertilization and triple fusion, and post-fertilization development of polyploid endosperm, which also support the probable monophyletic origin of angiosperms.
13. Vegetative anatomy and floral anatomy have been proved to resolving controversial systematic position and classification of several taxa.
14. When morphological characters are solely unable to prove or no help in the preliminary identification of taxa, anatomical evidences may be helpful.
15. Undoubtly morphology (external features) provides primary taxonomic evidence but internal structure of plants can provide more information in solving taxonomic problems.
16. Stomata are very useful anatomical tool in the field of plant taxonomy for resolving the appropriate position of several taxa.
17. There are 31 known types of arrangements of subsidiary cells in the stomatal complex of vascular plants.
18. Scattered vascular bundles are feature of monocot stems, while in dicot stems vascular bundles are arranged in ring. Bicollateral vascular bundles are found in members of family Cucurbitaceae and Gentianaceae.
19. Based on wood on wood anatomy, several taxonomic problems have been resolved successfully.
20. Wood anatomy has helped to establish the systematic position of primitive vesselless angiosperms.
21. Floral anatomy proves to be significant taxonomic evidence in identification and classification of angiospermic plants.
22. Palynology deals with the study of pollen grains (modern and fossil) and spores generally focusing on the wall structure rather than on internal or living features and its applications.
23. Outer special covering of pollen is called sporoderm, which provides another important character for consideration.
24. The NPC analysis can be applied in systematic investigation in various taxonomic groups like sub-family, genera, species, *etc.*
25. Palynology has proved significant value in the field of plant taxonomy.
26. There are stenopalynous (constant or narrow range) and Eurypalynous (diverse or broad range) two broad categories of angiospermic taxa based on range of pollens found.
27. The use of chemicals found in plants naturally as taxonomic tool in plant classification or for solving taxonomic problems is called chemotaxonomy or chemosystematics.
28. On the basis of their molecular weight, Jones and Luchsinger (1987) have divided the natural chemical plant products useful in taxonomy, into two major groups: 1. Micromolecules and 2. Macromolecules.

29. Micromolecules are compounds of relatively low molecular weight (1000 or less) *e.g.* amino acids, alkaloids, cyanogenic glucosides, fatty acids, terpenoids, flavonoids, anthocyanins, betalins, *etc.*
30. Macromolecules are high molecular weight compounds (over 1,000) e.g. proteins, DNA, RNA, complex polysaccharides, *etc.*

6.6 GLOSSARY

Anatomy: Branch of biology concerned with the study of the internal structure of organisms and their parts.

Androecium: Male reproductive whorl of flower, collective term for stamens.

Anther: Male reproductive part of flower that produces and contains pollen and is usually borne on a stalk.

Archegoniates: Collective term for archegonia containing taxa *e.g.* bryophytes, pteridophyte and most gymnosperms.

Biochemistry: Branch of science concerned with the chemical substances which occur within living organisms.

Chemotaxonomy: Solving taxonomic problems and classification on the basis of chemicals found in particular taxon.

Coenocytic: A cell which can result from multiple nuclear divisions without their accompanying cytokinesis.

Cystolith: Crystals of calcium carbonate arising from the cellulose wall of cells of higher plants.

Dendrogram: A tree or branch diagram, especially one showing taxonomic relationships.

Embryology: Branch of biology that deals with development of gametes, fertilization, and development of embryo.

Embryo-sac: The megaspore of a seed-bearing plant, situated within the ovule, giving rise to the endosperm and forming the egg cell or nucleus from which embryo develops after fertilization.

Endosperm: Endosperm is a nutritive tissue found in the seeds of nearly all the flowering plants after double fertilization.

Eurypalynous taxa: Taxa having diverse range of pollens.

Family: A taxonomic rank which comprises group of similar genera.

Flower: Reproductive or colorful part of plant.

Folk taxonomy: The vernacular naming or classification on the basis of cultural tradition, rather than on scientific principles.

Genera/Genus: A taxonomic rank which comprises one or more than one of similar species.

Gynoecium: Female part/whorl of flower.

Inflorescence: Arrangement of flowers on inflorescence axis.

Morphology: Branch of biology that deals with the form and structure of organisms.

Order: A taxonomic rank which comprises one or more than one similar families.

Ovule: The part of the ovary of seed plants that contains the female germ cell and after fertilization becomes the seed.

Paleobotany: Botany related the study of fossil plants.

Palynology: Science related to study pollen grains.

Perianth: Outermost whorl of a flower, consisting of the calyx (sepals) and corolla (petals).

Phenogram: A diagram depicting taxonomic relationships among organisms based on overall similarity of many characteristics without regard to evolutionary history.

Raphides: Needle-shaped crystal of calcium oxalate occurring in clusters within the tissues of certain plants.

Species: Group of organisms consisting of similar individuals and capable of exchanging genes or interbreeding.

Sphaeraphides: Globular clusters of minute crystals in certain plant cells actually spherical aggregation of raphides in a plant cell.

Sporoderm: The covering or coating of a spore or pollen.

Stamen: Male organ of a flower, typically consisting of a pollen-containing anther and a filament.

Stenopaiynous taxa: Taxa having constant pollens.

Systematics: The branch of biology that deals with identification, classification and nomenclature, taxonomy.

Taxometrics/Taximetrics: A classification system in biological systematics which deals with the grouping by numerical methods of taxonomic units based on their character states; Numerical taxonomy.

Taxon (pl. Taxa): A taxonomic group of any rank, such as a species, family, or class.

Taxonomy: Arrangement according to rules or branch of science related to naming of organisms.

6.7 SELF ASSESSMENT QUESTION

6.7.1 Multiple choice questions (MCQs):

1. Most primitive type of ovule is:

(a) Orthotropous (b) Anatropous

(c) Circinotropous (d) Amphitropous

2. Circinotropus ovule is characteristic feature of family.

(a) Cactaceae (b) Papilionaceae

(c) Rhamnaceae (d) Moraceae

3. Term treme used for:

(a) Aperture of Pollen (b) Sculpture of Pollen

(c) Aperture of ovule (d) All of these

4. Stenopalynous taxa have:
(a) Constant pollens types (b) Diverse Pollen types
(c) Taxa without pollens (d) None of these

5. OTU in taxonomy stands for**:**
(a) Operative Taxonomic Unit (b) Only Taxonomic Unit
(c) Operational Taxonomic Unit (d) One Taxonomic Unit

6. Volatile compounds found in plants.
(a) Flavanoids (b) Phenolics
(c) Terpenoids (d) Iridoids

7. Taxa having diverse pollen types called.
(a) Stenopalynous (b) Eurypalynous
(c) Stenotremous (d) Eurytremous

8. Violet colouration in members of Chenopodiaceae is due to:
(a) Anthocyanins (b) Betalins
(c) Carotenes (d) Phycobilins

9. The disputed position of Garryaceae and Amentiferae has been resolved by:
(a) Embryological evidences (b) Anatomical evidences
(c) Morphological evidences (d) Palynological evidence

10. *Paeonia* was previously kept under family:
(a) Orchidaceae (b) Rosaceae
(c) Ranunculaceae (d) Chenopodiaceae

11. Term Alpha taxonomy was coined by:
(a) Turril (b) Hutchinson
(c) Linnaeus (d) Sokal

12. Scattered vascular bundles are feature of:
(a) Monocot stems (b) monocot roots
(c) Dicot stems (d) Dicot roots

13. Identification of taxa with the help of chemicals found in them called:
(a) Biosystematics (b) Taximetrics
(c) Chemotaxonomy (d) All of the above

14. Bicollateral vascular bundles are feature of family:

(a) Cruciferae (b) Gentianaceae

(c) Cucurbitaceae (d) Both (b) and (c)

15. The book Principles of Numerical Taxonomy is compiled by:

(a) Sokal and Sneath (b) Linnaeus

(c) Adanson (d) Bentham and Hooker

6.7.2 Fill in the blanks:

(1) ____________ is the science deals with identification, nomenclature and classification.

(2) The term Alpha taxonomy was given by___________________.

(3) The use of chemicals found in plants as taxonomic tool is called _______________.

(4) ___________ is the branch of science that deals with the study of sporogenesis, gamete formation, fertilization, formation of zygote and embryo.

(5) NPC stands for __________, ________ and ___________.

(6) _____________vascular bundles are feature of monocot stems.

(7) Nonporous wood is mainly found in____________.

(8) Sporoderm or pollen wall is made up of biologically very resistant substance__________.

(9) ___________ a kind of classification based on numerical comparison of large number of equally weighted characters.

(10) ____________are largest group of naturally occurring phenols mostly found in vacuoles of plant cells.

6.7.3 True and False:

(1) The embryological characters have been utilized by plant taxonomists in analysis of evolutionary trends.

(2) Orthotropus ovule considered as evolutionary advance.

(3) The micro-sporogenesis is of simultaneous type in Cyperaceae and out of three in tetrad degenerate and only one remains functional.

(4) The family Liliaceae and Amaryllidiacae have been resolved based on embryological evidences.

(5) Wood of gymnosperms is porous.

(6) DNA and RNA molecule fall under category of semantides.

(7) Violet colour of cactus fruits is due to anthocyanis.

(8) Stenopalynous taxa are those, which bear broad range of pollen grains.

(9) Flavanoids are largest group of naturally occurring phenols.

(10) Comparison of large number of equally weighted characters scored consistently for all groups is called numerical Taxonomy.

6.7.4 Very short answer questions:

(1) What is OTU?
(2) Define treme.
(3) What do you understand by palynology?
(4) Define semantides.
(5) What are terpenoides?
(6) What do you mean by dendrogram?
(7) Define taximatrics.
(8) Give the definition of eurypalynous taxa.
(9) What is sporoderm?
(10) What do you understand by chemotaxonomy?

6.7.1 Answer Keys: 1-(a), 2-(a), 3-(a), 4-(a), 5-(c), 6-(c), 7-(b), 8-(b), 9-(a), 10-(c), 11-(a), 12-(a), 13-(c), 14-(d), 15-(a).

6.7.2 Answer Keys: 1-Taxonomy, 2-Turril (1938), 3-Chemotaxonomy, 4-Embryology, 5-Number, Position, Character, 6-Scattered, 7-Gymnosperms, 8-Sporopollenin, 9- Numerical taxonomy 10- Flavanoids.

6.7.3 Answer Keys: 1-True, 2- False, 3-True, 4- True, 5- False, 6- True, 7- False, 8- False 9-True, 10- True.

6.8 REFERENCES

- Bailey I.W. 1949. Origin of the Angiosperms: need for a broadened outlook. Journal of the Arnold Arboretum. 30(1): 64-70.
- Bailey, I.W. 1944. The development of vessels in angiosperms and its significance in morphological research. American Journal of Botany: 31:421-428.
- Bailey, I.W. and Nast, C.G. 1943. The comparative morphology of the Winteraceae. I. Pollen and stamens. Journal of the Arnold Arboretum. 24:340-346.
- Bailey, I.W. and Nast, C.G. 1943. The comparative morphology of the Winteraceae. II. Carpels. Journal of the Arnold Arboretum. 24:472-481.
- Bailey, I.W. and Nast, C.G. 1944. The comparative morphology of the Winteraceae. IV. Anatomy of the node and vascularization of the leaf. Journal of the Arnold Arboretum. 25:215-221.
- Bailey, I.W. and Nast, C.G. 1944. The comparative morphology of the Winteraceae. V. Foliar epidermis and sclerenchyma. Journal of the Arnold Arboretum. 25:342-348
- Barthlott, W. 1984. Microstructural Features of Seed Surfaces. In: Current Concepts in Plant Taxonomy, Heywood, V.H. and D.M. Moore (Eds.). Academic Press, London, pp: 95-104.

- Bureau, E. 1872. Valeur des caracteres tires de la structure de la tige, pour le classification des Bignoniacées. Bulletin de la Société Botanique de France 19: 14-20.
- Davis, G.L. 1966. Systematic embryology of the angiosperms. John Wiley & Sons. London.
- Eames, A.J. 1953. Floral anatomy as an aid in generic limitation. Chronica Botanica. 14: 126-132.
- Erdtman, G. 1957. Pollen and spore morphology/plant taxonomy: Gymnospermae, Pteridophyta, Bryophyta. Almqvist & Wiksell, Stockholm.
- Erdtman, G. 1969. Hand Book of Palynology: Morphology-taxonomy-ecology: An Introduction to the Study of Pollen Grains and Spores. Hafner Publishing Company, New York.
- Fossard, R.A.D.E.1969. Development and histochemistry of the endothecium in the anthers of *in vitro* grown *Chenopodium rubrum* L. Botanical Gazette.130:10-22
- Hallock, F.A.1930. The Relationship of Garraya. Annals of Botany. 44:771-812.
- Heywood, V. H. 1967. Plant taxonomy. Edward Arnold, London.
- Hyde, H.A. and D.A. Williams. 1945. Studies in atmospheric pollen: II. Diurnal variation in the incidence of grass pollen. New Phytologist. 44(1): 83-94.
- Jones, S.B. and Luchsinger, A.E. 1987. Plant Systematic, 2nd Edn. New York: McGraw-Hill Book Company, New York.
- Mentzer, C. 1966. Comparative phytochemistry (eds.) T, Swain. Academic Press London. pp. 21-31
- Nilson, S. and Prglowski, J. 1992. Erdtman`s Hand Book of Palynology. 2nd Edn. Munksgaard, Copenhagen.
- Puri, V. 1958. floral anatomy and taxonomy. Indian Botanocal Society. 1: 15-18.
- Radlkofer, L. 1888. Ergänzungen zur Monographie der Sapindaceen-Gattung Serjania. = Monographiae generis Serjaniae supplementum. München Abhandlungen: Bd. 16, Abth. 1 = [1]. http://publikationen.badw.de/en/003083028.
- Ram, M. 1956. Floral morphology and embryology of *Trapa bispinosa* Roxb. With a discussion on the sysytematic posiyion of the genus. Phyto morphology. 6:312-323.
- Schnarf, K. 1931. Vergleichende Embryologie der Angiospermen. Berlin Bornträger.
- Sneath, R.R. and Sokal, P.H.A.1973. Numerical Taxonomy, W.H. Freeman, San Francisco:
- Sokal, P.H.A. and Sneath, R.R.1963. Principles of Numerical Taxonomy, San Francisco: W.H. Freeman.
- Sporne, K.R. 1956. The phylogenetic classification of the Angiosperms. Biological Reviews. 31(1):1-29.
- Turrill, W.B. 1938. The Expansion of Taxonomy with Special Reference to Spermatophyta. Biological Reviews.13: 342–373.
- Vasil, I.K. 1967. Physiology and cytology of anther development. Biological Reviews. 42: 327-373.

- Wodehouse, R.P. 1935. Pollen grains: their structure, identification, and significance in science and medicine. Mc Graw-Hill, New York.

6.9 SUGGESTED READINGS

- Davis, G.L. 1966. Systematic embryology of the angiosperms. John Wiley & Sons. London.
- Davis, P.H. and V.H. Heywood. 1973. Principles of Angiosperm Taxonomy. Kreiger, New York.
- Erdtman, G. 1969. Hand Book of Palynology: Morphology-taxonomy-ecology: An Introduction to the Study of Pollen Grains and Spores. Hafner Publishing Company, New York.
- Erdtman, G. 1969. Hand Book of Palynology: Morphology-taxonomy-ecology: An Introduction to the Study of Pollen Grains and Spores. Hafner Publishing Company, New York.
- Heywood, V. H. 1967. Plant taxonomy. Edward Arnold, London.
- Heywood, V. H. 1976. Plant taxonomy, 2nd edn. Edward Arnold, London.
- Jones, S.B. Jr. and Luchsinger, A.E. 1986. Plant Systematics. McGraw-Hill Book Co., New York.
- Saxena, N.B. and Saxena, S. 2017. Plant Taxonomy X, Pragati Prakashan, Meerut.
- Subrahmanyam N.S. 2003. Modern Plant Taxonomy. Vikas Publishing House Pvt.Ltd. New Delhi.

6.10 TERMINAL QUESTIONS

6.10.1 Short answer questions

(1) Write short note on Taxonomic Evidences.
(2) What are OTUs and their significance in taxonomy?
(3) Write a note on embryological evidences in taxonomy.
(5) Briefly describe role of terpenes in taxonomy.
(6) What is numerical taxonomy? Describe briefly.
(7) Discus anatomical evidences in taxonomy.
(8) Give a short note on role of phenolic compounds in solving taxonomic problems.
(9) Write short note on betalins.
(10) What are stenopalynous and eurypalynous taxa?

6.10.2 Long answer questions:

(1) Give a detailed account on taxonomic evidences.
(2) Explain Numerical Taxonomy in detail.

(3) What do you understand by chemotaxonomy? Give an account on phytochemicals used in chemotaxonomy.

(4) Write a note on embryology and its role in plant taxonomy.

(5) Describe palynology and palynological evidences in taxonomy.

BLOCK-3 DIAGNOSTIC FEATURES OF SELECTED FAMILIES

UNIT-7 RANUNCULACEAE, MAGNOLIACEAE, BRASSICACEAE, DIPTEROCARPACEAE, MALVACEAE, RUTACEAE

7.1 OBJECTIVES

After going through this unit learner will be able –

- To know the diagnostic features, systematic position, floral formula of the families Ranunculaceae, Magnoliaceae, Brassicaceae, Dipterocarpaceae, Malvaceae and Rutaceae
- To understand about the important-genera of these families.
- To learn the economic importance.

7.2 INTRODUCTION

You must have read the classification of flowering plants by different taxonomists in the previous chapter (Unit-1). These classifications are based either on morphological characters of plants or on the phylogenetic characters. Bentham and Hooker described the flowering plants in *Genera Plantarum* on the basis of their morphological characters and the classification is known as natural system of classification while phylogenetic classification was given by Hutchinson in the *Families of Flowering Plants*, which is based on evolutionary characters.

Though you have read the classification in previous chapter but before starting the description of plant families it is suggested for the learner to warm up with previous unit which will obviously help you to understand the family. In this unit the plan adopted for describing the families is given by Bentham and Hooker. Bentham and Hooker divided flowering plants into dicotyledons and monocotyledons. However in the present unit we are going to describe dicotyledonous plants only.

Dicotyledons include all those angiosperms in which embryo possesses two cotyledons, leaf with reticulate venation and the vascular bundles are open and arranged in a ring .Secondary growth and tap root are also characteristic features of dicotylendons. These dicotyledons are again divided into 3 subclasses viz., Polypetalae (petals free), Gamopetalae (fused petals) and Monochlamydae (incomplete). All the families in this unit (7) come under subclass Polypetalae which is further divided into Disciflorae, Calyciflorae and Thalamiflorae. Now we are going to discuss with following 6 families viz., Ranunculaceae, Magnoliaceae, Brassicaceae, Dipterocarpaceae, Malvaceae and Rutaceae.

7.3 RANUNCULACEAE (BUTTERCUP FAMILY)

7.3.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Phanerogams	Dicotyledons

Dicotyledons	Herbaceae
Polypetalae	Ranales
Thalamiflorae	Ranunculaceae
Ranales	
Ranunculaceae	

Distribution

There are about 50 genera and over 1200 species of family Ranunculaceae that are known. The members are distributed mainly in north temperate and arctic region. In India, family is represented by 20 genera and 154 species mainly confined to mountainous regions. Some common examples are *Ranunculus* (butter cup), *Delphinium* (larkspur), *Clematis* (virgin's bower), *Anemone* (wind flower), *Nigella* (love-in-a-mist) and *Thalictrum* (meadow-rue).

7.3.2 General Characters

Habit: They are mainly annual or perennial herbs but species of *Clematis* are woody climbers. Some species of *Ranunculus* are aquatic herbs (*R. aquatilis*). They perennate by means of tuberous roots (*Aconitum*) or rhizome.

Root: Tap as well as adventitious roots. Tuberous roots of *Aconitum*, *Paeonia* and *Ranunculus* store food swell and form tuber like structure.

Stem: Herbaceous, in some climbing (*Clematis*) or underground rhizome or erect, branched. The vascular bundles in the stems of *Actaea* and *Thalictrum* are not arranged in a ring but are scattered (scattered vascular bundles are the characteristic feature of monocotyledons).

Leaves: Generally simple *(Ranunculus)* or opposite (*Clematis*), usually exstipulate with sheathing bases rarely stipulate (*Thalictrum*), petiole rarely sessile (*Delphinium*). In some of aquatic species leaves show heterophylly with submerged leaves finely dissected. Leaves are modified into tendrils in *Clematis aphylla* and the function of photosynthesis is carried over by the stem.

Inflorescence: Various types of inflorescences are present in Ranunculaceae. The flowers are solitary and terminal in *Anemone* and *Nigella*, axillary in *Clematis*, long racemes in *Delphinium* and *Aconitum* while dichasial cymes in *Ranunculus*.

Flowers: The flowers are bracteate (*Ranunculus*, *Thalictrum, Clematis)*, ebracteate (*Anemone*) hermaphrodite, unisexual in *Thalictrum*, actinomorphic, zygomorphic in *Delphinium*, Pentamerous and hypogynous. The floral parts are arranged spirally on an elongated receptacle.

Calyx: 5 to 8 sepals usually 5 (*Ranunculus*) polysepalous, in *Delphinium* and *Aconitum* the sepals are petaloid and the posterior sepal is spurred. In *Nigella* and *Anemone* there is some time an involucre of green leaves below the flowers usually alternate with calyx. The aestivation is imbricate or valvate.

Corolla: Petals five, polypetalous, variously coloured, caducous or wanting. Nectariferous glands are often present at the base of each petal.

Androecium: Indefinite stamens, polyandrous and spirally arranged on the thalamus. Anthers are adnate, dithecous, extrorse having longitudinal dehiscence. In *Thalictrum* filaments are colourful.

Gynoecium: Mostly polycarpellary but in some taxa the number definite (1 in *Delphinium*, 3-5 in *Aconitum*), apocarpous rarely syncarpous (*Nigella*) ovary superior marginal placentation, axile in *Nigella* and basal in *Ranunculus*.

Fruits: May be aggregate, etario of achenes (*Ranunculus*), etario of follicles (*Aconitum*), follicle (*Delphinium*), berry (*Actaea*), capsule (*Nigella*), etario of drupes (*Adonis*).

Seed: Endospermic small and contain oily substances with minute embryo.

Pollination: Through insects i.e. entomophilous (*Aconitum*, *Delphinium*) or anemophilous in *Thalictrum*.

Floral Formula: $\oplus$ ⚥ $K_{4-5}, C_5, A_\infty, \underline{G}_\infty$

7.3.3 Important Genera

Ranunculus sceleratus **Linn.**

Habit: An annual herbaceous plant.

Root: Branched tap root.

Stem: Green, herbaceous, solid, erect, branched, aerial, having distinct nodes and internodes.

Leaf: Leaves are simple, petiolate, trilobed each lobe further divided with obovate, cuneate segment, stipules fused with the leaf base, multicostate reticulate venation.

Inflorescence: Inflorescence is cymose.

Flower: Flowers yellow in colour, pedicillate, hermaphrodite, bracteate, actinomorphic, complete and hypogynous.

Calyx: Sepals are five, polysepalous petaloid, qunicuncial.

Corolla: Five petals polypetalous pocket shaped nectary present at the base of each petal, yellow in colour, imbricate.

Androecium: Stamens are indefinite, spirally arranged, polyandrous, extrorse anthers, yellow and basifixed.

Gynoecium: Carpels indefinite (polycarpellary), apocarpous, unilocular superior ovary, placentation is basal.

Fruit: An etario of achenes.

Floral Formula: $\oplus$ ⚥ $K_5, C_5, A_\infty, \underline{G}_\infty$

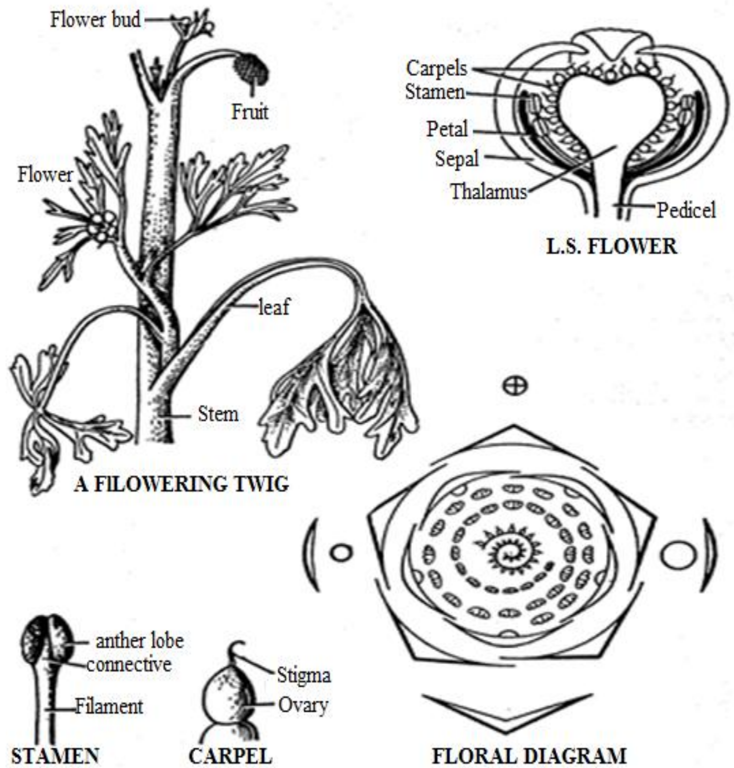

Fig.7.1 Ranunculus scleratus Linn. (Courtesy: Bendre & Kumar, 2017)

7.3.4 Economic Importance

Ranunculaceae family has the ornamental as well as medicinal values.

1 Plants of ornamental value: Large number of ornamental plants are in cultivation due to their beautiful flowers, few are as follows-

- *Ranunculus repens* (buttercup)
- *Clematis paniculata* (virgins flower)
- *Anomone sylvestris* (wing flower)
- *Delphinium ajacis* (larkspur)
- *Aconitum vulgare* (columbine)
- *Nigella domascena* (love- in- a- mist)

2 Plants of medicinal value: Important drugs are obtained from the following plants.

- *Aconitum napellus*: Aconite, a drug obtained from the root of plants used in rheumatism.
- *Clematis:* Plants used to cure leprosy and blood diseases.
- *Ranunculus arvensis* and *R. muricatus*: Juice is used in intermittent fever.
- *Nigella sativa* (kalajeera) seeds are used as condiments and also used in the treatment of fever, cough and asthma.

Systematic relationship

The family Ranunculaceae is one of the most primitive of the dicotyledons. Hutchinson, Bentham and Hooker have placed the family in the class of very early dicotyledons. Engler, Rendle and others put the family under the Archichlamydeae. The family is in its close relationship with the monocotyledons due to the formation of rhizomes, development of sheathing leaf base and copious endosperm. The family can be linked with Rosaceae on account of free and numerous stamens and carpels. The dimorphic leaves and hypogynous flowers of Ranunculaceae trace the relationship with the family Nymphaeaceae.

7.4 MAGNOLIACEAE OR MAGNOLIA FAMILY

7.4.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Polypetalae	Lignosae
Thalamiflorae	Magnoliales
Ranales	Magnoliaceae
Magnoliaceae	

Distribution

There are about 12 genera and 230 spp. of family Magnoliaceae that are known. The members are distributed mainly to the temperate region of northern hemisphere with the centres of distribution in eastern Asia, Malaysia, eastern-North America, West Indies, Brazil, and north east and south east India. The familiar examples are *Michelia champaca*, *Magnolia grandifolia*, *Liriodendron tulipifera*.

7.4.2 General Characters

Deciduous or evergreen often aromatic shrubs or trees sometimes plant reaches 20 to 65 m in height, climbers are also present.

Root: Tap root and branched.

Stem: Aerial, woody, erect and branched.

Leaves: Alternate, simple, entire, commonly evergreen. Stipulate, stipules large, stipules absent in Winteraceae, oil glands present.

Inflorescence: Flowers usually solitary, either axillary (*Michelia*) or terminal (*Magnolia*).

Flowers: Large, showy, bracteates, complete, actinomorphic, unisexual or bisexual, hypogynous, aromatic.

Perianth: Mostly the perianth is not differentiated into calyx and corolla. Nine to many, free, all alike and petaloid or the three outer ones green (*Liriodendron*), arranged in whorl of three, imbricate and cyclic (*Magnolia* and *Michelia*) or acyclic (spiral) arranged on an elongated or semi-elongated convex torus, free, inferior.

Androecium : Stamens numerous, free spirally arranged in a beautiful series on the basal part of floral axis, anthers long, dithecous, basifixed or adnate, introrse but extrorse in *Liriodendron*, dehiscence longitudinal, with a prolonged connective.

Gynoecium: Carpels numerous, apocarpous (free) superior arranged spirally on a cone shaped elongaled thalamus (gynophores rarely, carpels are fused e.g. *Zygogynum*).

Fruits and seeds: Fruit is an aggregate of berries *(Schizandra*) or follicle (*Magnolia*), sometimes a samara (*Liriodendron*), seed large, with abundant oily endosperm and bright and orange testa which makes them highly decorative.

Pollination: Entomophilous due to large and scented flowers.

Floral Formula: $\oplus$ ⚥ $P_{9 \text{ or } \infty}$, A_{∞}, $\underline{G}_{\infty}$

7.4.3 Important Genera

Michelia champaca (Champa)

Habit: Evergreen, tall, graceful tree with dark grey bark.

Habitat: Temperate region of northern Himalaya, with centres of distribution in eastern Asia, Malaysia, West Indies, Brazil and North east and south east India.

Root: Branched tap root.

Stem: Woody solid, aerial branched and erect.

Leaf: Ramal leaf arrangement, alternate, stipulate, stipules convolute, petiolate, simple, ovate or ablong-lanceolate, entire with acute apex, dark green, glabrous with reticulate venation.

Inflorescence: Clusters of axillary flowers.

Flower: Hermaphrodite, pale yellow with very mild fragrance, large actinomorphic, hypogynous, bracteate, pedicellate, ebracteolate.

Perianth: Having 9 tepals, 3 whorls of 3 each, all 3 whorls may be petalloid or sometimes the outer most of 3 tepals become sepaloid.

Calyx: 3, free, greenish, valvate inferior, corolla-6 in two whorls of 3 each, polypetalous petals of outer whorl are having valvate aestivation while those of inner whorl one narrow having twisted aestivation, pale yellow.

Androecium: Polyandrous, indefinite in number, spirally arranged, anthers are distinguished into anther lobes, filament and connective, basifixed, dithecous, extrorse.

Gynoecium: Superior, polycarpellary, apocarpous, each carpel with swollen ovary curved style, stigma simple and beaked unilocular, many ovules in each carpel, marginal placentation.

Fruit: Dark coloured with white speck or spot. Fruit is an etario of follicles.

Seed: Large endospermic with small embryo.

Pollination: Through insect, i,e. entomophilous

Floral Formula: $\mathbf{Br} \oplus ⚥ \mathbf{P_{3+3+3}, A_{\infty}, \underline{G}_{\infty}}$ or $\mathbf{Br} \oplus ⚥ \mathbf{K_{3}, C_{3+3}, A_{\infty}, \underline{G}_{\infty}}$

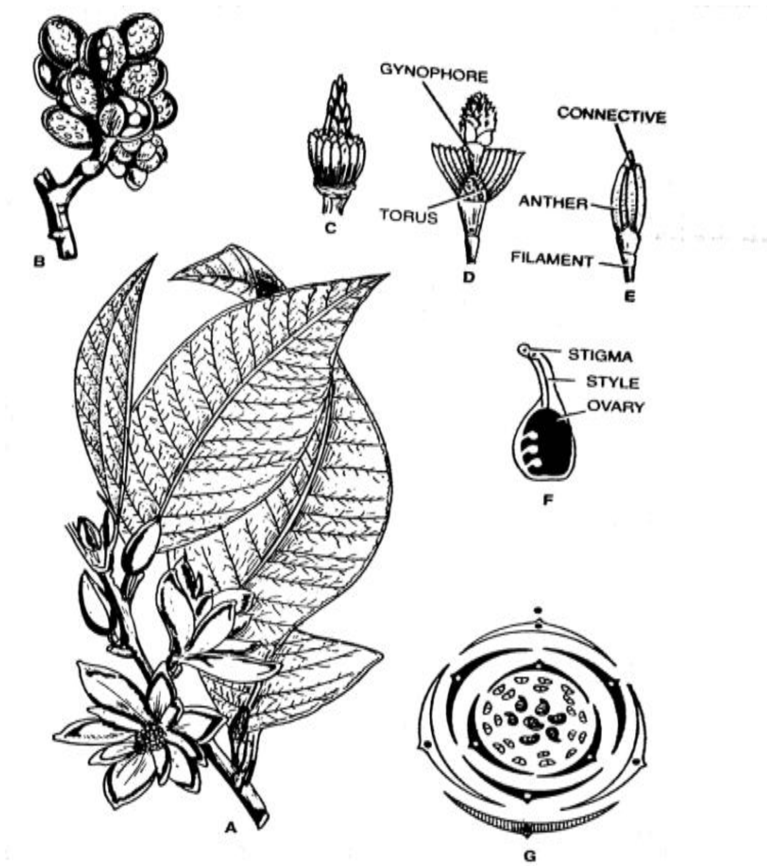

Fig.7.2 Michelia champaca A. Twig, B. Fruits, C. Flower (perianth removed), D. V.S. of Flower, E. Stamen, F. Carpel and G. Floral diagram (Courtesy Saxena & Saxena, 2012).

7.4.4 Economic Importance

The Magnoliaceae family is known for its beautiful ornamentals and as a source of wood.

Ornamental plants-

- *Magnolia grandifolia* (Dulee Champa)
- *Magnolia fuscata* (Chidi Champa)- a source of essential oil.
- *Magnolia pterocarpa*
- *Magnolia campbellii* (Lal Champa)
- *Michelia champaca* (Champa; also a source of volatile oil)

Wood yielding plants

- *Magnolia acuminata*

- *Liriodendron tulipifera*
- *Talauma phellocarpa*

Systematic relationship

Affinities of the family Magnoliaceae are akin to Annonaceae. Engler, Rendle and other botanists put the Magnoliaceae under the Ranales. But Hutchinson placed the family within the Magnoliales and considered it as the most primitive among the dicotyledons. The primitiveness of this family is shown by the spiral arrangement of stamens and carpels and apocarpous pistil - characters also shared with the Ranunculaceae. Smith, however, cast some doubt on the assumption of the primitive nature of the Magnoliaceae and thought that the family is relatively specialised from vegetative and reproductive aspects. From the stand-point of construction and organisations of flowers, the Magnoliaceae is allied to the Annonaceae. The two families, however, can be set apart from each other by the following features:

Magnoliaceae	**Annonaceae**
Stipules present	Stipules absent
Flowers large, showy	Flower small not showy
Corolla valvate	Anthers extrorse
Endosperm watery-fleshy, not ruminate	Endosperm ruminate or marbled

The Magnoliaceae has a great deal of affinity with the gymnosperms. The most striking thing about the wood of *Drimys* is the presence of tracheids with bordered pits in the xylem. This coniferous nature of the wood is "discounted by the fact that the structure of the bast is characteristically dicotyledonous, having sieve-tubes with companion cells". Furthermore, the receptacle of *Magnolia* flower bears numerous spirally arranged free sporophylls. This can be compared with the strobilus of Bennettites, consisting of a central conical axis covered with megasporophylls. This has led to the suggestion that the order Bennettitales may be ancestral to the modern angiosperms initiated by the Magnoliaceae.

7.5 BRASSICACEAE (MUSTARD FAMILY)

7.5.1 Systematic Position

Bentham & Hooker	**Hutchinson**
Phanerogams	Dicotyledons
Dicotyledons	Herbaceae
Polypetalae	Brassicales
Thalamiflorae	Brassicaceae
Parietales	
Brassicaceae	

Distribution

Members of Brassicaceae are widely distributed throughout the world and mostly abundant in North Temperate Zone, besides those members are also present in the Mediterranean region and north temperate region. The family includes about 375 genera and 3200 species, covering many vegetable crops and wild and cultivated flowers. The most important genera of the family are *Brassica campestris, Brassica nigra, Raphanus sativus, Iberis amara*.

7.5.2 General Characters

Habit: Generally the plants are annual, biennial or perennial herbs, rarely undershrubs. The species of *Brassica* are annual, sometime biennial or perennial herbs.

Roots: Tap root, which in some genera gets swellon due to storage of food and shows modification in tap root e.g. napiform root in *Brassica rapa*, and fusiform root in *Raphanus sativus*.

Stem: Stem is usually herbaceous. In *Raphanus sativus* (radish) it is very condensed while in case of *Brassica oleracea* var. *caulorapa* (ganthgobhi) stem becomes very thick and corm like and is eaten as vegetable.

Leaves: Alternate or some time sub opposite, simple, exstipulate (*B. campestris*) usually radial (*Raphanus*) or cauline, radical leaves form rosette like structure while cauline leaves are alternate or opposite.

Inflorescence: Raceme in *Brassica campestris*, corymb in *Iberis*. Bracts and bracteoles are absent.

Calyx: 4 sepals are present in two whorls of two each. Polysepalous, outer whorl is anterio-posterior. Imbricate aestivation.

Corolla: 4 petals, polypetalous, cruciform corolla arranged in a cross manner. Petals alternate to sepals. In *lberis* two anterior petals are larger and the flowers become zygomorphic.

Androecium: 6 stamens are arranged in two whorls. The inner four stamens are long while the outer two are short, this condition is known as tetradynamous condition. This is the characterstic feature of family Brassicaceae. Polyandrous, anthers dithecous, basifixed and introrse. Disc like nectories are present at the base of stamens. Some time the number of stamens may be 4 (*Nasturtium*), 2 *(Coronopus*) and 16 (*Megacarpaea)*.

Gynoecium: Usually bicarpellary (having two carpels), rarely tricarpellary, syncarpous superior ovary, unilocular and become bilocular due to the development of false septum or replum. Parietal placentation having many ovules, simple or bifid stigma with a short style.

Fruit and seed: Fruit siliqua (*Brassica*) or silicula (*Capsella bursa-pastoris*), sometimes fruit is lomenstum (*Raphanus sativus*). Seeds are small, non endospermic with curved embryo.

Pollination: Pollination is through the agency of insects (entomophilous), insects attracted due to the presence of nectaries at the base of short stamen.

Floral Formula: $\oplus$ ⚥ K_{2+2}, C_4, A_{2+4}, $\underline{G}_{(2)}$

7.5.3 Important Genera

Brassica campestris Linn.

Habit: An annual cultivated herb.
Root: Branched tap root
Stem: Herbaceous branched, erect, green slightly hairy.
Leaf: Simple, alternate, sessile, lower leaves lyrate, upper leaves entire, exstipulate, unicostate reticulate venation.
Inflorescence: Typical raceme, racemose.
Flower: Yellow, pedicillate, actinomorphic, ebracteate, complete cyclic, tetramerous.
Calyx: Sepals four, polysepalous arranged in two whorls, each whorl with two sepals, sepals of inner whorl are longer, aestivation is imbricate.
Corolla: Petals are four, polypetalous, each petal with a limb and claw, alternating the sepals, cruciform, aestivation is imbricate or valvate.
Androecium: Stamens six, arranged in two whorls, the outer whorl with two smaller stamens, the inner whorl with four larger stamens (tetradynamous condition), anthers basifixed, introrse, bicelled.
Gynoecium: Bicarpellary, syncarpous, unilocular ovary but becomes bilocular later on due to the development of false septum (replum), ovary is superior, placentation parietal, bilobed stigma, style short.
Fruit: Siliqua

Floral Formula: $\oplus ⚥ K_{2+2}, C_{4}, A_{2+4}, \underline{G}_{(2)}$

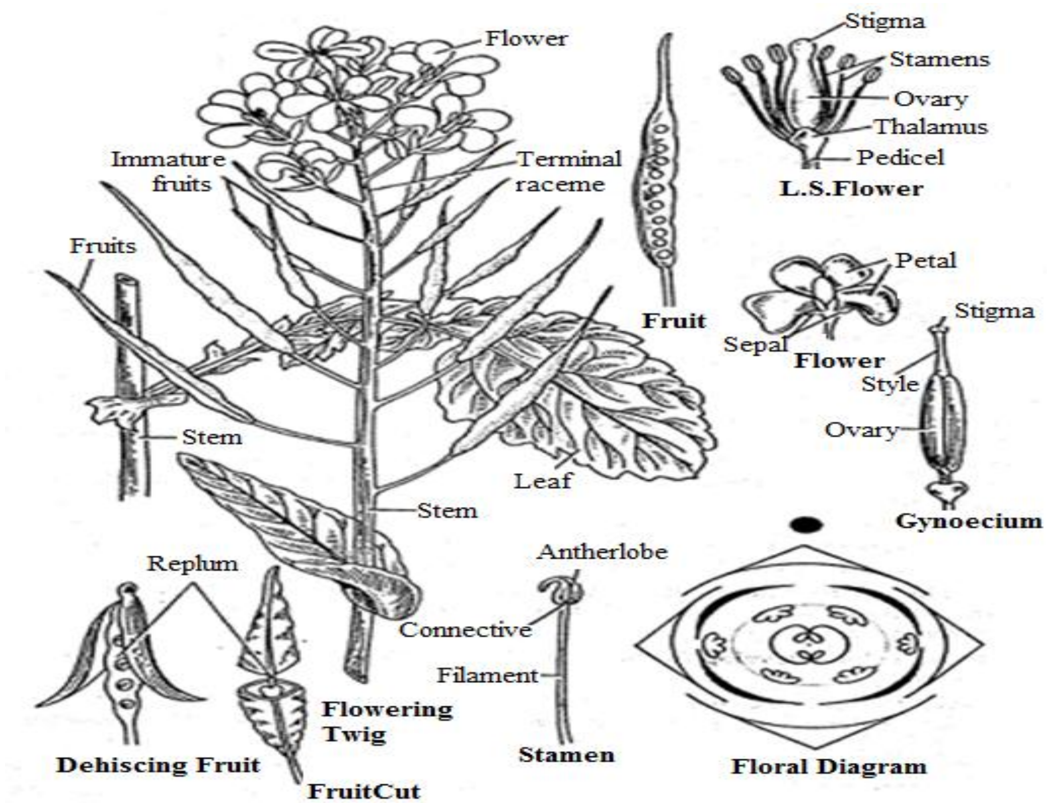

Fig.7.3. Brassica campestris Linn. (Courtesy: B. P. Pandey, 2007)

7.5.4 Economic Importance

Brassicaceae family provides large number of vegetables, oil, medicinal and ornamental plants.

Important vegetables

- *Brassica campestris*(sarson)
- *Brassica rapa* (shaljam, turnip)
- *Brassica oleracea* var.*capitata* (cabbage, band gobhi)
- *Brassica oleracea*var. *botrytis* (cauliflower, phoolgobhi)
- *Raphanus sativus* (common radish, muli)

Oil producing plants

- *Brassica nigra* (black mustard)
- *Brassica juncea*(Indian mustard)
- *Brassica alba* (white mustard)
- *Brassica campestris* (mustard, sarson)
- *Brassica napus* (rape seed, toria)

Ornamental plants

- *Iberis amara*(candytuft)

- *Mathilola* (stocks)
- *Alyssum* (basket of gold)
- *Nasturtium*

Condiments

Seeds of *Brassica nigra* and *Brassica alba* are used as condiments.

Systematic relationship

Rendle placed this family under the order Rhoedales; Bentham-Hooker placed it under the cohort Parietales. The family is related to the Papaveraceae on one hand and to the Capparidaceae on the other. Bentham & Hooker, and Hutchinson (1948, 1964) hold the view that Brassicaceae is derived from the Papaveraceous ancestors whereas Eames, Arber, Hayek and Puri believe it to have a Capparidaceous alliance. The three families, Capparidaceae, Brassicaceae (Cruciferae) and Papaveraceae have in common the features of tetramerous perianth, bicarpellary syncarpous gynoecium and parietal placentation. These characters gave problematic issues as to whether the Brassicaceae (Cruciferae) originated from the Capparidaceae or descended from the Papaveraceae. The anatomy and morphology of stamens and carpels of cruciferous flower bear testimony to a papaverous ancestory. But in Brassicaceae the stamens are tetradynamous and not in Papaveraceae. Comparison of floral diagram indicates that Brassicaceae is closely allied to Capparidaceae. But in Brassicaceae gynophore and variable number of stamens are absent where as these are the prominent characters of Capparidean flowers. Within the Rhoedales reduction seems to have taken place in the number of stamens. In the Papaveraceae there are numerous stamens but in its two subfamilies reduction has occurred. In the Hypecoideae there are only four stamens; in the Fumarioideae the stamens are arranged in two bundles each with one dithecous and two monothecous anthers. In the Capparidaceae the numbers of stamen ranges between several (as in *Capparis*) to six (as in *Gynandropsis*). Finally in *Cleome* there are only four stamens. The floral diagram of *Cleome spinosa* with six stamens is remarkably similar to that of the Brassicaceae (Cruciferae). In this family the general condition is tetradynamous but may be reduced to only two (as in *Coronopus*). Celakovasky considers the above view as most satisfactory. Cronquist (1968) too considers that the Brassicaceae (Cruciferae) evolved from the Capparidaceae.

7.6 DIPTEROCARPACEAE

7.6.1 Systematic position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Polypetalae	Lignosae
Thalamiflorae	Ochnales
Guttiferales	Dipterocarpaceae

Dipterocarpaceae

Distribution: Dipterocarpaceae are a family of 25 genera and approximately 375 known species of mainly tropical lowland rainforests of Old World, Malaysia, Philippines. In India *Shorea robusta* (Sal) is distributed in Assam, Terai, Central provinces, Bihar and forming extensive Sal forests. *Monoporandra* is endemic to Sri Lanka. The large genera are *Shorea*, *Hopea*, *Dipterocarpus* and *Vatica*. Many are large forest emergent species, typically reaching heights of 40–70 m, some even over 80 m in the genera *Dryobalanops*, *Hopea* and *Shorea*. The species of this family are of major importance in the timber trade. They provide valuable woods, aromatic essential oils, balsam, and resins are a source for plywood.

7.6.2 General Characters

Habit: Tall trees, rarely shrubs

Root: Tap root

Stem: Erect, high, woody, few branches, resin ducts and mucilage cells characteristic of this family.

Leaf: Simple, entire, coracious, stipulate, stipules small sometimes surrounds the internode.

Inflorescence: Paniculate, terminal or axillary spikes or racemes, sweet scented.

Flowers: Actinomrphic, hermaphrodite, hypogynous, pentamerous; flower axis broad. Saucer shaped or concave sometimes; complete.

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

Corolla: Petals 5, polypetalous, imbricate contorted or much imbricate.

Androecium: Stamens 5 to 15 or indefinite, in one to several whorls; filaments short usually, rarely long, anther lobes unequal, connective produced at the apex very often.

Gynoecium: Carpels 3-5, usually syncarpous, superior, trilocular, axile placentation, ovules 2 in each locule; stigma always exceeds the stamens.

Fruit: Leathery, one seeded nut, woody, indehiscent, surrounded by persistent winged calyx segments.

Seed: Non-endospermic.

Pollination: Entomophilous, sweet scented flowers.

Floral formula: $\oplus$ ⚥ $K_5, C_5, A5_{-\infty} \underline{G}_{(3)}$

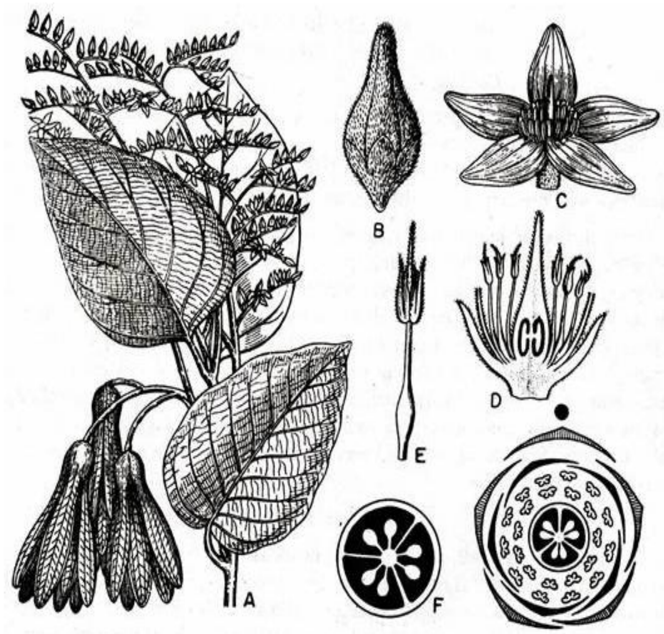

Fig.7.4 Floral parts of Shorea robusta, A. Leafy branch with inflorescence and fruits, B. Flower bud, C. Open flower, D. L.S. through the flower showing stamens and ovary with ovules, E. Stamen, F. T.S. of ovary

7.6.3 Important genera

- *Dipterocapus turbinatus* – Garjan balsam – A huge tree.
- *Issuxis*
- *Vatica*
- *Hopeaodorata* – A tall garden ornamental plant.
- *Vateria indica*– Yields edible seeds.
- *Dryobalanops*
- *Shorea robusta* – Sal tree of India

7.6.4 Economic Importance

1. Food: The starchy seeds of *Vateria acuminata*, *Vatica* are used as food. The seeds of *Shorea robusta* produce 'sal butter' which is used as an adulterant clarified butter for ghee and instead of Cocoa butter in the manufacture of Chocolates. The seeds of *Vateria indica* produce vegetable butter, 'Malabur tallow' or vateria fat or 'pincy tallow' is used in confectionary as a substitute for ghee and its bark is in demand in the manufacture of arak and jaggery.

2. Timber: Timber is obtained from *Shorea robusta* (sal). It is valuable timber for house building, gun carriage manufacture, ships, railway sleepers, etc. It is durable under water and is termite proof. *Hopea parviflora* yields excellent timber which is particularly useful in pile and bridge construction. The timber of *Dipterocarpus turbinatus* is used for boat-building and structural work.

3. Resin and turpentine: *Shorea koordarsis* yields turpentine and dammar resin called 'dhoona' and used as incense. The stems of *Dipterocarpus turbinatus* are exploited for 'garjan oil', a balsam or resin, which is useful in making varnishes and lithographic inks. 'Chooa' a dark strong-smelling thick balsam is obtained from *Isauxis lanceaefolia.*

Hopea micrantha produces the valuable dammar called 'mata Kuching'. Yellow camphor, the 'Borneo camphor' or 'Sumatra camphor' is obtained from *Dryobalanops aromatica,* from it (*D. aromatica*) resins, oils, turpentines etc. are also obtained. The oleoresin obtained from the trunk of *Vateria indica* is 'piney varnish' when soft and 'Indian copal' or 'Copal varnish' when hard.

Systematic relationship

The family shows resemblance with Clusiaceae and Theaceae but can be distinguished by enlarged persistant calyx, stipulate leaves and resin ducts. Bentham & Hooker included the genera *Ancistrocladus* and *Luphira* in Dipterocarpaceae, but E. Gilg transferred them to the families Ancistrocladaceae and Ochnaceae, respectively. Hence, the Dipterocarpaceae has relationship with the families. Gilg estabilished relationship of Dipterocarpaceae with Tiliaceae. Dipterocarpaceae resembles with the Magnoliaceae in the possession of large stipules but differs from it in the presence of persistent calyx. The family name is after the type genus *Dipterocarpus*, which is derived from Greek (*di* = two, *pteron* = wing and *karpos* = fruit) and refers to the two-winged fruit. This family is also known as Sal family.

7.7 MALVACEAE

7.7.1 Systematic position

Bentham and Hooker	**Hutchinson**
Dicotyledon	Dicotyledons
Polypetalae	Lignosae
Thalamiflorae	Malvales
Malvales	Malvaceae
Malvaceae	

Distribution: The members of this family are represented by nearly 85 genera and 1500 species found mostly in tropical parts of world. In India, common plant species are *Hibiscus, Malva*, *Gossypium, Sida* etc.

7.7.2 General characters

Habit: Herbs, shrubs, or trees sometimes under shrubs, annual, perennial.

Root: Branched, tap root.

Stem: Herbaceous or woody, erect, branched, usually with stellate hairs. Mucilage sacs are very common in the tissues.

Leaves: Simple alternate, stipulate having stellate hairs, round or palmately divided.

Inflorescence: Cymose type, rarely racemose. It may be compound cyme or solitary axillary terminal.

Flowers: Bracteolate which are arranged in epicalyx, pedicellate, actinomorphic, hermaphrodite, complete, hypogynous, pentamerous.

Calyx: 5 sepals, gamosepalous, sepaloid inferior, having valvate aestivation, colourful.

Corolla: 5 petals, polypetalous, inferior petals, twisted aestivation.

Androecium: Indefinite stamens arranged on a staminal tube. Monadelphous, epipetalous. Anthers are one celled and dorsifixed.

Gynoecium: Polycarpellary, 5 to indefinite carpels, syncarpus ovary multilocular having one to many ovules in each locule, superior, axile placentation.

Fruit: Schizocarp or loculicidal capsule sometimes fleshy berry.

Seed: Seeds are reniform or ovoid in shape with mucilaginous endosperm and a curved embryo, generally covered with wooly hairs (*Gossypium*).

Pollination: Entomophilous.

Floral formula: - Ɵ □ K (5), $\overline{C\ 5,\ A}$ (∞), $\underline{G}_{(5)}$

7.7.3 Important Genera

Hibiscus rosa- sinensis (**Gurhal)**

Habit: Bushy evergreen, perennial shrub or small tree.

Root: Branched tap root.

Stem: Aerial, erect, cylindrical, woody and branched.

Leaf: Simple, alternate, petiolate, stipulate, ovate shape, tip is acute and margin is serrated. Venation is multicostate reticulate.

Inflorescence: Cymose, solitary axillary.

Flower: Complete (bisexual), actinomorphic, bracteolate or ebracteolate pedicellate, regular, pentamerous, hypogynous.

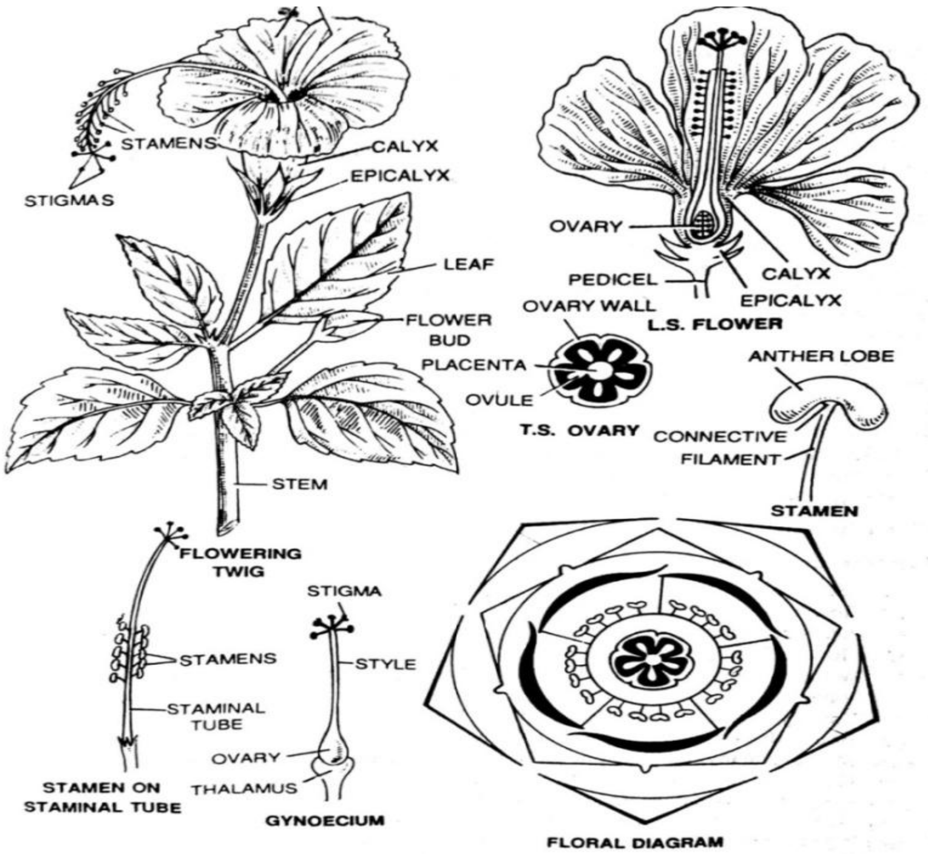

Fig.7.5 Hibiscus rosa-sinesis Linn. (Courtesy B. P. Pandey – Angiosperms, 2007)

Epicalyx: 5-7 bracteoles constitute epicalyx situated below the calyx.
Calyx: 5 sepals, gamosepalous, valvate aestivation green in colour.
Corolla: 5 petals, polypetalous, united below slightly, adnate to the stamina tube, twisted aestivation.
Androecium: Stamens form a staminal tube round the style, indefinite in number monadelphous, basifixed monotheous anthers.
Gynoecium: Carpels 5 (pentacarpellary), syncarpous ovary pentalocular, superior, placentation axile.
Fruit: Capsule.
Floral formula: $\oplus$ ⚥ Epi$_{5-7}$ K$_{(5)}$ $\widehat{C_5 A_\infty}$ $\underline{G}_{(5)}$

7.7.4 Economic importance

Plants of this family are used as vegetables, fibers, oil, medicines and ornamental. Some important plants are as follows:

- ***Abelmoschus esculentus*:** (Lady's finger) **Bhindi,** the fruits are used as vegetable.

- ***Gossypium arboreum*:** (Tree cotton) **Kapas,** grown in India. The fibre obtained from seed surface is most important textile fiber. Stalks are used for making paper. Seed cakes are used as fodder and oil from seed is used in manufacture of soaps, lubricants.
- ***Gossypium herbaceum***: (Asiatic cotton) **Kapas,** grown in India, mainly in Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka. Seed fibre is utilized in the textile industry and other woven products.
- ***Gossypium hirsutum*:** (Upland cotton) **Kapas,** grown in Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra. Seed fibre is utilized in the textile industry and other woven products.
- ***Hibiscus cannabinus*: Patsan,** grown in Assam, Bihar, Punjab, West Bengal. Stem fibre used for making ropes, paper pulp etc. Seed oil is edible.
- ***Hibiscus rosa-sinensis***: **Gurhal,** ornamental shrub. It also yields purplish dye, used for making shoe polishes.
- ***Hibiscus macrophyllus*: - Baiza,** small shrub found in Bengal and East Peninsula. Fibre obtained from stem is used for making cordage and ropes.
- ***Hibiscus vitifolius***: **Ban Kapas**, found in northern India and Madhya Pradesh. Strong fibres are obtained from bark.

Systematic relationship

Malvaceae is related to Sterculiaceae and Tiliaceae in having mucilaginous sap, simple alternate and stipulate leaves. According to Bentham and Hooker it differs from them in having monothecous anthers, monadelphous condition and presence of involucre or epicalyx. Hutchinson placed the single family under Malvales. Engler and Prantl put this family together with Tiliaceae, Bombaceae and Sterculiaceae in the order Malvales.

7.8 RUTACEAE (CITRUS FAMILY)

7.8.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Phanerogames	Dicotyledons
Polypetalae	Lignosae
Disciflorae	Rutales
Geraniales	Rutaceae
Rutaceae	

Distribution

The members of family are distributed in tropical and temperate regions. The family Rutaceae comprises of about 150 genera and 1500 species. In India, about 25 genera and 71 species are so far known. The family is well known for its several juicy citrus fruits. Some important plants of the family are *Murraya*, *Aegle*, *Feronia* and *Ruta*.

7.8.2 General Characters

Habit: Trees or shrubs are common in the family while herbs are rare, often xerophytic (*Aegle marmelos*), and aromatic. Sometimes the shrubs become tree like in habit (*Citrus sp*.). They are rich in vitamin C. *Paraminya grifithii* plants are woody climbers having strong curved spines.

Root: Branched tap roots.

Stem: Erect, woody, cylindrical, branched, rarely herbaceous, solid often with spines and thorns (*Aegle* and *Citrus*) usually aromatic.

Leaves: Both simple and compound (*Murraya*) usually alternate (*Citrus*, *Aegle*), rarely opposite (*Evodea*), sometimes reduced to spines (*Citrus*, *Aegle*), exstipulate margin entire or serrate, oil glands are present on the leaves having volatile essential oil, which gives a very typical smell to the leaves. Winged petiole is very common in *Citrus* sp.

Inflorescence: Various types of inflorescences are present in the members of family Rutaceae. Generally cymose, rarely raceme (*Feronia*). In some plants the flowers are solitary axillary (Citrus). In *Murraya exotica* the flowers are arranged in axillary or terminal corymbs.

Flowers: The flowers are actinomorphic rarely zygomorphic, pedicellate, ebracteate, complete hermaphrodite, unisexual (*Feronia*), hypogynous, complete. Mostly pentamerous rarely tetramerous or trimerous.

Calyx: 4 to 5, sepals free (polysepalous). In zygomorphic flowers the calyx becomes tubular or united. Aestivation is imbricate or quincuncial.

Corolla: Petals 5 to 4, polypetalous, rarely gamopetalous, variously coloured, imbricate aestivation.

Androecium: The number of stamens is generally 10, obdiplostemonous condition, in *Citrus* numerous stamens with polyadelphous condition. 10 stamens are present in *Murraya exotica* in two whorls of five each. Anther introrse, dithecous, basifixed or versatile.

Gynoecium: Usually 4 to 5 carpels, rarely less or indefinite, carpels usually united at the base or the sides forming a deeply lobed ovary with fused style originating from centre. Carpels are fully united in *Citrus*, axile placentation, ovary superior, rarely unilocular with parietal placentation (*Feronia*), ovule anatrapous.

Fruit: Various types of fruits are present in different genera, hesperidium in *Citrus*, capsule in *Flindersia*, drupe in *Acronychia* and berry in *Murraya*.

Seed: Endospermic or non endospermic.

Pollination: Entomophilous due to coloured corolla various insects are attracted. Dispersal of seeds takes place mainly by animals and also by human.

Floral Formula: $\oplus$ ⚥ $K_{5 \text{ or } (5)}, C_5, A_{10}, \underline{G}_{(3\text{-}5)}$

7.8.3 Important Genera

***Citrus aurantium* Linn.**

Habit: A shrub or small tree.

Root: Branched tap root.

Stem: Solid, branched, woody, erect.

Leaf: Alternate, petiolate, cauline, stipulate, more or less serrate, unicostate reticulate venation.

Inflorescence: Cymose, either in small cymes or solitary axillary.

Flower: Hermaphrodite, bracteate, pedicillate, pink or white scented, complete, actinomorphic, hypogynous.

Calyx: Sepals five gamosepalous, quincuncial aestivation, inferior.

Corolla: Five petals, polypetalous, scented, white in colour, imbricate aestivation, inferior.

Androecium: Stamens may vary from 15-60 polyadelphous, filaments variously connate, anthers oblong, introrse basifixed.

Gynoecium: Polycarpellary, syncarpous multilocular, superior ovary, below the ovary is present nectar secreting disc, placentation axile, stout style, capitates stigma.

Fruit: Berry (hesperidium)

Floral Formula: ⊕ ⚥ $K_{(5)}, C_5, A_{(\infty)}, \underline{G}_{(\infty)}$

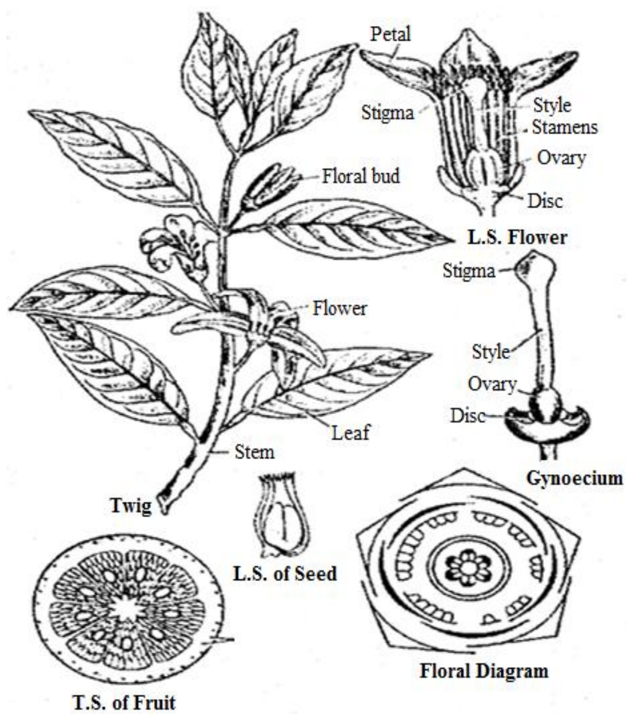

Fig.7.6 *Citrus aurantium* Linn. (Courtesy:B P Pandey, 2007)

7.8.4 Economic Importance

This family is an important source of various fruits and medicinal as well as ornamental plants.

1 Important fruits

- *Citrus reticulata* (santra)
- *Citrus limon* (lemon)
- *Citrus aurantifolia* (lime)
- *Citrus maxima* (chakotra)
- *Citrus sinensis* (malta)
- *Citrus medica* (citron)

2 Plants of medicinal value

- *Murraya koenigii* (karipatta) used in hair fall problem, in high blood pressure. Also used as condiment for flavouring curries.
- *Aegle marmelos* (bael) fruit pulp is a good remedy for dysentery and other stomach problems.
- *Zanthoxylum armatum* (tejbal) bark of plant is carminative, stomachic and anthelmintic. Plant is also act as an insect repellent.
- *Toddalia asiatica* root bark of plant is a potent antimalarial drug.

Systematic relationship

Rutaceae is related to the Meliaceae, Sapindaceae and Anacardiaceae in habit, leaf structure, presence of disc around the ovary and obdiplostemonous condition of androecium. The family Rutaceae is also related to Euphorbiaceae on account of the presence of ventral raphe of the ovule in some genera. According to Tillson and Bamford (1938) the disc in the members of sub-family Aurantioideae represents the vestigial third whorl of stamens. Engler and Prantl included the family in the Geraniales along with Zygophyllaceae, Euphorbiaceae and Burseraceae. Hallier attached particular phylogenetic significance to the Rutaceae and derived it from stocks ancestral to Berberidaceae; Rendle placed the family in a separate order between Geraniales and Sapindales. Wettstein included Rutaceae along with Meliaceae in the order as Terebinthales.

7.9 SUMMARY

Now you can summarize this unit on the basis of the characters mentioned below:

Ranunculaceae also known as butter cup family is a large angiospermic family and often considered as the most primitive of the herbaceous plants due to the presence of bisexual and actinomorphic flowers, number of stamens are usually the twice as many as petals, unilocular ovary with free central placentation. The advance characters of the family are presence of zygomorphic flowers and achenial fruit. Ranunculaceae is important for ornamental and drug plants. The important genera of the family are *Ranunculus, Delphinium*, etc.

Magnoliaceae is considered as most primitive family among the woody plants. Flowers of this family are actinomorphic, hypogynous, bisexual but due to reduction of perianth becoming unisexual, apocarpous having numerous stamens. The family is known for its beautiful flowers having soothing fragrance. The important genera of the family are *Michelia, Magnolia* etc.

Brassicaceae earlier known as Cruciferae is important due to the presence of characteristic cruciform corolla. Plants are generally herbs with alternate exstipulate leaves, stamens tetradynamous. Bicarpellary unilocular, syncarpous superior ovary but becomes bilocular due to the development of false septum. Silicula and siliqua are the characteristic fruit of the family. The family is of considerable importance and provides fruits, vegetables, ornamental and medicinal plants. The important plants of the family are various species of *Brassica* and *Raphanus*.

Dipterocarpaceae (Sal family) is named after type genus *Dipterocarpus*, The family is identified by gigantic trees with an abundant resin; coracious leaves; flower actionomorphic, hermaphrodite, hypogynous; sepals 5, polysepalous, persistent; petals 5, polypetalous; stamens many in one to several whorls, slightly polyandrous, carpels 3, syncarpous, superior; Fruit samara enclosed in persistent sepals.

Malvaceae or the mallows family is well known for number of fibrous plants, mostly found in tropical parts of world. Includes cotton, okra, **patsun** and garden plants. Most important genera of this family are *Gossypium* (Cotton), *Hibiscus, Malva, Abutilon* etc.

Rutaceae family is commonly known as citrus family. This family includes woody shrubs and trees. Flowers polypelatous, hypogynous having annular disc, ovary syncarpous, multicarpellary, superior with axile placentation. Leaves exstipulate having aromatic oil glands, stamens few to many, obdiplostemonus, fruit is hesperidium. The family is the source of several important citrus fruits (rich source of vitamin C) and few ornamental and medicinal plants. The important plants are the species of *Citrus, Aegle marmelos, Murraya koenigii,* etc.

7.10 GLOSSARY

Actinomorphic: Regular or symmetrical.

Axile placentation: Each carpel entirely closed thus making as many chambers as carpels with the placentae at the center of pistil.

Apocarpous: Carpels not united.

Adnate: When the anther filament is attached to the back of the anther throughout its whole length.

Bicarpellary: Pistil composed of two carpels.

Basifixed: When the filament is attached to the base of the anther.

Berry: Pulpy, indehiscent, few or many seeded fruit.

Calyciflorae: Thalamus usually cup shaped and ovary inferior.

Cruciform corolla: Corolla in a cross (X) manner as in Brassicaceae.

Cauline: Belonging to an obvious stem or axis.

Disciflorae: Flowers hypogynous and ovary superior.
Dithecous: Anthers having two anther lobes.
Drupe: A one seeded fleshy indehiscent fruit with seed enclosed in a stony endocarp.
Entomophilous: Insect pollinated.
Etario of achenes: In this aggregate fruit, each fruit is an achene.
Gamopetalous: Petals are united, at least at the base.
Glabrous: Not hairy.
Hermaphrodite: Bisexual.
Hesperidium: Many celled fruit. Epicarp and mesocarp fused and form skin while endocarp projects inwards forming distinct chambers.
Introrse: Anther facing towards the centre of the flower.
Obdiplostemonous: With the stamen in two alternating whorls, and the outer whorl opposite to the petals.
Perigynous: Borne or arise from around the ovary and not beneath it.
Polyadelphous: When stamens are united by their filaments into more than two bundles.
Polyandrous: Production of an indefinite number of stamens in an androecium.
Polypetalous: Corolla having free or separate petals.
Pome: Generally fruit of rosaceous genera e.g. apple, pear.
Perianth: A collective term for the calyx and corolla.
Rhizome: Underground stem.
Reticulate: Netted.
Siliqua: Long, slender capsule of two carpels, ovary bilocular due to false septum.
Superior ovary: Sepals petals and stamens hypogynous i e ovary is on the top of receptacle and all floral parts are present below the ovary.
Syncarpous: Carpels united.
Tetradynamous: An androecium with 6 stamens, 4 longer than outer 2 smaller. Mostly found in Brassicaceae.
Thalamiflorae: Hypogynous flower with superior ovary.
Torus: Receptacle.

7.11 SELF ASSESSMENT QUESTIONS

7.11.1 Tick the right answer:

1. Botanical name of radish is:
(a) *Nigella sativa* (b)*Raphanus sativus*
(b)*Daucus carota,* (d)*Coriandrum sativum*

2. Botanical name of larkspur is:
(a)*Abelmoschus esculentus* (b) *Delphinium ajacis*
(c)*Solanum tuberosum* (d) *Ranunculus scleratus*

3. Tetradynamous condition is the characteristic feature of family:
(a) Fabaceae (b) Rutaceae
(c) Apiaceae (d) Brassicaceae

4. Leaves often with oil glands are present in family:
(a) Rutaceae (b) Solanaceae
(c) Rubiaceae (d) Magnoliaceae

5. False septum is present in-
(a) Brassicaceae (b) Euphorbiaceae
(c) Magnoliaceae (d) Ranunculaceae

6. Number of petals in family Malvaceae is –
(a) 4 (b) 3
(c) 2 (d) 5

7. *Hibiscus rosa-sinensis* belongs to family.
(a) Malvaceae (b) Cruciferae
(c) Rutaceae (d) Violaceae

8. Botanical name of Sal is
(a) *Solanum tubersum* (b) *Lycopersicum esculentum*
(c) *Capsicum frutescens* (d) *Shorea robusta*

9. Persistent calyx (in fruit) and samara is characteristic feature of which one of the following family
(a) Diptercapaceae (b) Acanthaceae
(c) Solanaceae (d) Poaceae

7.11.2 Fill in the blanks:

1) The anthers of Malvaceae are …………………………………..
2) Characteristic fruit of Rutaceae is…………………
3) *Aconitum heterophyllum* produces a drug known as ………………….
4) Tetradynamous condition is found in family………………..
5) Kalonji is a common name of …………….
6) Monoadelphous condition of stamen is found in ……………………………….
7) Rutaceae is commonly known as …………………
8) *Michelia champaca* is a member of family…………….
9) Siliqua or siliqula is the characteristic fruit of …………………
10) Mustard oil is produced by ……………….

Answer key:

7.11.1: 1(b), 2(b), 3(d), 4(a), 5(a), 6(d), 7(a), 8(d), 9(a)

7.11.2: 1. Monothecous, 2. Hesperidium, 3. Anconitine, 4. Brassicaceae, 5. *Nigella sativa*, 6. Malvaceae, 7. Citrus family, 8. Magnoliaceae, 9. Brassicaceae, 10. *Brassica campestris*.

7.12 REFERENCES

- Singh, V, Pandey, P.C and Jain, D.K. 1999. A Text Book of Botany, Angiosperms, Rastogi Publication Meerut, India.
- Sharma, O.P. 2010 Pant Taxonomy (second edition). The Mc Graw hill Company, New Delhi.
- Saxena, N.B. and Saxena, S. 2012 Plant Taxonomy. Pragati Prakshan Meerut India.
- Pande, B.P. 2012 A text book of Botany, Angiosperm S.Chand New Delhi.

7.13 SUGGESTED READINGS

- Bentham, G. and Hooker, J.D. 1982. *Genera Pantarum,* L. Reeve and Co. London.
- Engler, A. W. and Prantl K. 1887-1915 *Die Naturlichen Pflanzenflamilien*, 23 Vols Leipzig.
- Hutchison, J.1969. Evolution and Phylogeny of the Flowering Plants. Academic Press, London.
- Takhtajan, A. 1969. Flowering Plants Origin and Dispersal. Oliver and boyd. Ltd. Edinurgh.
- www.biologyboom.com
- www.britannica.com

7.14 TERMINAL QUESTIONS

1. Where will you place Rutaceae in Bentham and Hooker’s system of classification? Write the diagnostic features and the botanical names of the plants of economic importance.
2. Give an illustrated account of salient features of Ranunculaceae. Why the family is regarded as primitive?
3. With the help of suitable examples describe the floral characters of family Malvaceae.
4. Describe economic importance of family Dipterocarpaceae.

UNIT-8 FABACEAE (PAPILIONACEAE), CAESALPINIACEAE, MIMOSACEAE, ROSACEAE CUCURBITACEAE AND APIACEAE (UMBELLIFERAE)

8.1 OBJECTIVES

After reading this unit you will be able-

- To describe the systematic position, habit and habitat and general characters of the families Fabaceae, Caesalpiniaceae, Mimosaceae, Rosaceae and Cucurbitaceae.
- To understand the floral characters.
- To learn economic importance of these families for human welfare.

8.2 INTRODUCTION

The present unit deals with the general characters of five angiospermic families viz- Fabaceae, Caesalpiniaceae, Mimosaceae, Rosaceae and Cucurbitaceae.
Initially family Fabaceae (Papilionaceae), Caesalpiniaceae and Mimosaceae were placed under family Leguminosae as subfamily Papilionoidae, Caesalpinoidae and Mimosoidae, which were later raised to the rank of families as above.

8.3 FABACEAE (PAPILIONACEAE)

8.3.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Polypetalae	Lignosae
Calyciflorae	Leguminales
Leguminosae	Papilionaceae
Papilionatae	

Distribution

Family Fabaceae is the largest among the sub families belonging to Leguminosae. Plants are distributed in temperate regions of southern and northern hemispheres.

8.3.2 General Characters

Habit: Herbs or shrubs often climbers, trees are rare sometimes xerophytes.

Root: Branched tap root. Roots are with nodules containing *Rhizobia* the nitrogen fixing bacteria.

Stem: Branched, herbaceous or woody, climbing or erect.

Leaves: Usually compound, alternate, whorled or opposite sometimes simple, stipulate.

Inflorescence: Racemose, the raceme, the spike and the contracted raceme or head.

Flower: Pedicellate, zygomorphic, hermaphrodite, irregular, complete, papilionaceous and perigynous.

Calyx: 5 sepals which are united into a tube, gamosepalous, equal or unequal, five lobed or bilabiate, imbricate aestivation (ascending).

Corolla: 5 petals which are unequal, anterior pair of petals is united and known as carnia or keel, upper largest petal is known as vexillum or standard remaining two petals are free and lateral in position termed as wings or keel. Petals are of various colours, descending imbricate aestivation.

Androecium: Usually 10 stamens either in one bundle (monadelphous) or in two bundles (diadelphous) of 5+5 or 9+1. They are rarely free from each other. Bicelled dorsifixed anther.

Gynoecium: One carpel, unilocular superior ovary, placentation is marginal.

Fruit: Pod or legume sometimes indehiscent lomentum.

Seed: Exalbuminous

Pollination: By insects.

Floral formula: % □ $K_{(5)}$, $C_{1+2+(2)}$, $A_{(9)+1}$, $\underline{G}_1$

8.3.3 Important Genera

***Pisum sativum* (Matar)**

Habit: An annual cultivated herb.

Root: Branched tap root having nodules. Nitrogen fixing bacteria *Rhizobium* is present in them.

Stem: Branched, smooth stem, herbaceous, climber

Leaves: Stipulate, alternate, compound, having 4 or 6 leaflets, which are smooth, green, entire, net veined, oval, terminal leaflet is always a tendril.

Inflorescence: Racemose, either in axillary racemes or solitary.

Flower: Complete, pedicellate, irregular, hermaphrodite, zygomorphic, bracteate or ebracteate, hypogynous to perigynous, pink or white in colour.

Calyx: Sepals 5, gamosepalous, sepaloid. Calyx tube is campanulate. Aestivation is ascending imbricate.

Corolla: Petals 5, 2 wings, 2 keels united and 1 standard. Papilionaceous corolla, pink or white flower. Aestivation is descending imbricate.

Androecium: Stamens 10 arranged in two bundles (diadelphous) of 9+1. Anthers introrse, basifixed, bi-lobed.

Gynoecium: Monocarpellary, unilocular superior ovary, placentation marginal, many ovules, hairy ovary.

Fruit: Pod or legume.

Seed: Round, exalbuminous.

Floral formula: % □ $K_{(5)}$ $C_{1+2+(2)}$, $A_{(9)+1}$ $\underline{G_1}$

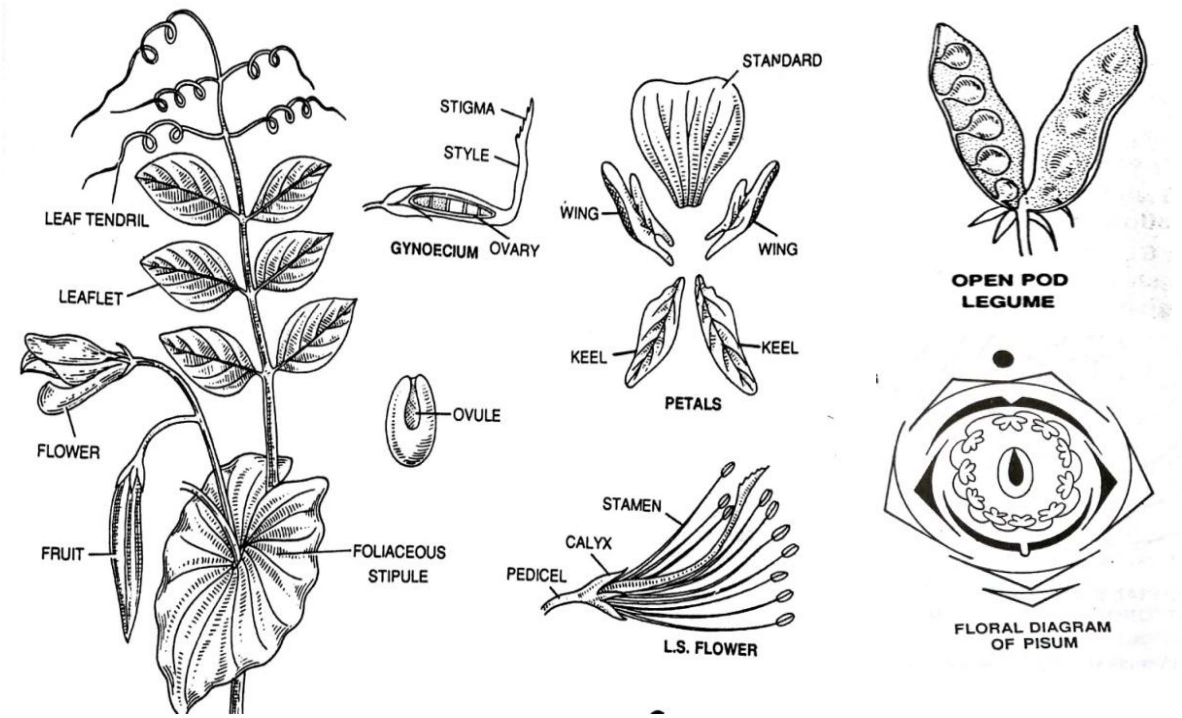

Fig. 8.1. Fabaceae: Pisum sativum Linn. (Courtesy B. P. Pandey – Angiosperms, 2007)

8.3.4 Economic importance

Some economically important plants of this family are –

- *Phaseolus vulgaris*: **Vilayatisem**, the pods are source of vegetable.
- *Cajanus cajan*: **Arhar**, the seeds are used as food, leaves are used as fodder.
- *Glycine max*: **Bhat**, the seed are rich in oil and kernel is rich source of protein it makes a good healthy food.
- *Cicer arietinum*: **Chana**, seeds are eaten as food either raw or as roasted, leaves are used as vegetable and fodder.
- *Pisum sativum*: **Matar**, seeds are used as vegetable. They are rich in protein.
- *Vigna sinensis*: **Lobia**, seeds are used as pulse and vegetable.
- *Dalbergia sissoo*: **Shisham**, wood is used for furniture and pulp is used for making papers.
- *Dalbergia latifolia*: **Kala Shisham**, wood used for furniture and cabinet work.

8.4 CAESALPINIACEAE

8.4.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons

Polypetalae	Lignosae
Calyciflorae	Leguminales
Leguminosae	Caesalpiniaceae
Caesalpinioideae	

Distribution

Plants belonging to this family are found in tropical and subtropical areas.

8.4.2 General Characters

Habit: Plants are shrubs and trees rarely herbs. Mostly wild but many are cultivated for timber and their beautiful flowers. Woody climbers are also found.

Root: Branched tap root.

Stem: Solid, branched, woody, sometimes climbing or herbaceous.

Leaves: Simple or compound (pinnate or bipinnate) if pinnate they are arranged in pairs, petiolate, at the base of petiole pulvinus present, entire, net veined, exstipulate, sometimes minute caducous stipules also present.

Inflorescence: Racemose, sometimes pendulous.

Flowers: Large or small, variously coloured, pedicellate, mostly zygomorphic, rarely actinomorphic complete, hermaphrodite, hypogynous.

Calyx: Sepals five, fused or free mostly petaloid, valvate or imbricate aestivation.

Corolla: Petals five, free, aestivation is ascending imbricate.

Androecium: Ten stamens, mostly free, rarely connate, sometimes altogether abortive or reduced to staminodes.

Gynoecium: Monocarpellary, unilocular, superior ovary, placentation is marginal.

Fruit: Lomentum or pod, stalked or sessile.

Seed: Exalbuminous.

Pollination: By insects.

Floral formula: Ɵ or % K5 or (5), C5, A_{10}, $\underline{G_1}$

8.4.3 Important Genera

Cassia fistula (**Amaltas)**

Habit: A tree of medium size.

Root: Branched tap.

Stem: Branched, solid, woody erect.

Leaves: Petiolate, compound alternate, paripinnate, pulvinus at the base, stipulate having caducous stipules, leaflets 4-8 pairs, entire, acute, ovate, unicostate reticulate venation.

Inflorescence: Racemose, typical raceme.

Flower: Bracteate (caduceus bracts) pedicellate, actionomorphic, hermaphrodite, hypogynous, complete, yellow in colour.

Calyx: Sepals 5, yellowish green, polysepalous, petaloid, aestivation quincuncial, inferior.

Corolla: Petals 5, yellow, polypetalous, aestivation imbricate (ascending), inferior.

Androecium: Ten unequal stamens, polyandrous, posterior three stamens reduced to staminodes, anthers basifixed with indehiscent lobes.

Gynoecium: Monocarpellary unilocular, superior ovary, placentation marginal.

Fruit: Legume, black after ripening.

Floral formula: Br % □ K5, C5, A7 + 3, G1

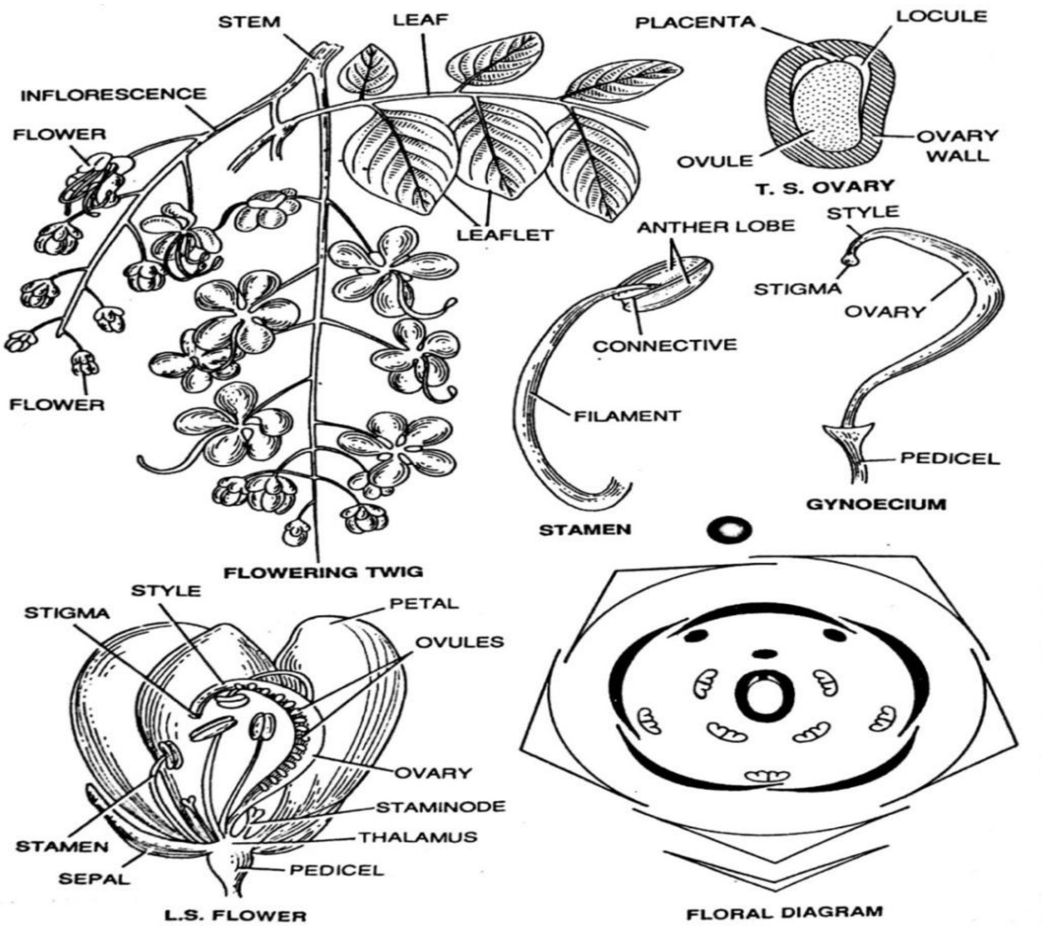

Fig. 8.2. Cassia fistula Linn. (Courtesy B. P. Pandey – Angiosperms, 2007)

8.4.4 Economic importance

A few economically important plants of this family are –

- ***Bauhinia variegata*: Kachnar**, a tree plant. Flower buds and leaves are used as vegetable; bark is used for tanning and dyeing purpose.
- ***Bauhinia acuminata*: Safed Kachnar**, small ornamental tree.
- ***Cassia fistula*: Amaltas,** ornamental plant, pulp of fruit is used as laxative.
- ***Cassia grandis***: Used as a hedge plant in garden.
- ***Cassia nodosa***: Ornamental plant with pink flowers.
- ***Delonix regia*: Gulmohur,** a shrub or small tree, cultivated for ornamental purpose.

- ***Tamarindus indica*: Imli,** a tree found throughout India. Fruits are edible. Bark and leaves are used in tanning. Unripe fruits contain tartaric acid used in various foods, chemicals and pharmaceutical industries.

8.5 MIMOSACEAE

8.5.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Polypetalae	Lignosae
Calyciflorae	Leguminales
Leguminosae	Mimosaceae
Mimosideae	

Distribution

It is the smallest of all three subfamilies which were under Leguminosae. Plants of this family are distributed in tropical and subtropical regions.

8.5.2 General Characters

Habit: Mostly shrubs or trees, rarely herbs sometimes climbers, xerophtic, thorny wild, however some are grown as sand binders and check soil erosion.

Root: Branched tap root deeply found in soil.

Stem: Woody, branched, erect solid. Tissue of stem is rich in gum passages and tannin sacs.

Leaves: Petiolate, base of petiole consists of pulvinus; alternate, stipulate, stipules modified into thorns, pinnate (generally bipinnate). Leaf movement is common in many species.

Inflorescence: Racemose spike or head.

Flower: Complete, small usually sessile, regular, actinomorphic, hermaphrodite hypogynous.

Calyx: Sepals 4 or 5, gamosepalous, more or less connate, green small, valvate aestivation , inferior.

Corolla: Petals 4 or 5, polypetalous slightly united towards the base, usually pentamerous, valvate aestivation, inferior.

Androecium: Stamens indefinite, sometimes numbers is reduced to ten or even four, attractive, bright coloured. Anther dorsifixed 2-celled.

Gynoecium: Monocarpellary, unilocular superior ovary. Placentation is marginal.

Fruit: Lomentum or legume.

Seed: Exalbuminous.

Pollination: Entomophilous

Floral formula: Ɵ □ K (5), C (5), A∞, $\underline{G1}$

8.5.3 Important Genera

Acacia nilotica (**Babul, Kikar)**

Habit: Spiny, medium sized tree.

Root: Branched tap root.

Stem: Branched, solid, woody erect.

Leaves: Petiolate, bipinnate, stipulate, stipules modified into spines, leaflet oval, unicostate reticulate venation.

Inflorescence: Flowers arranged in compound cymose head.

Flower: Fragrant, yellow, small, sessile, bracteate, actionomorphic, hermaphrodite, hypogynous, complete.

Calyx: Sepals 4 or 5, gamosepalous, aestivation valvate, inferior.

Corolla: Petals 4 or 5, gamopetalous, campanulate, aestivation valvate, inferior.

Androecium: Indefinite stamens, polyandrous, anthers minute, yellow, introse.

Gynoecium: One carpel, unilocular, superior ovary, placentation marginal.

Fruit: Lomentaceous pod.

Floral formula: ϴ K(4 – 5), C(4 – 5), A∞, $\underline{G1}$

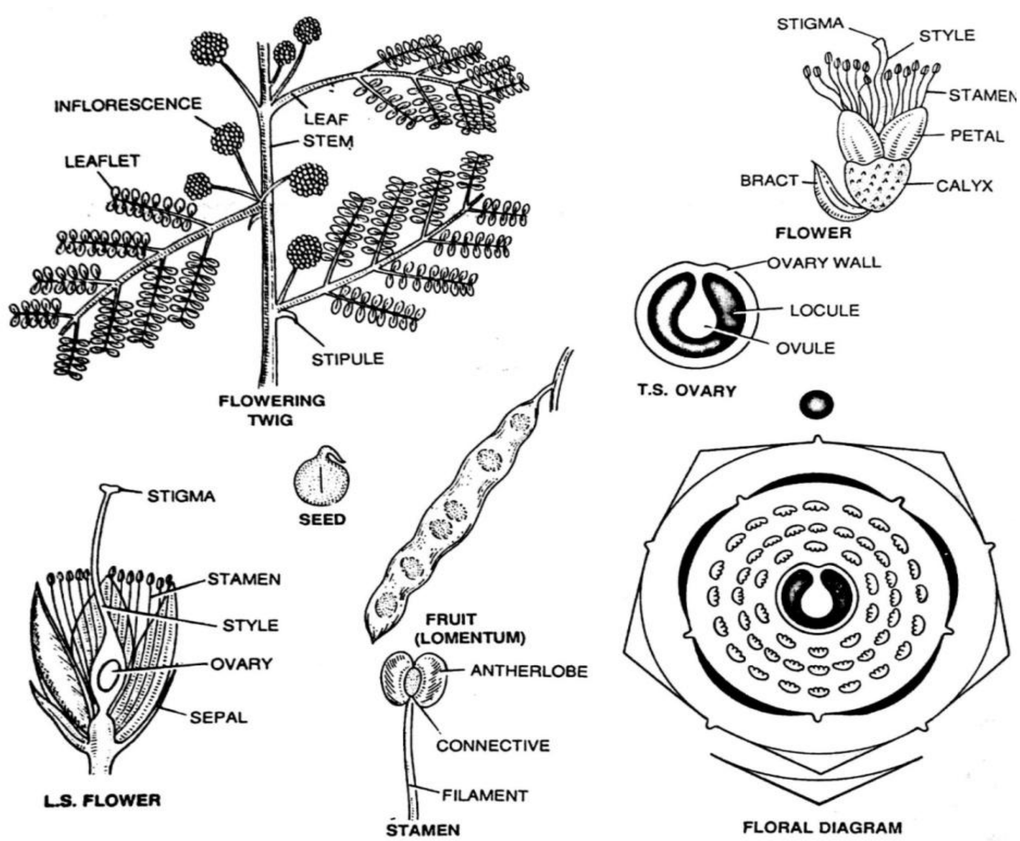

Fig.8.3. Acacia nilotica (Linn)Del. (Courtesy: B. P. Pandey – Angiosperms, 2007)

8.5.4 Economic importance

Some economically important plants of this family are –

- ***Acacia catechu*: Khair**, a tree. Kattha is obtained from heart wood, used as dyeing and preserving agent.
- ***Acacia nilotica*: Babul, Kikar,** a tree. Fruits are used as fooder. Gum obtained from bark. Twigs are used as datun.
- ***Albizia lebbeck*: Siris**, a common roadside tree grown for shade. The wood is used for furniture making, interior fittings and railway carriages.
- ***Mimosa pudica*: Lajwanti,** an under shrub grown for ornamental purpose.
- ***Mimosa rubicaulis*: Shiah-Kanta**, a shrub grown as a hedge plant.
- ***Xylia xylocarpa*: Jambu,** is a tree. Wood is used for making bridges, railway sleepers, construction work etc.

Systematic relationship

The three subfamilies of Bentham and Hooker usually treated distinct families (Papilionaceae, Caesalpinaceae and Mimosaceae). However, in some more recent treatments (e.g., Cronquist, 1968, 1981; Airy Shaw, 1973) also the Fabaceae are considered to comprise a single family. The Fabaceae are included in the order Rosales by Bentham and Hooker, Engler and Prantl, Cronquist, etc. However, those who consider them as consisting of separate families, include the three families in a single order, the Leguminales (Hutchinson, 1959, 1969) or Fabales (Takhtajan, 1969, 1980). Of the three families, Hutchinson (1969) considered Caesalpinaceae as the most primitive family. According to him, it is closest to Rosaceae and seems to have been to have been derived from the rosaceous stock. He considered the Fabales close to his Saxifragales and derived from their immediate ancestors.

8.6 ROSACEAE (ROSE FAMILY)

8.6.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Phanerogams	Dicotyledons
Dicolaylelons	Lignosae
Polypetalae	Rosales
Calyciflorae	Rosaceae
Rosales	
Rosaceae	

Distribution

Plants are mostly cosmopolitan in distribution and are mainly distributed in eastern Asia, Europe and North America. In India the members e.g. *Pyrus, Rubus, Prunus*, *Fragaria* are commonly found in hilly region. About 25 genera and 230 species of rosaceae have been reported from India.

8.6.2 General Characters

Habit: Members of the family Rosaceae show great variation in their habit. Trees like *Pyrus* spp., *Prunus* spp., *Eriobotrya* are more common in comparison to shrubs (*Spiraea*) and herbs (*Fragaria indica* and *Potentilla*). Plants are very often thorny climbers (*Rosa indica* and *Rubus*).

Root: Tap root, branched, sometimes adventitious arising from stem cutting.

Stem: Erect or creeping, herbaceous woody and hard. Vegetative reproduction takes place by means of suckers, runners and also by bud grafting.

Leaves: Mostly alternate, rarely opposite, simple or pinnately compound, petiolate and stipulate, stipules may by minute or caducous e.g. *Pyrus adnata* and persistent e.g. *Rosa indica* with conspicuous leaf base.

Inflorescence: Rosaceae family shows great variation in inflorescence from solitary flowers to racemose and cymose, cluster solitary (*Rosa*), racemose raceme (*Agrimonia*, *Prunus*), corymb (*Spiraea*), cyme (*Fragaria*), terminal corymbose (*Rosa moschata*).

Flower: Mostly actinomorphic or regular rarely zygomorphic, bracteate, bisexual rarely unisexual pentamerous flower, perigynous (*Rosa*), epigynous (*Prunus*) and sometimes may be hypogynous also (*Prunus*), stipules may be represented by epicalyx (*Fragaria*).

Calyx: Calyx consist of 5 sepals, united at the base i.e. gamosepalous, basal portions are usually adnate forming a hypanthium epicalyx is present some times, aestivation is valvate or imbricate.

Corolla: Variously coloured 5 petals polypetalous, rosaceous, inserted on the receptacle cup, petals may be indefinite (e.g. *Rosa* spp.), petals may be altogether absent (e.g. *Poterium*), sometimes stamens are modified into petal like structure, imbricate aestivation.

Androecium: Usually numerous, distinct stamens in whorls, 5 sometimes only 5 or 10 stamens, perigynous around the gynoecium and arise from the hypanthium. Anthers are small dithecous, introrse or dorsifixed, usually nectar secreting disc is present in between the stamens and carpel.

Gynoecium: One to many carpels, one carpel in *Prunus*, 5 in *Pyrus* and indefinite in *Fragaria* and *Rosa*. Gynoecium syncarpous or apocarpus when syncarpous placentation is axile having 2-5 locules while in apocarpous condition basal placentation is present, ovary is superior but sometimes inferior also e.g. *Pyrus*. In *Rosa* perigynous condition occurs.

Fruit: Various types of fruits are present in the family. Drupe in *Prunus*, etario of achenes in *Potentilla*, berry, pome in *Pyrus*. In *Eriobotrya* seed- non endospermic

Pollination: Entomophilous.

Floral Formula: $\mathbf{Br} \oplus \square \mathbf{K}_{(5)}, \mathbf{C}_5, \mathbf{A}_\infty, \mathbf{G}_{\infty \text{ or } \underline{(2\text{-}5)} \text{ or } \overline{(2\text{-}5)}}$

8.6.3 Important Genera

***Prunus persica* (L.) Stokes**

Habit: A small tree well known for its delicious fruits.

Root: Branched tap root.

Stem: Woody, branched

Leaf: Oblong-lanceolate, simple, alternate, petiolate, stipulate, entire or toothed.

Inflorescence: Racemose.

Flower: Pedicellate, hermaphrodite, regular, actinomorphic, pink in colour, complete.

Calyx: Sepals are five in number, gamosepalous, sepaloid, bell shaped.

Corolla: 5 petals, polypetalous, petals arranged on hypanthium, pink inferior .

Androecium: Stamen number may vary from 15-60, perigynous, stamens inserted on the hypanthium, anthers red or brown in colour, bi-celled, dehiscence by longitudinal split, introrse.

Gynoecium: Monocarpellary, having one carpel. Ovary situated within the calyx (hypanthium), unilocular, terminal style and stigma broad.

Fruit: Drupe with single seed, fleshy.

Seed: Exalbuminous.

Floral Formula: $\oplus$ □ $K_{(5)}, C_5, A_{\infty}, \underline{G}_1$

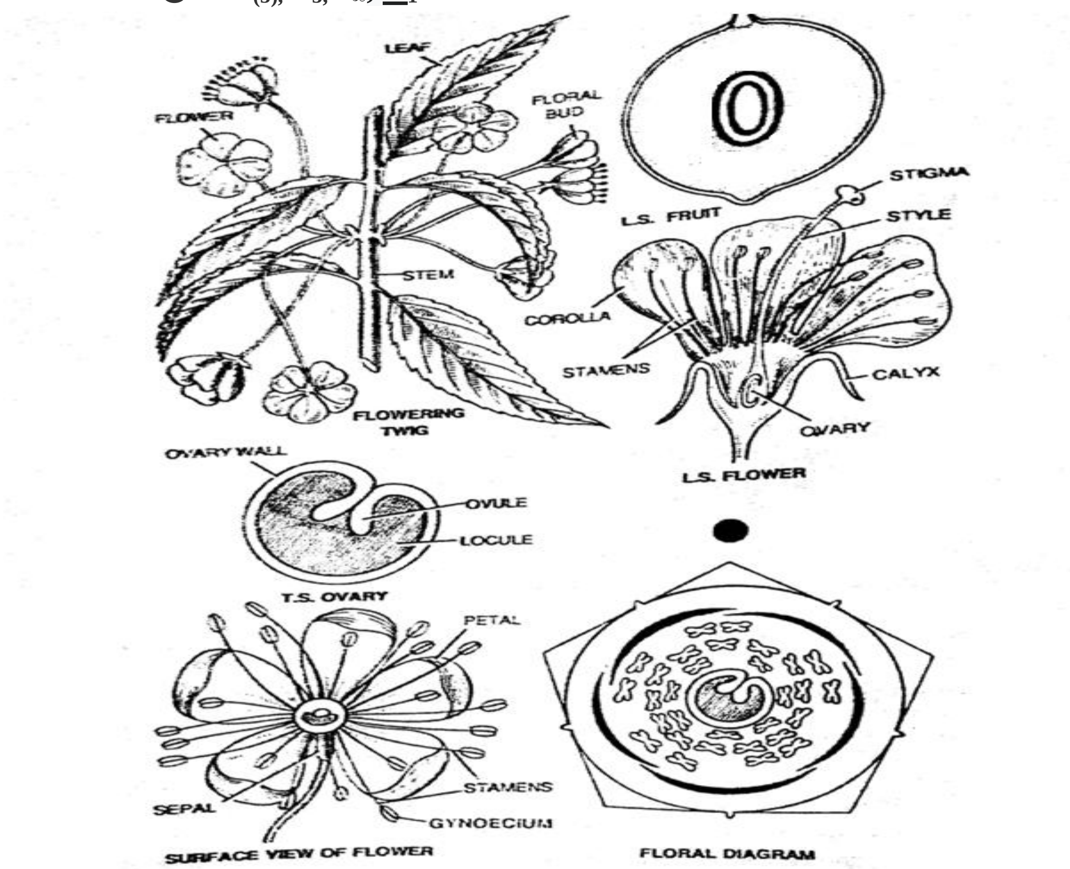

Fig. 8.4 Prunus persica (L). Stokes (Courtesy: B P Pandey, Angiosperms, 2007)

8.6.4 Economic Importance

The plants of Rosaceae family are of an immense value. Many members of the family provide a large number of important fruits, drug producing and ornamental plants.

Fruits

- *Pyrus communis* (pear)
- *Pyrus malus* (apple)
- *Prunus persica* (peach)
- *Prunus communis* var. *insititia* (plum)
- *Prunus armeniaca* (apricot)
- *Prunus amygdalus* (almond)
- *Fragaria chiloensis* (garden strawberry)
- *Eriobotrya japonica* (loquat)

Ornamental: Various species of *Rosa* are grown in the garden for their beautiful flowers e.g.

- *Rosa indica*
- *Rosa damascena*
- *Rosa centifolia*
- *Rubus* and *Potentilla* are also grown for their ornamental value.

Medicinal importance

- *Potentilla* spp. used in kidney stone, arthritis.
- *Geum urbanum* used in chronic dysentery and diarrhoea.
- *Hagenia abyssinica* provides anthelmintic drug.

Systematic relationship

Rosaceae is related to Leguminosae and Saxifragaceae due to the presence of stipules, pentamerous flowers, torus, and monocarpellary pistil. The Chrysobalanoideae with zygomorphy connects the Rosaceae with the Papilionaceae. In *Acioa* the filaments may be fused as in Papilionaceae. The members of the Rosaceae are very much like that of the Ranunculaceae in number of floral parts, apocarpous condition but differ in shape of the thalamus i.e. thalamus in Rosaceae is cup shaped with carpels either standing or embedded in the bottom of the cup and in Ranunculaceae in the form of a cone.

8.7 CUCURBITACEAE (GOURD FAMILY)

8.7.1 Systematic position

Bentham & Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Polypetalae	Lignosae
Calyciflorae	Cucurbitales
Passiflorales	Cucurbitaceae
Cucurbitaceae	

The **Cucurbitaceae**, also called **cucurbits** and the **gourd family**, is a plant family consisting of about 965 species in around 95 genera. Most of the plants in this family are annual vines, but some are woody lianas, thorny shrubs, or trees (*Dendrosicyos*). Many species have large, yellow or white flowers. The stems are hairy and pentangular. Tendrils are present at 90° to the leaf petioles at nodes. Leaves are exstipulate alternate simple palmately lobed or palmately compound. The flowers are unisexual, with male and female flowers on different plants (dioecious) or on the same plant (monoecious). The female flowers have inferior ovaries. The fruit is often a kind of modified berry called a pepo.

Distribution

The plants in this family are grown around the tropics and in temperate areas, where those with edible fruits were among the earliest cultivated plants in both the Old and New Worlds. The Cucurbitaceae family ranks among the highest of plant families for number and percentage of species used as human food.

8.7.2 General Characters

Habit: Mostly annual or perennial herbs, rarely shrubs (*Acanthosicyos*) or small trees (*Dendrosicyos*), usually trailing, climbing by means of tendrils.

Root: Tap root, branched may be thickened due to storage of food and water

Stem: Herbaceous, climbing, angular, fistular, and branched.

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

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

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

Male flower: Produced in large numbers.

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

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

Androecium: Stamens 5, sometimes free or combined to form a central column, anthers dithecous extrorse, dehiscence longitudinal or in curves; androecium may be modified in several ways.

Gynoecium: Reduced or rudimentary or absent.

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

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

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

Androecium: Staminodes 0, 3, 5.

Gynoecium: Tricarpellary, syncarpous, ovary inferior, unilocular with parietal placentation, the intruding placentae make the ovary to appear trilocular ovule bitegmic. Style stout and columnar and bears a forked stigma for each carpel. The stigmas are commissural i.e. stand above the dividing lines between the carpels. This is explained by assuming that each is a joint structure and composed of a branch of the stigmas of two adjacent carpels.

Fruit: Soft, fleshy, indehiscent and either a berry or pepo. Fruits sometimes very large in size (*Citrullus* spp., *Cucurbita* spp.). In *Ecballium* the fruit is highly turgid when ripe and dispersal is by explosion.

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

Pollination: Entomophilous.

Floral formulae:

Male flower: ⊕□ K(5), C5, A5, G_0

Female flower: ⊕ ♀ K(5), C5, A0 or 3-5 Staminodes $\overline{G}_{(3)}$

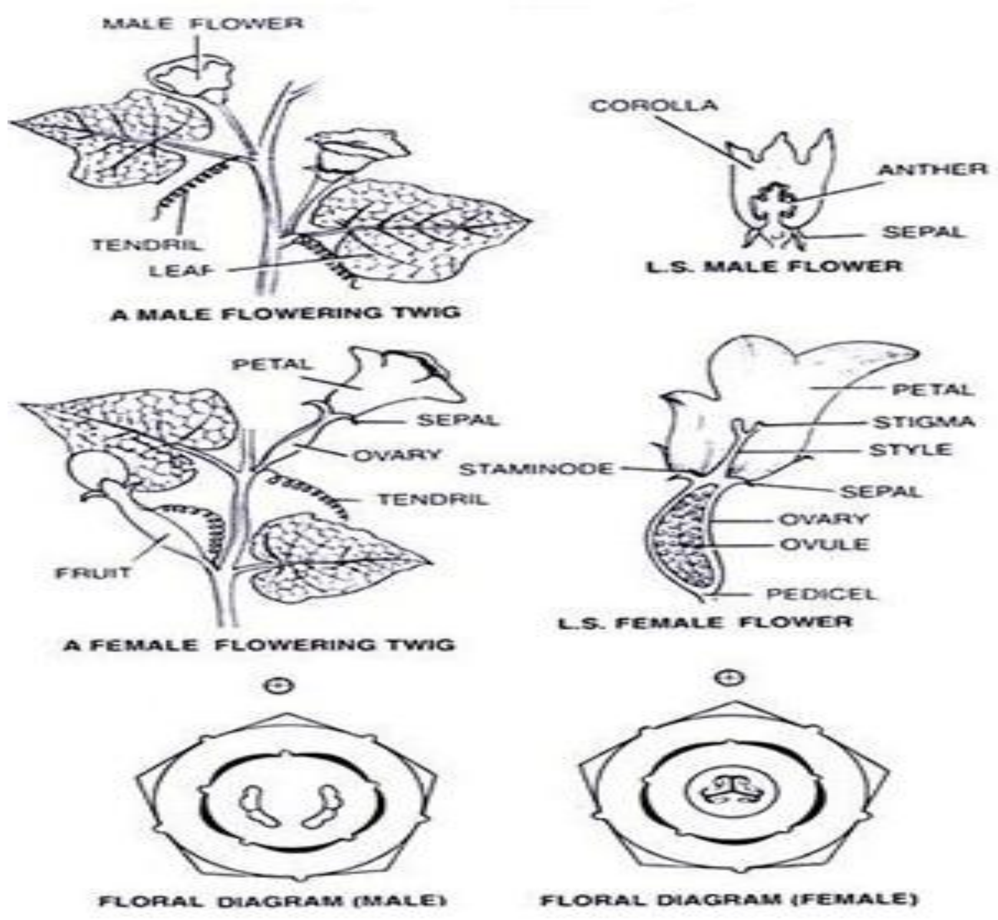

Fig. 8.5 Cucurbita maxima L.

8.7.3. Important Genera

1. *Cucumis melo* (melon)

2. *Cucumis sativa* (cucumber)
3. *Momordica charantia*
4. *Luffla cylindrica* (Ghia tori)
5. *Cucurbita pepo* (Safed Kaddu)

8.7.4. Economic Importance

This family is economically important for its fruits which are chiefly used as vegetables.

(A) Vegetables and fruits:

- ***Cucumis melo*** **(**Hindi – Kharbuza**):** The fruits are edible and a number of varieties are known. *C. melo var. momordica* is Phut and *C. melo var. utilissimus* is Kakri. *Cucumis sativus* is Khira.
- ***Citrullus vulgaris*** **(**Hindi – Tarbuz**).** The fruits are large and ripen during summers; it is cultivated on the sandy beds of rivers. *C. vulgaris var. fistulosus* is Tinda which is used as vegetable.
- ***Cucurbita maxima*** **(**Hindi – **Kaddu)**. *Cucurbita maxima* is Kaddu while *C. pepo* is Safed Kaddu; both are used as vegetable.
- ***Benincasa hispida*** **(**Hindi – **Petha)**. It is used as vegetable, and petha sweet is also prepared from the fruits.
- ***Lagenaria vulgaris*** **(**Hindi – **Lauki).** The fruit is commonly used as a vegetable. From ripe fruit-shells sitar is made.
- ***Trichosanthes dioica*** **(**Hindi – **Parwal).** The fruits are used in vegetable preparations. *T. anguina* is Chachinda which is also used as vegetable.
- ***Luffa acutangula*** **(**Hindi **– Torai)**. This is also a popular vegetable.
- ***Momordica charantia*** **(**Hindi – **Karela).** The fruits are bitter but used in vegetable preparations. It is said to be useful in gout and rheumatism.

(B) Medicine: There are a few plants also important medicinally.

- *Citrullus colocynthis*; produces the alkaloid colocynthin from its fruits. The fruits and roots are used against snake bite. The alkaloid is also used in other diseases.
- *Ecballium elatarium* fruits produce elaterium of medicine which has narcotic effect and useful in hydrophobia.

(C) Ornamental: Some plants *viz., Ecballium, Sechium, Sicyos* are grown in gardens.

Systematic relationship

The relationships of this family have been much disputed. Different authors have given different systematic position to this family. According to Robert Brown, De Candolle, and Bentham and Hooker this family is allied to Passifloraceae and placed with perigynous polypetalae under Calyciflorae.

Eichler, Engler and Wettstein on the other hand have considered it to be very advanced family of the sympetalae due to the gamopetalous corolla, epigynous and synandrous condition of the stamens.These authors have placed this family under the Cucurbitales just after the Rubiales and before the Campanulales. Cucurbitaceae shows affinities with Campanulaceae in synandrous condition of stamens, similar structure of calyx and corolla and also in the presence of bicollateral bundles. Chakravarty (1964) was of the opinion that the Cucurbitaceae has close connection with the Passifloraceae amongst the following points in having placenta retained on the wall, single-chambered ovary, fleshy fruit, tendril structure and extra-floral nectaries. The Cucurbitaceae compares well with the Passifloraceceae on the one hand and Bigoniaceae on the other.

8.8 APIACEAE OR UMBELLIFERAE

8.8.1 Systematic position

Bentham and Hooker	**Hutchinson**
Polypetalae	Dicotyledons
Calyciflorae	Herbaceae
Umbellales	Umbellales
Umbelliferae or Apiaceae	Umbelliferae or Apiaceae

Distribution

There are about 200 genera and 2900 species in this family. The plants of this family are cosmopolitan in their distribution, however, they are not found in arctic regions. They are very commonly found in northern temperate regions. In the tropical countries they are either found in the hilly tracts or cultivated in the winter season.

8.8.2 General Characters

Habit: Majority of the plants are annual, biennial or perennial herbs. Sometimes shrubs and undershrubs are also found. *Bupleurum falcatum* is an undershrub and *Pseudocarum* is a climbing plant.

Root: Usually the root is tap and branched.

Stem: Usually, erect, rarely climbing, herbaceous. It becomes fistular at maturity on account of the shrinkage of the pith. The nodes and internodes are quite distinct. The stem is usually green and becomes pinkish as the plants mature. The stems are very often ribbed and angled.

Leaves: The leaves are alternate, exstipulate, amplexicaul and much dissected, rarely the leaves are opposite, e.g., *Apiastrum*. Usually the leaves are pinnately compound. However, in some cases the leaves are simple, *e.g., Hydrocotyle, Bupleurum etc.* The species *Eryngium* and *Aciphylla* possess the leaves with parallel venation and sheathing bases like many monocotyledonous plants. Oil glands are present in all the aerial parts of the plant.

Inflorescence: The inflorescence is umbel. This may be simple or compound. In majority of cases compound umbel is found, e.g. *Coriandrum, Foeniculum*, etc., however, in some cases it is simple umbel, e.g. *Hydrocotyle*. The compound umbels are sometimes cymose in character and a terminal flower may occur, e.g. *Eryngium*. In compound umbels an involucre of bracts is present at the top of the main floral axis from where the umbels arise. At the base of each umbel involurce of the bracts is found.

Flower: The flowers are usually hermaphrodite but sometimes unisexual flowers are also found. In several genera the outer flowers of the inflorescence are male only. In *Astransia* sp., majority of the flowers of the inflorescence are bisexual and some are only male flowers. In *Echinophora* sp., the monoecious plants bear the unisexual flowers.The plants of *Arctopus* sp. are dioecious and bear unisexual flowers. In majority of the inflorescences the flowers are regular (actinomorphic) but sometimes the outer flowers of the umbles are zygomorphic and irregular, e.g. *Coriandrum sativum.* The flowers are usually pedicellate, bracteate, complete and epigynous.

Calyx: It consists of five sepals. These sepals are very minute in structure. The odd sepal being posterior. In many the calyx is absent, e.g., *Foeniculum vulgare.*

Corolla: It consists of five petals, polypetalous, i.e. the petals are free. They are usually white or yellow in colour. The petals vary in size. In many cases two of the petals being larger than the other three. The tips of the petals are usually reflexed. Sometimes the petals are bifid, e.g., *Coriandrum sativum.* The aestivation is either valvate or imbricate

Androecium: It consists of five stamens alternate to the petals. The stamens arise from an epigynous disc. The anthers are bilobed, introrse, basi or dorsifixed. The filaments are free. The anthers split by longitudinal slits.

Gynoecium: It consists of two carpels (bicarpellary), syncarpous. The ovary is inferior, bilocular, each locule contains a single pendulous, anatropous ovule. The placentation is axile. On the top of the ovary a nectar disc is found which surrounds the two capitate stigmas.

Fruit: The fruit is cremocarp. The ovary splits into two mericarps. The two mericarps remain temporarily attached to a very thin axial prolongation, between them, known as carpophore. Each mericarp is usually covered by five longitudinal ridges known as costae. Between costae there are furrows known as valleculae. Under these furrows there lay special oil ducts known as vittae.

Seed: The seed is endospermic containing a minute embryo.

Pollination: The pollination is usually entomophilous. The insects are attracted towards the beautiful condesed umbels having outer zygomorphic flowers. The nectar secreting disc situated at the top of the ovary is the main attraction of the insects. The flowers are protandrous and thus cross pollination is affected.

Floral formula: ⊕ K (5) C5 A5 G(2)

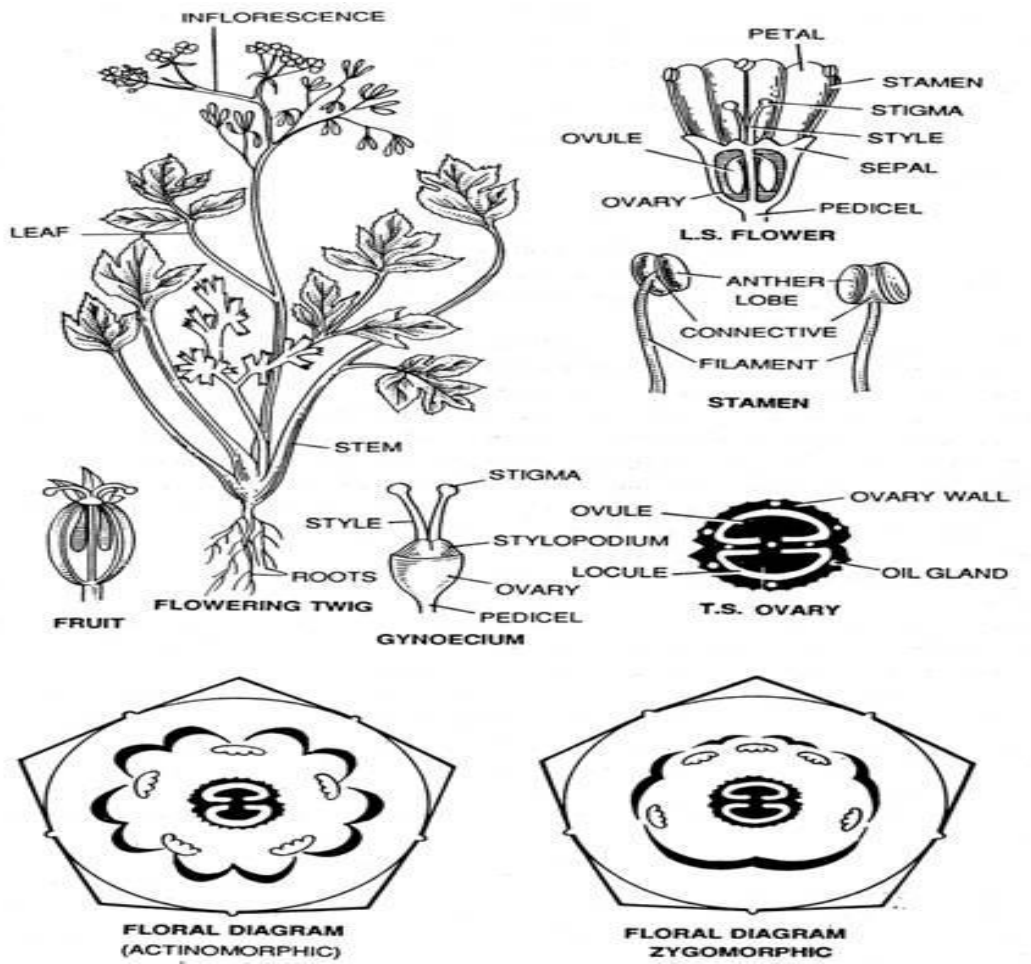

Fig.8.6 Coriandrum sativum Linn.

8.8.3. Important Genera

Daucus carota, Carrot - Gajar
Foeniculum vulgare, Fennel - Saunf
Coriandrum sativum, Corriander - Dhania
Apium graveoloens, Celery - Ajmud

8.8.4. Economic importance

Food: This family has many vegetables like carrot, parsely, parsnip and sowa.

Fodder: Several members of this family are important as forage plants for cattle and horses. Some of these plants are carrot, wild parsely, cow-parnip, angelicas, etc.

Condiments: Many members of this family are used as condiments. For example, *Ferula*, *Carum*, *Cuminum*, *Foeniculum* and *Coriandrum*. Volatile oils, resins etc. are produced in the bark, leaves, and fruits give the plant their fragrance.

Medicinal: This family has many medicinal plants. For example, *Ligusticum*, *Ferula* (Hing), *Foeniculum* (Saunf), Anethum (Dill or Sowa) are used in many drugs for digestive disorders. Hing is obtained from resinous gum produced from the roots of *Ferula asafoetida* in Afghanistan and Iran. *Hydrocotyle* (Brahmibooti) is useful for brain.

Systematic relationship

Engler has put three families, i.e., Araliaceae, Umbelliferae and Cornaceae in the order Umbelliflorae. Bentham and Hooker also placed these three families in the Umbellales. Rendle has also adopted the same arrangement. Hallier recognized only two families, i.e ., Cornaceae and the Umbelliferae. He merged the Araliaceae with Umbelliferae. Hutchinson (1948) has included the single family Umbelliferae in the order Umbellales. He has treated the Araliaceae as a separate order the Araliales, derived from the Cornaceae. According to Rickett (1945) there are two orders the Umbellales and the Cornales. The Umbellales consists of the Araliaceae and Umbelliferae and the Cornales consists of the Cornaceae and the Nyssaceae.

8.9 SUMMARY

Fabaceae (Papilonaceae) is the one among the families of flowering plants having more than 800 genera and 20,000 species; possessing a large number of agricultural crops. It is large, economically as well as medicinally important family of angiosperms. The members of this family have the ability of fixing atmospheric nitrogen via rhizobial bacteria. Plants of this family are important source of protein. It is commonly known as legume, pea or bean family. The family is represented by trees, shrubs and herbs (perennial or annual) which are recognized by legume type of fruits.

Rosaceae family is a medium sized family of angiospermic plants. The name is derived from the type genus *Rosa*. The diagnostic features of the family are plants perennial, herbs shrubs or trees, with fibrous tap root, rosaceous corolla, cup shaped thalamus, superior or semi-inferior ovary, alternate stipulate leaves. The family provides a large number of important fruits and some beautiful ornamental flowers. Some important fruit producing plants are various species of *Pyrus* and *Prunus* and species of *Rosa* as ornamental plants.

Cucurbitaceae also called **cucurbits** or the **gourd family**, are a plant family consisting of about 965 species in around 95 genera. Most of the plants in this family are annual vines, but some are woody lianas, thorny shrubs, or trees (*Dendrosicyos*). Many species have large, yellow or white flowers. The stems are hairy and pentangular. Tendrils are present at 90° to the leaf petioles at nodes. Leaves are exstipulate alternate simple palmately lobed or palmately compound. The flowers are unisexual, with male and female flowers on different plants (dioecious) or on the same plant (monoecious). The female flowers have inferior ovaries. The fruit is often a kind of modified berry called a pepo.

Apiaceae or **Umbelliferae**, is a family of mostly aromatic flowering plants named after the type genus *Apium*. Unique characters of the family are presence of oil glands, that are present in all the aerial parts of the plant. The inflorescence is umbel. This may be simple or compound. The fruit is cremocarp. The ovary splits into two mericarps. The two mericarps remain temporarily attached to a very thin axial prolongation, between them, known as carpophore.

8.10 GLOSSARY

Actinomorphic: Regular, symmetrical

Acute: Sharp, ending in a point, the sides of the tapered apexessentially straight or slightly convex.

Aestivation: The arrangement of the perianth or its parts in the bud or flower.

Alternate: Any arrangement of leaves or other parts not opposite or whorled, placed singly at different heights on the axis or stem.

Androecium: The male reproductive organ of plant.

Anther: The upper part of stamen which bears pollen.

Apocarpous: Carpels not united

Ascending: Rising upward.

Axile: Belonging to the axis.

Berry: Pulpy, few to many seeded fruit.

Bilabiate: Two lipped, applied to a calyx or corolla. The lips may or may not be lobed or toothed.

Caducous: Falling of early, as the sepals in some plants.

Calyx: The outer whorl of flower, composed of sepals. They are brightly colored and attract insects for pollination.

Campanulate: Bell shaped.

Carpel: Female reproductive organ of flower; consisting of ovary, stigma and style.

Corolla: The second whorl of flower; composed of petals.

Didynamous: With four stamens, in two pairs of two different lengths.

Entomophilous: Insect pollinated.

Epipetalous: Adnate to the petals or corolla.

Exstipulate: Without stipules.

Fruit: A ripened ovary with the adnate parts; seed bearing organ of plant.

Gamopetalous: Corolla with all the petals united or fused with each other.

Gamosepalous: Calyx with all the sepals united or fused with each other

Gynoecium: The female reproductive part of flower consisting of one or more carpels.

Hermaphrodite: Bisexual

Inflorescence: The mode of development and arrangement of flowers on an axis.

Introrse: Turned or faced inward or toward the axis, as an anther whose line of dehiscence faces toward the center of flower.
Legume: Simple fruit dehiscing on both sutures, the product of a simple unicarpellate ovary.
Loment: A leguminous fruit, contracted between the seeds, the one seeded segments separating at fruit maturity.
Monadelphous: Stamens united in one group by connation of their filaments.
Monoecious: A plant having both male and female reproductive organs in the same individual.
Nutlet: A small or diminutive nut.
Ovary: The ovule bearing part of a pistil.
Ovule: Egg containing unit of ovary, which after fertilization, becomes the seed.
Papilionaceous Corolla: Butterfly like flower with a keel, wings and standard.
Perianth: A collective term for calyx and corolla.
Phylloclade: A branch which is modified into a leaf like structure for photosynthesis.
Placentation: The arrangement of ovules within the ovary.
Polypetalous: Petals are separate.
Pulvinus: A minute gland or swollen petiole base responsive to vibrations and heat, as in leaves of sensitive plants (*Mimosa* spp.).
Raceme: A single elongated indeterminate inflorescence with pedicelled or stalked flowers.
Stipule: A basal appendage of a petiole.
Unilocular: Containing a single chamber or cell.
Verticillate: Arranged in whorls.
Whorl: Three or more leaves or flowers at one node, in a circle.
Zygomorphic: A flower having one plane of symmetry, or bilaterally symmetrical.

8.11 SELF ASSESSMENT QUESTIONS

8.11.1 Multiple Choice type Questions:

1. Family Leguminosae was divided into-
(a) 4 subfamilies (b) 3 subfamilies
(c) 2 subfamilies (d) 5 subfamilies

2. No of sepals in family Fabaceae is –
(a) 3 (b) 4
(c) 5 (d) 6

3. Fruit in family Fabaceae is –
(a) Siliqua (b) Nut
(c) Schizocarpic (d) Legume

4. Marginal placentation is seen in which of the following.

(a) Brassicaceae (b) Fabaceae
(c) Rutaceae (d) Solanaceae

5. Pulses are obtained from
(a) Solanaceae (b) Fabaceae
(c) Cruciferae (d) Liliaceae

6. In Cucurbitaceae the fruits are usually
(a) Follicle (b) Nutlets
(c) Capsule (d) Pepo

7. *Asafoetida* 'heeng'is obtained from which of the following families
(a) Caesalpinaceae (b) Apiaceae
(c) Papilionaceae (d) Asclepiadaceae

8. Nodulated roots are characteristic feature of which of the family
(a) Fabaceae (b) Asteraceae
(c) Poaceae (d) Solanaceae

9. Swollen placenta is the characteristic feature of the family
(a) Solanaceae (b) Asteraceae
(c) Rosaceae (d) Orchidaceae

10. Persistent calyx is the characteristic feature of the family
(a) Solanaceae (b) Asteraceae
(c) Rosaceae (d) Brassicaeae

8.11.2 Fill in the blanks: -

1. Apple is the member of family……………….
2. Vexillary aestivation can be seen in ………………………
3. Botanical name of loqat is ………………
4. Botanical name of Khair is……………………..
5. *Cucurbita pepo* belongs to family……………………

8.11.1 Answer Key: 1(b), 2(c), 3(d), 4(b), 5(b), 6(d), 7(b), 8(a), 9(a), 10(a)
8.11.2 Answer Key: 1. Rosaceae**,** 2. Fabaceae, 3. *Eriobotrya japonica*, 4. *Acacia catechu*
5. Cucurbitaceae

8.12 REFERENCES

- Singh, V, Pandey, P.C. and Jain, D.K. 1999. A textbook of Botany, Angiosperms. Rastogi Publications, Meerut.
- Sharma, O.P. 2010. Plant Taxonomy (2^{nd} Edition). The Macro Hill Company, Kolkata.
- Lewis, G., Schrire, B., Mackinder, B., Lock, M., (eds). 2005. Legumes of world. Royal Botanical Gardens, Kew, U.K.
- www.boilogyboom.com
- www.britannica.com

8.13 SUGGESTED READINGS

- Cronquist, A. 1981, An integrated system of classification of flowering plants, Columbia University Press, New York.
- Davis, P.H. and Heyhood, V.H, 1973, Principles of Angiosperms Taxonomy, Robert E. Kreign Pub Co. New York.
- Hutchinson, J. 1973 The families of flowering plants 2 vols. Oxford University Press Oxford.
- Takhtajan A. L. 1997. Diversity and classification of flowering plants. Columbia University Press. New York.
- Pandey B. P. 2012 A textbook of botany Angiosperms. S. Chand New Delhi

8.14 TERMINAL QUESTIONS

1. Give important distinguishing features of family Fabaceae.
2. Describe the range of floral structure in Rosaceae. Name five plants of economic importance.
3. Rosaceae show great diversity in types of fruit explain. Also write a note on the edible fruits of this family.
4. What do you understand by umbel inflorescence?

UNIT-9 ERICACEAE, ASCLEPIDACEAE, SOLANACEAE, ACANTHACEAE, LAMIACEAE AND EUPHORBIACEAE

9.1 OBJECTIVES

After reading this unit student will be able-

- To understand about the given families- Ericaceae, Asclepiadaceae, Solanaceae, Acanthaceae, Lamiaceae and Euphorbiaceae

Detailed description of the general distribution, systematics, general characters, important genera and economic importance etc. of each of above mentioned will be studied. An outline of the phylogenetic and evolutionary relations of the families will be drawn. Figures of some of the important genera of the concerning families are also given here for correlating this text to your surrounding nature.

9.2 INTRODUCTION

You have already studied characteristic features of families Fabaceae, Cesalpinaceae, Mimosaceae, Rutaceae, Cucurbitaceae and Apiaceae. In the present unit you will be introduced with families- Ericaceae, Asclepidaceae, Solanaceae, Acanthaceae, Lamiaceae and Euphorbiaceae.

9.3 ERICACEAE - THE HEATH FAMILY

The family name comes from the type genus *Erica*, which appears to be derived from the Greek word *ereike*. The exact meaning is difficult to interpret, but some sources show it as meaning 'heather'.

Diagnostic characters: Woody stems, simple evergreen leaves growing alternately, clusters of flowers , flowers with 4 or 5 petals forming a tube or trumpet ,stamens not attached to the flower tube and are found in acidic condition.

Distribution: This is a family of around 3000 species in 100 genera, found all over the world except Australia. Almost half of them are in the genus *Rhododendron*; there are around 500 species of *Erica*. This is a family mainly of shrubs or climbers, and almost all of them are found in acidic habitats, and are dependent on fungal mycorrhiza. In Britain, acidic moorlands are often covered in wild heather (*Calluna* and *Erica* species).

9.3.1. Systematic position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Gamopetalae	Lignosae

Heteromerae	Ericales
Ericales	Ericaceae
Ericaceae	

9.3.2. General Characters

General Habit: Many members of this family are evergreen shrubs or climbers, with woody stems rarely with small trees (*Arbutus*), or trailing or scrambling vines attaining a length up to 20 meters

Leaves: The leaves are simple without stipules, usually alternate sometimes opposite or whorled exstipulate, entire, elliptical or oblong (*Rhododendron*) and are often thick, leathery and shiny. Species growing in dry conditions often have thin needle-like leaves (*Erica*).

Inflorescence: Flowers solitary in axils or in axillary or terminal clusters, racemose racemes or panicles, flowers form terminal umbel like raceme in *Rhododendron* or leafy or one sided raceme in *Erica*

Flowers: The flowers are usually in clusters or spikes, but may be solitary, showy, hermaphrodite, complete, actinomorphic sometimes zygomorphic show considerable variability. The petals are often fused (sympetalous) with shapes ranging from narrowly tubular to funnelform or widely bowl shaped. The corolla is usually radially symmetrical (actinomorphic), but many flowers of the genus *Rhododendron* are somewhat bilaterally symmetrical (zygomorphic).

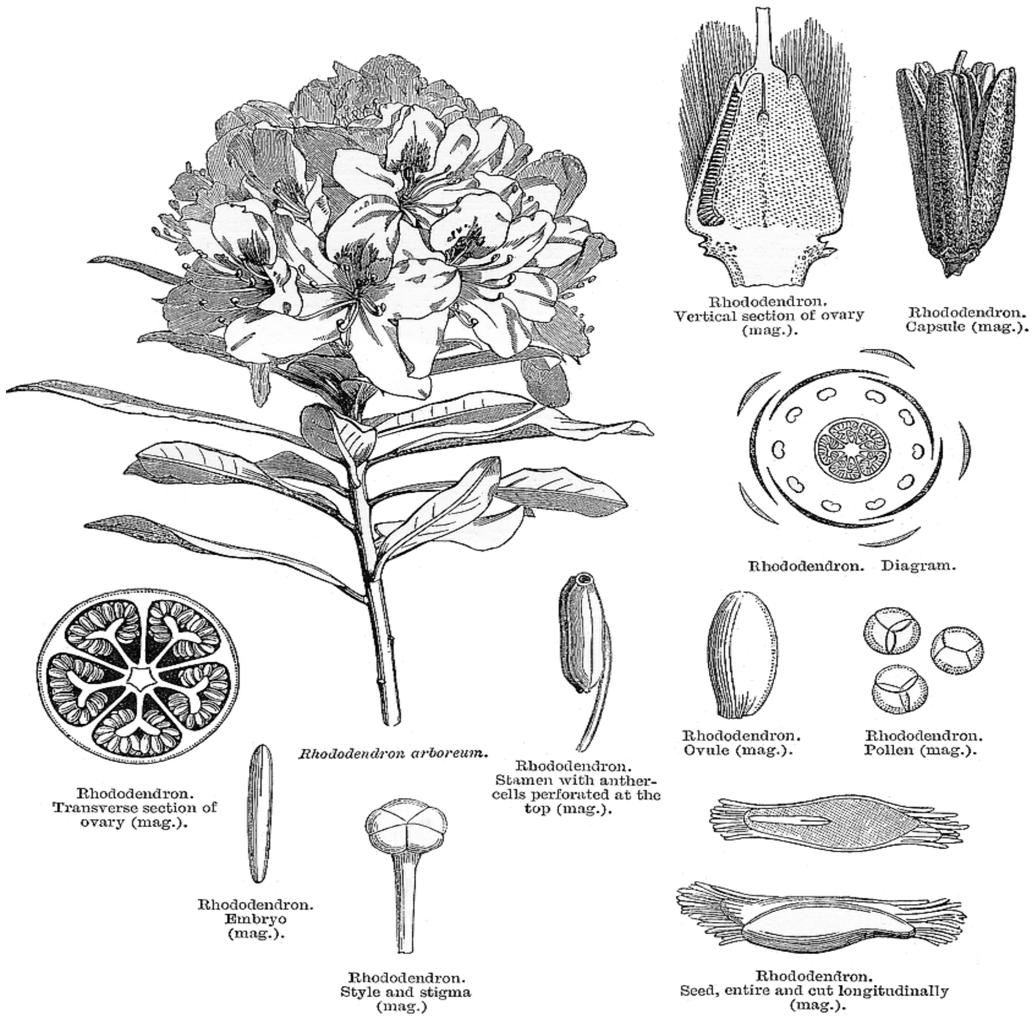

Fig 9.1: Floral details of Rhododendron

Calyx: sepals 4 to 5 more, less connate at base.
Corolla: 4 to 5 fused at base, often bell-shaped (campanulate) or urn shaped (urceolate), white or brightly coloured.
Androecium: Stamens are as many as number of petals, and they are not attached to the corolla. There is a single style.
Gynoecium: Carpels 4-5, usually syncarpous, axile placentation. There is a single style. The ovary is usually superior but may be inferior.
Fruit: The fruit is usually a capsule or a berry.
Seed: Endospermous.
Floral Formula: $\oplus$ or % ⚥ $K_{4-5}\ C_{(4-5)}\ A_{8-10}\ G_{\overline{(4-5)}}$

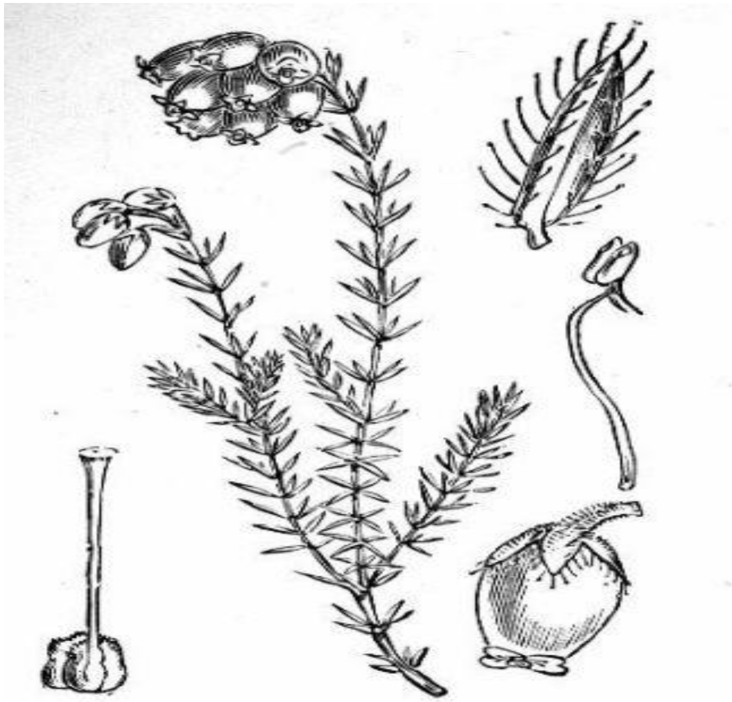

Fig. 9.2: Floral details of Erica tetralix L.

9.3.3. Important Genera: *Rhododendron- R. arboreum, Erica, Gaultheria, Pernettya Vaccinium myrtillus* –Bilberry, *Kalmia, Vaccinium uliginosum*- Bog Whortle berry, *Vaccinium oxycoccos* - Cranberry

9.3.4. Economic Importance: Although the family is not economically important, yet it has ecological importance. The members of this family used for medicinal purposes are very poisonous; the honey produced by bees pollinating Kalmia latifolia (Mountain Laurel) is reportedly toxic.

Most are grown as ornamentals, often as hedges, including *Gaultheria* and *Pernettya*, although the leaves of *Kalmia* species are poisonous to stock and humans. Many species of *Rhododendron* are ornamental.

The fruits of a few species, e.g. Bil berry (*Vaccinium myrtillus*) and Bog Whortle berry (*Vaccinium uliginosum*) are edible, but only the Cranberry (*Vaccinium oxycoccos*) is cultivated for this purpose.

Systematic relationship

Historically, the Ericaceae included both subfamilies and tribes. In 1971, Stevens, who outlined the history from 1876 and in some instances 1839, recognized six subfamilies

(Rhododendroideae, Ericoideae, Vaccinioideae, Pyroloideae, Monotropoideae, and Wittsteinioideae), and further subdivided four of the subfamilies into tribes, the Rhododendroideae having the tribes (Bejarieae, Rhodoreae, Cladothamneae, Epigaeae, Phyllodoceae, and Diplarcheae) In 2002, systematic research resulted in the inclusion of the formerly recognised families Empetraceae, Epacridaceae, Monotropaceae, Prionotaceae, and Pyrolaceae into the Ericaceae based on a combination of molecular, morphological, anatomical, and embryological data, analysed within a phylogenetic framework. The move significantly increased the morphological and geographical range found within the group. One possible classification of the resulting family includes 9 subfamilies, 126 genera, and about 4000 species.

9.4 ASCLEPIADACEAE (MILKWEED FAMILY)

They form a group of perennial herbs, twining shrubs, lianas or rarely trees but notably also contain a significant number of leafless stem succulents. The name comes from the type genus *Asclepias* (milkweed).

9.4.1 Systematic position

Bentham & Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Gamopetalae	Lignosae
Bicarpellattae	Apocynales
Gentianales	Asclepiadaceae
Asclepiadaceae	

According to APG II, the Asclepiadaceae is a former plant family now treated as a subfamily (subfamily Asclepiadoideae) in the Apocynaceae (Bruyns 2000). The florally advanced tribe Stapeliae within this family contains the relatively familiar stem succulent genera such as *Huernia*, *Stapelia* and *Hoodia*. They are remarkable for the complex mechanisms they have developed for pollination, which independently parallel the unrelated Orchidaceae, especially in the grouping of their pollen into pollinia. The fragrance from the flowers, often called "carrion", attracts flies. The flies pollinate the flowers.

Distribution

There are 175 genera, with about 2,200 species mainly located in the tropics to subtropics, especially in Africa and South America. Most common species are *Calatropis procera* and *Crptostegia grandiflora* cultivated in gardens.

9.4.2 General Characters

Habit: The members are herbs (*Asclepias*), shrubs (*Calotropis*), or rarely trees or woody climbers (lianas) or plants of very peculiar vegetative form; sometimes (e.g. *Stapelia*) ‘cactoid’, with succulence. *Hoya* has fleshy photosynthetic stems mesophytic or xerophytic. Perennial, self supporting or climbing. When climbing, stem twiners or root climbers, or scrambling, the twiners twining anticlockwise (*Araujia*, *Ceropegia*, *and Stephanotis*).

Root: Tap root fleshy and tuberous.

Leaves: Opposite decussate (rarely alternate), simple, entire or whorled 'herbaceous'or fleshy or membranous, or modified into spines (*Stapelia*). Leaves stipulate or exstipulate. A thick waxy covering is found in the leaves of *Calotropis*. Leaves of *Asclepias* are petiolate where as semiamplexicaul in *Calotropis*., pulvinous in C*ryptostegia grandifolia.*

Inflorescence: It is usually dichasial cyme, arising from leaf axil or flowers aggregated in racemose (*Asclepias* and *Calotropis*).

Flower: Flowers are bractate, usually bracteolate, perfect pentamerous and bi-sexual cyclic. Their symmetry is mostly actinomorphic, zygomorphy is very rare. Hypogynous, disc absent.

Calyx: 5 sepals, usually gamosepalous (at the base) to form calyx tube. Calyx lobes markedly longer than the tube.Calyx regular; imbricate or valvate, with the median member posterior.

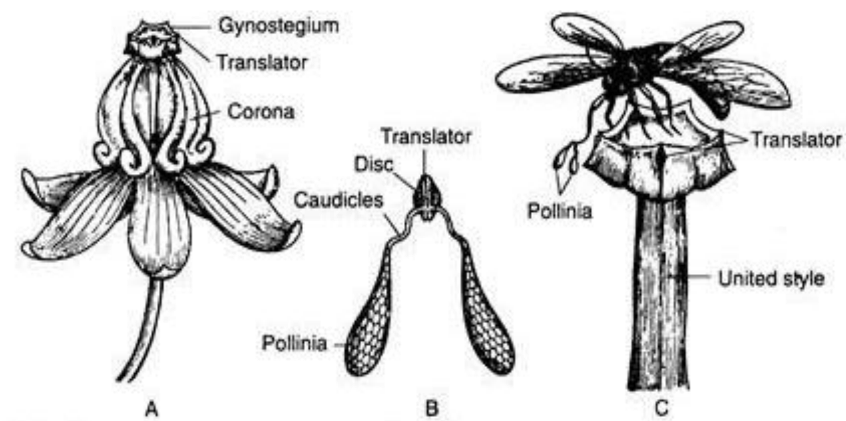

***Fig 9.3 Pollination mechanism in Calotropis, A-Flower, B- A pair of pollinia, C- A bee removing a pair of pollinia from the gynostegiu*m**

Corolla: 5 gamopetalous (the tube short) usually rotate or 5 lobed but sometimes campanulate (*Gymnema*) or funnel form (C*ryptostegia*). Corolla lobes about the same length as the tube.

Androecium: 5 stamens. Epipetalous and inserted at or near the base of the corolla tube. Anthers are united and form a blunt cone. In the subfamily Periplocoideae, the filaments are free. The anthers are coherent and apprises to the expanded stylar head. The pollen is granular and united into tetrads, the pollen of the one half of the two adjacent anthers discharge on the spathulate translator arising from the style head and alternating with the anthers. Each translator ends below in an adhesive disc. Usually a staminal corona of five free lobes arises from the base of the filaments.In the subfamily Euasclepiadeae, the filaments are connate in a short fleshy column androecial members adnate; united with the gynoecium forming a gynostegium which is coherent via the filaments, forming a short sheath around the style (by contrast with Periplocoideae). The pollen grains are united in two waxy masses (pollinia) in each cell. The pollinia are united in pairs by caudicles (retinaculae) of various shapes to a gland (corpusculum) which lies on the stigma. The short filaments are ornamented with necteriferous corona which varies in form in different genera.

Gynoecium: Bicarpellary. Ovary is mostly superior, the ovaries of the two carpels are free and so their styles which are united by their apices and dilate in the form of peltate stigma with five lateral stigmatic surfaces. The ovary of each carpel is unilocular with a single (ventral) placenta bearing numeropus anatropous ovules.

Fruit: Non-fleshy, an aggregate of two carpels dehiscent, comprising a pair of 'follicles' with thin papery placental flaps.

Seeds: endospermic, seeds conspicuously hairy (with a terminal coma of long, silky hairs), The purpose of long hairs is for dispersal. Winged (usually, all round), or wingless.

Floral Formula : Br $\oplus$ ⚥ K(5) or 5 C (5) A (5) $\underline{G}$(2)

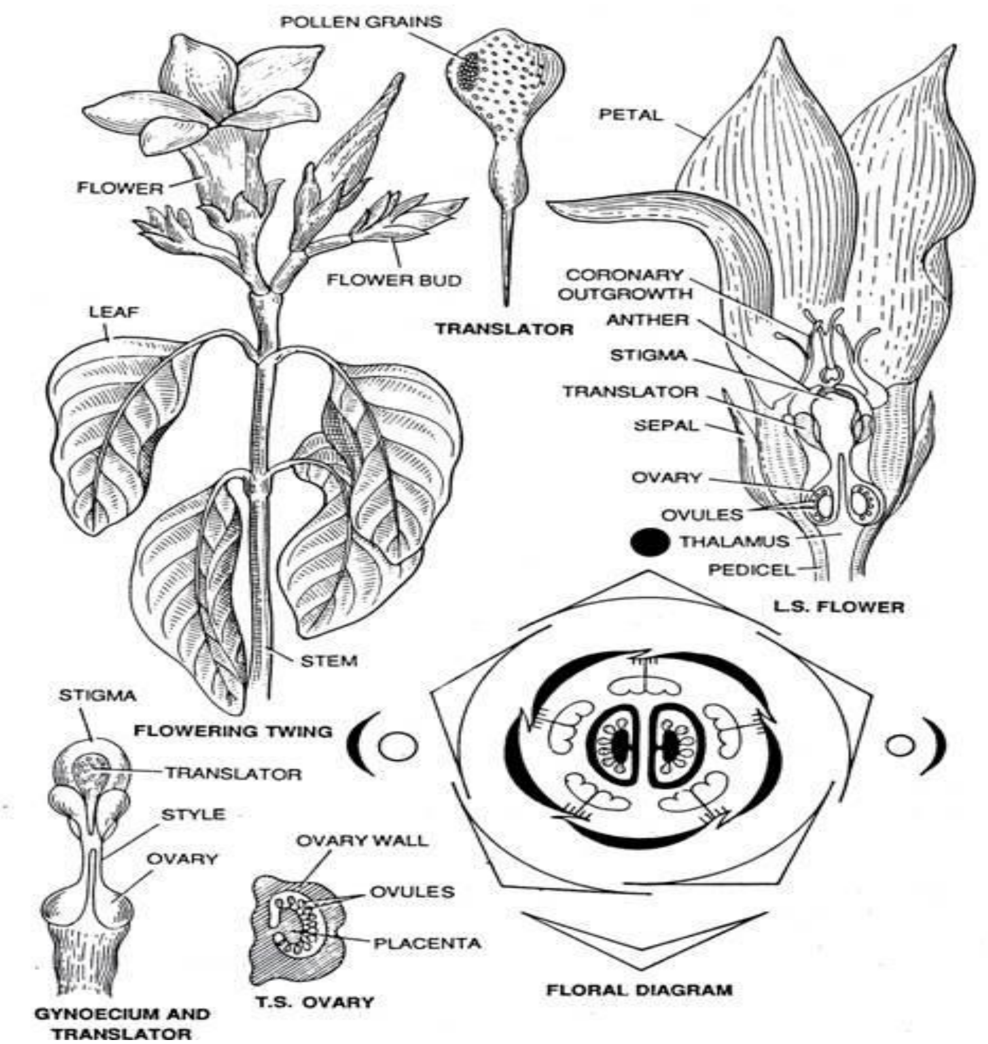

Fig. 9.4, Cryptostegia grandiflora (Courtesy: Bendre & Kumar, 2007)

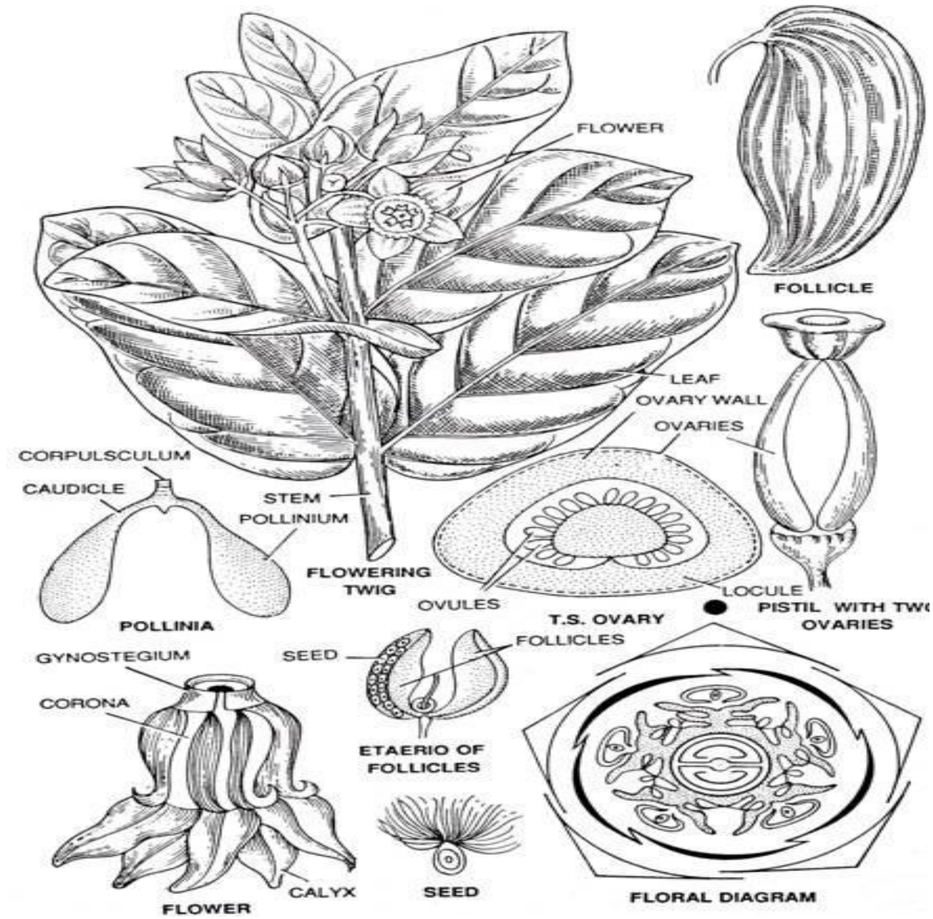

Fig.9.5, Floral details of Calotropis procera (Courtesy B.P. Pandey, Angiosperms, 2007)

9.4.3. Important Genera

Asclepias curasssavica (Milkweed), *Oxystelma esculentum*, *Calotropis procera* (Madar), *C.gigantea*, *Stapelia variegata*, *Hoya longifolia*, *Daemia extensa*, *Cryptostegia grandiflora.*

9.4.4 Economic Importance

The family is important for ornamental and drug plants.

Ornamentals: Species of *Asclepias curasssavica* (Milkweed), *Stapelia variegata*, *Cryptostegia grandiflora* (Rubber vine) are grown for ornamental purpose.

Medicinal: Roots of *Tylophora indica* (Indian Impecacuanha) are used for the treatment of asthma, bronchitis and whooping cough. Dried root of *Hemidesmus indicus* (Indian sarasparilla) constitute *Hemidesmus* or Anantmul which is blood purifier. *Gymnema sylvertre* is stomachic, stimulant; laxative and diuretic and useful in cough and sore eyes.

Other uses: The latex of *Calotropis procera* (Madar) and *C. gigantea* is used in tannin industry for deodorizing hair and imparting yellow colour to hides. The latex of *Cryptostegia grandiflora* is commercial source of rubber.

Systematic relationship

Benthum and Hooker devided Asclepiadaceae into two subfamilies: Periplocoideae and Euasclepiadaceae. The subfamily Periplocoideae has been raised to the status of a separate family Periplocaceae by some botanists like Hutchinson (1959, 1969) and Airy Shaw (1973). The family resembles to Apocynaceae in many characters.

9.5. SOLANACEAE

9.5.1 Systematic Position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Gamopetalae	Herbaceae
Bicarpellatae	Solanales
Polemoniales	Solanaceae
Solanaceae	

Distribution: The family Solanaceae is represented by about 85 genera and 2200 species which are commonly distributed in South and Tropical America. Plants are also found in temperate regions.The largest genus of this family is *Solanum.*

9.5.2 General Characters

Habit: Herbs (erect or climbing), shrubs or small tree.

Root: Branched tap root, sometimes adventitious.

Leaves: Simple, entire, exstipulate, alternate or opposite at or near the inflorescence, rarely in whorl.

Inflorescence: Cymose, typical axillary cyme or cymes in combination.

Flowers: Complete, pedicillate, usually actinomorphic sometimes zygomorphic regular, hypogynous, without bracts, bracteoles.

Calyx: Sepals 5 in number gamosepalous (limb usually with 5 lobes).

Corolla: Petals 5, gamepetalous rotate to tubular, funnel shaped.

Androecium: Stamens 5, sometimes there number may be 4 or two, epipetalous petals unequal in size, dithecous, introse anther.

Gynoecium: Bicarpellary, syncarpous bilocular superior ovary, but sometimes ovary becomes tetralocular by false septation. Placentation is axile.

Fruit: Septicidal capsule or a berry.

Seed: Endospermic

Pollination: By insects

Floral formula: $\oplus$ □ $K_{(5)}\ \widehat{C_{(5)}\ A_{5}}\ G_{\underline{(2)}}$

9.5.3 Important Genera

Withania somnifera (**Ashwagandha)**

Habit: A shrub or undershrub (perennial).

Root: Branched tap root.

Stem: Solid, branched, erect with terminal herbaceous and basal woody part.

Leaf: Simple, entire, petiolate, exstipulate, alternate, cauline and ramal, unicostate reticulate.

Inflorescence: Cymose, axillary umbellate cyme.

Flower: Regular, complete, pedicellate, ebracteate, actinomorphic, pentamerous, hermaphrodite, hypogynous, cyclic.

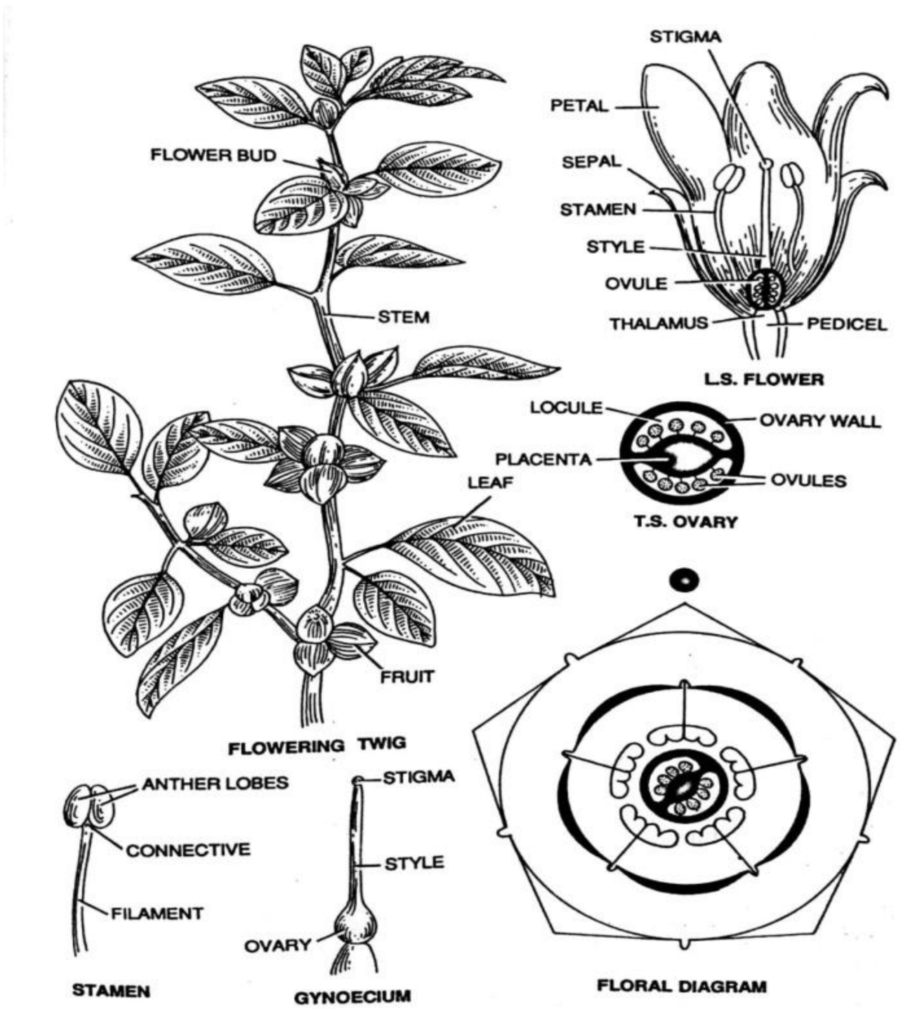

Fig.9.6 Withania somnifera Dunal (Courtesy B. P. Pandey – Angiosperms, 2007)

Calyx: Sepals are 5, gamosepalous, aestivation valvate, inferior.

Corolloa: Petals are 5, gamopetalous, whitish yellow in colour, inferior, valvate aestivation.

Androecium: Stamens 5, epipetalous, polyandrous, anthers basifixed, dithecous, introrse.

Gynoecium: Bicarpellary, syncarpous bilocular, superior ovary, each locule contains many ovules, placentation axile.

Fruit: Berry.

Floral formula: ⊕ K_5 $C_{(5)}$ $A_{5(5)}$ $G_{\underline{(2)}}$

9.5.4 Economic importance

Some economically important plants of this family are –

- ***Solanum tuberosum*: Aloo,** tubers are rich source of starch and used as vegetable.
- ***Solanum melongena*: Baigun**, seeds used as stimulant, and fruits used as vegetable.
- ***Solanum nigrum*: Makoi**, plant possesses medicinal property. Fruits are used in eye disease, diarrhoea and fevers. Plant juice is used in dysentery and piles. Fruits are edible.
- ***Nicotiana tabacum*: Tambaku,** Leaves are used as insecticides and fumicatory purpose for making cigarettes.
- ***Datura stramonium*: Dhatura**, a weed plant used in treatment of asthma. The seeds and leaves are narcotic.
- ***Atropa belladona*: Sag-angur**, medicinal plant used to derive atropine.
- ***Lycopersicum esculentum*: Tamatar,** a herbaceous plant cultivated for its fruits which are used in vegetable and as a salad.
- ***Withania somnifera*: Ashwagandha**, an undershrub, used for cough and rheumatism.

Systematic relationship

Hallier regarded Solanaceae as a primitive member of the Tubiflorae together with the Scrophulariaceae and both have arisen very likely from the Linaceae. Wettstein placed the family in the Tubiflorae along with Convolvulaceae. Rendle placed the family in the Tubiflorae, assigning a separate position for the Convolvulaceae under the order Convolvulales. Solanaceae bears a close relationship to the Boraginaceae in alternate leaves, regular flowers and five stamens. It is related to Convolvulaceae in the presence of persistent calyx, twisted corolla and false septum. It is allied to Scrophulariceae but the latter differs from it in actinomorphic flowers and obliquely placed carpels.

9.6 ACANTHACEAE (ACANTHUS FAMILY)

Distribution pattern: This family of dicotyledonous flowering plants contains almost 250 genera and about 2500 species. Most are tropical herbs, shrubs, or twining vines, some are epiphytes. Only a few species are distributed in temperate regions.

9.6.1 Systematic position

Bentham and Hooker **Hutchinson**

Dicotyledons	Dicotyledons
Gamopetalae	Herbaceae
Bicarpellatae	Personales
Personales	Acanthaceae
Acanthaceae	

9.6.2 General Characters

Habit: They are mostly annual or perennial herbs, undershrubs or shrubs or sometimes climbing as species of *Thunbergia* and *Mendonica*, *Justicia*. Hydrophytic, or halophytic (including a few mangroves), or mesophytic (many in damp places in tropical forests), or xerophytic (*Barleria*). Trees (rarely, but including a few mangroves).

Stem: Well developed (usually), or much reduced. In annual to perennial herbs there is basal aggregation of leaves, or no conspicuous aggregation of leaves. Self supporting**.**When climbing, stem twiners, or root climbers or scrambling. Stem of the climbing species show anomalous secondary growth. Cystoliths very commonly present (showing as streaks in the lamina). They are very characteristic and are useful in distinguishing various genera and tribes.

Leaves: Leaves opposite decussate simple exstipulate. Lamina margins entire.

Inflorescence: Inflorescence commonly dichasial cymes, becoming monochasial in the ultimate branches, and frequently condensed in the leaf axils. The cymes are often condensed into axillary whorls (*Hygrophila*) or dense spikes (*Adhatoda*, *Daedalacanthus*) the flowers are axillary solitary in *Thunbergia*

Flowers: Flowers are bracteate, bracteolate (the bracts and bracteoles often showy), perfect (sessile in *Adathoda*), perfect hermaphrodite zygomorphic and hypogynous, somewhat irregular, tetracyclic.

Calyx: 5 sepals or it is usually five-partite and the calyx –segments are imbricate or valvate in bud. In *Peristrophe* the sepals are free. In *Thunbergia* the calyx is reduced to a narrow ring.

Corolla: The corolla **is** gamopetalous with a long or short tube. The limb is sometimes almost equally five-lobed as in *Thunbergia* and R*uellia* but usually it is two lipped or rarely one lipped as in *Acanthus* where upper lip is completely absent. When corolla is bi-lipped the upper lip is usually erect and bifid and the lower lip is horizontal and trifid. The aestivation of the corolla is imbricate or contorted

Androecium: The stamens are more often four and didynamous and frequently two as in *Blepharis*, *Acanthus* and *Justica*. The one to three missing stamens are frequently staminodes.In *Pentstemon, Acanthus* all the stamens are fertile (rarely), inserted near the base of the corolla tube, or midway down the corolla tube, or in the throat of the corolla tube. Anthers bilobed with often one smaller lobe than the other, connective often long, introrse, longitudinal dehiscence.

Gynoecium: Bicarpellary, syncarpous superior, ovary 2 locular. Ovules 2 to many anatropous to campylotropous in each locule, Placentation axile; style narrow and long; stigma 2, of which anterior one is often larger, usually with hypogynous nectar secreting disc.

Pollination: Pollination entomophilous, flowers are suited to insect pollination because of coloured bilabitate corolla and abundant nectar in hypogynous disc, protandry favours cross-pollination.

Friuts and seeds: Fruit usually a capsule, loculicidal to the very base, rarely a drupe (*Mendonica*), seed one to many, of which the funiculus develops into a hook like *retinaculum* or *jaculator*, seed often non-endospermic.

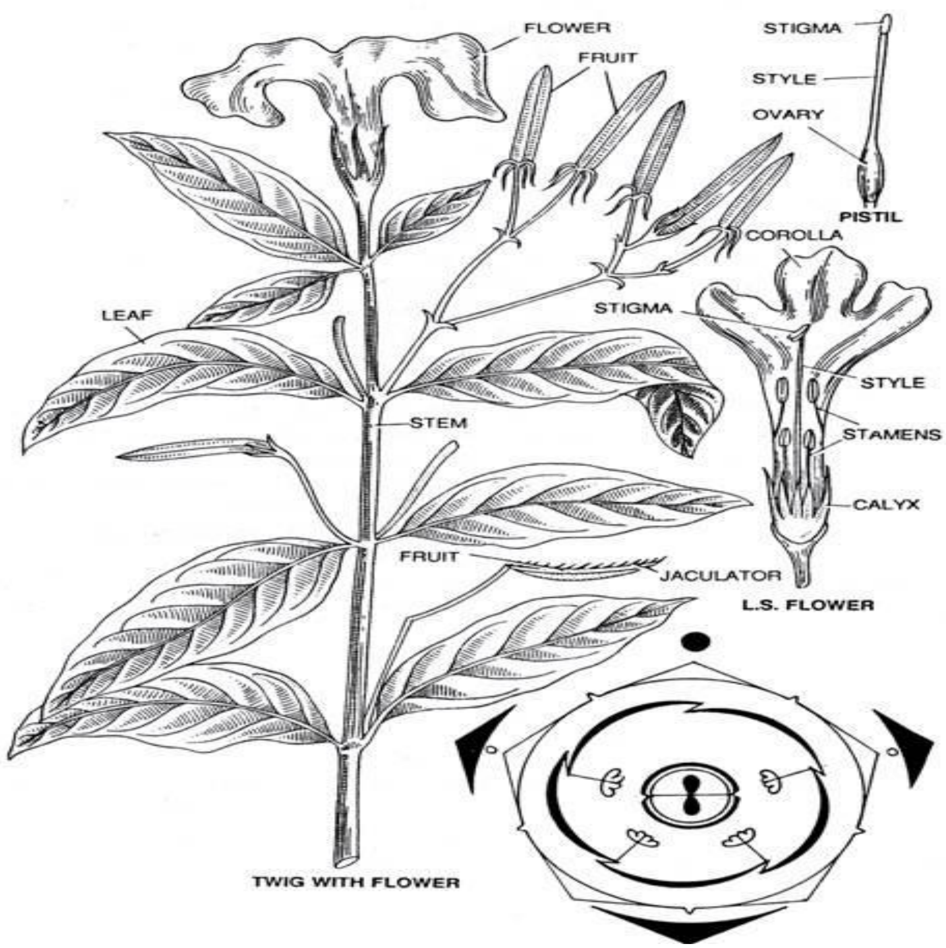

Fig.9.7. Floral details of Ruellia prostrate.

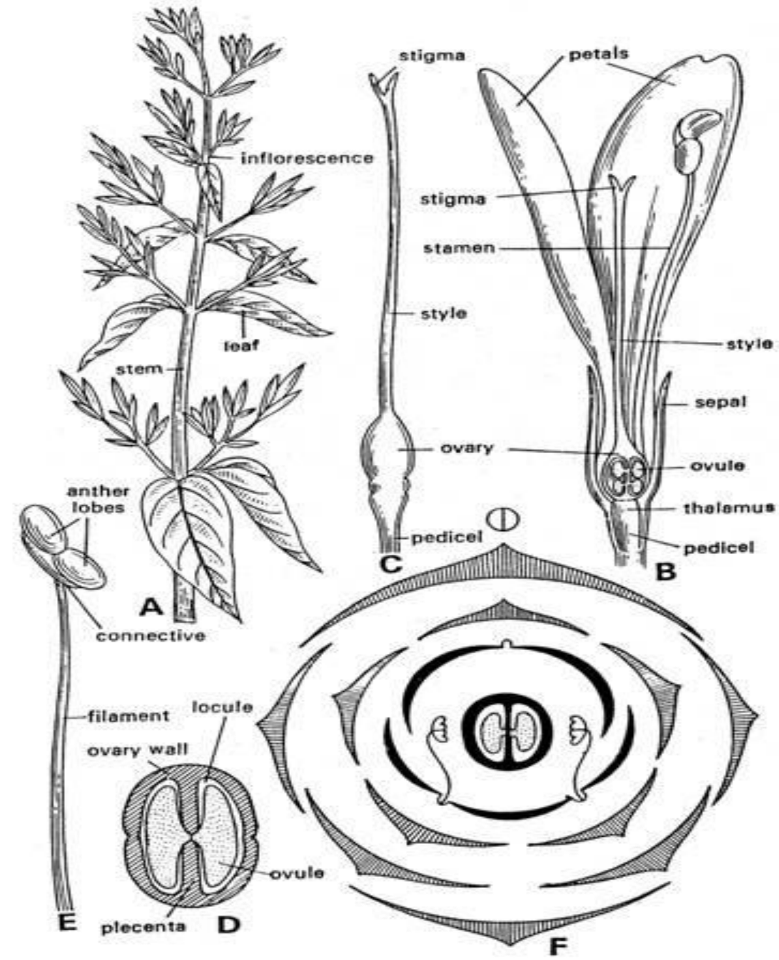

Fig.9.8 Floral details of Peristrophe bicalyculata

General Floral Formula: Br brl $\oplus$□ $K_{(5)\text{ or }5}$ $C_{2\text{or }3}$ $\overparen{C_{(5)}\ A}_5$ $G_{\underline{(2)}}$

9.6.3 Important Genera:

Acanthus ilicifolius-A mangrove plant with prickly and handsome flowers, *Barleria*- A medicinal shrub bearing two long thorns at each node., *Adathoda vasica* (syn. *Justica adathoda*), *Ernathemum, Peristrophe, Ruellia, Thunbergia;* are some common plants of family Acanthaceae found in our country.

9.6.4 Economic Importance: Species of several genera are cultivated as garden ornamentals and as medicines.

- **Ornamentals*:*** A number of species are used as ornamentals in the gardens. These are:

Thunbergia (clock-vine) - *T. grandiflora, T. alata, T. coccinefra*
Ernathemum-E.nervosum, E.bicolor, E.reticulata

Barleria- B. polytricha, B. cristata
Justica gendarusa
Ruellia ruberosa

- **Medicines:** A few species provide some well known drugs used in indigenous system of medicine.

(i) The leaves and roots of *Adhatoda vasica* (Vasaka) provide a well known drug used for bronchitis, asthma and cough.
(ii) The roots and leaves of *Hygrophila spinosa* are used for jaundice and rheumatism.
(iii) The leaves and roots of several species of *Barleria* such as *B. buxifolia*, *B. cristata*, *B. longifolia*, *B. prionitis (kalabansa) and B. strigosa* are used for cough and inflammations.
(iv) *Rungia parviflora*, the juice of its leaves is given to children in small-pox.

Systematic relationship

Family Acanthaceae is varyingly placed under order Personales (Bentham & Hooker and Hutchinson), Tubiflorae (Engler and Prantl) and Scrophulariales (Takhtajan, Cronquist). It is usually divided into 4 subfamilies Nelsonioidae, Mendoncioideae, Thunbergioideae and Acanthoideae. Subfamily Nelsonioidae is very close to family Scrophulariaceae and its genera are included in that family by several workers. Subfamily Mendoncioideae and Thunbergioideae are intermediate between Bignoniaceae and Acanthaceae and are usually considered as independent families).

9.7 LAMIACEAE (MINT FAMILY)

9.7.1 Systematic position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Gamopetalae	Herbaceae
Bicarpillatae	Lamiales
Lamiales	Lamiaceae
Lamiaceae	

Distribution: - The family Lamiaceae commonly known as mint family is cosmopolitan in its distribution, containing 200 genera and 3200 species. Plants are chiefly distributed in Mediterranean region. In India two main centers of distribution are South India and North-Western India. The common plants are basil, mint, oregano, sage, lavender, etc.

9.7.2 General Characters

Habit: Plants are mostly annual or perennial herbs inhabiting the temperate regions. Plants become shrubby in warmer climatic zones. Trees and climbers are rare.

Root: Branched tap root

Stem: Quadrangular, more or less hairy, having glandular hairs.

Leaves: Simple, decussate, opposite, exstipulate, 3-8 leaves arranged in a whorled system are found in some genera. Leaves are with small hairs.

Inflorescence: Verticillaster inflorescence is characteristic feature of this family.

Flower: Hermaphrodite, mostly zygomorphic, rarely actinomorphic, complete, hypogynous.

Calyx: 5 sepals, gamosepalous, sepals are campanulate or tubular, persistent, inferior, having free lobes or teeth, sometimes bilabiate, valvate, imbricate aestivation is common, quincuncial aestivation is rare.

Corolla: Petals 5, gamopetalous, consists of tube and limb. The tube is straight or bent and wide towards the mouth. The limb is generally two lipped. The imbricate aestivation is common.

Androecium: Stamens are four in number, sometimes two, didynamous, epipetalous and alternate with the lobes of corolla. Two celled anther having connective in between the two cells. Anther dehisce by longitudinal slits.

Gynoecium: Bicarpellarysyncarpous superior ovary, in early stage ovary is bilocular but later on tetralocular due to the formation of false septum. Style arises from the ovary base in between the four loculi. Such style is called gynobasic style. Placentation axile.

Fruit: Four one-seeded nutlets within persistent calyx.

Seed: Either non endospermic or with scantly endosperm.

Pollination: Entomophilous.

Floral formula: % □ $K_{(5)}$ $C_{(5)}$ $A_{4 \text{ or } 2}$ $G_{\underline{(2)}}$

Important Plant

Ocimum sanctum (**Tulsi)**

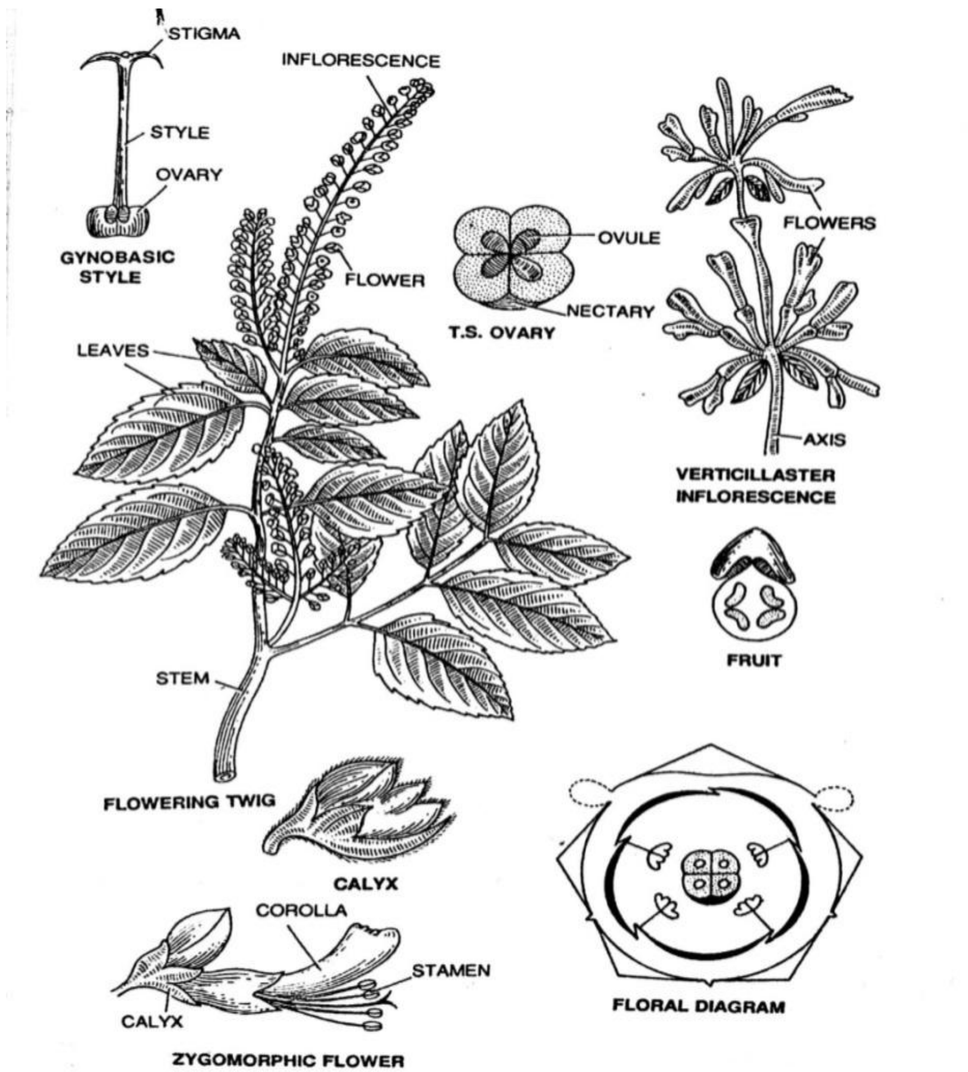

Fig.9.9 ***Ocimum sanctum*** **Linn. (Courtesy B. P. Pandey – Angiosperms, 2007)**

Habit: Aromatic cultivated perennial herb branched, aerial, somewhat woody below, hairy, green.

Root: Tap root.

Leaf: Simple opposite, ramal and cauline, exstipulate, ovate, acute, serrate, unicostate reticulate venation, aromatic smell.

Inflorescence: Verticillaster.

Flower: Bracteate, pedicellate, hermaphrodite, complete, zygomorphic, hypogynous, purple in colour.

Calyx: Sepals 5 in number, gamosepalous, bilabiate, anterior lip with 4 small lobes, posterior lip broad boat shaped, aestivation is imbricate, inferior.

Corolla: Petals are five in number, gamopetalous, bilabiate , lower large, upper lip four lobed; corolla tube short, aestivation is imbricate, inferior, purple white colored.

Androecium: Stamens are four in number, polyandrous, epipetalous, fifth stamen on posterior side is completely suppressed, didynamous, anthers introrse, bicelled, dorsifixed.

Gynoecium: Carpels two, syncarpous, bilocular ovary in starting stage but later becomes tetralocular, ovary superior, four chambered, placentation axile. Each locule with single ovule. Style arises from the base of ovary i.e gynobasic style, bifid stigma.

Fruit: Schizocarpic (carcerulus) made up of four nutlets.

Floral formula: % □ $K_{(1+4)}\ \overparen{C_{(5+1)}\ A_{2+2}}\ G_{\underline{(2)}}$

9.7.4 Economic importance

The plants of this family are ornamental, yield essential oils and possess medicinal properties. Some important plants are as follows: -

- ***Coleus amboinicus*: Pathorchur,** A herbaceous plant, leaves are used for flavoring food products.
- ***Coleus rotundifolius*: Koorkan,** the tuberous stem are used as vegetable.
- ***Mentha arvensis*: Pudina,** a perennial aromatic herb, leaves are used for flavouring purpose, carminative, essential oil is obtained from the leaves.
- ***Leucas zeylanica*: Gattatumba,** leaf juice is used in cold, headache and skin diseases.
- ***Menthas picata*: Paharipudina,** essential oil known as spearmint oil is obtained from the leaves which is used for flavoring food products.
- ***Ocimum sanctum*: Tulsi** plant is treated as holy plant all over the country. Small shrub with several medicinal properties. Seeds are used to control urino-genital diseases.
- ***Salvia officinalis*: Sage,** used as ornamental plant and in herbal medicine.
- ***Origanum vulgare*:** Oregano, culinary herb. Used for flavoring meat, to flavor salad most frequently used with fried, roasted vegetables.

Systematic relationship

Benthum and Hooker have included five families in the order Lamiales. They are Myoporineae, Selagineae, Verbenaceae, Labiateae and Plantagineae. Hutchinson has included the families Myoporaceae, Selagineae, Globularaceae and Labiateae in his order the Lamiales and the Verbenaceae in the Verbenales.

9.8. EUPHORBIACEAE

9.8.1 Systematic position

Bentham and Hooker	**Hutchinson**
Dicotyledons	Dicotyledons
Monochlamydeae	Lignosae
Unisexuales	Euphorbiales
Euphorbiaceae	Euphorbiaceae

Distribution: Euphorbiaceae, commonly called as spurge family is one of the largest known families of flowering plants. About 283 genera and 7300 species are reported in this family which is found throughout the world.

9.8.2 General Characters

Habit: Herbs, shrubs or tree, some are climbers, majority of plants possess laticiferous vessels containing latex.

Root: Branched tap root, in some plants tuberous roots are also common.

Stem: Erect, woody or herbaceous, branched. Some species possess phylloclades. Sometimes stem becomes green, fleshy. Spines are also common in many stems.

Leaves: Simple, stipulate, alternate, sometimes opposite, in many Euphorbias leaves are caducous and scaly. Sometimes they are reduced to spines, in some cases the leaves are replaced by cladodes.

Inflorescence: Great variation is seen in inflorescence. It may be cymose, racemose or sometimes complex. In *Euphorbia* the inflorescence is the modification of cyme called cyathium, in which a large number of male flowers (each represented by a stalked stamen) are found arranged around a central stalked female flower which consists of only gynoecium. Thus complete inflorescence looks like a single flower. Bracts form a cup-like structure and arranged like a perianth.

Flower: Unisexual, regular, actinomorphic, complete, hypogynous.

Perianth: In majority of plants either calyx or corolla or both are absent. Occasionally both calyx and corolla are present; if present they consist of 4 or 5 sepals or petals. Imbricate or valvate aestivation is found.

Androecium: One to many stamens. Usually the number of stamens is equal to number of perianth leaves. The anthers are dithecous.

Gynoecium: Tricarpellary, syncarpous superior trilocular ovary. Each locule of ovary contains one or two anatropous ovules. Axile placentation.

Fruit: Schizocarpic regma or drupe.

Seeds: Endospermic

Pollination: By insects

Floral formula

Euphorbia (male): ♂ K_0 C_0 A_1

Euphorbia (female): ♀ K_0 C_0 $G_{\underline{(3)}}$

Important Plant

Euphorbia hirta **(Dudhi)**

Habit: Wild herb. Annual

Root: Tap, branched

Stem: Herbaceous, erect, unbranched (sometimes branched), solid, having yellow crisped hairs.

Leaf: Simple, subsessile, acute, oblong, lanceolate, stipulate (caducous stipules), unicostate reticulate venation.

Inflorescence: Many cyathia are crowded densely and arranged in peduncled axillary cymes.

Flower: Unisexual pedicellate, enclosed within small involucre of bracts forming cupular structure.

Male flowers:

Perianth: Absent

Androecium: A single stalked stamen forms male flower, bracteate, anther with two cells.

Female flowers:

Perianth: Absent

Gynoecium: Single stalked tricarpellary bracteate pistil represents female flower, which remains surrounded by stalked stamen (male flower). Three chambered, superior ovary having one ovule in each chamber.

Fruit: Capsule

Floral formula

Male flower: ⊕♂ K_0 C_0 A_1

Female flower: ⊕♀ K_0 C_0 $G_{\underline{(3)}}$

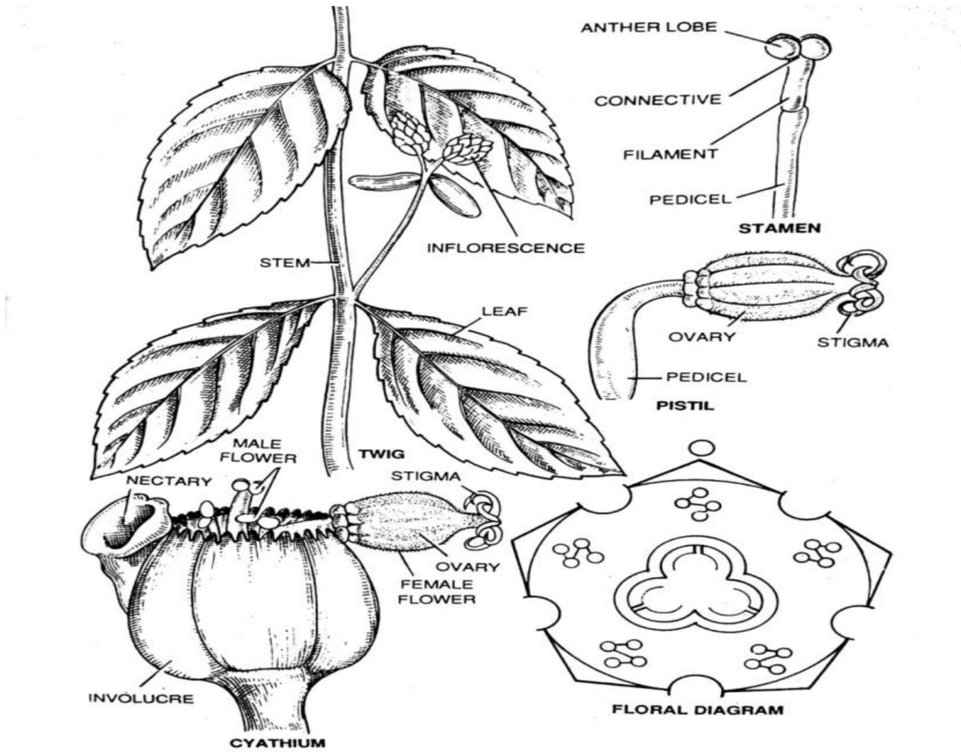

Fig .9.10 Euphorbia hirta Linn. (Courtesy B. P. Pandey – Practical Botany)

9.8.4 Economic importance

Some economically important plants of this family are as follow:-

- ***Acalypha hispida*****:** herbaceous ornamental plant
- ***Cleistanthus collinus*****: Garari**, small tree. Leaves, fruits and bark are used as tan.
- ***Euphorbia pulcherrima*****: Lalpatta**, an ornamental plant.
- ***Euphorbia hirta*****: Dudhi,** medicinal plant.
- ***Euphorbia royleana*****: Thar**, used in hedges. Its latex is used as medicine.
- ***Jatropha curcas*****: Safed arand**, seed oil is used for making soaps, candles.
- ***Hevea brasiliensis*****: Rubur,** tall tree, bark is used for preparing rubber which is useful in making tyres and inner tubes, various electrical goods.
- ***Emblica officinalis*****: Amla**, tree with edible fruits, rich in vitamin C. The wood yields charcoal. Leaves, bark and fruits used in tanning and dyeing.
- ***Ricinus communis*****: Arand,** small cultivated tree. Castor oil is obtained from seeds it is used in manufacture of transparent soaps perfumes, varnishes and paints. Also used as a medicine.

Systematic relationship

Hallier included Euphorbiaceae in his order Passionales, while Wettstein and Rendle have placed it in the Tricoccae (created order) between Malvales and Geraniales.
The family Euphorbiaceae is very closely related to the members of the Malvales particularly Sterculiaceae in the floral structure such as the occurrence of monadelphous androecium in 25% of the total genera, valvate sepals, structure of petals when present, presence of pistillode and staminode, presence of caruncle and nature of embryo. It also shows resemblances with the Geraniales and the Sapindales in the occasional presence of disc and the number and structure of ovules. The family Euphorbiaceae might have evolved from ancestors of Malvales due to suppression or reduction of the inner whorl of perianth and abortion of one of the members of essential whorls viz., stamens or carpels during the course of evolution. Pax (1924) regarded the Euphorbiaceae as advanced without any primitive characters. According to him the unisexuality in flower is due to reduction from early bisexual types.

9.9 SUMMARY

Now you can sum up the important criteria of the families you studied in this unit-9 viz. **Ericaceae, Asclepidaceae, Solanaceae, Acanthaceae, Lamiaceae and Euphorbiaceae** in this unit.

Ericaceae, name of the family comes from the type genus *Erica*, which appears to be derived from the Greek word *ereike*. The exact meaning is difficult to interpret, but some sources show it as meaning 'heather'. Woody stems, simple evergreen leaves growing alternately, clusters of flowers , flowers with 4 or 5 petals forming a tube or trumpet ,stamens not attached to the flower tube and are found in acidic conditions.

Asclepiadaceae (Milkweed family) form a group of perennial herbs, twining shrubs, lianas or rarely trees but notably also contains a significant number of leafless stem succulents. The name comes from the type genus *Asclepias* (milkweed).

In the subfamily Periplocoideae (*Hemidesmus, Cryptostegia*), the filaments are free. The anthers are coherent and appressed to the expanded stylar head. The pollen is granular and united into tetrads, the pollen of the one half of the two adjacent anthers discharge on the spathulate translator arising from the style head and alternating with the anthers.

In the subfamily Euasclepiadeae (*Calotropis, Asclepias*), the filaments are connate in a short fleshy column.Androecial members adnate; united with the gynoecium forming a gynostegium with it coherent (via the filaments, forming a short sheath around the style.The pollen grains are united in two waxy masses (pollinia) in each cell. The pollinia are united in pairs by caudicles (retinaculae) of various shape to a gland (Corpusculum) which lies on the stigma.

Solanaceae is economically important family of flowering plants. It is represented by annual and perennial herbs, shrubs, trees, epiphytes and includes a number of medicinal plants, agricultural crops, spices and ornamental plants. The most important genus of the family is *Solanum* which contains potato thats why the family is called as potato family. Tomato, capsicum, tobacco, datura and egg plant are other important plants. Tobacco and *Petunia* are nowadays used as biological models for cellular, molecular and genetic studies.

Acanthaceae have simple, opposite, decussated leaves with entire (or sometimes toothed, lobed, or spiny) margins, and without stipules. Simple leaves arranged in opposite pairs, with cystoliths in streaks or protuberances in the vegetative parts. The bisexual flowers are frequently bilaterally symmetrical and are usually enclosed by leaf like bracts, often coloured and large. Sepals and petals number five or four each and are often fused into tubular structures. There are usually two or four stamens that extend beyond the mouth of the flower, often with one to three staminodes (sterile stamens). The pistil is superior (i.e., positioned above the attachment point of the other flower parts) and generally consists of two fused carpels (ovule-bearing segments) enclosing two locules (chambers), each of which has two to many ovules in two rows along the central axis of the ovary. The fruits are often exploding capsules containing seeds borne on hooks on the placenta.

Lamiaceae is a family of angiosperms, commonly known as mint family. Most of the plants are aromatic and used for culinary purpose and for oils. Plants are widely cultivated not only for their aromatic qualities but also for tier edible leaves, tubers. Some are grown for ornamental purpose.

Euphorbiaceae or the spurge family is one of the largest families of angiosperms. It has a number of economically important plants like cassava, castor oil plant, rubber plant etc. Majority of plants possess latciferous vessels containing latex. Many plants have medicinal value and also grown for ornamental purpose.

9.10 GLOSSARY

Adnate: The fusion of unlike parts (anthers and filament).

Basifixed: Fixed to the filament (stalk) at the base.

Berry: A superior (rarely inferior) indehiscent, usually many seeded,fleshy or pulpy fruit developing from single carpelor more commonly from a syncarpous pistilwith axile or parietal placentation e.g. tomato.

Bilabiate: Two lipped zygomorphic gamopetalous corolla, *e.g. Justicea.*

Bipinnate: Twice pinnate, the primary leaflets being again divided into secondary leaflets.

Capsule: A dry dehiscent fruit produced from a compound pistil, e.g. fruit of a tobacco, *Catalpa*, *Dianthus*.

Cyme: A more or less flat-topped determinate inflorescence whose outer flowers open last, e.g. *Sambucus*, elderberry.

Dichasial (Biparous) cyme: Dichotomously branched cymose inflorescence.

Didynamous: In an androecium four stamens in two pairs one pair shorter than the other.

Dithecous: Two-celled anther.

Epipetalous: Stamens born on the petals or corolla tube *e.g. Justicea, Solanum*

Extrorse- Facing outward from the centre of flower referred for anthers.

Gamosepalous : With coherent sepals.

Hairy: Pubescent with long hairs.

Hermaphrodite (bisexual): The flower having both male and female reproductive organs.

Imbricate: A mode of aestivationin which one member of whorl outside all the other (*i,e.* its margins are free) and one inside all the others (both margins are overlapped), the other overlap by one margin only.

Inferior: Beneath, below; said of an ovary when situated below the apparent point of attachment of stamens and perianth.

Jaculator: Structural modification of the funiculus develops into a hook like on which the seed rest.

Locule: Chambers, the ovary may be unilocular (*Ranunculus*), bilocular (*Solanum*), trilocular (*Allium*), tetralocular (*Ocimum*), Pentalocular (*Hibiscus*) or multilocular (*Citrus*).

Milky Sap: Whitish in color, often thicker than water.

Monochasial (Uniparous) cyme: Having a cymose inflorescence with one axis at each branching

Multiple fruit: A fruit formed when the pistils of separate flowers form a single structure with a common axis (e.g. *Morus*, mulberry)

Oblique: Lop-sided, as one side of a leaf base larger, wider or more rounded than the other.

Opposite: Describing leaves that are situated in pairs at a node along an axis.

Panicle: An indeterminate inflorescence whose primary axis bears branches of pedicelled flowers (at least basally so); a branching raceme.

Pedicel: Stalk of a single flower in an inflorescence.

Peduncle: Stalk of a flower or inflorescence.

Persistent: Remaining attached till maturation.

Personate: Zygomorphic, gamopetalous corolla with two lips.

Pinnate: Compound, with leaflets or pinnae arranged feather-like on either side of a common axis or rachis.

Pollination: Transference of pollen grain from anthers to stigma.

Polygamous: Bearing unisexual and bisexual flowers on the same plant.

Pubescent: Downy; covered with short, soft, erect hairs.

Raceme: A simple indeterminate inflorescence, having a single long axis, with pedicelled flowers.

Staminode: Sterile stamen with reduced anther.

Syncarpous: United carpels, compound ovary.

Tendril: A modified stem or leaf, usually filiform, branched or simple, that twines about an object providing support.

Thorn: Modified stem/branch; since a stem comes from a bud, thorns are located above leaves. Examples include apple, *Pyracantha* and *Cotoneaster*.

Unisexual: Bearing either stamens or pistils but not both.

Trifoliate: Three-leaved, e.g. *Trillium*.

Umbel: An indeterminate inflorescence, usually but not necessarily flat-topped with the pedicels and peduncles (termed rays) arising from a common point, resembling the stays of an umbrella.

Zygomorphic: Asymmetrical, irregular.

9.11 SELF ASSESSMENT QUESTION

9.11.1 Multiple Choice Questions:

1.Which one of the following is known as Milkweed family

(a) Caesalpiniaceae (b) Rosaceae

(c) Papilionaceae (d) Asclepiadaceae

2. *Rhododendron arborerum belongs to family*

(a) Euphorbiaceae (b) Apocynaceae

(c) Ericaceae (d) Solanaceae

3. *Adathoda vasica* belongs to which one of the following families

(a) Lamiaceae (b) Acanthaceae

(c) Solanaceae (d) Poaceae

4. Epipetalous and didynamous stamens and presence of staminode is characteristic feature of which one of the following

(a) Lamiaceae (b) Acanthaceae

(c) Solanaceae (d) Poaceae

5. A hook like projection known as 'jaculator'in which the seed rests is found in

(a) Lamiaceae (b) Acanthaceae

(c) Solanaceae (d) Poaceae

6. Gynostegium is found in

(a) Rutaceae (b) Rosaceae

(c) Asclepiadaceae (d) Caryophyllaceae

7. Verticillaster inflorescence is found in –

(a) Solanaceae (b) Euphorbiaceae

(c) Lamiaceae (d) Fabaceae

8. *Ocimum sanctum* belongs to family.

(a) Lamiaceae (b) Solanaceae

(c)Rosaceae (d) Euphorbiaceae

9. Gynobasic style is found in –
(a) Lamiaceae (b) Acanthaceae
(c) Solanaceae (d) Rosaceae

10. Cyathium inflorescence found in.
(a) Pea (b) Rose
(c) *Euphorbia* (d) Lady finger

9.11.2 Fill in the blanks: -

1. The characteristic inflorescence of family Lamiaceae is ………………………..
2. In Lamiaceae the fruits are usually …………………………
3. When a style arises from the base of ovary it is known as ………………………………
4. Castor oil is obtained from the seeds of ………………………………….
5. *Atropa belladona* is the source of drug …………………………..

9.11.1 Answer Keys: 1.(d), 2.(c), 3.(b), 4.(b), 5.(b), 6.(c), 7.(c), 8.(a), 9.(a), 10.(c).

9.11.2 Answer Key: 1.Verticillaster, 2.Nutlet, 3.Gynobasic, 4.Euphorbiaceae, 5.Solanaceae

9.12 REFERENCES

- Bentham, G and J.D. Hooker, 1862. *Genera Plantarum* 3 Vols, Reeve &Co.,London.
- Bessey,C.E., 1915, *Phylogenetic taxonomy of flowering plants*, *Ann. Mo..Bot. Gard*, 2: 109-164
- Engler, A.W and K. Prantl, 1887-1915 *Die NaturlichenPflanzenfamilien*, 23, Vols. Leipzig
- Hutchinson, J., 1969 Evolution *and Phylogeny of the Flowering Plants*, Academic Press, London
- Takhtajan, A. 1969, *Flowering Plants: Origin and Dispersal* Oliver & Boyd. Ltd. Edinurgh

9.13 SUGGESTED READINGS

- Singh, V, and D.K. Jain 1981. *Taxonomy of Angiosperms*, RastogiPublications,Merrut
- Singh ,V, Pande , P.C. and D.K. Jain 1999. *A Text book of Botany: Angioperms.*
- Pandey, B.P. 2007.Botany for Degree Students-B.Sc. Second year, S. Chand Publication, New Delhi
- Sharma, O.P. *Plant Taxonomy* (Second edition) 2010 The Mc Graw Hill Company, Kolkata.

9.14 TERMINAL QUESTIONS

1. Write descriptive note on floral features of Acanthaceae
2. Give characteristics feature of family of *Rhododendron*.

3. Write short notes on the following
   (i) Jaculator (ii) Pollinia (iii) Gynostegium
4. Give characteristic floral features of family Asclepiadaceae.
5. Give comparative account of taxonomic characters of families Acanthaceae and Solanaceae.

UNIT-10 ORCHIDACEAE, LILIACEAE, ARECACEAE (PALMAE), CYPERACEAE AND POACEAE (GRAMINAE)

10.1 OBJECTIVES

After reading this unit student will be able-

- To understand about the given families- Orchidaceae, Liliaceae, Arecaceae, Cyperaceae and Poaceae.

Present unit comprises of introductory account on some of the important monocotyledonous families *viz.* Orchidaceae, Liliaceae, Arecaceae, Cyperaceae and Poaceae. Detailed description on their distribution, their systematics, general characters, important genera and economic importance *etc.* of each families will be studied as sub chapter of each family. Moreover, an outline of the phylogenetic and evolutionary relations of the families will be enlightened. Figures of some of the important genera of the concerning families are also given here for correlating this text to your surrounding nature.

10.2 INTRODUCTION

In previous units you have studied characteristic features of dicotyledons. Now, you will be familiarized with the monocotyledon families mentioned in your syllabus *i.e.* Orchidaceae, Liliaceae, Arecaceae, Cyperaceae and Poaceae.

Bentham and Hooker (1862-1883) recognized 34 families under monocots and divided them into varying number of series. Takhtajan (1969) divided class Liliatae (or Monocotyledons) into 69 families. Cronquist (1981) included 65 families under class Liliopsida (Monocots) whereas Thorne (1983) treated Monocotyledons (=Liliidae) as a subclass of class Angiospermae (Annonpsida) and discussed 53 families under this subclass.

According to Bentham and Hooker 7 series of Monocotyledons are **Microspermae, Epigynae, Coronarieae, Calycineae, Nudiflorae, Apocarpeae, Glumaceae.**

Family Orchidaceae comes under **Series-** Microspermae, Liliaceae under Series- Coronarieae, Palme (Arecaceae) within series- Calycineae while Cyperaceae and Poaceae are included under Series- Glumaceae.

Series- Microspermae is characterized by the presence of epigynous flowers, inferior ovary, parietal placentation and very small and numerous non-endospermic seeds. It includes three families. *e.g*. Orchidaceae.

Series- Coronarieae is characterized by coloured or petaloid perianth, superior ovary and endospermic seeds. It includes 8 families. *e.g*. Liliaceae.

Series- Calycineae has perianth sepaloid, small, rigid or herbaceous, Inner series sub-petaloid or small. Ovary free, endosperm copious *e.g*. Palmae (Arecaceae)

Series- Glumaceae is characterized by small, scale like or chaffy perianth or no perianth, large scaly bracts, flowers in spikelets or heads, ovary unilocular with one ovule in each locule and seeds with abundant and starchy endosperm. It includes 5 families *e.g.* Cyperaceae, Poaceae.

10.3 ORCHIDACEAE (ORCHID FAMILY)

10.3.1 Systematic position

Bentham and Hooker	**Hutchinson**
Monocotyledons	Monocotyledons
Microspermae	Corolliferae
Orchidaceae	Orchidales
	Orchidaceae

Distribution

Orchidaceae is one of the largest families of the flowering plants. It is represented by about 900 genera and 20,000 species, which are cosmopolitan in distribution primarily distributed in tropical areas. It is second largest angiospermic family of Indian flora it is represented by about 130 genera and over 800 species, distributed mainly, in the Himalayas, Western Ghats and Khasia Hills.

Diagnostic characters

Perennial herbs, epiphytes or saprophytes may be terrestrial; flower zygomorphic, hermaphrodite, epigynous, resupinated; perianth 6, in two whorls, the posterior segment of the inner whorl developed as lip or labellum; presence of peculiar structure-labium, column and rostellum; Stamens 1-2, one or two staminode pollen grains united into pollinia; gynoecium tricarpellary, inferior unilocular with parietal placentation; the fertile stamen is adherent to the style and forms with it the column or gynostemium, which projects more or less in the centre of the flower; stigma 2 or 3 lobed, in some two fertile and one sterile and modified into rostellum.

10.3.2 General Characters

Habit: They are perennial terrestrial, succulent, scapose herbs; many are epiphytic or saprophytic, sometimes climbers *Vanilla*. The tropical species are mostly epiphytes while those occurring in the temperate zone are largely terrestrial.

The terrestrial forms (*Orchis*) are sympodial. In most of them the internodes are often swollen which serve as storage reservoir of food. Other develop thick or fleshy adventitious root forming a large tuber acting as perennating body.

The epiphytic forms (*Cypripedium*, *Cymbidium*) are mostly sympodial or sometimes monopodial. They develop aerial roots which have an outer layer of water absorbing tissue, the 'Velamen'.

Their internal tissue is green which helps in photosynthesis. Most of the epiphytic forms drop their leaves during dry season. They usually develop one fleshy pseudo-bulb each year. Those not having pseudo bulbs have fleshy leaves which store water and other reserves.

The saprophytic forms (*e.g*. *Neottia*) do not develop green leaves. They produce a much branched fleshy rhizome with or without roots, which absorbs food material from humus.

Root: Adventitious, tuberous (*Orchis*), fleshy climbing or aerial. Main roots always absent.

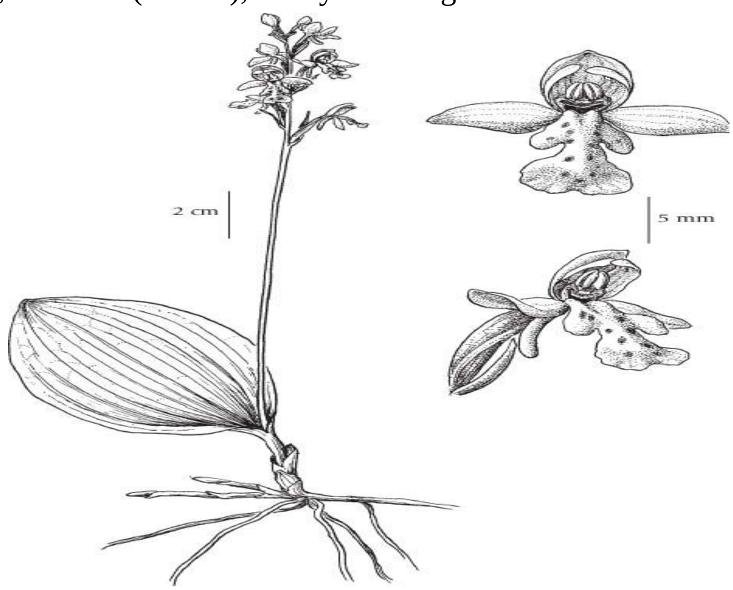

Fig 10.1 Amerorchis rotundifolia *(Banks ex Pursh) Hultén*

Stem: Erect sometimes climbing or trailing, annual in terrestrial forms, perennial in epiphytic forms; generally thickened into rhizomes or pseudo bulbs (*Phaius*, *Bulbophyllum*), bearing aerial assimilatory roots (*Taeniophyllum*).

Leaves: Simple alternate sometimes opposite or whorled, usually fleshy, linear to ovate, sheathing base, sometimes reduced to achlorophyllous scales.

Inflorescence: Solitary (*Cypripedium*) or are borne in racemes, spike, panicle (*Oncidium*).

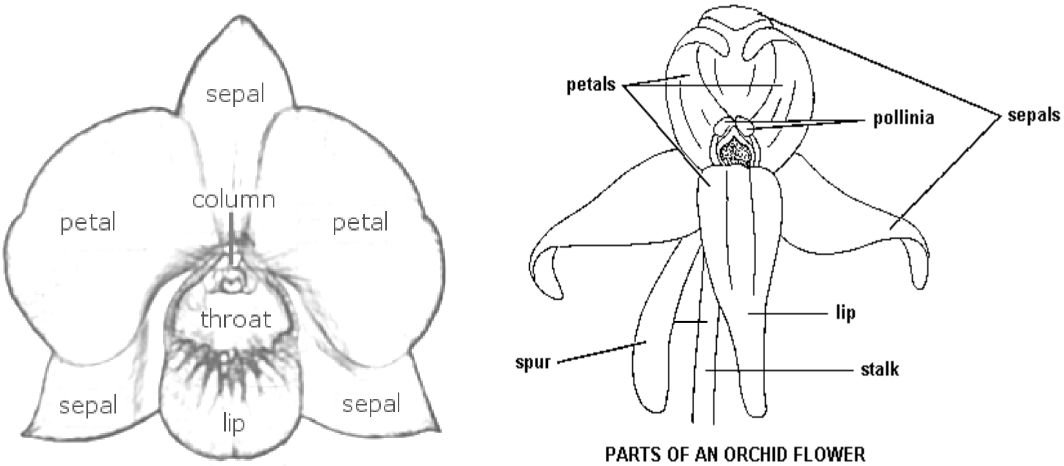

Fig. 10.2 Floral details of typical Orchidaceae flower

Flower: Flowers are of variable and peculiar shape, size and beautifully coloured, often showy, bracteate, complete, zygomorphic, bisexual or rarely unisexual, epigynous, trimerous, mostly resupinate *i.e.* twisted to 180^0 or upside down.

Perianth: Usually 6 tepals in two whorls of 3 each, outer 3 tepals (representing calyx) green, the three outer tepal are alike in appearance. They are imbricate or sub valvate in bud. Inner three tepals coloured (representing corolla), dissimilar- the 2 lateral or wings like, the third posterior tepals is highly modified in shape, size and colour often projected basally into a spur, called the **labellum or lip**. It is broad, shoe-like spur, tubular, star-shaped or butterfly shaped or variously branched and contributing most to the oddity and beauty of the flower.

The labellum is actually the uppermost (posterior) petal but looks as if located on the lower side of the flower in most orchids. It comes to lie on the anterior side of the flower due to twisting (or resupination) of the inferior ovary through 180^0 (in many flowered orchids) or by the bending back of pedicel over the apex of the stem (as in single flowered orchid).

The most characteristics part of the orchid flower is gynandrium or column which is highly complex structure formed by the adnation of stamens, style and stigma.

Androecium: It is represented by usually one or sometimes two sessile anthers. In monandrous forms there is only single fertile stamen, terminal on the column. This stamen is considered to represent the anterior member of the outer whorl, the two other (lateral) stamens of this whorl and also all the tree of the inner whorl are entirely absent. The two lateral members of the outer whorl are sometimes represented by staminodes (*Epipactis*).

In diandrous forms (*Cypripedium*) there are two fertile stamens belonging to the inner whorl and

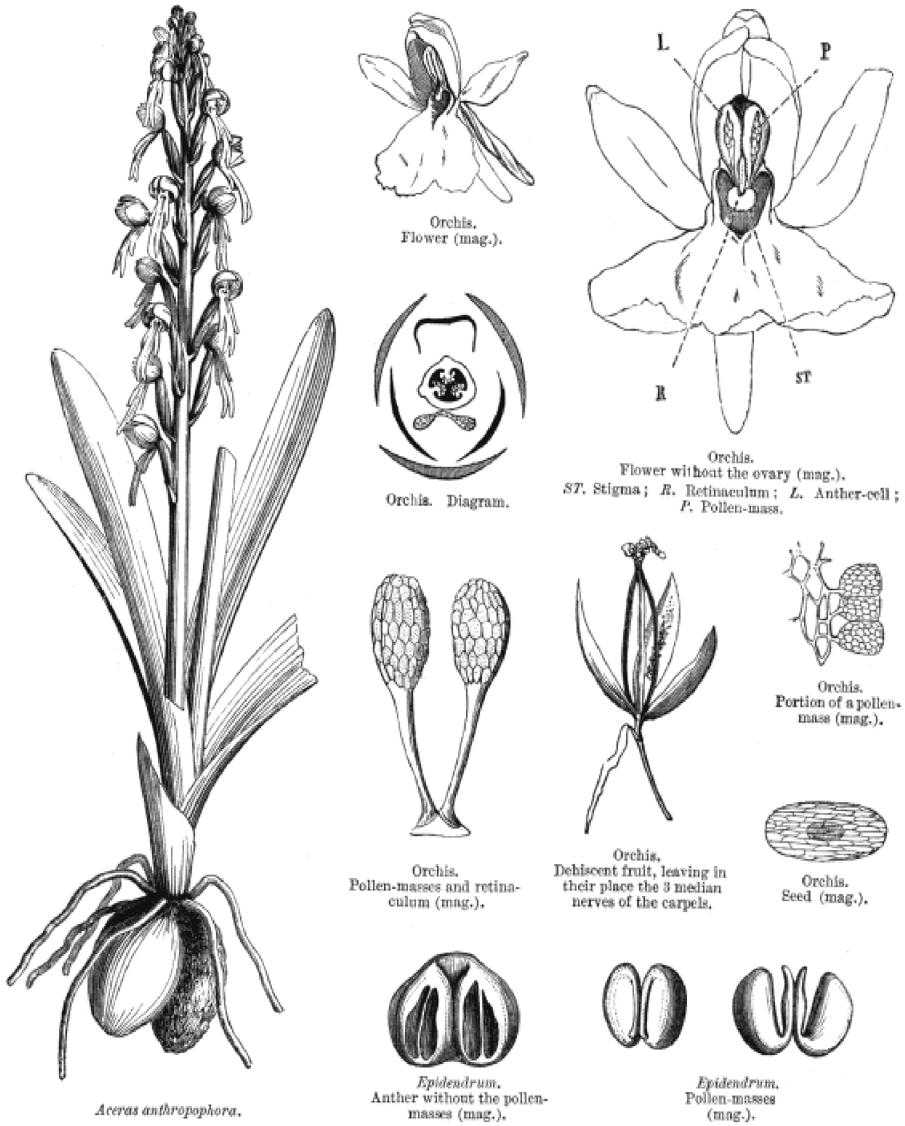

Fig 10.3 Floral details of some orchids

they are lateral to the column. The medium member of the outer whorl (which is fertile in monandrous forms) is represented by large staminode. The outer staminal member is completely absent. Anthers are bithecous, introrse; pollen granular or coherent in each cell into one, 2 or 4 stalked pollen masses which are mealy waxy or bony masses or pollinia. One end of the pollinium is extended into sterile structure, the caudicle.

A connection between ovary and stamen is made by the beak-like sterile stigma, occupying almost the centre of the column, sometimes the staminodes are also present.

Gynoecium: Tricarpellary, syncarpous, ovary inferior, unilocular, parietal placentation, rarely trilocular and axile placentation (*Apostasia*); stigma 3 of which 2 lateral are often fertile, the third stigma is sterile forming a small beaked outgrowth - the rostellum lying in the centre of column between the anther and the fertile stigma. In *Cypripedium* and *Paphiopedium*, all the 3 stigmas are functional.

In Monandrous the column has two fertile stigmas and a specialized organ the rostellum, which represent the third stigma. Sometimes (*e.g. Habenaria*) a portion of the rostellum is modified into a viscid disk (*viscidia*) in which pollinia are attached.

In diandrous forms there is no rostellem and all the three stigmas are simple and fertile.

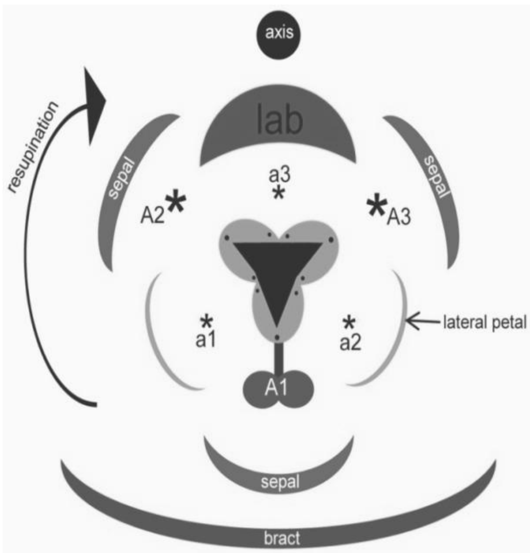

Fig 10.4 Floral diagram of Monandrous orchid ***Fig 10.5 Floral diagram of Diandrous orchid***

Fruit: Fruit usually a capsule opening laterally by three to six hygroscopically sensitive valves containing a very large number of seeds.

Seed: Numerous very small, non-endospermic seeds, which are distributed easily by wind.

Pollination: Flowers of Orchidaceae are admirably adapted to insect pollination (Entomophilous). Insects are attracted by beautiful form, colour and fragrance of flowers and the nectar secreted in the sac or spur or labellum in several taxa. In others where spur has no free nectar the insect has to bore the tissue of spur to reach the sweet sap contained in the labellum. The resupination of flowers brings the labellum into a position where it makes an effective landing place for the insects.

General Floral Formula: Br % □P $_{3+3}A_{1-2}\overline{G(3)}$

10.3.3 Important Genera

The familiar examples are Lady's slipper (*Cypripedium sp,*), Vein orchid (*Habenaria* spp), Vanda (*Vanda* spp.) *Epidendrum* (Green fly orchid), *Oncidium* (butterfly orchid), *Odontoglossum* (lady orchid) and *Cattleya* spp. are some of the most popular florists orchids.

10.3.4 Economic Importance

Orchidaceae are important for their ornamental value chiefly. Beside this, it is also valuable for flavoring and medicines.

- **Ornamentals:** Many orchids are cultivated in the green houses for their beautiful sweet-scented flowers of various forms, shapes with highly attractive labellum of various hues and bright colours. The orchid flowers are in great demand and are much more sought after than any other flowers. Hence extensively grown from a commercial point of view. Some commonly grown orchids are *Cypripedium* (lady's slipper), *Epidendrum* (Green fly orchid), *Habenaria* (fringe orchid), *Oncidium* (butterfly orchid), *Vanda*, *Vanill*a, *Odontoglossum* (lady orchid).
- **Food:** During scarcity the tuberous roots of *Habenaria susannae* and *Orchis latifolia* are used as food and also 'Salep' of commerce which is used as farinaceous food and nervine tonic. It is also used as sizing material in silk industry.
- **Flavour:** The capsules of *Vanilla planifolia*, *V. fragrans* yield commercial "Vanilla" a flavoring agent for chocolates and confectionary.
- **Medicinal:** The root-stocks of *Eulophia epidendraea used* as vermifage.
- **Dyes:** The leaves of *Calanthe veratrifolia* contain a glycoside "indicant", which on hydrolysis yields "indigo blue".

Systematic relationship

Bentham and Hooker placed Orchidaceae under Microspermae. It was placed under a separate order Orchidales by majority of the later workers including Hutchinson (1959), Takhtajan (1969) and Cronquist (1981). Thorne (1983) however placed Orchidaceae under the suborder Orchidineae of order Liliales. Several taxonomists consider Orchidaceae to be the most advanced and highest evolved among monocotyledons. The characters which support this view include (i) reduction in number of stamens (ii) resupinate epigynous ovary (iii) presence of rostellum (iv) non endospermic seeds (v) Herbaceous habit and (vi) presence of several epiphytes.

10.4 LILIACEAE

10.4.1 Systematic position

Bentham and Hooker	**Hutchinson**
Monocotyledons	Monocotyledons
Coronarieeae	Corolliferae
Liliaceae	Liliales
	Liliaceae

Distribution

The members of the family are cosmopolitan in distribution. They are abundantly found in temperate and tropical regions. It includes 250 genera and 4000 species, which are worldwide in distribution. In India, it is represented by 35 genera and 169 species. The plants are usually annual and perennial herbs. In our country it is chiefly occurring in Himalayas. The familiar examples are Lily (*Lilium* spp.), Dracaena (*Dracaena* spp.), Asparagus (*Asparagus spp.*), etc.

10.4.2 General Characters

Habit: Mostly herbs (*Asphodelus*), Perennating by rhizome (*Aloe*), bulbs (*Lilium*, *Tulipa*), tree (*Dracaena*), climber (*Asparagus*, *Smilax*), xerophytic plants like *Yucca*, *Aloe*; cladodes in *Asparagus* and *Ruscus*.

Root: Fibrous adventitious, sometimes tuberous (Asparagus).

Stem: Herbaceous or woody, solid or fistular, underground; aerial climbing or erect; underground stem may be corm, bulb or rhizome. In *Ruscus* and *Asparagus* aerial stems bear phylloclades (modified leaf like branches), corm (*Colchicum*); secondary growth in *Yucca* and *Dracaena*.

Leaves: Alternate, opposite or whorled, basal (*Lilium*) or cauline, exstipulate, sessile or petiolate, sheathing leaf base; shape is variable scale like (*Asparagus*), thick succulents and mucilaginous in *Aloe*, broad in *Phormium tenax*. In *Smilax* stipulate and stipules are modified into tendrils, venation is usually parallel but reticulate in *Smilax* and *Trillium*. In *Asparagus* and *Ruscus* leaves are reduced to scale.

Inflorescence: Variable inflorescence, solitary (*Tulipa*, *Fritillaria*), panicled raceme (*Asphodelus*), cymose umbel (*Smilax*), solitary axillary (*Gloriosa*), unisexual flowers, trimerous rarely 2 or 4- merous (*Maianthemum*, *Paris*).

Flower: Pedicellate, bractate actinomorphic or zygomorphic (*Lilium*, *Hemerocallis*), hermaphrodite or unisexual in *Smilax*, *Ruscus*; hypogynous, complete or incomplete.

Perianth: 6 tepals arranged in two whorls of three each, polyphyllous (*Lilium*, *Tulipa*) or gamophyllous (*Aloe*, *Asparagaus*) and of various shapes, petaloid or sepaloid, imbricate in bud, usually valvate in aestivation, perianth may be scarious or membranous.

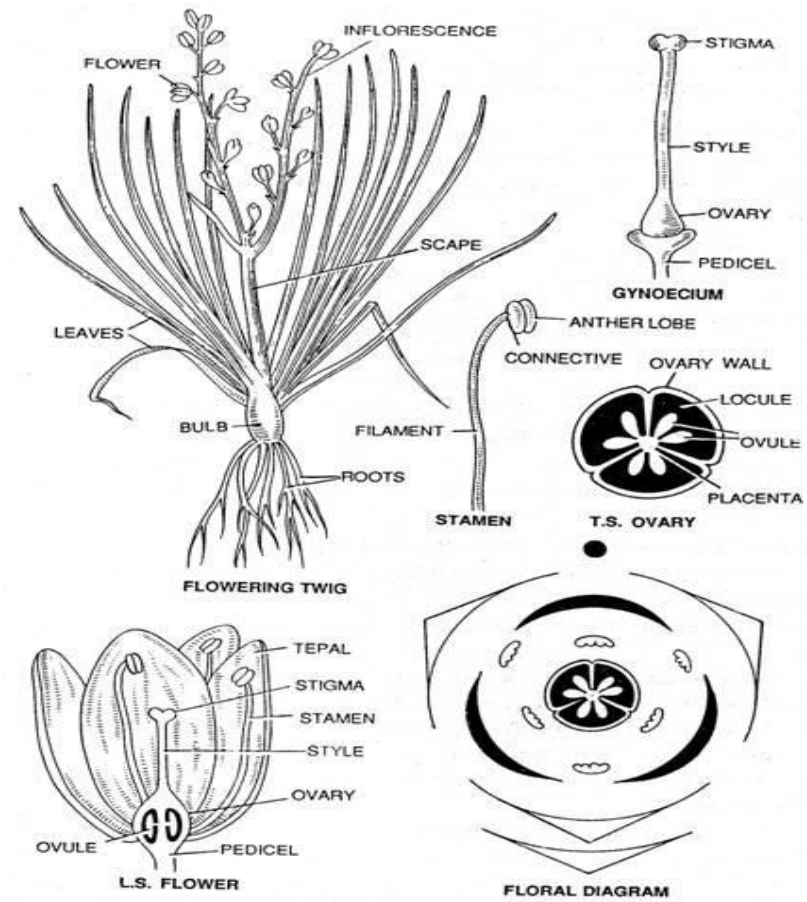

Fig 10.6 Asphodelus tenufolius

Androecium: Stamens usually 6 arranged in two alternate whorls of three members each. They are always opposite to the tepals and sometimes adnate to perianth or 3 (*Ruscus*), 8 in *Paris*; polyandrous, epiphyllous, filament long, anthers versatile or basifixed, dithecous, introrse or extrorse. In *Ruscus* outer whorl of stamens is reduced to staminodes.

Gynoecium: Tricarpellary, syncarpous, ovary superior or half inferior, trilocular or unilocular with two ovules, axile placentation, style simple; stigma trilobed or 3-parted. Usually the ovary has three septal nectarines one on each septum.

Fruit: Usually a loculicidal or septicidal capsule (*Asphodelus*) or a berry (*Asparagus*, *Smilax*).

Seed: Endospermic; endosperm horny or cartilaginous.

Pollination: Entomophilous rarely self-pollination.

Floral Formula: Br ⊕ □ $P_{3+3 \text{ or } (3+3)}$ A_{3+3} $\underline{G}_{(3)}$

10.4.3 Important Genera

The familiar examples are Lily (*Lilium* spp.), Dracaena *(Dracaena* spp.), Asparagus (*Asparagus* spp.).

10.4.4 Economic Importance

Family Liliaceae provides food, drug, fibre plants and is of important ornamental values.

- **Edibles:** Fleshy shoots of *Asparagus officinalis* are used as vegetable.
- **Medicinal:** *Smilax, Aloe, Gloriosa, Veratrum, Colchicum, Scilla, and Urginea* yield useful drugs. *Aloe vera* yields "Aloin" used in treatment of piles and fissure. The roots of *Asparagus racemosus* yield a tonic. Corms and seeds of *Colchicum luteum* are useful in rheumatism and liver diseases. An alkaloid 'Colchicine' is obtained to induce polyploidy in plant breeding.
- **Fibres:** *Yucca, Phormium tenax* yield fibers of commerce used in cordage.
- **Resin:** *Dracaena* and *Xanthorrhoea* yield resin. From the acrid resin of *Xanthorrhoea* sealing wax is prepared.
- **Ornamentals:** The common cultivated garden plants are *Tulipa, Lilium, Gloriosa, Aloe, Ruscus, Dracaena, Asparagus, Yucca, Hemerocallis, etc.*

Systematic relationship

Bentham and Hooker divided the family into 20 tribes. Engler and Krause divided the family into 12 subfamilies. The family has close affinity with Amaryllidaceae from which it can be distinguished by the presence of superior ovary, and absence of corona. It is also close to Juncaceae as in both the seeds have albumen but differs from Juncaceae in petaloid perianth. The family, on account of marked variabilities in cytological, embryological and anatomical structures, appears to be polyphyletic in origin. Its origin from Helobieae or its ancestor may be assumed from floral structures and helobial endosperm formation in some of the genera of Liliaceae as *Petrosavia*, *Protolirion*. The helobian origin is further supported by the flower construction of *Helonias* which is similar to the members of Juncaceae. Liliaceae is regarded as a typical monocot family and represents the basic monocot stock from which many families have arisen. Hutchinson has excluded many genera which are included by many botanists in the family Liliaceae. He has included *Allium*, *Agapanthus* in the family Amaryllidaceae of his order Amaryllidales; *Yucca*, *Dracaena*, *Sanseviera*, *Phormium* in the family Agavaceae of his order Agavales; Xanthorrhoea in the family Xanthorrhoeaceae of his order Agavales. He has also included *Smilax* in the family Smilacaceae and *Ruscus* in Ruscaceae in his order Liliales.

10.5 ARECACEAE (PALMAE)

10.5.1 Systematics position

Bentham and Hooker	**Hutchinson**
Monocotyledons	Monocotyledons
Calycinae	Corolliferae
Arecaceae (Palmae)	Palmales
	Arecaceae (Palmae)

Primitive characters:

1. Mostly plants are trees.
2. Leaves are spirally arranged.
3. Flowers are actinomorphic, hypogynous and hermaphrodite.
4. Gynoecium is apocarpous (*Phoenix, Rhapis*).
5. Ovary superior.

Advanced characters:

1. Small herbaceous forms are also present.
2. Leaves are compound and exstipulate.
3. Inflorescence is a spadix.
4. Perianth is present.
5. Flowers are usually unisexual (*Phoenix, Cocos*).
6. Flowers trimerous.
7. Stamens epiphyllous.
8. Gynoecium tricarpellary, syncarpous rarely unilocular.
9. Style very short or absent.
10. Axile placentation.

According to Eames (1961)**, "The palms give evidence of great age; they are primitive taxa that have become greatly diversified and advanced in many characters, each character giving evidence of long specialization."**

Distribution

It includes 217 genera and 2500 species. The members are confined to tropics in both the hemispheres and extending in the warmer regions of the world. In India, it is represented by 225 species belonging to 25 genera.

10.5.2 General Characters

Habit: Large unbranched trees (*Phoenix*, *Areca catechu*), shrubs or garden palms, trailing woody vines (*Calamus*), herbs (*Reinhardtia*).

Root: Adventitious roots arising from the base of bulbous stem. Thick aerial roots are also found in some species of *Manicaria*.

Stem: Stout or slender aerial, woody, erect, unbranched; very rarely branched (*Hyphaene*), in some short rhizome (*Nipa*), cylindrical, hairy, old stem protected by woody leaf bases, climbing (*Calamus*).

Inflorescence: It is simple racemose (*Borassus*), or compound racemose (*Cocos*) or even profusely branched panicle (*Daemonorops*) usually a spadix with a woody spathe which opens by two valves, spadix may have sessile or pedicellate flowers.

Flower: Sessile or shortly pedicellate, bracteate, mostly unisexual (*Phoenix*) or hermaphrodite (*Livingstonia*), actinomorphic, incomplete or complete, hypogynous trimerous, flowers are of small size and produced in large numbers. Plant may be monoecious or dioecious.

Perianth: Tepals 6, in two whorls of 3 each, polyphyllous or slightly connate at the base; perianth lobes tough, persistent, coriaceous, leathery or fleshy, valvate or imbricate aestivation, white or petaloid.

Androecium: In male or hermaphrodite flowers, stamens are 6 in number, two whorls of 3 each, polyandrous, staminodes may be present in the female flowers; anthers versatile, dithecous, basifixed or dorsifixed, introrse, filament short and distinct.

Fruit: Usually a berry, fleshy or fibrous waxy coating on the fruit; the mature fruit contains a single seed (*Phoenix*); drupe (*Cocos nucifera*).

Seed: Endospermic.

Pollination: Anemophilous or entomophilous.

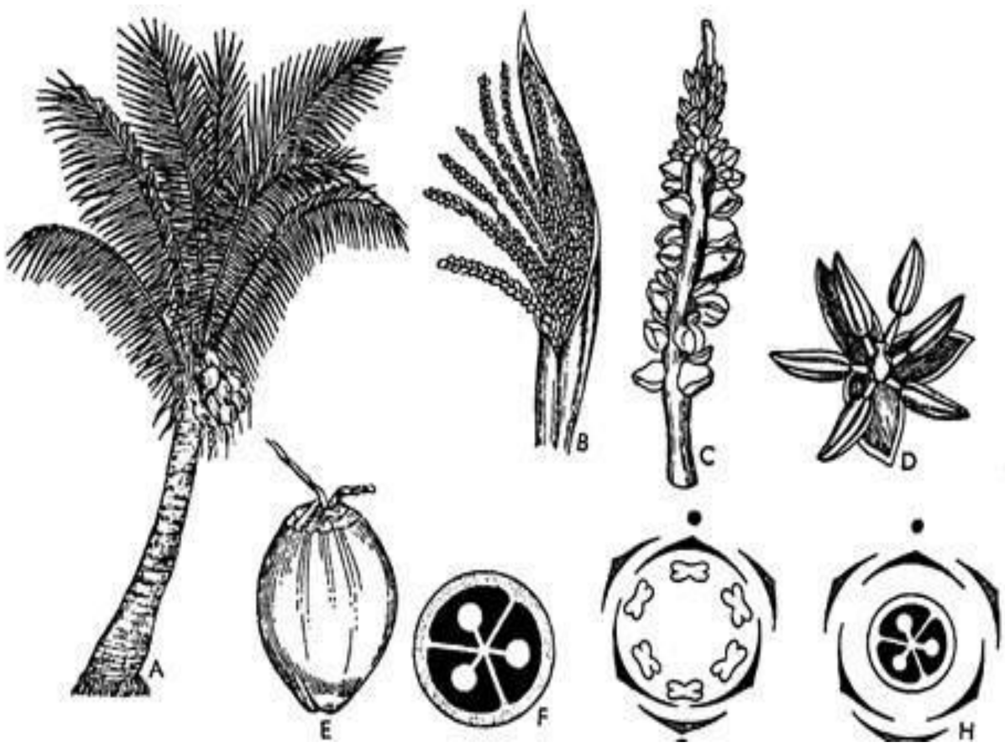

***Fig.10.7 Floral details of Cocos nucifera A. Plant, B. Inflorescence, C. Single rachilla, D. Single Staminate flower, E. Fruit with persistent calyx, F. T.S. Ovary, G. Floral Diagram of Staminate Flower and H. Floral Diagram* of Pistillate Flower**

Gynoecium: In female or hermaphrodite flower- carpels 3 in number, apocarpous or syncarpous, ovary superior, trilocular, axile placentation, single ovule in each locule; style short, stigma small or broad or 3 lobed.

In monoecious plants the position of male and female flowers is variable i.e. male flowers at the base or at the apex and the female flowers at the upper part (*Ruffia, Raphis*) or male and female flowers are inter-mingled or female flowers in the centre, made on the either side as the *Cocos*, *Caryota.*

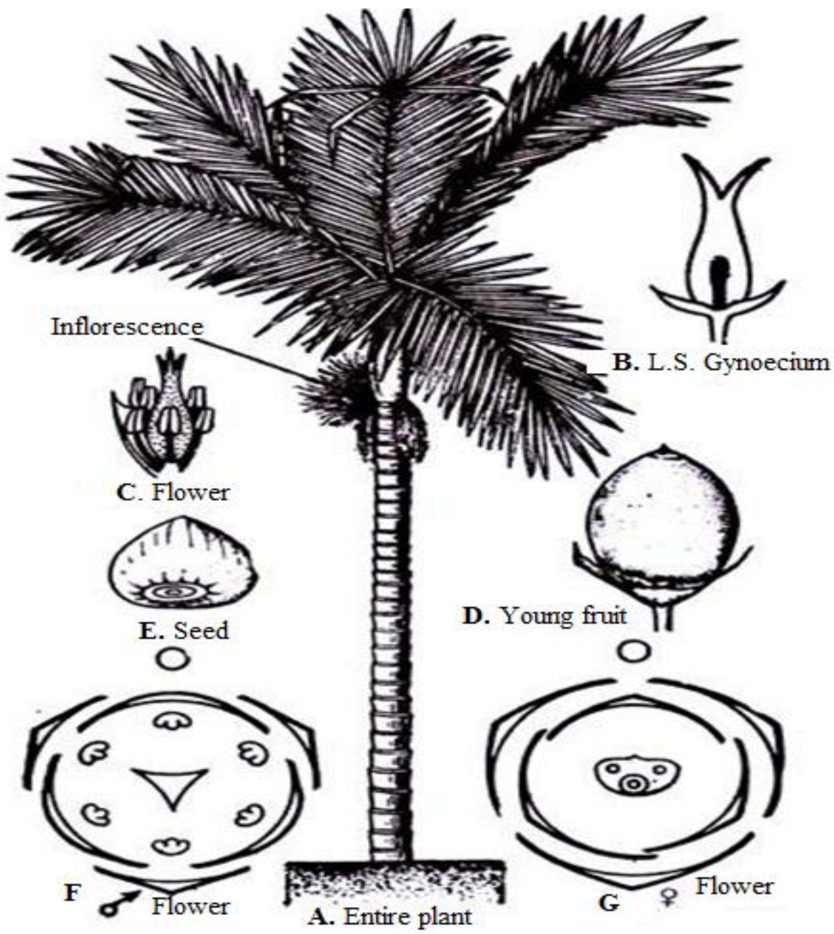

Fig.10.8 Floral details of Areca catechu

Floral formulae:

Hermaphrodite flower: $\oplus$ ♀ P_{3+3} A_{3+3} $\underline{G}_{(3)or3}$

Female flower: $\oplus$ ♀ P_{3+3} A_0 G_0 $\underline{G}_{(3)or3}$

Male flower: $\oplus$ ♂P_{3+3} A_{3+3} G_0

10.5.3. Important Genera

1. *Areca catechu* L. – Betlenut palm (Supari)
2. *Borassus flabellifer* L. – Palmyra palm (Toddy Palm)
3. *Cocos nucifera* L. – Coconut palm (Narikel)
4. *Corypha elata* Roxb. – Tolipot palm

5. *Calamus rotang* L. – Cane palm (Bet)
6. *Phoenix dactylifera* L. – Date palm (Khajur)
7. *P. paludosa* Roxb. – A mangrove plant
8. *P. sylvestris* Roxb. – Wild date palm (Janglikhajur)
9. *Nypa fruticans* Wurmb. – a mangrove plant
10. *Roystonea regia* (Kunth) Cook – Royal palm

10.5.4 Economic Importance

- **Food:** Pith of *Metroxylon rumphii* and *M. leave* (Sago palm) yield sago of commerce. The sap of *Borassus* yields a sugar, which on fermentation gives alcoholic drink "Toddy". Fruits of *Phoenix dactylifera* (Khajoor) are very delicious and eaten throughout the Arab world. The nuts of *Areca catechu* (Supari) serve as a masticatory and used with betel leaves. The milk of *Cocos nucifera* makes a refreshing drink; endosperm is eaten raw and stored when dry.
- **Medicinal:** Tender leaves of *Calamus travancoricus* are given in bilousness, worms and dyspepsia.
- **Fibres:** Mesocarp of the drupes of Coconut are extensively used for stuffing pillows and sofa sets. The cane of commerce is obtained from *Calamus tenuis* and *C. rotang* are used for making mats, baskets and other furniture.

  Borassus flabellifer – yields palmyra fibres which are used to prepare brushes and brooms. The leaves are used in the manufacture of hand fans, umbrellas, baskets and mats.
- **Wax and oil:** Wax is obtained from the leaves of *Copernicia cerifera* and *Ceroxylon andicola*. The wax earlier was used in making gramophone records. Now used in making candles and models.

  Coconut oil is obtained from the *Cocos nucifera* and is used as hair oil, in soap industry and also for cooking.
- **Ornamentals:** *Roystonea regia* (Royal palm), *Corypha elata* (Talipot palm).

Systematic relationship

Rendle placed the family together with the Araceae under Spadiciflorae due to unisexual flowers and occurrence of spadix. Hutchinson (1959) traces the origin of Palms from Liliflorean stock directly from Liliaceae through *Dracaena*- *Cordyline*. Erdtman also reports similar pollen structure of Palms and *Dracaena*. Palmaceae is closely related to Liliaceae in palm-like habit of *Yucca*, *Dracaena* of Liliaceae, perianth segments, stamens in two whorls, tricarpellary, syncarpous ovary, and structure of pollen grains (*Dracaena*).

10.6 CYPERACEAE (THE SEDGE FAMILY)

10.6.1 Systematic position

Bentham and Hooker	**Hutchinson**
Monocotyledons	Monocotyledons
Glumaceae	Glumiflorae
Cyperaceae	Cyperales
	Cyperaceae

Primitive characters:

1. Leaves are simple, alternate with sheathing base.
2. Flowers are hypogynous, hermaphrodite and bracteate.
3. Flowers are actinomorphic.
4. Ovary superior.
5. Seeds are endospermic.

Advanced characters:

1. Plants are herbs, mostly annuals.
2. Leaves are exstipulate.
3. Flowers are small and arranged in spikelets.
4. Flowers are zygomorphic in *Scirpus.*
5. Perianth lobes are absent or represented by hairs.
6. Reduction in the number of stamens.

Distribution

The family is commonly known as ‘Sedge family’. It is distributed throughout the world but most abundant in temperate zones. It comprises 70 genera and 4000 species. In India, it is represented by 441 species.

10.6.2 General Characters

Habit: Plants are commonly perennial herbs rarely annual; perennating by means of creeping rhizomes or tubers. The members are inhabitants of damp places.

Root: Adventitious, fibrous, branched or tuberous.

Stem: Underground rhizomes, tubers or stolons, aerial shoots terete (angled), solid glaucous or glabrous, without distinction into nodes and internodes; usually unbranched rarely branched near the tip.

Leaves: Exstipulate, sessile, leaf base sheathing, sheath closed, eligulate, arranged in three rows, alternate, simple, lamina linear, narrow, pointed, sharply edged.

Inflorescence: Inconspicuous flowers arranged in spikelets, panicles or in spikes of cymose rarely solitary terminal (*Oreobolus*).

Flower: Sessile, bracteate, zygomorphic, hermaphrodite or unisexual arising in the axil of a single glume, hypogynous, small.

Perianth: Usually absent but in some represented by hairs or scales (*Oreobolus)*; flowers naked (*Cyperus*, *Carex*).

Androecium: In male or hermaphrodite flowers stamens usually 3, may be 1 to 6 or one (*Hemicarpa*), polyandrous; anthers dithecous, basifixed, oblong or linear; filaments long and thread -like.

Gynoecium: In female flowers or hermaphrodite flowers gynoecium is bicarpellary (*Rhyncospora*) or tricarpellary (*Carex*), syncarpous, superior, unilocular, single basal ovule; style single or divided into the equal number of carpels; stigma linear or feathery corresponding to the number of carpels. In *Kobresia* ovary is enclosed in a bract or utricle.

Fruit: A flattened 3-angled nut.

Seed: Endospermic.

Floral formulae:

Hermaphrodite flower: % □ P_0 A_{3or6} $\underline{G}_{(3)\text{ or }(2)}$

Male flower: % ♂P_0 A_3G_0

Female flower: % ♀ P_0 A_0 $\underline{G}_{(3)}$

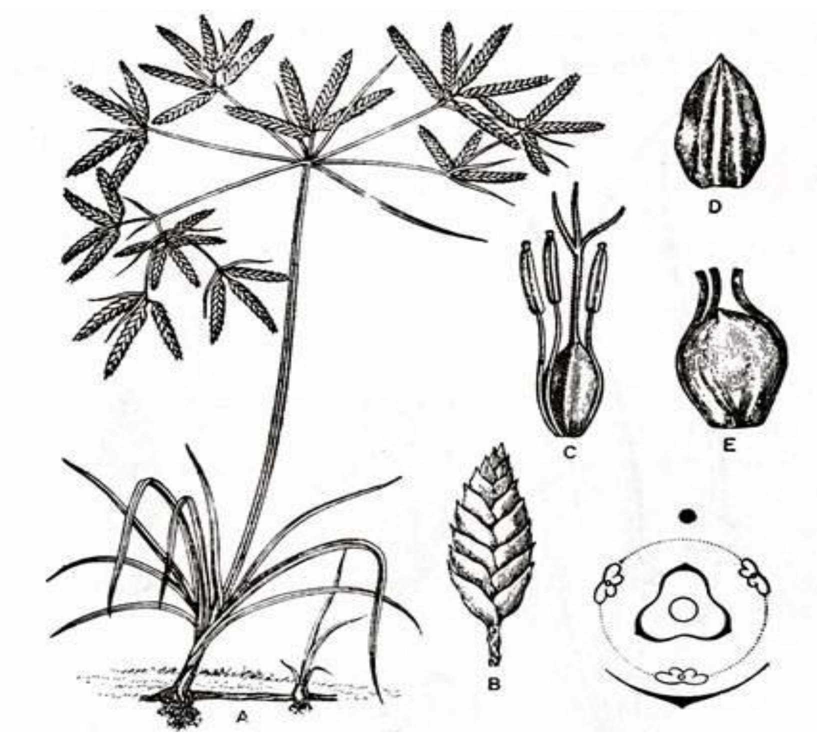

Fig. 10.9 Cyeprus rotundus L. A. plant with leaves and inflorescence, B. part of Spikelet, C. A flower Glume, E. Fruit

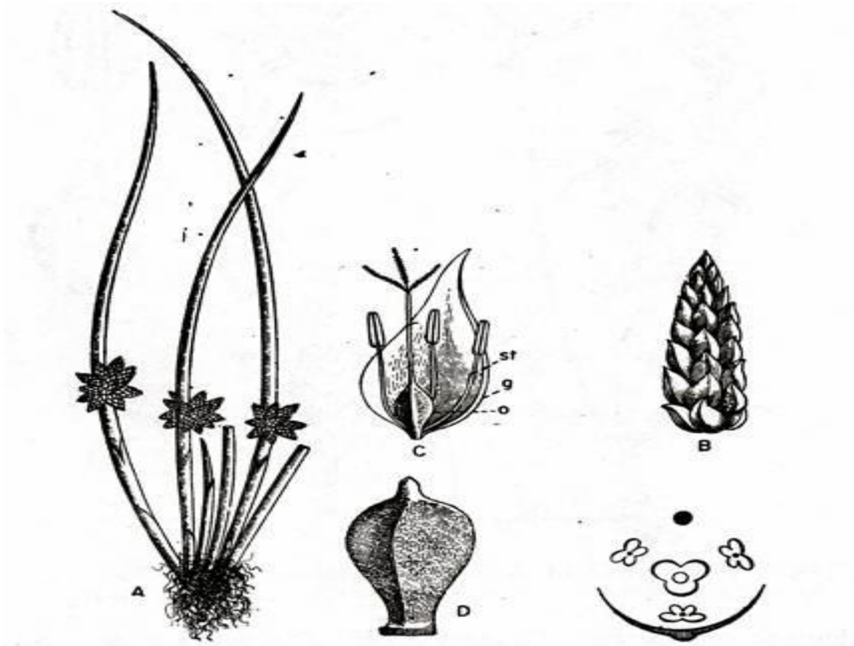

Fig. 10.10 Scirpus articulatus Linn. A. a cluster of leaf like stem, B. part of Spikelet, C. A flower subtended by glume, stamen and ovary, D. Fruit

10.6.3 Important Genera

1. ***Cyperus rotundus*** **(ordinary sedge):** A weed of cultivated lands.
2. ***Carex*****:** Leaves of many species have sharp and saw-like edges.
3. ***Eriophorum comosum*** **(Cotton sedge):** A glabrous herb used for stuffing.
4. ***Fimbristylis:*** A weed having glabrous stem.
5. ***Kyllinga*****:** A perennial glabrous herb common in Western Himalayas.
6. ***Scirpus*** **(Club-rush or bull rush):** A perennial herb found in bogs and marshes.

10.6.4 Economic Importance

The family is of little economic importance.

- **Food:** The tubers of *Cyperus esculentus* are used as food due to their high oil content. The tubers yield 25 to 30% oil of pleasant taste. The tubers of *Eleocharis tuberosa* are also edible.
- **Fodder:** Many species of *Cyperus* are used as fodder.
- **Medicinal:** The tubers and rhizomes of *Cyperus articulatus*, *C. iria* and *C. longus* are carminative, stimulant and tonic. The tubers of *Cyperus stoloniferous* are stimulant for heart.
- The tubers of *Scirpus kysoor*, *S. grossus* are used in diarrhoea and vomitting. *Scirpus articulatus* is purgative. *Kyllingia triceps* is used in diabetes.
- **Poisonous:** *Carex cernua* is cattle poison.
- **Other uses:** *Carex arenaria* and species of *Cyperus* are good sand binders.

- *Scirpus lacustris* is used for matting. Aromatic scented oil is obtained from *Cyperus stoloniferous*.
- **Ornamentals:** *Cyperus alterifolius* and *Isolepis* are cultivated in gardens.

Systematic relationship

The family Cyperaceae closely resembles Poaceae (Gramineae), hence most of the taxonomists have included it with Poaceae under Glumiflorae. Hutchinson and Wettestein placed the family Cyperaceae in a separate monotypic order Cyperales and considered it to have been derived from the members of Juncales or Juncaceae on parallel line with Poaceae (Gramineae). Snell, R.S. (1936) and Blasser, H.W. (1940) indicated that Cyperaceae is not related to Poaceae (Gramineae).

10.7 POACEAE (GRAMINEAE)

10.7.1 Systematic position

Bentham and Hooker	**Hutchinson**
Monocotyledons	Monocotyledons
Glumaceae	Glumiflorae
Poaceae	Graminales
	Poaceae

Distribution

Family Poaceae is one of the largest families in monocots consisting of 620 genera and about 6000 species. Members are cosmopolitan in distribution. The plants represent all the three ecological types as hydrophytes, xerophytes and mesophytes. Around 900 species are present in India.

10.7.2 General Characters

Habit: Mainly herbs (annuals or perennials) or shrubs. Some are trees like (*Bambusa*, *Dendrocalamus*) which attain a height of 30 meters or more in Asiatic bamboos.

Root: Adventitious, fibrous, branched or stilt (as in maize).

Stem: Underground rhizome in all perennial grasses. The aerial stems terminated by inflorescences are known as culm with distinct nodes and internodes, cylindrical, internode usually hollow or sometimes solid (*Zea*), herbaceous or woody.

Leaves: Basal leaves are crowded in a tuft but the leaves on the culm are alternate, simple, exstipulate, sessile, ligulate. Each leaf is usually composed of two parts the sheath and the blade (lamina). The sheath which forms leaf base encircles the culm forming tubular sheath, sheath open. The blade which is the upper portion of leaf is usually flat or sometimes convolute, long, entire, hairy or rough, linear, parallel venation. At the junction of sheath and blade on the inner surface a ligule is present which is a delicate membranous outgrowth varying much in form in different genera.

Inflorescence: The inflorescence terminates the culm and its branches. The basic unit of inflorescence is called spikelet. The spikeltes are sessile or pedicelled and several to many are combined in various ways into spikes (*Triticum*), racemes (*Paspalum*) or panicles (*Avena*). The spikes or racemes are solitary, digitate or scattered along the main axis (rachis).

Each spikelet consists of very short axis called rachilla on which one to many sessile or short stalked florets are borne. The florets may be arranged in alternate or opposite manner on the central axis. At the base of rachilla two sterile scales called glumes are present. The glumes are present one above the other on opposite sides. The lower one is called first glume and the upper is called second glume. Both the glumes are boat shaped and sterile. Sometimes (*Panicum*) there are more than two empty glumes. The sterile glumes are followed by a variable number (1-50) of fertile or flowering glume or lemma. They are often greenish, keeled or rounded. The lemma frequently bears a long, stiff hair (awn) and awned or awnless. A membranous binerved or are bikeeled structure is present in between the fertile glume and the rachilla the strcture known as **palea** which is partially or wholly enclosed by the fertile glume. The palea morphologically represents bracteole below the flower. Each floret has inferior palea or lemma and above it a superior palea.

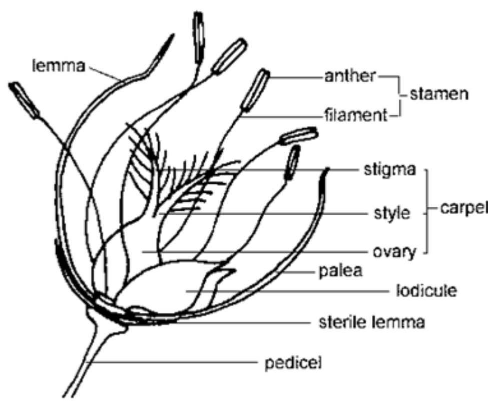

Fig 10.11 Typical spikelet of family Poaceae

Flower: Small, inconspicuous, bracteate, bracteolate, sessile, incomplete, bisexual or unisexual (*Zea mays*), irregular, zygomorphic, hypogynous, cyclic.

Perianth: It is highly modified and much reduced and usually represented by two minute or fleshy and hyaline membranous scales like structure called **lodicules**. The lodicules are situated above and opposite the superior palea or may be absent or many (*Ochlandra*) or three or two.

Androecium: Stamens usually three, sometimes six (*Bambusa*, *Oryza*) rarely one (species of *Festuca*). Rarely numerous stamen (*Pariana*) polyandrous, filaments are long and free, basifixed, anthers dithecous, versatile and linear, extrorse, pollen grains dry.

Gynoecium: Monocarpellary (presumed to be three of which two are aborted), ovary superior unilocular with single anatropous ovule adnate to the adaxial side of the ovary, basal placentation, style short or absent, bifid (trifid in *Bambusa*), feathery or papillate and branched, stigma plumose.

Fruit: A caryopsis with pericarp completely united with the seed coat, rarely a nut (*Dendrocalamus*) or a berry (*Bambusa*).

Seed: Endospermic with a single cotyledon called scutellum which is shield shaped and pressed against the endosperm.

Floral Formula: **% □P** $_{0 \text{ or } 2 \text{ (Lodicules)}}$ **A** $_{3 \text{ or } 6}$ $\underline{G}_1$

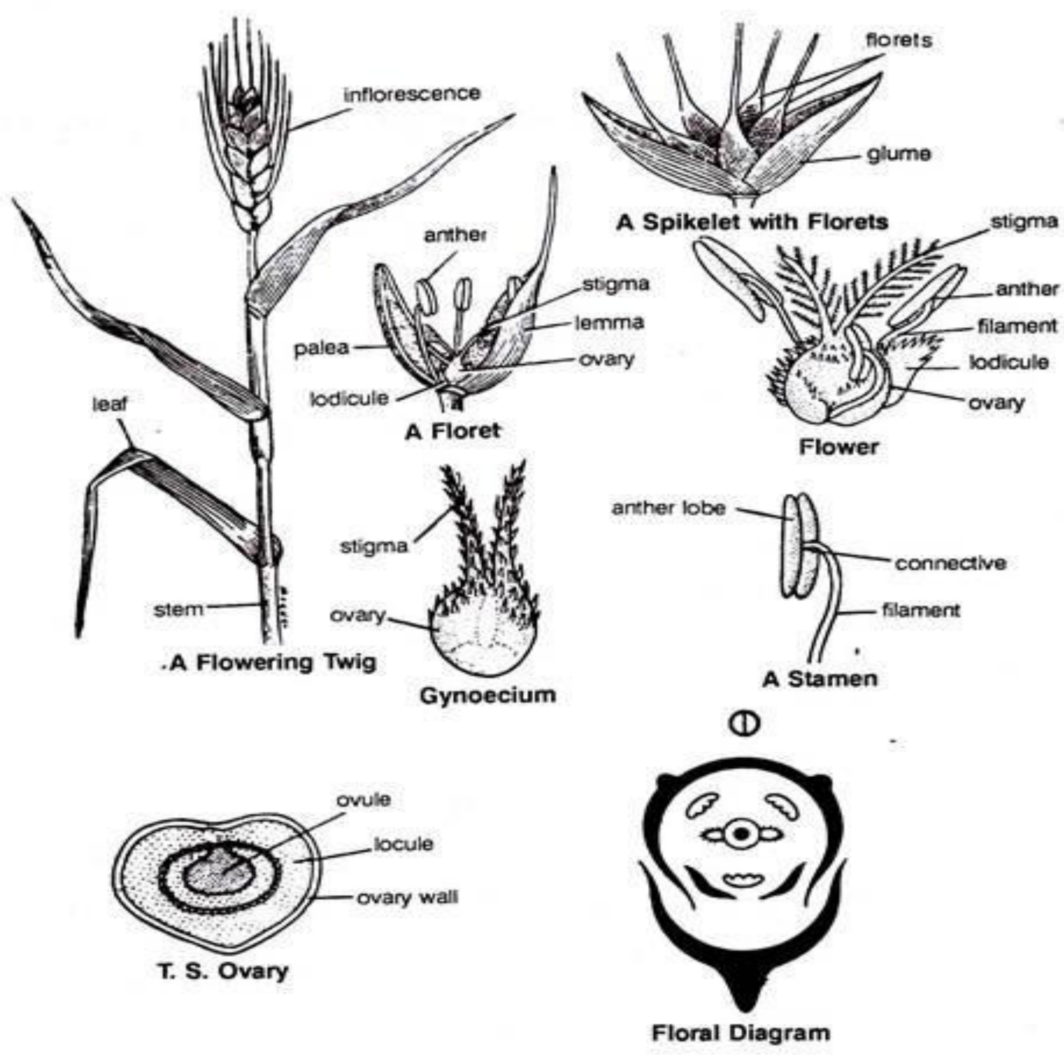

Fig 10.12 Floral details of Triticum aestivum

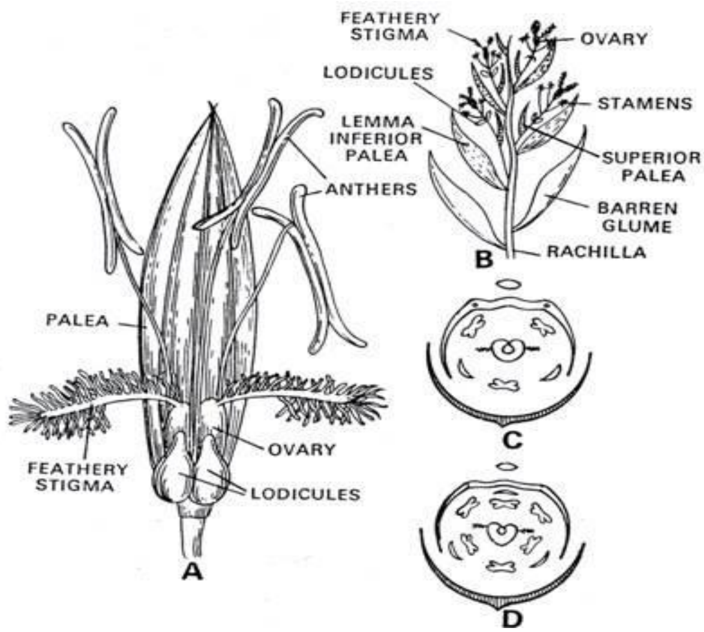

Fig. 10.13 A. Spikelet of Festuca sp.; B. spikelet of grass; C. Floral diagram of grass; D. Floral diagram of Bambusa

10.7.3 Important Genera

Triticum aestivum (wheat), *Zea mays* (corn), *Avena sativa,Oryza sativa* (rice), *Bambusa* (bamboo), *Saccharam officinarum* (Sugarcane), *Hordeum vulgare* (Barley), *Scale cereale* (rye), *Sorghum vulgare* (Jowar), *Pennisetum typhoides* (Bajra), *Cynodon dactylon, Panicum, Cymbopogon, Poa.*

10.7.4 Economic Importance

Family Poaceae stands first and foremost in respect of economic importance in whole of angiosperms. The staple food grains of the population of world are derived from *Oryza sativa* (Rice) and *Triticum aestivum* (Wheat). Economic categories of the family are as follows-

- **Food**: All the cereals and millets belong to this family. These form the basic food of mankind. These plants are: *Tirticum* spp. (Wheat), *Avena sativa* (Oats), *Zea mays* (Corn), *Oryza sativa* (Rice), *Hordeum vulgare* (Barley), *Secale cereale* (rye), *Sorghum vulgare* (Jowar), *Pennisetum typhoides* (Bajra), *Setaria italica* (Italian millet), *Panicum miliaceum (*commom millet), *Eleusine coracana* (Finger millet, Ragi), etc.
- **Fodders**: Most of the fodders of the animals also belong to this family. Many grasses such as *Cynodon dactylon, Panicum, Cymbopogon, Poa* are grown as fodder. The dried stems and leaves of the cereal crops are used as fodder for the cattle.
- **Sugar**: Sugar is obtained from the juice of *Saccharum officinarum* (sugar cane).
- **Aromatic oils:** Many grasses yield aromatic oils which are used in perfumery viz. *Vetiveria zizanoides* (Khus- khus) yield vetiver oil from the roots, *Andopogon odoratus*

(Ginger grass), *Cymbopogon citratus* (Lemon grass), *Cymbopogon martinii* also yield aromatic oil. This oil is used in perfumes and soap industry for making infusions.

- **Paper industry:** Some species of grasses and Bamboos are used for making papers.
- **Alcohol and beverages:** Ethyl alcohol and many other beverages are prepared form cereals. For example, wine is prepared from rye, corn and rum molasses form sugar cane.
- **Ropes:** Fibers are obtained from the leaves of *Saccharum munja*. These fibers are used for making ropes.
- **Uses of Bamboo**: *Bambusa* (bamboo) are used as building material. These are used for thatching huts, making boats, carts pipes etc. Their spilt stems are woven into mars, fans, hats and 'course umbrella'.

Systematic relationship

The family Poaceae closely resembles the family Cyperaceae and the two families have been placed in the same order Glumiflorae by Engler and Prantl and Glumaceae by Bentham and Hooker. Hutcinson (1964) and other modern botanists placed the families into two separate orders the Cyperales and Graminales on the basis of many differences *viz.*

1. Leaf sheath,
2. Jointed and unjointed stem,
3. Single bract and lemma and palea,
4. Seed coat etc.

Hutchinson (1959) believes that the origin of grasses took place on parallel line with Cyperaceae.

10.8 SUMMARY

Monocotyledons are usually characterized by the presence of one cotyledon, fibrous and adventitious roots arising from the base of stem, narrow leaves with parallel veins, herbaceous stem, irregular distribution of the vascular bundles in the stem, trimerous flowers and perianth often not clearly divisible into calyx and corolla. As per Bentham and Hooker, family Orchidaceae comes under series- Microspermae, Liliaceae under series- Coronarieae while Poaceae are included under series- Glumaceae.

Orchidaceae is characterized by perennial herbs, epiphytes or saprophytes may be terrestrial; flower zygomorphic, hermaphrodite, epigynous, resupinated; perianth 6 in two whorls, the posterior segment of the inner whorl developed as lip or labellum; presence of peculiar structure-labium, column and rostellum; Stamens 1-2, one or two staminodes pollen grains united into pollinia; gynoecium tricarpellary, inferior unilocular with parietal placentation; the fertile stamen is adherent to the style and forms it with the column or gynostemium, which projects more or less in the centre of the flower; stigma 2 or 3 lobed, in some two fertile and one sterile and modified into rostellum.

Several taxonomists consider Orchidaceae to be the most advanced and highest evolved among monocotyledons. The characters which support this view include (i) reduction in number of stamens (ii) resupinate epigynous ovary (iii) presence of rostellum (iv) non-endospermic seeds (v) herbaceous habit and (vi) presence of several epiphytes.

Liliaceae is regarded as a typical monocot family and represent the basic monocot stock from which many families have arisen. Herbs rarely shrubs, stem underground rhizome, corn or bulb; leaves alternate, flowers actinomorphic, trimerous, hypogynous, perianth 6 in two whorls of 3 each, free or fused; stamen 3+3, epiphyllous, antiphyllous; gynoecium tricarpellary, syncarpous, ovary superior, axile placentation, two to many ovules per loculus; fruits capsule or berry; seeds endospermic. It has close affinity with Amaryllidaceae from which it can be distinguished by the presence of superior ovary and absence of corona. It is also close to Juncaceae as in both the seeds have albumen but differs in petaloid perianth. The family on account of marked variability in cytological, embryological, and anatomical structures appears to be polyphyletic in origin.

Arecaceae is a botanical family of perennial climbers, shrubs, acaules and trees commonly known as **palm trees.** The family is alternatively called **Palmae.** Plants are generally trees with stout unbranched stem ending in crown of leaves; leaves large, compound, alternate, young leaves are plicate, exstipulate with long petioles; inflorescence enclosed in a persistent spathe; flowers unisexual; perianth 6 in two whorls of 3 each; in male flower 6 stamens in two whorls, anthers versatile; in female flowers carpels three; apocarpous or syncarpous, superior, trilocular or rarely unilocular; fruit berry or drupe; seed endospermic. It includes 217 genera and 2500 species. The members are confined to tropics in both the hemispheres and extending in the warmer regions of the world. In India it is represented by 225 species belonging to 25 genera.

Cyperaceae, sedge family of monocotyledonous flowering plants, a division of the order Poales. The Cyperaceae are grass like herbaceous plants found especially in wet regions throughout the world. Plants usually herbs with 3 angled stem, solid culm; leaves with entire sheathing base not split on one side; flowers in spikelets of cymes, subtended by a single glume, naked or with perianth of scales or hairs; stamens 1 to 3; carpels 2 or 3, ovary superior, unilocular with single basal ovule; fruit an achene or nut, seed endospermic. The family is commonly known as ‘Sedge family’. It is distributed throughout the world but most abundant in temperate zones. It comprises 70 genera and 4000 species. In India, it is represented by 441 species.

Poaceae (Gramineae) is the large and nearly ubiquitous family of monocotyledonous flowering plants known as grasses. Grasses have stems that are hollow except at the nodes and narrow alternate leaves borne in two ranks. The lower part of each leaf encloses the stem, forming a leaf-sheath.

Mostly herbs, stem jointed, fistular, cylindrical, leaves simple, alternate, sheathing, sheath open , ligulate, inflorescence compound spike, flowers zygomorphic, hypogynous, protected by **palea**, perianth represented by 2-3 minute scale (**lodicules**), stamens 3 , versatile, carpel one style 2or 3, stigma feathery, basal placentation, fruit caryopsis, testa fused with pericarp.

Comparison of Graminae and Cyperaceae

Gramineae	Cyperaceae
1. Stem: Cylindrical, hollow; nodes present.	Triquetrous, solid; nodes absent.
2. Leaves: Distichous, ligulate; sheath split on one side.	Tristichous, not ligulate; sheath closed.
3. Bracts: Glumes, lemma and palea; no involucral bracts.	Single floral bract, leafy involucral bracts present.
4. Perianth: 2–3 lodicules.	Absent or represented by hairs or bristles.
5. Androecium: Anthers versatile.	Anthers basifixed.
6. Gynoecium: Carpels 3 of which 2 abortive.	Carpels 3, united.
7. Fruit: Usually caryopsis.	Achene, nut or utricle.
8. Embryo: Lies outside the endosperm, coleoptile and coleorhiza present.	Lies embedded in the endosperm, no coleoptile or coleorhiza.
9. Germination: No part of the cotyledon comes out during germination.	Terminal part of the cotyledon comes out during germination.

10.9 GLOSSARY

Achene: Small dry indehiscent one seeded fruit seed not totally fused with ovary wall.
Adventitious root: growing from stems or leaves.
Alternate: Leaves occur single at each node and so arranged that a line drawn on the stem through the leaf base.
Anemophilous pollination: Adapted for wind pollination.
Basifixed: Fixed to the filament (stalk) at the base.
Bract: A leaf or scale in whose axil an inflorescence, flower or floral organ is produced.
Caryopsis: A seed like fruit resembling achene, seed coat firmly united to the wall of ovary.
Cauline: leaf borne on the main stem.
Dormant bud: Inactive bud due to season i.e. winter or summer.
Dorsifixed: When filaments appear to be inserted at the back of the anther.
Endosperm: The tissue that stores food outside the embryo. It originates from union of second sperm nucleus with the secondary nuclei.
Entomophilous: Adapted for insect pollination.
Fibrous: Slender and usually tough.
Hairy: Surface with hair.
Herbaceous: Die at the end of season’s growth.
Lanceolate: Narrow and tapering towards the end.
Ligule: The extension at the top of the leaf sheath of grasses. In Poaceae the collar like extension

of the leaf sheath clasping the stem above the attachment of the blade.
Linear: Very narrow without parallel margins.
Lobed stigma: Stigma having lobes.
Nut: Like achene but pericarp hard, tough, woody protecting seed.
Opposite: Two leaves at a node on opposite sides.
Panicle: Indefinitely branching, long pedicelled loosely branched compound raceme.
Parallel venation: Veins run parallel to each other.
Radical: Leaf borne on reduced stem and appears to come from root.
Ramal: Leaf borne on the branches.
Sheath: Basal portion of grass or sedge leaves surrounding the stem.
Spike: A central axis bearing sessile flowers along its sides.
Staminode: Sterile stamen with reduced anther.
Stipules: Scale like attachment at the base of the petiole.
Versatile: When the filament is attached to the back of the anther by a fine point so that the anther swings freely e.g. grasses.
Zygomorphic: Flower divisible into two equal in one plane only.

10.10 SELF ASSESSMENT QUESTION

10.10.1 Multiple Choice Questions:

1. In Poaceae the fruits are usually
(a) Follicle (b) Nutlets
(c) Capsule (d) Caryopsis

2. Resupination *i.e.* twisting to 180^0 or upside down is characteristic feature of which one of the following families
(a) Liliaceae (b) Acanthaceae
(c) Orchidaceae (d) Poaceae

3. A plant that belongs to Liliaceae in which stipules are modified into tendrils is
(a) *Gloriosa* (b) *Yucca*
(c) *Lilium* (d) *Smilax*

4. The inflorescence of Paddy is
(a) Racemose (b) Catkin
(c) Panicle (d) Verticillaster

5. In Poaceae the lodicules are
(a) Petals (b) Perianth leaves
(c) Sepals (d) Bract

6. Genus *Colchicum* belongs to which one of the following families

(a) Liliaceae (b) Acanthaceae

(c) Orchidaceae (d) Poaceae

7. The highly modified tepal of orchidaceous flower is called

(a) Lip or labellum (b) Standard

(c) Spur (d) Wings

8. Gynandrium or column, which is the most characteristic part of orchid flower is formed by

(a) Stamen (b) Style and stigma

(c) Perianth (d) By adnation of stamen style and stigma

9. Which one of the following families stands first and foremost in respect of food and fodder

(a) Asteraceae (b) Poaceae

(c) Liliaceae (d) Brassicaceae

10. Which of the following family is known as the 'Sedge family'

(a) Cyperaceae (b) Poaceae

(c) Arecaceae (d) Liliaceae

10.10.2 Fill in the blanks:

1. Caryopsis fruit is the characteristic feature of family…………………………
2. *Vanilla*, is a member of …………………. family.
3. Labellum is the characteristic feature of …………………………..family.
4. Fruit of *Cocos nucifera* is……………………………….
5. *Zea mays* is the member of family…………………….

10.10.1 Answers Key: 1(d), 2(c), 3(d), 4(c), 5(b), 6(a), 7(a), 8(d), 9(b), 10(a).

10.10.2 Answers Key: 1.Poaceae, 2.Orchidaceae, 3.Orchidaceae, 4.Drupe, 5.Poaceae

10.11 REFERENCES

- Bentham, G and J.D. Hooker, 1862. *Genera Plantarum 3*Vols, Reeve &Co., London.
- Bessey,C.E., 1915, *Phylogenetic taxonomy of flowering plants, Ann. Mo. Bot. Gard*, 2: 109-164
- Engler, A.W and K. Prantl, 1887-1915 *Die Naturlichen Pflanzenfamilien*,23, Vols. Leipzig
- Hutchinson, J., 1969 Evolution *and Phylogeny of the Flowering Plants*, Academic Press, London
- Takhtajan, A. 1969, *Flowering Plants: Origin and Dispersal*. Oliver & Boyd. Ltd. Edinurgh

10.12 SUGGESTED READINGS

- Singh, V, and D.K. Jain 1981. *Taxonomy of Angiosperms*, Rastogi Publications,Merrut
- Singh, V, Pande , P.C. and D.K. Jain 1999. *A Text book of Botany: Angioperms*
- Pandey, B.P. Botany for Degree Students- B.Sc. Second year, 2007. S. Chand Publications, New Delhi
- Sharma ,O.P. *Plant Taxonomy* (Second edition) 2010. The Mc Graw Hill Company, Kolkata

10.13 TERMINAL QUESTIONS

1. Write descriptive note on economic importance of family Poaceae.
2. Describe economic importance of family Liliaceae.
3. Write descriptive note on floral features of Orchidaceae.
4. Write comparative account on feature of families Poaceae and Cyperaceae.
5. Write short note on the following:
   (i) Lodicules (ii) Gynostegium (iii) Labellum (iv) Lemma and Palea (v) Resupination
6. Give comparative account of monandrous and diandrous types of orchids.
7. Describe family Arecaceae in semi-technical language.
8. Write Botanical name, family and plant part from which the following products come
   (i) Date (ii) *Areca* nut (iii) Coconut