BSCBO- 201

B.Sc. II YEAR

Taxonomy of Angiosperm And Biodiversity

DEPARTMENT OF BOTANY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

BSCBO-201

TAXONOMY OF ANGIOSPERMS AND BIODIVERSITY

SCHOOL OF SCIENCES
DEPARTMENT OF BOTANY
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CONTENTS

BLOCK-1ANGIOSPERMS: GENERAL CONSIDERATION	PAGE NO.
Unit-1- Historical background and Evolution of classification of Angiosperms	6-37
Unit-2- Basic principles, Plant nomenclature and ICBN	38-59
Unit-3- Tools and techniques in collection and Preservation of specimens	60-77
Unit-4- Botanical Gardens and Herbaria	78-105
BLOCK-2 FAMILIES	**PAGE NO.**
Unit-5- Ranunculaceae, Caryophyllaceae and Rutaceae	107-129
Unit-6- Rosaceae, Fabaceae and Asclepiadaceae	130-157
Unit-7- Solanaceae, Acanthaceae and Lamiaceae	158-180
Unit-8- Orchidaceae, Liliaceae and Poaceae	181-202
BLOCK-3 BIODIVERSITY AND CONSERVATION	**PAGE NO.**
Unit-9- Biodiversity- Basic concepts	204-227
Unit-10-Biodiversity Conservation - *In situ* and *Ex situ*, Gene bank, NBPGR	228-246
Unit-11-Biodiversity –Hotspots and Megabiodiversity countries	247-259
Unit-12- Floristic diversity of India and Endemism	260-275

BLOCK-1 ANGIOSPERMS: GENERAL CONSIDERATION

UNIT-1 HISTORICAL BACKGROUND AND EVOLUTION OF CLASSIFICATION OF ANGIOSPERMS

1.1 Objectives
1.2 Introduction
1.3 History
1.4 Fundamental components of Taxonomy
1.5 Aims of Taxonomy
1.6 Bentham and Hooker's System
1.7 Engler and Prantl System
1.8 Hutchinson's Classification
1.9 Summary
1.10 Glossary
1.11 Self Assessment Questions
1.12 References
1.13 Suggested Readings
1.14 Terminal Questions

1.1 OBJECTIVES

The main goal of this chapter is to broaden your understanding about the following issues:-

- Definition of classification
- History of classification
- Aims of Taxonomy
- Bentham and Hooker's system
- Hutchinson's system of classification

1.2 INTRODUCTION

Plant taxonomy is one of the earliest disciplines of Botany. It was started as "Folk Taxonomy" in early 15^{th} century but it has grown and gone very long way in the last 500 years. The concept and scope of Taxonomy has changed a lot. Though the flora of the earth was invented in the last three centuries yet the modern taxonomists are facing challenges. The tropical countries with rich flora are under threat. So far 4,000,000 plant species are identified of which 2, 86,000 are of angiosperms. Among the identified plants about seventy percent belong to tropical regions.

In the modern times people are running for the applied sciences as cytology, genetics, experimental biology, ecology, molecular biology etc. but a few people are thinking of the basic or fundamental branches of botany like Taxonomy and Morphology. It has become an old fashion. No applied branch can be approached without the proper identification of the plant material on which he/she is working and for this taxonomists are very much needed.

With the increased need for conservation of biological resources, the need for biodiversity assessment during the last few years has increased. The trend has, however, reversed and taxonomic studies are being encouraged throughout the world.

Simpson (1961) suggested that systematics included identification, taxonomy, classification and nomenclature and used as the scientific study of the kinds and diversity of organism and of any and all relationship between them. de Candolle (1813) first coined the term taxonomy.

Classification denotes the arrangement of a single plant or group of plants in distinct category following a system of nomenclature and in accordance with a particular and well established plan. The basic unit of classification is species which are grouped into genus and further grouped into family suborder, order, subclass, classes and divisions.

The beginning of the classification of organism took place at remote times by the non civilized people for their usage and in their own language, with the development of language the distinction between carnivores, herbivores, poisonous plants, edible plants etc. became clear. They feel the necessity of different plants and animals for their use. They selected certain plants and animals for festivals. In this way, the classification in crude sense got the foothold in the

society. Folk systematics is gaining popularity among the pre civilized men. They recognized groups of plants on the basis of gross morphology. This is the beginning of the artificial system of classification. Their ways of classification are rooted in their practical considerations. The history of classification starts from the time of the earliest Indian Philosophers like Charak, Sushruta, early Greek philosophers like Aristotle, Plato, Pliny and others also tried to classify plants from their own viewpoint which invariably were more philosophical in nature than scientific. The various classifications of plants proposed so far, belong to either of the three categories:

(a) Artificial: System classifies plants with the help of one or few characters, primarily with a intention of easy identification of the organism e.g. Banhin, Tournefort, John Ray, Carl Linnaeus.

(b) Natural: System is mainly based on from relationship realizing all informations available at that time. e.g., de Candolle, Robert Brown, de Lamarck, Bentham and Hooker's classification.

(c) Phylogenetic: System tries to classify plants based on their genetic relationships and according to their evolutionary sequences. e.g., Eichler, Hutchinsm, Bessey.

C. Jeffrey (1982) presented that the system of classification can be divided into four main types:

(a) Artificial: Habit based classification made upto 1830.

(b) Pre evolutionary Natural Systems: Overall similarly between plants were much more natural e.g., Bentham & Hooker, A. P. de Candolle, de Jussieu.

(c) Phylogenetic Systems: Natural grouping as a result of decent or common character are related to each other through a common ancestry, e.g., Eichler, Engler.

(d) Phenetic System: Maximal generalizations of the totality of the features of all phenotypes e.g. Hutchinson.

1.3 HISTORY

History of taxonomy begins with the categorization of useful plants of folk taxonomy. People differentiated them as economic plants. This paved the way for herbal taxonomy. The history can be studied in different phases as follows:

I. Initial Stage

- Theophrastus (370-285 BC) a Greek Naturalist also known as Father of Botany published "Enquiry into Plants". He proposed *Crataegus, Daucus* (daukan), *Asparagus* (aspargos) and *Narcissus* etc. in his work. He classified plants on habit base as herbs, undershrubs, shrubs, trees. He gives the name and description to 500 plants in *Historia Plantarum* oldest botanical work in existence. He pointed out the differences between dicots and monocots.
- Pliny (23-29) AD wrote multivoluminous *Natural History* of which 37 volumes are present.

- Pedanion Dioscorides (62 - 128 AD), a physician of Asia minor described 600 medicinal plants. His book was named *Materia Medica* in Greek.
- Andrea Caesalpino (1519 - 1603 AD) a Italian physician wrote *De Plantis* (1583), 1500 plants were described, Woody / herbaceous.
- Gaspard Bauhin (1560 - 1624 AD) Collected the plants from Italy, France, Switzerland, Books are *Prodromus Theati Botanici* (1620), *Penax Theati Botanici* (1623). He first attempted to use binomial system of nomenclature.
- John Ray (1628 - 1705 AD). British Botanist published 3 volumes *Historia Plantarum* (1686 - 1704). He is the first who divided the herbs / trees and divided monocotyledons and dicotyledous on the basis of one and two cotyledons.
- J. P. de Tournefort (1656 - 1708) described trees and herbs and considered corolla.
- The first herbarium was established in 1553 in Padua (ITALY)
- In the middle of 17th century, herbaria were established in different parts of the world.
- Carolus Linnaeus (1707 - 1778), a Swedish Naturalist also known as father of modern botany / taxonomy. He published *Genera Plantarum* (1737), *Classes Plantarum* (1738), *Philosophia Botanica* (1751), *Species Plantarum* (1753). 7300 species were described and arranged on sexual system. It was an artificial system based on few characters. He introduced Binomial system eg., *Rhododendron arboreum*. 24 classes of Linnaeus are (1) Monandria (one Stamen) (2) Diandria (2 stamen) ..... (24) Cryptogamia (No flower).
- In initial stage taxonomy was merely started for exploration and naming of species.

II. Natural System Stage

- Antoine L de Jussieu (1686 - 1758) published *Genera Plantarum* and classified plants into 15 classes.
- Augustin Pyrame de Candolle (1778 - 1841), a French botanist published *Theorie elementaire de la botanique* in 1813 and developed morphological approach to classification. He classified plants as Vasculares and Cellulares, Monumental works - *Prodromus Systematis Naturalis Regni Vegetabilis*. A. P. de Candolle could not complete his work and later his son Alphonse de Candolle completed the work.
- Charles Darwin (1859) published *Origin of Species*, where he suggested the principle of natural selection and evolutions of species.
- Bentham and Hooker (1800 - 1884) published *Genera Plantarum* (1862 - 1883) gave practical use of classification "ever since been as inspiration to generations of the Kew Botanists".

III. Phylogenetic Stage

- Phylogenetic classification was based on the ideas of evolution. It started with Endlichler (1804-1849) and Eichler (1837-1887).
- Engler and Prantl. (1887-1915) suggested semi-phylogenetic system of classification.
- *Die Natiirlichen Pflanzen Familien* (1887 - 1899) and S*yllabus der Pflanzen Familien* (1964). He placed monocots before dicots and orchids were considered more evolved than grasses.
- Class 1 : Monocotyledons - 11 orders
- Class 2 : Dicotyledons
- Sub class - 1. Archichlamydeae - 29 orders.
- Sub class 2. Metachlamydeae (Sympetalae) - 9 orders
- A. B. Rendle (1865 - 1938) Classification of flowering plants. He treated monocots as primitive to dicots and amentiferae and apetalous as primitive dicots.
- The first purely phylogenetic system based on *Dictas of Phylogeny* was given by Charles Edwin Bessey (1845-1915) which was improved by Hans Hallier (1868-1938)
- John Hutchinson (1884 - 1972)) Britishers, put forth his 24 principles of phylogeny and based on that suggested phylogenetic classification of value, in *Families of Flowering Plants* (1959). His classification was based as Bentham and Hooker and Bessey. First volume deals with Dicots (1928), second with Monocots (1934) and published *British Flowering Plants* (1940).

IV. Recent Stage

- The system was improved by contemporary Botanists like Takhtajan in *Flowering Plants: Origin and Dispersal* (1969); Cronquist in *"Evolution and Classification of Flowering Plants"* (1981) Stebbins in *Flowering Plant Evolution above the Species Level* (1974) and Robert Thorne in "*A Phylogenetic Classification of Angiospermae"* (1976) etc.
- The Classifications were based on distribution, Ecology, Anatomy, Palynology Cytology and Biochemistry apart from Morphology.
- Techniques of herbarium preparation and presentation were developed and established.

V. Biosystematic Phase

- The last fifty years have seen a qualitative improvement in the area of taxonomic concept and application by advancement of Biosystematics.
- The "New systematics" is aimed at achieving the goal of "holotaxonomy".
- Huxley (1940) proposed the term "New systematics."
- Camp and Gilly (1943) proposed the term "Biosystematics" to new systematics.

- The number, size and shape of chromosomes were considered by cytotaxonomists as very reliable parameters for cytotaxonomic classification.
- The development of techniques like two-dimensional paper chromatography, identification of chemical substances in plants as secondary metabolites led to the development of "Chemotaxonomy".
- The new techniques can give details as amino acid sequencing and determining nucleotide sequences in DNA and RNA.

VI. Holotaxonomic Phase

Information is gathered, analysed, and a meaningful inference is drawn for understanding phylogeny.

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

1.4 FUNDAMENTAL COMPONENTS OF TAXONOMY

Taxonomy is a fundamental science with the increase in knowledge of various components developed.

(i) **Alpha Taxonomy** (Descriptive taxonomy): The aspect of taxonomy is concerned with the description and designation of species. Typically on the basis of morphological characters, it developed in 19th century. It started with work of Tournefort, de Jussieu and Linnaeus**.**

(ii) **Beta Taxonomy** (Macrotaxonomy): The arrangement of species into hierarchical system of higher categories or taxa. It developed in 20^{th} century.

(iii) **Gamma Taxonomy:** Aspects of taxonomy concerned with intraspecific population and with phylogenetic trends are included in gamma taxonomy. An attempt is made to account for the origin and development of species. To determine the origin of a species, a taxonomist has to depend on paleobotany which includes all taxa of extinct plant groups.

(iv) **Omega taxonomy:** It is an ultimate perfect system, based upon all available characters.

The best is the concept of Alpha-Omega Taxonomy. As alphataxonomy forms the basis of biology while the final accumulation of all data is ultimately incorporated into Omega taxonomy.

1.5 AIMS OF TAXONOMY

There are three main aims of taxonomy, *i.e.,* Identification, nomenclature and classification. There are two main approaches:

(a) **Empirical approach:** It is based on practical aspects, observation of characters etc.

(b) **Interpretive approach:** The classification is based on interpretation and evolution of a taxon, e.g., phylogenetic system. Modern taxonomy combines both approaches with the following aims:

1. To provide a convenient method of identification and communication.
2. To provide classification which is based on natural affinities of organisms as far as possible.
3. To provide an inventory of plant taxa by means of flora.
4. To detect evolution at work, discovering its process of interpreting into results.
5. To provide an integrating and unifying role in the training of biology students regarding the relationships between many biological fields and data gathering science.

Deme Terminology

Gilmour and Gregor (1939) proposed the new system of terminology providing an infinitely flexible series of categories used to define any group of individuals. The system is known as Deme terminology. It is non-hierarchical and does not consider genus, species etc. Deme implies to a group of related individuals of a particular taxon. The precise meanings of the term are provided by various prefixes.

Topodeme: A deme occuring within a specified geographical area.

Ecodeme: A deme occuring within a specified kind of habitat.

Gamodeme: A deme composed of individuals which interbreed in nature.

Phenodeme: A deme differing from others phenotypically.

Plastodeme: A deme differing from others phenotypically but not genotypically.

Genodeme: A deme differing from others genotypically.

Autodeme: A deme composed of predominantly self fertilizing or autogamous individuals.

Endodeme: A deme composed of predominantly closely in-breeding (endogamous) but dioecious individuals.

Agamodeme: A deme composed of predominantly apomictic (non-sexually reproducing) individuals.

Clinodeme: A deme which together with other such deme forms a gradual variational trend over a given area.

Cytodeme: A deme composed of individuals all with the same karyotype (chromosome morphology).

Genoecodeme: An ecodeme differing from others genotypically (Ecotype)

Plastoecodeme: An ecodeme differing from others phenotypically and not genotypically (Ecophene).

1.6 BENTHAM AND HOOKER'S SYSTEM

The well known English systematists who brought out jointly '*Genera Plantarum*' (1862 - 1883) and their classification is used throughout the British empire. In our country the Central National Herbarium at Sibpur (Howrah) W. Bengal is maintained according to this system.

The system of classification is based on that of de Candolle, but greater stress is being given on the contrast between free and fused petals. The dicots are divided into Polypetalae, Gamopetalae and Monochlamydeae. The position of Gymnosperms between dicots and monocots is only for convenience rather than an indication of affinities.

An outline classification of Bentham and Hooker's system (1862 - 1883) is given below.

Class : Dicotyledons

Sub class 1 Polypetalae comprises three series

Series A: Thalamiflorae - 6 orders and 34 families

Order 1. Ranales - 8 families

Families: Ranunculaceae, Dilleniaceae, Calycanthaceae, Magnoliaceae, Annonaceae, Menispesmaceae, Berberideae, Nymphaeaceae.

Order 2. Parietales : 9 families

Families: Sarraceniaceae, Papaveraceae, Cruciferae, Capparideae, Resedaceae, Cistineae, Violaceae, Canellaceae, Bixineae.

Order 3. Polygalineae : 4 families

Families: Pittosporeae, Tremendreae, Polygaleae, Vochysiaceae.

Order 4. Caryophyllinae : 4 families

Families: Frankeniaceae, Caryophylleae, Portulacaceae, Tamariscineae.

Order 5. Guttiferales : 6 families

Families: Elatrineae, Hypericineae, Guttiferae, Ternstroemiaceae, Dipterocarpeae, Chlaenaceae.

Order 6. Malvales : 3 families

Families: Malvaceae, Sterculiaceae, Tiliaceae.

Series B: Disciflorae - 4 orders and 23 families

Order 7. Geraniales : 11 families

Families: Lineae, Humiriaceae, Malphighiaceae, Zygophyllaceae, Geraniaceae, Rutaceae, Simarubeae, Ochnaceae, Burseraceae, Meliaceae, Chaillentiaceae.

Order 8. Olacales : 3 families

Families: Olacineae, Ilicineae, Cyrilleae.

Order 9. Celastrales : 4 families

Families: Celastrineae, Stockhousieae, Rhamneae, Amplelideae.

Order 10. Sapindales : 5 families

Families: Sapindaceae, Sabiaceae, Anacardiaceae, Anomalous families Coriarieae and Moringeae.

Series C: Calyciflorae - 5 orders and 25 families

Order 11. Rosales: 9 families

Families: Connaraceae, Leguminosae, Rosaceae, Saxifrageae, Crassulaceae, Droseraceae, Hamomelideae, Bruniaceae, Halorageae.

Order 12. Myrtales : 6 families

Families: Rhizophoraceae, Combretaceae, Myrtaceae, Melastomaceae, Lythrarieae, Onagrarieae.

Order 13. Passiflorales : 7 families

Families: Samydaceae, Loaceae, Turneraceae, Passifloreae, Cucurbitaceae, Begoniaceae, Datisceae.

Order 14. Ficoidales : 2 families

Families: Cacteae, Ficoideae

Order 15. Umbellales : 3 families

Families: Umbelliferae, Araliaceae, Cornaceae

Sub class III Gamopetalae - Comprises three series.

Series A: Inferae - 3 order and 7 families.

Order 1. Rubiales : 2 families

Families: Caprifoliaceae, Rubiaceae.

Order 2. Asterales : 4 families

Families: Valerianeae, Dipaceae, Calyceerae, Compositae.

Order 3. Campanulales : 3 families.

Families: Stylideae, Goodeniaceae, Campanulaceae.

Series B: Heteromerae - 3 orders and 12 families

Order 4. Ericales : 6 families

Families: Ericaceae, Vaccinieae, Monotropeae, Epacrideae, Diapensiaceae, Lennoaceae.

Order 5. Primulales : 3 families

Families: Plumbaginaceae, Primulaceae, Myrsineae.

Order 6. Ebenales : 3 families

Families: Sapotaceae, Ebenaceae, Styraceae.

Series C: Bicarpellatae - 4 orders and 23 families

Order 7. Gentianales : 5 families

Families: Oleaceae, Salvadoraceae, Apocynaceae, Asclepiadaceae, Loganiaceae, Gentianaceae.

Order 8. Polemoniales : 5 families

Families: Polemoniaceae, Hydrophyllaceae, Boraginaceae, Convolvulaceae, Solanaceae.

Order 9. Personales

Families: Scrophalariaceae, Orobanchaceae, Lentiburaceae, Columelliaceae, Gesneraceae, Bignoniaceae, Pedalineae, Acanthaceae.

Order 10. Lamiales : 5 families

Families: Myoporineae, Selagineae, Verbenaceae, Labiatae, Anomalous family Plantagineae.

Sub class III. Monochlamydeae or Incomplete comprises A-H or 8 series.

Series A. Curvembyae : 7 families.

Families: Nyctagineae, Illecebraceae, Amarantaceae, Chenopodiaceae, Phytolaccaceae, Batideae, Polygonaceae.

Series B. Multiovalatae Aquaticae : 1 family

Family: Podostemaceae.

Series C: Multiovulatae Terrestris : 3 families.

Families: Nepenthaceae, Cytinaceae, Aristolochieae.

Series D: Microembryae : 4 families.

Families: Piperaceae, Chloranthaceae, Myristicaceae, Monimiaceae.

Series E: Daphnales : 5 families

Families: Laurineae, Proteaceae, Thymeleaceae, Penaeaceae, Elaeagnaceae.

Series F: Achlamydosporeae : 3 families

Families: Loranthaceae, Santalaceae, Balanophoreae.

Series G: Unisexuales : 9 families

Families: Euphorbiaceae, Balanopseae, Urticaceae, Platanaceae, Leitneriaceae, Juglandeae, Myricaceae, Casurinaceae, Cupuliferae.

Series H: Ordines Anomali (Anomalous families : 4)

Families: Salicaceae, Lacistermaceae, Empetraceae, Ceratophylleae.

Class 2: Gymnospermae : 3 families.

Families: Gnetaceae, Coniferae, Cycadaceae.

Class 3: Monocotyledons (A - G) : 7 series.

Series A: Microspermae : 3 families

Families: Hydrocharideae, Burmanniaceae, Orchideae.

Series B: Epigynae : 7 families.

Families: Scitamineae, Bromeliaceae, Haemodoraceae, Irideae, Amaryllideae, Taccaceae, Dioscoreaceae.

Series C: Coronarieae : 8 families

Families: Roxburghiaceae, Liliaceae, Pontederiaceae, Philydraceae, Xyrideae, Mayaceae, Commelinaceae, Rapateaceae.

Series D: Calycinae: 3 families

Families: Flagellarieae, Juncaceae, Palmae.

Series E: Nudiflorae : 5 families

Families: Pandanaceae, Cyclanthaceae, Typhaceae, Aroideae, Lemnaceae.

Series F: Apocarpeae : 3 families

Families: Triurideae, Alismaceae, Naidaceae.

Series G: Glumaceae : 5 families

Families: Eriocauleae, Centrolepideae, Restiaceae, Cyperaceae, Gramineae.

Characteristics of Bentham & Hooker

Emryo with two cotyledons: stem with open vascular bundles; leaves netted (reticulate) venation; flowers usually pentamerous, *Class*: *Dicotyledons*

Embryo with a single cotyledon: stem with vascular closed bundles; leaves with parallel venation; flowers usually trimerous *Class*: *Monocotyledons*

Class Dicotyledons

Sub-class I Flowers usually with two whorls of perianth i.e. (calyx and corolla). Petals free.....*Polypetalae*

Sub-class II Flowers usually with two whorls of perianth i.e. (calyx and corolla). Petals united.....*Gamopetalae*

Sub-class III Flowers usually with one whorl of perianth. commonly sepaloid or absent..... *Monochlamydeae*

Sub-Class I — Polypetalae

Series (i): Petals and stamens hypogynous. disc absent!..... *Thalamiflorae*

(1) Androecium rarely definite gynoecium free or immersed in toms, rarely united: embryo minute albuminous ..... *Ranales*

(2) Gynoecium syncarpous, parietal placentation.....*Parietales*

(3) Gynoecium syncarpous. free central placentation: Herbs. sepals 5 or 4. petals 5 or 4 stamens twice petals. Obdiplostemonous .....*Caryophyllineae*

(4) Flowers rarely irregular; sepals 5, 2 or 4. free or united: petals as many or (0); stamens indefinite monadelphous; gynoecium 3 to indefinite numbers of carpels. carpels united .....*Malvales*

Series (*ii*) Stamens hypogynous. disc present, ovary superior .....*Disciflorae*

(1) Ovary superior or inferior, syncarpous; stamens twice the number of sepals, in two or one whorl: .....*Geraniales*

Series (*iii*) Flower perigynous or epigynous: ovary sometimes inferior: ovary enclosed by developments of floral axis. .....*Calyciflorae*

(1) Gynoecium one or more carpellary, apocarpous: flower actinomorphic or zygomorphic. Perigynous. .....*Rosales*

(2) Flower regular, usually bisexual: Ovary syncarpous. inferior: styles undivided or very rarely styles are free…..*Myrtales*

(3) Flowers bisexual or unisexual. parietal placentation. styles free or connate ... ……*Passiflorales*

(9) Flowers bisexual, locules in Ovary one to indefinite number. inflorescence umbel….....*Umbellales*

Sub-Class III - Gamopetalae

Series (i): Ovary inferior. stamens usually as many as petals.....*Inferae*

(1) Flowers regular or irregular, stamens epipetalous, ovary with 2 - indefinite number of locules. ……..*Rubiales*

(2) Flowers regular or irregular, stamens epipetalous, ovary with one locule and one ovule; stamens, syngenesious .....*Asterales*

Series (ii) Ovary superior; stamens as many as petals or numerous, petals opposite or alternate to petals.....*Heteromerae*

(1) Flowers regular, petals 4-5, stamens as many as the petals or numerous, inserted on receptacle……..…….*Ericales*

(2) Flowers regular, petals 5, stamens 5 or numerous, ovary superior, herbaceous, prostrate or climbing plants ……*Primulales*

(3) Flowers regular, petals 4-5, stamens as many as the petals, inserted on the corolla, ovary superior……..……*Ebenales*

Series (iii) Ovary usually superior; stamens as many as or fewer than corolla lobes. alternipetalous: gynoecium 2 rarely to 1-3-carpellary.. ...*Bicarpellatae*

(3) Flower regular, hypogynous; stamens epipetalous: leaves generally opposite. ……..*Gentianales*

(4) Flower regular, hypogynous; leaves alternate; stamens epipetalous; ovary 1-5 loculed.....*Polemonianles*

(5) Flowers usually irregular, corolla often bilipped; stamens generally fewer than corolla lobes. usually 4, didynamous or 2; ovary 1-4 locular, ovules usually indefinite..... *Personales*

Indefinite number of ovules per loculus; sepals 5, fused; petals 3 + 2, gamopetalous; stamens 4 or 5, gynoecium bicarpellary. syncarpous.. ……*Acanthaceae.*

(6) Corolla usually bilpped; flower hypogynous, rarely regular;

Ovary 2 - 4 loculed. ovules solitary in loculus or rarely more than one; first a drupe or nutlets..... *Lamiales*

Sub-class - Monochlamydeae

Flowers usually with one whorl of perianth commonly sepaloid or perianth absent.

Series A. Terrestrial plants with usually bisexual flowers; stamens generally equal in number to perianth lobes; ovules usually solitary; embryo curved or coiled in endosperm..... *Curvembryae*

Series B. Plants are many seeded submerged aquatica ….*Multiovulatae Aquaticae*

Series C. Plants are many seeded terrestrial ……*Multiovulatae Terrestres*.

Series D. Seeds are endospermous and with aminute embryo ….*Microembryeae*.

Series E. Ovary is monocarpellary and one ovuled ……..*Daphnales*.

Series F. Ovary is one locular, inferior, no of ovules is 1 to 3.. *Achlamydosporeae*.

Series G. Flowers are unisexual, ovary is monocarpellary or syncarpous ……..*Unisexuales*

Series H. Unisexual families of doubteful or unknown affinities ……*Ordines Anomali*.

Class 2 : Gymnospermae

Class 3 : Monocotyledons

Series A. Ovary is inferior, seeds are minute ……..*Microspermae*

Series B. Ovary is inferior, seeds are large and with a copiuns endosperms ……. *Epigynae*

Series C. Perianth atleast the inner one is petatoid, the ovay is superior ……*Coronarieae*.

Series D. Perianth is sepaloid ovay is superior ……*Calycinae*.

Series E. Perianth is usually absent or reduced to minute scales, seeds are albuminous ……..*Nudifloreae*.

Series F. The perinath is about or uni-biseriate, ovary is superior with one or more than one tree coupels. Seeds albumiuoue ……*Apocarpeae*.

Series G. Perianth is scaly or glumaceous or about the ovary is usually one ovuled, seeds are alluminous..... *Glumaceae*.

Advantages and Disadvantages of Bentham & Hooker's Classification

Advantage is it provides easy means and ways of identifying plant.

Disadvantage are:

- Retention of Monochamydeae in which biseriate perianth as a rule in order.
- Family salicineae and cupuliferae are similar to now extinct.
- Simple flower to Paronychieae as elaborate primitive, thus Chenopodiaceae are apetalous allies of Caryophyllaceae.
- Position of Monochlamydeae and delimitation due to their affinities (Rendle)
- In Monocots greater emphasis on relative position of ovary, so Iridaceae, Amayllidaceae shows greater affinity to Liliaceae then Scitamineae and Bromelliaceae as common epigyuous character.

Key to the identification of the Families

(*a*) Flowers mostly penta or tetramerous

(*b*) Calyx and corolla mostly distinct.

(*a*) Flowers mostly trimerous

(*b*) Calyx and corolla mostly not distinguished as separate whorls; perianth present, Monocotyledons.

……*Dicotyledons*

I. DICOTYLEDONS

(i) Corolla consisting of mostly free petals ……*Polypetalae*

(ii) Corolla consisting of mostly fused petals…….. *Sympetatae* (Gamopetalae)

(i) Polypelatae

(A) Ovary Superior

1. Flowers unisexual……..*Euphorbiaceae*
2. Gynoecium apocarpous, fruit never drupe. calyx and corolla sometimes not distinguished. ……..*Ranunculaceae*
3. Gynoecium either apocarpous or monocarpellary, fruit may be a drupe. epicalyx often present. ……*Rosaceae*

4. Gynoecium monocarpellary

(a) Fruit drupe. …… *Rosaceae*

(b) Fruit legume or lomentum

(i) Flowers actinomorphic, stamens mostly indefinite ……*Mimosoideae*

(ii) Flowers zygomorphic, aestivation of the corolla ascending imbricate; stamens 10 but never diadelphous……..*Caesalpinoideae*

(iii) Flowers zygomorphic, aestivation of the corolla descending imbricate, stamens ten, diadelphous,.....*Papilionatae*

5. Gynoecium syncarpous

(a) Placentation free-central ……..…*Caryophyllaceae*

(b) Placentation parietal

(i) Gynoeceum tricarpellary ……..*Violaceae*

(ii) $K_{2 \text{ or } 3}\, C_{2+2 \text{ or } 3+3}\, A_{\square}\, G_{(2-\square)}$ ……*Papaveraceae*

(iv) $K_{2+2}\, C_4\, A_{2+4}$ (tetradynamous). $G_{\underline{(2)}}$ ……*Cruciferae*

(c) Placentation axile .

(i) Epicalyx present, stamens monadelphous ……*Malvaceae*

(ii) Prominent disc present below gynoecium, stamens obdiplostemonous or polyadelphous. ……*Rutaceae*

(d) *Ovary inferior:*

(i) Leaves exstipulate, inflorescence umbel ……*Umbelliferae*

(ii) Leaves exstipulate, inflorescence mostly cymose or a spike, petals often nearly circular, stamens indefinite ….*Myrtaceae*

(iii) Leaves mostly stipulate, the latter often adnate to the petals, never circular: epicalyx often present ……*Rosaceae*

(ii) Sympetalae (Gamopetalae)

(A) Ovary superior:

(a) Corolla actinomorphic

(i) Stamens often included in the corolla tube, anthers mostly sagittate and convinient round the stigmatic head, stigma dumble-shaped. ……*Apocynacease*

(ii) Gynostegium present, gynoecium free below and fused above ……*Asclepiadaceae*

(iii) Ovary bilocular with typically two ovules in each loculus. ……..*Convolvulaceae*

(iv) Carpels obliquely placed in the flower, ovary bilocular, placenta swollen, ovules shining and indefinite. ……*Solanaceae*

(b) Corolla zygomorphic

(i) Corolla mostly bilabiate, style gynobasic. ……*Labiatae*

(ii) Corolla often bilabiate, ovary elongated, style long and terminal. ……*Acanthaceae*

(B) Ovary inferior

(i) Mostly climbing plants with well developed tendrils, flowers unisexual, androecium complex, anthers twisted. ……*Cucurbitaceae*

(ii) Inflorescence capitulum, calyx in the form of pappus, anthers cohering by their edges (syngenesious), placentation basal. ……*Compositae*

(iii) Stipules prominent, either inter or intrapetiolar, placentation axile. ……*Rubiaceae*

II. MONOCOTYLEDONS:

(i) Gynoecium monocarpellary with two feathery stigmas, perianth absent, ovary superior ……*Gramineae*

(ii) Flowers unisexual, minute and produced in very large numbers, ovary superior. ……*Palmaee*

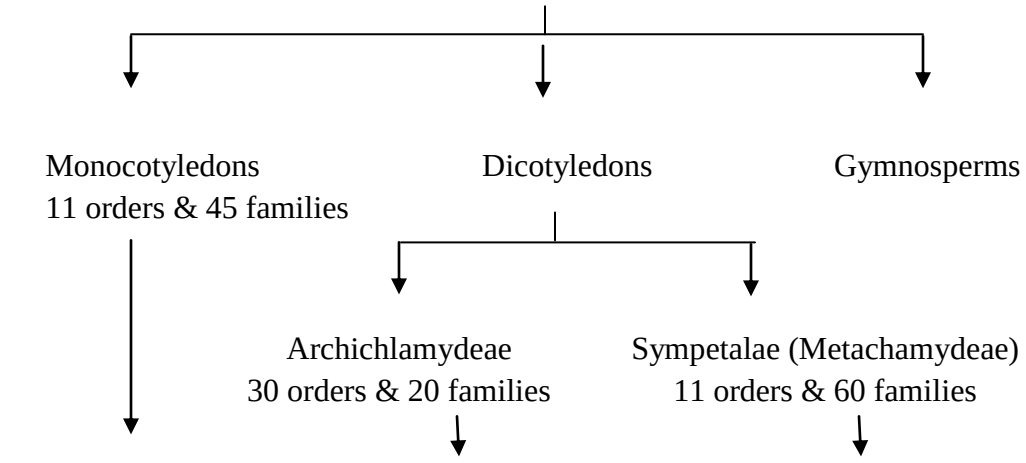
(iii) Flowers bisexual, six stamens in two whorls, ovary superior..*Liliaceae*

(iv) Flowers mostly bisexual, stamens five in two whorls, ovary inferior ……..M*usaceae*

1.7 ENGLER AND PRANTL'S SYSTEM

Adolf Engler (1844-1930) Professor of Botany at Berlin University adopted the main features of Eichler's classification and with Karl Prantl (1849-1893) published *Die Naturlichen Pflanzenfamilien* in 1909. The significant feature of this system is that monocotyledons take precedence over the dicotyledons, the polypetalae, monochlamydeae are united and form the single group Archichlamydeae. Amentiferae were regarded as primitive. Evolution is traced from hypogynous to epigynous. This system is also not perfect because the group Amentiferae is not artificial assemblage of families but probably reduced rather than primitive group as indicated. The placing of monocots before dicots is also not in present line. The general outline of the system proposed by Engler and Prantl is given below:

Phanerograms
(Seed plants)



1.	Pandanales	1.	Verticillate	1.	Diapensiales
2.	Helobiae	2.	Piperales	2.	Ericales
3.	Triuridales	3.	Salicales	3.	Primulales
4.	Glumiflorae	4.	Hydrostachyales	4.	Plumbaginales
5.	Principes	5.	Garryales	5.	Ebenales
6.	Synanthae	6.	Myricales	6.	Contortae
7.	Spathiflorae	7.	Balanopsidales	7.	Tubiflorae
8.	Farinose	8.	Leitnerales	8.	Plantaginales
9.	Lilliflorae	9.	Juglandales	9.	Rubiales

10. Scitamineae
11. Microspermae

10. Batidales
11. Julianales (Archichlamydeae)
12. Fagales
13. Urticales
14. Podostemonales
15. Proteales
16. Santalales
17. Aristolochiales
18. Balanophorales
19. Polygonales
20. Centrospermae
21. Ranales
22. Rhoedales
23. Sarraceniales
24. Rosales
25. Pandales
26. Geraniales
27. Sapindales
28. Rhamnales
29. Malvales
30. Parietales
31. Opuntiales
32. Myrtiflorae
33. Umbelliflorae

10. Cucurbitales
11. Campanulatae

1.8 HUTCHINSON'S CLASSIFICATION

The classification based on principles of phylogeny was suggested by John Hutchinson in his *"The Families of Flowering Plants"*. He was a British Botanist from England (1884-1972). He proposed 24 principles of Phylogeny parallel to Bessey's Dicta of phylogeny. In 1969, he published "*Evolution and Phylogeny of Flowering plants*." His other work is *Genera of Flowering plants* (1964-67). His classification was revised from time to time (1955, 1969) and finally appeared in 1973.

The classification suggests that origin of Angiosperms is Monophyletic; originating from hypothetical proangiosperms. Initially Angiosperms were regarded to have evolved along two evolutionary lines.

(*a*) **Herbaceae** (Herbaceous families starting from Ranales to Lamiales, 28 orders)

(*b*) **Lignosae** (Arborescent or woody plants starting from Magnoliales to Verbenales, 54 orders)

However, he considered monocots to be derived from Ranales. Monocots were divided into three groups based on nature of Perianth into Calciferae, Corolliferae and Glumiflorae within all 29 orders and 69 families.

In the new revised classification published in 1973 small alterations were made as: Lytherales were transferred to Myrtales, in Lignosae from Herbaceae. Now Dicots include 82 orders and 342 families while Monocots include 29 orders and 69 families.The important points are:

1. The system is based on Bessey's system.
2. It is based on the assumption that flowering plants with sepals and petals, associated with other floral and anatomical characters are phylogenetically primitive, than the plants without sepals and petals.
3. This system is based on considerable knowledge of phylogeny.
4. The Monocotyledons are placed after the Dicotyledons from which they were considered to have been derived at an early stage.
5. The Magnoliales and Ranales are considered most primitive orders of the Dicotyledons, where flowers are bisexual with numerous free stamens and carpels are spirally arranged.
6. Emphasizing resemblances rather than differences, the Gamopetalae and Monochlamydeae are distributed amongst the Polypetalae according to their relationships.
7. The flowering plants are divided into smaller groups on the basis of a combination of characters and closely allied families are placed together.
8. The Gymnosperms are considered as a distinct group.
9. The families of Monocotyledons are arranged in 29 orders and he proposed new conceptions for several families resulting in more natural groupings.
10. The Butomales and the Alismatales are placed at the beginning of the Monocotyledons. They share with the Ranales androecium of numerous stamens, apocarpous gynoecium and folicular and achenial fruits.
11. The Gramineae are considered as the most advanced family of the Monocotyledons which is inconsistent with the present understanding of the group.
12. He recognized 411 families of Angiosperms.

Principles of Classification

Hutchinson laid great stress on the phylogenetic arrangement of plants and predicated their classification on 24 principles which are briefly enlisted below:

1. Evolution is both upwards and downwards, the latter involving degradation and degeneration.

2. Evolution does not necessarily involve all organs of the plant at the same time, and one organ or set of organs may be advancing while another set is stationary or retrograding.
3. Evolution has generally been consistent and when a particular progression or retrogression has set in it is persisted into the end of the phylum.
4. In certain groups, trees and shrubs are probably more primature than herbs.
5. Tree and shrubs are older than climbers.
6. Perennials are older than biennials and from them annuals have been derived.
7. Aquatic flowering plants are as a rule more recent than terrestrial and same may be said for epiphytes, saprophytes and parasites.
8. Plants with collateral vascular bundles arranged in a cylinder (dicotyledons) are more primitive in origin than those with scattered bundles (monocotyledons), though it does not necessary follow that the latter have been directly derived from the former.
9. The spiral arrangement of leaves on the stem and of the floral leaves (sepals and petals) preceded that of the opposite and whorled types.
10. As a rule simple leaves precede compound leaves.
11. Bisexual precedes unisexual flowers, and the dioecious is probably more recent than the monoecious condition.
12. The solitary flower is more primitive than the inflorescence, the highest forms of the latter being the umbel and capitulum.
13. Spirally imbricate floral parts are more premature than whorled and valvate.
14. Many parted flowers (polymerous) precedes, and the type with few parts (oligomerous) follows from it, being accompanied by a progressive sterilization of reproductive parts.
15. Petaliferous flowers precede apetalous one, the later being the result of reduction.
16. Polypetaly is more primitive than sympetaly.
17. Actinomorphic flowers are more primitive than zygomorphic flowers.
18. Hypogyny is the primitive condition, and from it perigyny and epigyny derived later.
19. Apocarpy is more primitive and from it syncarpy has resulted.
20. Many carpels precede few carpels.
21. The endospermic seed with small embryo is primitive and the non-endospermic seed is more recent.
22. In primitive flowers there were many stamens and is more advanced flower, few stamens.
23. Separate stamens precede connate stamens.
24. Aggregate fruits are more recent than single fruits, and as a rule the capsule precedes the drupe or berry.

Detailed Classification (1959)

Phylum Angiospermae
Sub. Phylum Dicotyledones

Division 1 Lignosae

	Order	Family
1.	**Magnoliales**	1. Magnoliaceae, 2. Illicidaceae, 3. Winteraceae, 4 Canellaceae, 5. Schisandraceae, 6. Himantandraceae, 7. Lactoridraceae, 8. Trocoendraceae, 9. Cercidiphyllaceae.
2.	**Annonales**	10. Annonaceae, 11. Eupomatiaceae.
3.	**Laurales**	12. Monimiaceae, 13. Austrobaileyaceae, 14. Lauraceae, 15 . Trimeniaceae, 16. Hernandiaceae, 17. Gomortegaceae, 18. Myristicaceae.
4.	**Dilleniales**	19. Dilleniaceae, 20. Connaraceae, 21. Crossosomataceae, 22. Brunelliaceae.
5.	**Coriariales.**	23. Coriariaceae.
6.	**Rosales**	24. Rosaceae, 25. Dichapetalaceae, 26. Calycanthaceae.
7.	**Leguminales**	27. Caesalpiniaceae, 28. Mimosaceae, 29. Fabaceae.
8.	**Cunoniales**	30. Pterostemonaceae, 31. Cunoniaceae, 32. Philadelphaceae, 33. Hydrangeaceae, 34. Crossulariaceae, 35. Oliniaceae, 36. Greyiaceae, 37. Escalloniaceae, 38. Baueraceae, 39. Crypteroniaceae.
9.	**Styracales**	40. Lissocarpaceae, 41. Styracaceae, 42. Symplocaceae.
10.	**Araliales**	43. Cornaceae, 44. Alangiaceae, 45. Garryaceae, 46. Nyssaceae, 47. Araliaceae, 48. Caprifoliaceae
11.	**Hamamelidales**	49. Tetracentraceae, 50. Hamamelidaceae, 51. Myrothamnaceae, 52. Platanaceae, 53. Stachyuraceae, 54. Buxaceae, 55. Daphniphyllaceae, 56. Bruniaceae.
12.	**Salicales**	57. Salicaceae.
13.	**Leitneriales**	58. Leitneriaceae.
14.	**Myricales**	59. Myricaceae.
15.	**Balanopsidales**	60. Balanophoraceae.

16. Fagales	61. Betulaceae, 62. Fagaceae, 63. Corylaceae.
17. Juglandales	64. Rhoipteleaceae, 65. Juglandaceae, 66. Picrodendraceae.
18. Casuarinales	67. Casuarinaceae.
19. Urticales	68. Ulmaceae, 69. Cannabinaceae, 70. Moraceae, 71. Urticaceae, 72. Barbeyaceae, 73. Eucommiaceae.
20. Bixales	74. Bixaceae, 75. Cistaceae, 76. Flacourtiaceae, 77. Cochlospermaceae, 78. Hoplestigmataceae, 79. Achatocarpaceae, 80. Lacistemaceae.
21. Thymeleales	81. Gonystylaceae, 82. Aquilariaceae, 83. Geissolomataceae, 84. Penaeaceae, 85. Thymeleaceae, 86. Nyctignaceae.
22. Proteales	87. Proteaceae.
23. Pittosporales	88. Pittosporaceae, 89. Byblidaceae, 90. Stegnospermaceae, 91. Vivianiaceae, 92. Tremandeaceae.
24. Capparidales	93. Capparaceae, 94. Moringaceae, 95. Tovariaceae
25. Tamaricales	96. Frankeniaceae, 97. Tamaricaceae, 98. Fouquieriaceae.
26. Violales	99. Violaceae
27. Poligalales	100. Polygalaceae, 101. Krameriaceae, 102. Trigoniaceae, 103. Vochysiaceae.
28. Loasales	104. Turneraceae, 105. Loasaceae,
29. Passiflorales	106. Malesherbiaceae, 107. Passifloraceae, 108. Archariaceae.
30. Cucurbitales	109. Cucurbitaceae ,110. Begoniaceae, 111. Datiscaceae, 112. Caricaceae.
31. Cactales	113. Cactaceae.
32. Tiliales	114. Dirachmaceae, 115. Scytopetalaceae, 116. Tiliaceae 117. Sterculiaceae, 118. Peridiscaceae, 119. Bombacaceae.
33. Malvales	120. Malvaceae.

34. Malpighiales	121. Ixonomthaceae, 122. Malpighiaceae. 123. Humiriaceae, 124. Linaceae, 125. Irvingiaceae, 126. Huaceae, 127. Ledocarpaceae, 128. Erythroxylaceae, 129. Ctenolophonaceae, 130. Lepidobotryaceae, 131. Blanitaceae, 132. Zygophyllaceae.
35. Euphorbiales	133. Euphorbiaceae.
36. Theales	134. Bonnetiaceae,135. Theaceae, 136. Sauraniaceae, 137. Actinidiaceae, 138. Pellicieraceae, 139. Pentaphyllaceae, 140. Tetrameristaceae, 141. Marcgraviaceae, 142. Caryocaraceae, 143. Medusagynaceae.
37. Ochnales	144. Straburgeriaceae, 145. Ochnaceae, 146. Rhodolaenceae, 147. Sphaerosepalaceae, 148. Dipterocarpaceae, 149. Ancistrocladaceae.
38. Ericales	150. Clethraceae, 151. Pyrolaceae, 152. Ericaceae, 153. Epacridaceae, 154. Diapensiaceae, 155. Monotropaceae, 156. Lennoaceae, 157. Vacciniaceae.
39. Guttiferales	158. Hypericaceae, 159. Clusiaceae, 160. Eucryphiaceae, 161. Quiinaceae.
40. Myrtales	162. Myrtaceae, 163. Lecythidaceae, 164. Rhizophoraceae, 165. Sonneratiaceae, 166. Punicaceae, 167. Combretaceae, 168. Melastomataceae.
41. Celastrales	169. Pandanaceae, 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. Hippocaseaceae, 185. Erythropalaceae, 186. Capusiaceae, 187. Scyphostegiaceae.

42. Olacales	188. Olacaceae, 189. Opiliaceae, 190. Octoknemaceae, 191. Aptandraceae, 192. Dipentodontaceae, 193. Medusandraceae.
43. Santalales	194. Loranthaceae, 195, Grubiaceae, 196. Santalaceae, 197. Myzodendraceae, 198. Balanophoraceae.
44. Rhamnales	199. Heteropyxidaceae, 200. Elaeagnaceae, 201. Rhamnaceae, 202. Vitaceae.
45. Myrsinales	203. Myrsinaceae, 204. Theophrastaceae, 205. Aegicerataceae.
46. Ebenales	206. Ebaenaceae, 207. Sapotaceae, 208. Sarcospermataceae.
47. Rutales	209. Rutaceae, 210. Simaroubaceae, 211. Burseraceae, 212. Averrhoaceae.
48. Meliales	213. Meliaceae.
49. Sapindales	214. Melianthaceae, 215. Sapindaceae, 216. Podoaceae, 217. Sabiaceae, 218. Anacardiaceae, 219. Aceraceae, 220. Hippocastanaceae, 221. Staphyleaceae, 222. Akaniaceae, 223. Julianiaceae, 224. Didiereaceae.
50. Loganiales	225. Potaliaceae, 226. Loganiaceae, 227. Buddlejaceae, 228. Antoniaceae, 229. Spigeliaceae, 230. Strychnaceae, 231. Oleaceae.
51. Apocynales	232. Plocospermataceae, 233. Apocynaceae, 234. Periplocaceae, 235. Asclepiadaceae,
52. Rubiales	236. Dialypetalanthaceae, 237. Rubiaceae,
53. Bignoniales	238. Cobaeaceae, 239. Bignoniaceae, 240. Pedaliaceae, 241. Martyniaceae.
54. Verbenales	242. Ehretiaceae, 243. Verbenaceae, 244. Stilbaceae, 245. Chloanthaceae, 246. Phrymataceae.
Division II	**Herbaceae**
55. Ranales	247. Paeoniaceae, 248. Helleboraceae, 249. Ranunculaceae, 250. Nymphaeaceae, 251. Podophyllaceae, 252. Ceratophyllaceae, 253. Cabombaceae.
56. Berberidales	254. Sargentodoxaceae, 255. Lardizabaiaceae, 256. Menispermaceae, 257. Nandinaceae, 258. Cicaeasteraceae, 259. Berberidaceae

57. Aristolochiales	260. Aristolochiaceae, 261. Hydnoraceae, 262. Rafflesiaceae, 263. Nepenthaceae.
58. Piperales	264. Piperaceae, 265. Saururaceae, 266. Choranthaceae
59. Rhoeadales	267. Papaveraceae, 268. Fumariaceae.
60. Brassicales	269. Brassicaceae.
61. Resedales	270. Resedaceae
62. Caryophyllales	271. Elatinaceae, 272. Molluginaceae, 273. Caryophyllaceae, 274. Ficcidaceae, 275. Portulacaceae
63. Polygonales	276. Polygonaceae, 277. Illecebraceae
64. Chenopodiales	278. Barbeniaceae, 279. Phytolaccaceae, 280. Gyrostemonaceae, 281. Agdestidaceae, 282. Petiveriaceae, 283. Chenopodiaceae, 284. Amaranthaceae, 285. Theligonaceae, 286. Batidaceae, 287. Basellaceae.
65. Lythrales	288. Lythraceae, 289. Onagraceae, 290. Trapaceae, (Onagrales) 291. Halorrhagidaceae, 292. Callitrichaceae.
66. Gentianales	293. Gentianaceae, 294. Menyanthaceae.
67. Primulales	295. Primulaceae, 296. Plumbaginaceae.
68. Plantaginales	297. Plantaginaceae
69. Saxifragales	298. Crassulaceae, 299. Cephalotaceae, 300. Saxifragaceae, 301. Eremosynaceae, 302. Vahliaceae, 303. Francoaceae, 304. Donatiaceae, 305. Parnassiaceae, 306. Adoxaceae.
70. Sarraceniales	307. Droseraceae, 308. Sarraceniaceae
71. Podostemales	309. Podostemaceae, 310. Hydrostachyaceae
72. Umbellales	311. Apiaceae (Umbelliferae)
73. Valerianales	312. Valerianaceae, 313. Dipsacaceae, 314. Calyceraceae.
74. Campanulales	315. Campanulaceae, 316. Lobeliaceae
75. Goodeniales	317.Goodeniaceae, 318. Brunoniaceae, 319. Stylidiaceae.
76. Asterales	320. Asteraceae (Compositae)
77. Solanales	321. Solanaceae, 322. Convolvulaceae, 323. Nolanaceae.

78.	**Personales**	324. Scrophulariaceae, 325. Acanthaceae. 326. Gesneriaceae, 327. Orobanchaceae, 328. Lentibulariaceae, 329. Columelliaceae.
79.	**Geraniales**	330. Geraniaceae, 331. Limnenthaceae, 332. Oxalidaceae, 333. Tropaeolaceae, 334. Balsaminaceae.
80.	**Polemoniales**	335. Polemoniaceae, 336. Hydrophyllaceae, 337. Cuscutaceae.
81.	**Boraginales**	338. Boraginaceae.
82.	**Lamiales**	339. Myoporaceae, 340. Selaginaceae, 341. Globulariaceae, 342. Lamiaceae (Labiatae).
	Sub-phylum:	**Monocotyledones**
	Division 1:	**Calyciferae**
83.	**Butomales**	343. Butomaceae, 344. Hydrocharitaceae,
84.	**Alismatales**	345. Alismataceae, 346. Scheuchzeriaceae, 347. Petroniaceae.
85.	**Triuridales**	348. Triuridaceae
86.	**Jucaginales**	349. Jucaginaceae, 350. Liliaceae, 351. Posidoniaceae.
87.	**Aponogetonales**	352. Aponogetonaceae, 353. Zosteraceae.
88.	**Potamogetonales**	354. Potamogetonaceae, 355. Ruppiaceae.
89.	**Najadales**	356. Zannichelliaceae, 357. Najadaceae.
90.	**Commelinales**	358. Commelinaceae, 359. Cartonemataceae, 360. Flagellariaceae, 361. Mayacaceae.
91.	**Xyridales**	362. Xyridaceae, 363. Rapateaceae.
92.	**Eriocaulales**	364. Eriocaulaceae.
93.	**Bromeliales**	365. Bromeliaceae.
94.	**Zingiberales**	366. Musaceae, 367. Strelitziaceae, 368. Lowiaceae, 369. Zingiberaceae, 370. Cannaceae, 371. Marantaceae.
	Division-2-	**Corolliferae**
95.	**Liliales**	372. Liliaceae, 373. Tecophilaeaceae, 374. Trilliaceae, 375. Potenderiaceae, 376. Smilacaceae, 377. Ruscaceae.
96.	**Alstroemeriales**	378. Alstroemeriaceae, 379. Petermanniaceae,

	380. Phileriaceae.
97. Arales	381. Araceae, 382. Lemnaceae.
98. Typhales	383. Sparganiaceae, 384. Typhaceae.
99. Amaryllidales	385. Amaryllidaceae.
100. Tridales	386. lridaceae.
101. Dioscoreales	387. Stenomeridaceae, 388. Trichopodaceae, 389. Roxburghiaceae, 390. Dioscoreaceae.
102. Agavales	391.Xanthorrhoeaceae,392.Agavaceae.
103. Palmales	393. Palmae (Arecaceae)
104. Pandanales	394. Pandanaceae.
105. Cyclanthales	395. Cyclanthaceae.
106. Haemodorales	396. Haemodoraceae, 397. Hypoxidaceae, 398. Velloziaceae, 399. Apostasiaceae, 400. Taccaceae, 401. Philydraceae.
107. Burmanniales	402. Burmanniaceae, 403. Thismiaceae, 404. Corsiaceae.
108. Orchidales	405.Orchidaceae
Divison 3:	**Glumiflorae**
109. Juncales	406. Juncaceae, 407. Thurniaceae, 408. Centrolepidaceae, 409. Retionaceae.
110. Cyperales	410. Cyperaceae.
111. Graminales	411. Gramineae (Poaceae)

Merits of Hutchinson's System

1. It is a phylogenetic system purely based on principles of phylogeny.
2. This system provided a base for the phylogenetic system of Oswald Tippo, Cronquist, Takhtajan and Dahlgren etc.
3. The system considers Ranales as primitive Herbaceous dicots while Magnoliales as primitive Lignoceous dicots.
4. Families and orders are very small and comprises of only very much related taxa.
5. The arrangement of families in Monocots is widely accepted.
6. Monocots are considered to be more advanced than Dicots.

Demerits of Hutchinson's System

1. Dicots were divided on the basis of habit into two major groups, *i.e.,* Lignosae and Herbaceae. Lignosae includes woody plants. This was not accepted by many as otherwise closely related plants were kept far apart and the two evolutionary lines cannot be considered distinct.
2. The two related families on the basis of floral structure were separated, *e.g.,* closely related families of Ranales as Ranunculaceae and Magnoliaceae were kept far away.
3. Several herbaceous families which are closely related or even derived from woody families, e.g., Apiaceae (Herbaceous) is considered to be derived from Cornaceae and Araliaceae (woody) or Brassicaceae (Herbaceous) is derived from woody Capparidaceae via Cleomaceae.
4. This system is not very practical for plant classification.

Phylum Angiosperms

Subphylum Dicotyledones

Div I Lignosae (54 orders)

Magnoliales (9)
Annonales (2)
Laurales (7)
Dilleniales (4)
Coriariales (1)
Rosales (3)
Leguminales (3)
Cunoniales (10)
Syracales (3)
Araliales (6)
Hamamelidales (8)
Salicales (1)
Leitneriales (1)
Myricales (1)
Balanopsidales (1)
Fagales (3)
Juglandales (3)
Casuarinales (1)
Urticales (6)
Bixales (7)
Thymeleales (6)
Proteales (1)
Pittosporales (5)
Capparales (3)
Tamaricales (3)
Violales (1)
Polygalales (4)
Loasales (2)
Passiflorales (3)
Cucurbitales (4)
Cactales (1)
Tiliales (6)
Malvales (1)
Malpighiales (12)
Euphorbiales (1)
Theales (10)
Ochnales (6)
Ericales (8)
Guttiferales (4)
Myrtales (7)
Celastrales (10)
Olacales (6)
Santalales (5)
Rhamnales (4)
Myrsinales (3)
Ebenales (3)
Rutales (4)
Meliales (1)
Sapindales (11)
Loganiales (7)
Apocynales (4)
Rubiales (2)
Bignoniales (2)
Verbenales (5)

Div II Herbaceac (28 orders)

Ranales (7)
Berberidales (6)
Arstolochiales (4)
Piperales (3)
Rhoeadales (2)
Brassicales (1)
Resedales (1)
Caryophyllales (5)
Polygonales (2)
Chenopodiales (10
Onagrales (5)
Gentianales (2)
Primulales (2)
Plantaginales (1)
Saxifragales (9)
Sarraceniales (2)
Podostemales (2)
Umbellales (1)
Valerianales (3)
Campanales (2)
Goodeniales (3)
Asterales (1)
Solanales (3)
Personales (6)
Geraniales (5)
Polemoniales (3)
Boraginales (1)
Lamiales (4)

Total orders 110
Total families 411

Subphylum Monocotyledones

Div I Calyciferae (12 orders)

Butomales (2)
Alismatales (3)
Triuridales (1)
Juncaginales (3)
Aponogetonales (2)
Potamogetonales (2)
Najadales (2)
Commelinales (4)
Xyridales (2)
Eriocaulales (1)
Bromeliales (1)
Zingiberales (6)

Div II Corolliferae (14 Orders)

Liliales (6)
Alstroemeriales (3)
Arales (2)
Typhales (2)
Amaryllidales (1)
Iridales (1)
Dioscoreales (4)
Agavales (2)
Palmales (1)
Pandanales (1)
Cyclanthales (1)
Haemodorales (6)
Burmanniales (3)

Div III Glumiflorae (3 orders)

Juncales (4)
Cyperales (1)
Graminales (1)

1.9 SUMMARY

In this unit plant classifications were discussed. Plant taxonomy is one of the earliest disciplines of Botany. Simpson (1961) suggested that systematics includes identification, taxonomy, classification and nomenclature. Classification denotes the arrangement of single plant or group of plants in distinct category following a system of nomenclature and in accordance with a particular and well established plan. The basic unit of classification is species. The various classifications of plants proposed so far, belong to either artificial, natural and phylogenetic systems. Initially classification of plants was based on own principles. In this unit fundamental components of taxonomy, aims of taxonomy and deme terminology are also discussed. Natural system proposed by Bentham and Hooker in *Genera Plantarums* (1862-1883) which is based on free and fused petals was discussed in details. Advantages and disadvantages of Bentham & Hooker's classification have also been provided. Engler and Prantl published their plant classification in *Dienaturlichen Pflanzen Familien* in 1909. In this classification monocots precede dicots. Hutchinson proposed plant classification based in phylogeny in *Families of Flowering Plants* plants. 24 basic principles were also discussed proposed by Hutchinson with 411 families.

1.10 GLOSSARY

Classification: arrangement of a single plant or group of plants in distinct category following a system of nomenclature with a particular and in accordance and well established plan.
Taxonomy: includes identification, taxonomy, classification and nomenclature.
Artificial: system with the help of few characters with a intention of easy identification.
Nature: system based on form relationships.
Phylogenetic: System based on genetic relationship and evolution.
Alpha taxonomy: taxonomy of description and designation of species.
Beta taxonomy: arrangement of species in hierarchical manner.
Gamma taxonomy: taxonomy with intraspecific population and with phylogenetic trends.
Omega taxonomy: perfect system based on available characters.
Aims of taxonomy: Identification, nomenclature and classification
Polypetalae: free petals
Gamopetalae: fused petals

1.11 SELF ASSESSMENT QUESTIONS

1.11.1 Fill in the blanks:

(i) Natural system of classification was proposed by.....

(ii) Phylogenetic classification was proposed by.....

(iii) "*Genera Plantarum*" was written by.....

(iv) The term taxonomy was coined by.....

(v) Who is known as father of botany.....

(vi) The first herbarium was established in 1553 at ……..

(vii) The aspect of taxonomy is concerned with the disciplined designation of species is called ……..

(viii) "*Die Naturlichen Pflanzen Familien*" was written by ……

(ix) Hutchison recognized …… families.

(x) Hutchinson published his classification in ……..

1.11.1 Answers Key:

(i) Bentham & Hooker, (ii) Hutchinson, (iii) Bentham & Hooker, (iv) de Candolle, (v) Theophrastus, (vi) Panua (Italy), (vii) Alpha taxonomy, (viii) Engler and Prantl, (ix) 411, (x) The families of flowering plants.

1.12 REFERENCES

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1.13 SUGGESTED RADINGS

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- Angisoperms by B. P. Pande, S. Chand & Co., Delhi.
- Chopra G.L. (1977). Angiosperms (Systematic and Life cycle), Nagin and Company, Delhi.
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1.14 TERMINAL QUESTIONS

1.14.1 - Long answer questions:

1- Describe classification proposed by Bentham and Hooker.
2-Describe classification proposed by Engler and Prantl.
3-Discuss the history of classification.
4- Describe Hutchison's classification with its principles.
5- Describe different types of classification.

UNIT-2BASIC PRINCIPLES, PLANT NOMENCLATURE AND ICBN

2.1 Objectives
2.2 Introduction
2.3 Binomial nomenclature
2.4 ICN
2.5 Principles
2.6 Focal points of ICN
2.7 Phylocode
2.8 The rule
- 2.8.1 Rank of taxa
- 2.8.2 Principle of Prinity
- 2.8.3 Effective and valid publication
- 2.8.4 Publication of names
- 2.8.5 Citation of Author's name
- 2.8.6 Retention, choice and rejection of names
- 2.8.7 Rejection of names
- 2.8.8 Names of cultivated plants
- 2.8.9 Names of hybrid plants

2.9 Summary
2.10 Glossary
2.11 Self Assessment Questions
2.12 References
2.13 Suggested Reading
2.14 Terminal Questions

2.1 OBJECTIVES

After reading this unit students will be able to understand-

- Definition of names
- ICBN (Different Codes)
- Principles of ICBN
- Phylocode
- Rules

2.2 INTRODUCTION

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.

The process of naming plants based on international rules proposed by botanists to ensure a stable and universal uniform system is called botanical nomenclature.

Common Names

Common name is the name of the plant in a particular area or locality given by the people of that particular area. Such names vary from place to place and language to language. In India the name changes with the dialect.

Scientific Name

Scientists suggested name in such a way that it is accepted in the world and is used internationally. But again, the problem remains 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 in Latin. Botanical Latin is an international language used by botanists the world over for naming and describing plants. It originates from the Latin of the Roman plant writers, notably Pliny the Elder (A.D. 23-79). The Swedish botanist Carolus Linnaeus (1707-79) formally established the tradition that all plants should be given Latin names (or names of Latin form) and that works relating to them should also be in Latin. It is because:

1. Latin is a dead language, so the meanings of words do not change in the same way as those for living languages.
2. Botanical, Latin is very descriptive, with many terms for shape, texture and colour.
3. Latin does not inspire the political jealousies that might emerge if botanists were to convert to, say, English or Spanish.

During 1600 to 1850 AD Europe, particularly Greece, had dominated the world of science. The language was Latin but the script was Roman.

2.3 BINOMIAL NOMENCLATURE

Linnaeus for the first time proposed that every living being has a binomial name, *i.e.*, a name with two epithets. One is generic and the other is specific epithet. If an organism has a variety also, then the name becomes trinomial. Linnaeus proposed some rules for generic names of plants in Fundamental 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). Swedish Naturalist Carolus Linnaeus who started naming plants in 1753 as Binomial names. It was published in his book "Species Plantarum".

The generic name is always a noun showing colour, name or adjective, *e.g., Sarracenia* named after a scientist Michel Sarracin. Species is always an adjective, *e.g.,* for white flower, it is alba., for edible one it is sativa, black colour-nigrum etc.These names are not used always. Species may be a Pronoun, *e.g., americana, indica, benghalensis,* etc. It may be shape of a leaf (character of plant), *e.g., sagittifolia,* name of other scientist to whom the plant is dedicated, *e.g., Sahnii* etc.

2.4 INTERNATIONAL CODE FOR NOMENCLATURE OF ALGAE, FUNGI AND PLANTS (ICN)

At the middle of 18^{th} century, plant names were generally polynomial consisting of several words in a series. Linnaeus proposed the elementary rules in Philosophia Botanica in 1751. In 1813 A.P.de Candolle proposed details of the rules regarding plant nomenclature in *Theorie elementaire de la botanique*. Alphonse de Candolle son of A.P.de Candolle convened an assembly of botanists of the world to present a new set of rules. Candolle convened the first International Botanical Congress at Paris in 1867. The *International Code for Nomenclature of Algae, Fungi and Plants (ICN)* passed by Melbourne Congress was earlier known as *International code Botanical Nomenclature (ICBN).*

(1) *Paris Code (1867)*

The first International Botanical Congress was held at Paris in August 1861. About 150 American and European Botanists were invited to make laws for Botanical Nomenclature (*Lois de la nomenclature botanique*). The laws were called Paris code, as they were adopted at French capital. According to this code, the starting-point, for all nomenclature was fixed with Linnaeus. The rule of Priority was considered as basic for valid publication, author citation was very important. Paris code has many inherent defects. After some years the American and British Botanists deviated from the rules and started following a new rule called Kew Rule.

(2) *Rochester Code (1892)*

N.L. Britton headed the Botanical Congress at Rochester, New York, USA in 1892. The Paris code was modified and with new recommendations, it was called as Rochester Code. Some important recommendations were

(i) Strict adherence to Principles of Priority.

(ii) Name and date of publication for interpretation of priority.

(iii) Acceptance of alternate bionomials resulting from employment of the principles of priority even in case of tautonyms.

(iv) Establishment of the type concept to ascertain the correct application of names.

(3) *Vienna Code (1905)*

The third International Botanical Congress was held at Vienna in June 1905. In this congress, it was established that Linnaeus *Species Plantarum* (1753) is the starting point for naming vascular plants. *Nomina generica conservenda* by which generic names having a wide use would be conserved over earlier but less well known names. Tautonyms are banned and the names of new taxa to be accompanied by Latin diagnosis.

(4) *American Code (1907)*

The botanists who proposed Rochester Code were dissatisfied with Vienna Code and refused to accept it in 1907. They modified the Rochester code to American Code. American code does not subscribe to the principle of *Nomina generica conservenda* or the requirement of Latin diagnosis. It accepts type concept. In American Code, a binomial cannot be used again for a plant in any way either has been employed previously for another plant.

(5) *Brussels Code (1912)*

Fourth International Botanical Congress was held at Brussels in 1910. This code accepts different starting points for priority of names of non-vascular plants. It recognizes the type concept and classification of the Vienna rules.

(6) *Cambridge Code (1935)*

The difference between Vienna code and American code was removed at the fifth Botanical Congress held at Cambridge (1930). The provisions suggested in this code are as follows:

(i) Type concept should be pursued.

(ii) A list of Nomina generica conservanda should be provided.

(iii) Tautonyms should be discarded.

(iv) Latin diagnosis of plants is necessary after January 1, 1932.

(7) *Amsterdam Code (1947)*

Sixth International Botanical Congress was held at Amsterdam in 1935. In this a major change in the rules was made, *i.e.,* from January 1,1935 names of new groups of recent plants, (except Bacteria) are to be considered as validly published only when they have a Latin diagnosis.

(8) *Stockholm Code (1952)*

The 7th International Botanical Congress was held at Stockholm in 1952. For the first time the word 'Taxon' was introduced to designate any taxonomic group or entity.

(9) *Paris Code (1956)*

8th International Botanical Congress was again held in Paris in July 1954. Here, the rule of compulsion of Latin diagnosis was scraped out and it was decided that it should be published in English, French and German languages. Preamble and Principles of the code were separated from the Rules and Recommendations. *Nomina Generica Conservenda* et *rejecienda* was amended and supplemented.

(10) *Montreal Code (1961)*

9th International Botanical Congress held at Montreal in August 1959, where a committee was appointed to study the question of conservation of family names. *Nomina familiarum conservanda* for Angiospermae was introduced. The code also assersted that the naming of fossil plants should also follow the same lines as those of recent ones.

(11) *Edinburgh Code (1966)*

In the 10th Botanical Congress held at Edinburgh in August 1964, the report of committee was presented. According to it, for family names the starting point should be A.L.de Jussieu's *Genera Plantarum* (1789). Some of the spellings of a few families were changed, (e.g., Capparaceae for Capparidaceae and Cannabaceae for Cannabinaceae) in the list of *Nomina familiarum Conservenda.* A new committee was formed to work upon the preparation of Glossary of technical terms which was called An Annotated Glossary of Botanical Nomenclature.

(12) *Seattle Code (1972)*

11th International Botanical Congress met at Seattle in August 1969. The code was published in 1972 by F.A. Stafleu. Seattle Code includes the tautonymous designations of taxa between genus and species and below it. Code introduced a new word Autonym, *i.e.,* automatically established names.

(13) *Leningrad Code (1978)*

12th International Botanical Congress was held at Leningrad in July 1975. The out-comes were published in 1978. It included minor changes, *e.g.,* concept of organ genera was eliminated for fossil plants. The code does not apply for bacteria. Principle of automatic typification was extended to the names of taxa above family rank, etc.

(14) *Sydney Code (1983)*

13th Botanical Congress was held at Sydney in August 1981 and the outcomes were published in 1983.

(15) *Berlin Code (1988)*

14th International Botanical Congress was held at Berlin in 1986 and the outcomes were published in 1988. *Nomina Specifica Conservenda* was introduced in the congress. Articles 66 and 67 were removed. In this two species names *Triticum aestivum* Linn, and *Lycopersicon esculentum* P .Miller were conserved against the rules of priority as these names were used widely and it was thought that if the names were changed confusion might arise.

(16) *Tokyo Code (1994)*

15th International Botanical Congress held at Yokohama in Japan in 1993. The code was translated into Chinese, French, German, Italian, Japanese, Russian and Slovak.

(17) *St. Louis Code (1999)*

16th International Botanical Congress was held at St Louis, Missouri in 1999. This code is also available in many languages. The code is divided into Rules, Articles and Recommendations. Rules are set up to put the nomenclature of the past into order and to provide space for the future.

(18) *Vienna Code (2005)*

17th International Botanical Congress was held in Vienna, Austria, July 2005. 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.

(19) *Melbourne Code (2011)*

The XVIII 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. This edition of the code changed the title of the code as ***International code for Nomenclature for algae, fungi and plants***

Recommendations deals with subsidiary points. According to it in future the names not following the recommended ones are rejected. Rules and Recommendations apply for all living and fossil organisms and fungi but do not include Bacteria. For Bacteria International Code of Nomenclature of Bacteria (ICNB) was proposed separately.

Presently, the rules and recommendations of Vienna code which were proposed by J. McNeill et al in 2005 are in practice.

The present International Code of Botanical Nomenclature (Lanjouw, 1956) is the result of many years of trial and error. 1956 edition of the code gives detailed instructions on the steps to be taken when any change appears necessary. It is interesting to note that during the last three or four International Botanical Congresses there have been, but few changes, except perhaps in the rearrangement of the code and in some less important points of nomenclature. The ICBN is based on Linne's own 'Philosophia Botanica', when he lays down the main points of nomenclature in the form of aphorisms (principles). The code is divided into three clear parts, principles, rules and recommendations. In addition there are a few interesting appendices. The principles are basic points on which the code is based. They do not give detailed rules about nomenclature, but show the main ideas that have guided the compilers of the code, and should be kept in view by any botanist attempting to publish a new taxon.

2.5 PRINCIPLES

There are six principles-

I. 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 (Plants do not include Bacteria).

II. Application of names of taxonomic groups is determined by means of nomenclature types.

III. The nomenclature of a taxonomic group is based upon priority of publication.

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

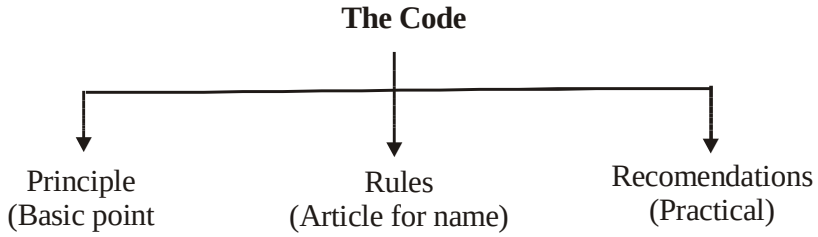
V. Scientific names of taxonomic groups are treated as Latin regardless of their derivation.

VI. The rules of nomenclature are retroactive unless expressly limited.

According to the code, every taxon or group of plants can bear only one correct name and vice versa a name can be applied to one group of plants. The rules or articles give detailed prescriptions on all the points connected with the naming of the plants. The recommendations are practical application of the rules.

2.6 FOCAL POINTS OF ICN (2011)

1. Plants require a precise and simple system of nomenclature used by Botanists in all countries, dealing, on the one hand, with the terms which denote the ranks of taxonomic groups or units, and on the other hand with the scientific names which are applied to the individual taxonomic groups of plants. The purpose of giving a name to a taxonomic group is not to indicate its character or history, but to supply a means of referring it and to indicate its taxonomic rank. The code aims at the provision of a stable method of naming taxonomic groups, avoiding and rejecting the use of names which may cause error or ambiguity or throw science into confusion. It avoids the useless creation of names.
2. The Principles form the basis of the system of Botanical Nomenclature.
3. The detailed provisions are divided into Rules and Recommendations. Examples are added to the rules and the recommendations to illustrate them.
4. The object of the Rules is to put the nomenclature of the past into order and to provide for the future; names contrary to a rule cannot be maintained.
5. The Recommendations deal with subsidiary points, their object being to bring about greater uniformity and clearness, especially in future nomenclature, names contrary to a recommendation cannot, on that account, be rejected, but they are not examples to be followed.
6. The provisions regulate the modification of this code from its last decisions.
7. The Rules and Recommendations apply to all organisms treated as plants (except Bacteria), whether fossil or non-fossil. Special provisions are needed for certain groups of plants. The International Code of Nomenclature of cultivated plants (1980) was adopted by the International Commission for the Nomenclature of Cultivated Plants.
8. The only proper reasons for changing a name are either a more profound knowledge of the facts resulting from adequate taxonomic study or the necessity of giving up nomenclature that is contrary to the rules.
9. In the absence of a relevant rule or where the consequences of rules are doubtful, established custom is followed.
10. This edition of the code supersedes all previous editions.



Some Important Rules and Recommendations

1. All those plants which belong to one genus must be designated 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)

2.7 PHYLOCODE

The Linnaean system of binomial nomenclature is now becoming unsuitable to govern the naming of clades and species. Clade is a group in which every member shares a common ancestor (a unique common ancestor). A clade is a group for which all the descendants of the last common ancestor of the members of the group are included in the group.

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) of 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 phylocode governs only clade names.

Phylogenetic nomenclature was established after meeting of the American Institute of Biological Sciences in San Diego, California, USA (1995). This was organized by Richard G. Olmstead and was entitled as "Translating Phylogenetic Analysis into Classification", Second Symposium was organized by J. Mark Porter (1996) at Ranchosanta Ana Botanic Garden in Claremont, California USA entitled as "The Linnean Hierarchy: Past, Present and Future". Third symposium was organized at XVI International Botanical Congress in 1999 at St. Louis, Missouri USA. It was entitled as "Overview and Practical."

Implications of phylogenetic Nomenclature

The initial draft of Article 21 was written by F. Pleijel, A. Minelli and K. Kron which was modified by M. Donoghue and P. Cartino. The initial drafts of Recommendations 10 D and 11.8 B were written largely by I. Eriksson and the Latin terms in Article 9.3 were provided by W. M. Owens.

Properties of Phylocode

The following are the properties of Phylogenetic system:

1. The system is rankless as assignment of rank is not a part of naming process.
2. Rules are framed for naming of clades.
3. The categories 'species' and 'clade' are not ranks. A species is a segment of a population lineage, and clade is a monophyletic group of species.
4. In Phylocode a supraspecific name is given a phylogenetic definition and is applied to the clade which fits that definition, irrespective of its hypothesized composition. Species specimens and synapomorphies cited within these definitions are called specifiers as they specify the clade to which the name applies and function somewhat like types.
5. Application of names is restricted with respect to clade composition.
6. Basic difference is there in the rules governing the super specific names. According to phylocode and earlier traditional systems there is the operational difference in the determination of synonymy and homonymy.

Pre-existing system suggests that synonyms are names of the same rank based on types within the group of concern, regardless of prior association with particular clades. According to phycogenetic system, synonyms are names whose phylogenetic definitions specify the same clade; regardless of prior association with particular ranks.

Advantages of Phylogenetic Nomenclature (Phylocode)

1. Phylocode allows naming the intermediate ranks such as super family etc.
2. It improves nomenclatural stability. The phylogenetic position can easily be indicated by associating the species name with the names of one or more clades to which it belongs.
3. The abandonment of ranks in Phylocode also eliminates the error caused by many taxonomists who treat taxa at the same rank.

Hierarchy of Classification

Kingdom - Division - Class - Subclass - Order - Suborder - Family - Subfamily - Genus - Subgenus - Section - Species - Categories - Subspecies (ssp) - Varieties (var.) - Sub varieties (sub var.) - Forma (f.) - Clone (cl.)

2.8 THE RULES

2.8.1 Rank of Taxa

Every individual plant when placed in classification, the species is the basic unit of classification. Each species belongs to a series of taxa of consecutively higher rank. In Article 3 "the principal ranks of taxa in ascending sequence are species, genus, family, order, class, division and kingdom. This code defines the categories only by listing their sequence. This may not be true for small order, family, or genus but the sequence must not be changed

Categories such as family (ending with- aceae, Polygonaceae) suborder (ending with ineae, Chenopodineae), order (ending with- ales, Malvales) and so on may be used. In other words, the code provides standardized grammatical endings for the categories from division down to subtribe. The name of taxonomic group which do not follow these ending should be changed. Following this procedure the name of family ending with- aceae, the alternative names of the families which do not confirm the endings are changed as.

Graminae into Poaceae

Palmae- Arecaceae

Cruciferae- Brassicaceae

Leguminosae- Fabaceae

Umbelliferae- Apiaceae

Labiatae- Lamiaceae

Compositae- Asteraceae

The ending with- aceae are used basing on its generic names e.g. Poa, Poaceae, Aster, Asteraceae etc.

oideae- subfamily, -eae tribe and -inae subtribe.

A unique exception to article 52 of the code is the name Leguminosae is sanctioned only as long as it includes all three subfamilies Papilionoideae, Caesalpinoideae and Mimosoideae. If the subfamilies are upgraded to family status the Papilionaceae shall be called Fabaceae.

Types of Taxon

Names of different taxonomic groups are based on the type method. The principles and articles of the ICBN provide that all taxonomic groups will be based on nomenclatural types, meaning thereby that all names are permanently attached with some taxon or specimen designated as type. For species (and intraspecific taxa) the type is a specimen or in some circumstances only an illustration. The name of the first author should be attached. Names of the taxa above the level of species, *i.e,* Section, Subgenus, genus, tribe, and family etc., are based on the name of immediately next lower taxon on which the group was originally based, *e.g.,* Lamiaceae was

based on genus *Lamium*. Orchidaceae was based on genus *Orchis* etc. When a new species is described, the author of new species has one or more specimen having characters which are distinctive enough to be segregated into new species.

A type is that constituent element of a taxon to which the name of the taxon is permanently attached. According to Principle II "the application of name of taxonomic groups is determined by means of nomenclatural types". This means that when a species is described as new the author must indicate type of specimen on which the new species is based. In the case of species or infra-specific names, the type is an individual specimen, which is the type specimen on which the new species is based. Small herbaceous plants all mounted on one herbarium sheet, the whole sheet may be marked as the type. When a specimen cannot be preserved, an illustration or figure or a description may be a type. The type of a genus is a species that of a family is a genus.

(a) **Holotype:** Single specimen, may be whole plant or a part of it with which the name of taxon is permanently attached, is known as holotype.

(b) **Isotype or Cotype:** An isotype is a biological specimen duplicate of the holotype collected in the same place and at the same time (in the type locality).

(c) **Paratype:** A paratype is any of one or more biological specimen other than the holotype listed as representative and used for the development of the original description of a species or subspecies.

(d) **Syntype:** The specimen which is the basis of new taxon when no holotype is designated by author is known as syntype. If author studies collection from different localities and by different collectors and decides to establish a new species, labels all of them as types, all these specimen become syntypes.

(e) **Lectotype:** It is type chosen to serve as Holotype, when either an earlier designated holotype was lost or destroyed or holotype was never designated and from the isotype, paratype or syntype a specimen is chosen by a specialist to serve as the type.

(f) **Neotype:** If holotpe, isotype, paratype or syntype are lost or not available a Neotype is selected from other specimens, to serve as Type. Some taxonomists call it Standard Specimen.

(g) **Topotype:** When no original type material is available and a specimen is collected from type locality is chosen to serve as type it is called Topytype.

It is also felt that a species might be undergoing some natural adaptation and variations in course of time and also in space. Type has served in valuable purpose in correct identification of

specimens. It is also agreed that a preserved specimen is always a better representation of any taxonomic group than a description or illustration.

2.8.2 Principle of Priority

Principle of Priority is concerned with the selection of a single correct name of taxonomic group. Only legitimate names should be retained while the illegitimate names should be rejected. According to article 11-12 rules for priority are:

(i) Each family or taxon of lower rank with a particular circumscription, position and rank can bear only one correct name (Art 11).

(ii) For any taxon from family to genus, the correct name is the earliest legitimate one, validly published with the same rank (Art -11).

(iii) A name of a taxon has no status under this code unless it is validly published (Art-12).

(iv) The application of both conserved and rejected names is determined by nomenclatural type (Art-14).

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

Valid Publication of names is usually considered beginning in May 1753, the date of publication of *Species **P**lantarum* vol. I by Linnaeus.

With many names of a taxon, the valid will be the earliest name which is regarded as correct name. Rule of Priority provides stability to this name.

The principle that seniority is fixed by the date of valid publication is known as Principle of Priority.

Example 1.

Nymphea nouchali Burro f. 1768; *N. pubescence Willd* 1799 and *N. torus* Hook. f. et. T., 1872 are names of the same species but if rule of Priority is applied the first name is the correct name and other two are synonyms.

Example 2.

Loureiro described a plant and named it *Physkium nataus* in 1790. A.L.de Jussieu transfered it in genus *Vallisneria* in 1828. He instead of *natans* gave the specific name as *V.physkium.* It is superfluous name. Graebner (1912)-described the same plant as *V.gigantee* and Miki (1934) named it as *V.asiatica.* Harg while studying Asiatic species confirned that all these names are synonymous. There is no legitimate combination based on *Physikium natans* (Leru) existed. He made *V. natans* Hara in 1974. The correct name of the specimen is now the recent name, but it is based on earliast basionym, others will be synonyms. *V. gigantea* and *V. asiatica* will be known as nomenclatural synonyms or homotypic synonyms. *V. gigantea* and *V. asiatica* are the

names based on separate types. Such synonyms are known as taxonomic synonyms or heterotypic synonyms.

With a few exceptions, where alternative names are permitted, each taxon of plants can bear only one correct name, "the correct name is the earliest legitimate one validly published except in cases of limitation of priority by conservation.

There are however many exceptions, as in the case of Musci, Fungi and Algae. For Algae the dates of publication only begin rather late in time e.g. for the Oedogoniaceae the date is 1900 when Hirm published his monographs *Iconographic der Oedogoniaceen*". All groups of fossil plants start from December 31, 1820.

When the specific name repeats unaltered the generic name this is called tautonym e.g. *Malus malus*. This method is accepted in zoological nomenclature when we find such names *Corvus corvus*.

Each taxon with a given circumscription, taxonomic position and rank can bear only one valid name, the earliest that in accordance with the rule of nomenclature. Whoever publishes the name validly and effectively first will be given the credit and all subsequently published names will be rejected.

Suppose a name was published by Linnaeus in 1753 and later two or more authors published the same plant name differently not knowing that it was already published say in 1780 or 1790, according to the rule of priority the name published by Linnaeus in 1753 will be taken as valid and all subsequently published names will be rejected.

2.8.3 Limitations of the Principle of Priority

1. **Starting dates:** Principle of Priority starts with the *Species Plantarum* of Linnaeus published on 1-5-1753.
2. **Limited only up to family ranks:** This principle does not apply over family rank.
3. The correct name should not be outside the rank. Only when a correct name in the taxon is not available, a combination with other rank is allowed.
4. The application of Principle of Priority resulted in numerous name changes. To avoid it a list of conserved generic and family names has been prepared and published in the code with some changes. Such Nomina conservanda *(nom. Cons.)* are to be used as correct name replacing earlier legitimate names, e.g., *Sesbania scop,* 1777 is the conserved genus as against *Sesban adam* 1763 and *Agati adam* 1763.

2.8.4 Effective and Valid Publication

From the discussion of the principles of priority, it seems that publication is the most important step in nomenclatural procedures. The name is effectively published when the published name should appear in printed from and distributed to the botanical institutions. The name is valid when the name is published in accordance with the provisions of the code.

In section 6 of the code the heading is "conditions and dates of valid publication of names". Here the effective publication means, the names must be published accompanied by a valid and effective publication.

A validly published name is one which has been (1) effectively published (2) accompanied by description of the taxon or by client or by direct or indirect reference to a previously and effectively published description of it. Effectively publication of a name deals with the mechanisms of its distribution, valid publication deals with both distribution of the name and with the preparation of the textual matter prior to distribution e.g. *Phalaris arundinacea* L. sp. Pl. 55, 1755 there is a literature citation, following the italicised name, the binomial name was published by Linnaeus in his "*Species Plantarum*" page 55 in 1753. The name was accompanied by Latin diagnosis. Hence the publication was effective and valid e.g. *Digitaria sanguinalis* (L.) Scop. Fl. Carn. Ed. 21:52, 1772, basionym (synonym) *Panicum sanguinalis* L. Sp. Pl. 47, 1753.

The name *Digitaria sanguinalis* was made by Scopoli which was effectively and validly published by him in his second edition of the *Flora Carniciola* page 52 Vol. 1 in 1772. Description of a taxon which is available to the public with direct or indirect reference to a previously and effectively published description. This means that if anybody wants to check back to the original publication of a name, it will be relatively easy to find the publication in which it appeared. The ICBN does not approve names which have not been published effectively.

A valid publication deals with both distribution of name and with preparation of the textual matter prior to publication. The name of the plant must be accompanied by the description of the plant. A plant though effectively published without description of the plant, is not validly published. Similarly names of plants which have not been validly published have not recognized by ICBN and the names must be ignored.

Art 29 states that publication of hand written description or descriptions printed in a nursery catalogue or seed exchange lists is not considered to be effective publication. Since 1935, all diagnosis of new taxa must be written in Latin nor will it be treated as valid.

Scopoli changed the name from *Panicum sanguinale* to *Digitaria sanguinale* retaining the species name *Sanguinale* originally published by Linnaeus. So as a rule of priority the name Linnaeus was included in brakets (L.) and new name as proposed by Scopoli is valid as *Digitoria sanguinale* (L.) Scop. Fl. Carn. Ed 2. 1:52, 1772. Scopoli did not accompany his name with diagnosis of the plant but referred to Linnaeus's earlier validly and effectively published description of it. The listing of the name of the plant on which the new name is based is called basionym.

Names of families and lower taxa except in certain hybrids published on or after January 1, 1958 are valid only if the nomenclature types are indicated. The legal botanical nomenclature must meet the above requirement when published.

2.8.5 Publication of Names

The name of a Taxon should fulfill certain requirements before its effective publication as:

(*i*) **Formulation:** It should indicate

(*a*) *sp. nov.* (species novum) for a new species

(*b*) *Comb. nov.* (combination novum) for change in the epithet of basionym. The name of the original author should be kept in Parantheses.

(*c*) *nom. nov.* (Nomen novum) when the original name is completely replaced.

(*ii*) **English or Latin diagnosis: -** As per ICN **(**The Melbourne Code) the requirement of Latin diagnosis for Names of New Taxa has been changed. As per this code the description of new names should be in English or Latin.

(*iii*) **Typification: -** Holotype should be designated. The name of new Taxon is valid only when the type of the name is mentioned after January 1, 1990. The name of the taxon whose type is a specimen or unpublished illustration; the herbarium or institution in which the type is conserved must be specified.

(*iv*) After January 1, 1996 the name of new taxon of fossil should be accompanied by a Latin or English description of character.

Article 32,1-2 of Tokyo Code (ICBN) is amended as new names of plants and fungi will have to be registered in order to be validly published after January 1, 2000.

2.8.6 Citation of Author's Name

A name cannot be complete without an author's name. The author's name is abbreviated, *e.g,* Linneaus is Abbreviated as Linn or L, Bentham as Benth; Hooker as Hook, Roxburgh as Roxb, Lamarck as Lamk etc.

According to Article 46 the indication of name of a taxon are to be accurate and complete. It is necessary to cite the name of the author who first validly published the name. If the author's name is too long it should be abbreviated. *e.g., Hibiscus L.,lndigofera grandulosa* var. *Syskessi* Baker, *Solanum nigrum* Linn etc. According to Article 49 when a genus or taxon of a lower rank is altered in upper rank but retains its name or epithet, the author who first published this as a legitimate name or epithet must be cited in parentheses; followed by the name of the author who effected the alteration *e.g., Citrus aurantium* var. *grandis L;* when raised to rank of species it becomes *Citrus grandis* (L) Osbeck. Here L is the first author and Osbeck altered it. Similarly, when a subdivision of a genus or a species is transferred to another genus or placed under another generic name (Articles 54 and 55), it will be written as

(i) *Saponaria* section *vaccaria* DC when transferred to *Gypsophila*, it becomes *Gypsophila* sec. *vacca ria* (DC) Godr.

(ii) *Limonia aurantifolia* Christm, when transferred to *Citrus* it becomes *Citrus aurantifolia* (Christm) Swingle.

In case of infraspecific changes it is, *Alysicarpus nummularifolius* DC when reduced to variety it becomes *Alysicarpus viginalis* var. *nummularifolius (DC) Baker.*

The names of two authors are linkded by ex. when the first author proposed a name but was validly published only by second author, the first author failing to satisfy all requirements of the code, *e.g.*

Cerasus cornuta Wall ex. Royle. When two or more authors publish a new species their names are linked by et, *e.g., Delphinium viscosum* Hook.f. et Thomson. When the first author publishes a new species or a name in a publication of another author, in is used, *e.g., Carex kashmirensis* Clarke in Hook.f, it means Clarke published the new species in Hooker's Flora of British India.

The names of two authors are linked using emend (emendavit) or person making amendment or correction in the diagnosis or circumscription of a taxon without altering the type, *e.g, Phyllanthus* Linn. emend. Mull.

When a name was already suggested but it is before 1753, *i.e.,* the starting of binomial system, the name of the author will be put in brackets [D, *e.g., Lupinus* [Tourne] Linn. here Tournefort suggested the name in 1719, i.e., before 1753 (Species Plantarum).

In the citation of infra specific taxon both authorities are called as *Acasia nilotica* (Linn) Del. ssp *indica* (Benth). In case of autonym, the infraspecific epithet does not bear author's name since it is based on same type as the species, *e.g., Acacia nilotica* (Linn.) Del. ssp *nilotica.*

The complete scientific name consists of a generic name, a specific epithet and the name of the author who originally described that taxon. The name of the author is cited in abbreviated from e.g. *Mangifera indica* Linn. This enables one to trace the original description and to ascertain its type and date of publication. If the name of the plant is published by two authors or more jointly, their names are linked by means of an ampersand and *et* instance respectively e.g. *Opuntia pollardii* Britt. et Rose. If an author takes upon unpublished name for a new species and valildly publishes it with his own description *ex* is usually inserted. Other examples are:

The complete name generic name/species epithet and author's name.

Mangifera indica Linn.

- Enable to trace original description, type and date of publication.
- When two authors jointly publish *Opuntia pollardii* Britt et Rose.
- If an author-unpublished and published/effected by another author/equal important to both eg., *Senecio nudicaulie* Buch. Ham ex D. Don.

Capparis lasiantha R. Br. ex DC

- When species described in one genus and later transferred to another.

– *Anthirrhinum spurium* L.
Linaria spurium by Miller
Linaria spurium (L.) Mill.- double citation with parenthesis

Abbreviations are:

Linnaeus – abbreviated L.
Adanson – Adan.
Scopoli – Scop.
Robert Brown – R. Br.
De Candolle – DC.
Sir J. D. Hooker.- Hook.f.

When a species has been described in one genus and later transferred to another, the name of the original author is cited in brackets followed by the name of the second author who transferred it (e.g. *Antirrhinum spurium* L. is treated as *Linaria spurium* by Miller. The citation will be *L. spurium* (L.) Mill. this is also referred as double citation and by this citation the description of the original specimen can be traced.

2.8.8 Retention, Choice and Rejection of Names

When a genus is divided into two or more genera or a species is split into two or more species, the original generic or specific name must be retained for the new taxon containing the type, this applies also to infra-specific taxa.

When a section of a genus or species is transferred to another genus or species without alternation in rank, the original name must be retained whenever possible.

When the rank of a genus or infra generic taxon is changed, the correct name of epithet is the earliest legitimate one available in the new rank.

When taxa of the same rank are united into the same rank or are united into one, the oldest legitimate name must be used for the new combined taxon, if the names are of same date, the author who first unites them has a right to choose one of the names and his choice must be followed by subsequent botanists.

A name or epithet must not be rejected merely because it is badly chosen or disagreable. The name must be rejected when it is illegitimate and superfluous when published or homonym or tautonym.

The authors have full liberty to coin their names but in Latin or Latinized form of other words; names of genera and higher taxa are written with a capital initial letter. Specific names should start with a small letter.

Example: Retention of names of epithets of taxa which are remodelled or divided:

When Genus is divided into 2 or more genera, the generic name must be retained for one of them.

When species is divided into two or more species the specific epithet must be retained for one of them.

Sugar Maple *Acer saccharum* Marsh. Later Michaux considered as composed of two taxa, each he treated as species.

Michaux – retained *Acer saccharum* Marsh. other – *Acer nigrum* Michx.

Retention of name or epithets of taxa below the rank of genus on transfer to another genus or species.

Species transferred to another genus without change of rank the specific epithet must be retained.

In 1753 Linnaeus named *Pinus Canadensis* Carrier later *Tsuga, Tsuga canadnsis* (L.) Carr. e.g. *Pinus laricina* du Roi corrected by Koch as *Larix laricina* (du Roi) Koch.

Choice of name when two taxa of same rank are united.

When two or more taxa of the same rank are united the oldest legitimate epithet is retained. If the names or epithet are of the same date, the author who united the taxa has right of choosing one of them.

Choice of names when the rank of taxon is changed.

When tribe becomes family

Subgenus – genus

Subdivision – species.

e.g. three varieties of the genus *Areria*

1. *A. canescens* (Hort.) Ebel (1827).

2. *A. majellensis* Briss. (1848).

3. *A. majellensis* var. *brachyphylla* Bris. (1879).

Later last two names (2 and 3) are treated as a single variant of *A. canescens.* By applying rule *A. majellensis becomes* a variety in the new category must be employed. Now named as *A. canesceus* var. *brachyphylla* Bris.

2.8.9 Rejection of Names

a) A name is rejected if name is illegitimate:
   i) Nomenclature superfluous
   ii) If published in contravention of specific rules (duplicate/invalidly published)
   iii) If it is rejected generic name.
   iv) If tautonym.

b) If owing to its use with different meaning source of confusion.

e.g. *Quercus rubra* L. American oak.

Quercus falcata Michx. Spanish oak.

Quercus borealis Michx. f. Red oak.

Reder proposed that *Quercus rubra* L. as nomen ambiqua and rejected *Quercus falcata* and *Quercus borealis* as valid name.

c). name of taxon must be rejected if the characters derived from 2 or more entirely discordant element, unless it is possible to select one of these element as site factory type of the name.

e.g. *Actinotinus* established by Oliver 1888 a specimen derived from *Viburnum* and *Aesculus* rejected.

The rules for rejection of names are

(i) ***Nomen nudunm (nom. nud):*** Name without description, without typification and Latin diagnosis etc is rejected.

(ii) **Tautonym:** Botanical nomenclature does not allow tautonym (repetition of generic name), *e.g., Malus malus.* Repetition of specific epithet in infra specific epithet does not constitute tautonym.

(iii) **Later homonym:** If a name which already exists is given to other taxa once again then the later homonym is rejected.

(iv) **Nomen *ambiguum* (nom. ambig):** The name is rejected in different sense by different authors.

(v) ***Nomen confusum (nom. confus):*** The name should not be confusing.

(vi) ***Nomen dubium (non. dub):*** Dubious name, *i.e.,* with uncertain application is also rejected.

2.8.10 Names of Cultivated Plants

The name of the cultivar is not analogous to the botanical variety and according to ICNCP the names are written with a capital letter preceded by abbreviation CV or placed in a single inverted comma. The name may be used after generic, specific or common names e.g. *Citrullus lanatus* CV Sugar baby. *Camelia japonica* CV. Purple Dawn etc.

It is recommended that cultivar names be registered with a recognised registration authority which undertakes to keep a list of cultivars for plants concerned. Registration is a precaution against duplication, misuse or fraudulent usage of cultivar names.

2.8.11 Names of Hybrids in Cultivation

The names of hybrids may follow the pattern of monohybrid crosses of Mendal between the species may be connected by multiplication sign (X). Again the name of the plant may be used in Latin for *Salix aurita* X *Salix caprea, Agrotis* X *Polypogon* X *Andropogon* etc.

2.9 SUMMARY

In this unit nomenclature process of plants was discussed. The process of naming plants on international rule proposed by botanists to ensure a stable and universal uniform is called botanical nomenclature. In this unit common name, scientific names, binomial nomenclature, different codes of ICBN (e.g. Paris code 1067 to Vienna code 2005) were also discussed. The principles (6), focal points of ICBN 1983, phylocode, The rules, rank of taxa, principle of priority, effective and valid publication, publications of names, citation of authors names, retention, choice and rejection of names, rejection of name, name of cultivated plants and names of hybrids in cultivation were discussed in detail.

2.10 GLOSSARY

Scientific name:	name of plan accepted to the world and used internationally.
Binomial:	A name with two epithels (one generic and another specific)
ICBN:	International Code of Botanical Nomenclature.
Phylocode:	proposed to promote clear communication and efficient storage and retrieval of biological information.
Species:	a unit of classification.
Type:	Name of the taxon is based on type.
Sp. Nov	(species novum) for a new species
ICNCP:	International Code for Nomenclature of Cultivated Plants

2.11 SELF ASSESSMENT QUESTIONS

2.11.1 Fill in the blanks:

(i) Three parts of ICBN are ……...
(ii) Valid publication initial date is ……..
(iii) Basic unit of classification is ……...
(iv) Suffix used for denoting order ……
(v) Suffix used for denoting family ……
(vi) Binomial name consists of two epithets ……
(vii) The name of a taxon is permanently attached with ……
(viii) Paris Code was formulated in the year …….

2.11.1 Answers Key:

(i) Principles, rules and recommendation, (ii) 1 May 1753, (iii) Species, (iv) ales, (v) aceae, (vi) Generic & specific, (vii) Holotype, (viii) 1956.

2.9 REFERENCES

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2.10 SUGGESTED READING

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- Angisoperms by B. P. Pande, S. Chand & Co., Delhi.
- Chopra G.L. (1977). Angiosperms (Systematic and Life cycle), Nagin and Company, Delhi.
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2.11 LONG ANSWER QUESTIONS

(i) Describe ICBN in detail.
(ii) What is type? Describe various kinds of type.
(iii) Describe various Codes of plant nomenclature.
(iv) What is effective and valid publication?

UNIT-3 TOOLS AND TECHNIQUES IN COLLECTION AND PRESERVATION OF SPECIMENS

3.1 Objectives
3.2 Introduction
3.3 Tools for Herbarium
3.4 Techniques in Collection
- 3.4.1 Collection
- 3.4.2 Field note
- 3.4.3 Taking pictures
- 3.4.4 Pressing
- 3.4.5 Drying
- 3.4.6 Poisoning
- 3.4.7 Mounting
- 3.4.8 Label
- 3.4.9 Preservation of specimens
- 3.4.10 Problems in Management
- 3.4.11 Index Herbarium (IH)
- 3.4.12 Important Herbarium of India
- 3.4.13 Steps for Herbarium
- 3.4.14 Functions of Herbarium

3.5 Botanical Museum
- 3.5.1 Definition of Museum
- 3.5.2 Museum Mission statements

3.6 Summary
3.7 Glossary
3.8 Self Assessment Questions
3.9 References
3.10 Suggested Reading
3.11 Terminal Questions

3.1 OBJECTIVES

After reading this unit students will be able to understand-

- Definition of Herbarium and Museum
- Different kinds of plant collection
- Preservation of plant specimen
- Tools of Herbarium

3.2 HERBARIUM

Herbarium is a collection of pressed and dried plant specimens mounted on appropriate sheets, arranged according to some known system of classification and kept in pigeon holes of steel or wooden cupboards usually specially prepared for this purpose. There are thousands of plants in the universe and it is not possible to identify them without assigning them in a definite system. This was the beginning of the systematic botany and arrangement of plants in definite system is one of the steps of the process. Before arranging them it is necessary to collect plants according to certain system. The collected plant is the plant specimen and the specimens are the prime sources for floristic studies. Plant materials must be carefully selected, collected and preserved in such a way that they provide a clue for identification and later arranged accurately for classification. The preserved specimen becomes a permanent record for investigation. This is herbarium specimen.

The science of creation of herbarium started way back in the 16^{th} century when Luca Ghini (1490-1556) developed the first Herbarium. Ever since then, there has been remarkable progress both in the areas of collection of plant specimens and the techniques that have been adopted through research over the years for enhancing the storage life of herbarium specimens. The concept of preserving plant specimens in dried form is 450 years old. The oldest preserved herbarium specimen is kept in Rome, collected by the naturalist Gherardo Cibo a pupil of Luca Ghini (1532). Luca Ghini made many plant collecting journeys in Italy. The plants were presented in this way by him and the first herbarium of the world was established in 1545 in University of Padua, Italy. The first Botanic Garden was also established in the same year. The word 'Herbarium' was originally applied not to collection of plants but to a book dealing with medicinal herbs. Tourneforte around 1700 used two terms as an equivalent to *Hartussiccus,* which was later on adopted by Linnaeus. In the middle of 16th century three students of Ghini namely Aldrovondi, Cesalpino (from Italy) and Turner (from England) also made their herbaria. Cesalpino's herbarium in Firenze is very important and is compared with his book "De Plantis libri XVI" introducing a scientific approach to the study and classification of plants. John Falconer prepared Herbarium in 1553.Dioscorides's "Materia Medica" includes an account of the medicinal use of about 100 plants. As the Renaissance developed in Italy, the Italians began teaching Botany and developed the first ever botanical garden. They prepared 'Book' of mounted dried specimens (plants) and called them "Dry gardens" or *"'Harti Sicci".*

3.3 TOOLS FOR HERBARIUM

The tools used in making herbarium are given below:

- Pocket knife
- Pruning sheets
- Newspaper
- Plastic bags or vasculum (metal box)
- Plant press (Plywood / Iron)
- Digging Tool
- Field note book
- Lead pencil
- Lox hand lens
- String tags
- Collecting vials & jars
- Fixing solution
- Field note book

Field Equipments

- **Field Equipment & Tools**
  * All-Pro Trowel
  * Clippers
  * Field Bags
  * Forceps
  * Hori-Hori
  * Manual Cover
  * Light-Duty Bags
- **Pressing**
  * Presses
  * Blotting
  * Ventilators
  * Straps
  * Newsprint
  * Polyurethane Foam
- **Mounting**

* Mounting Papers
* Adhesives
* Levels
* Bryophyte Packets
* Fragment folders
* Seed Envelopes
* Bond Paper
* Display Envelopes

- **Storage & Filing**
  * Genus Covers
  * Species Folders
  * Binding Tape
  * Cabinets
  * Bin Boxes
  * Shelf Markers
  * Insect Traps
  * Humidity Indicators
  * Zip-lock Style Bags
  * Cartons
- **Optics**
  * Hand Lenses
  * Microscopes
- **Books**
  * Presses
  * Blotting

3.4 TECHNIQUES IN COLLECTION

Making of herbarium involves collection, drying, poisoning, mounting, stitching, labeling and deposition etc.

3.4.1 Collection

Angiospermic material must be chosen that should have leaves, complete inflorescence, flower and fruit etc. If necessary one has to make many visits to the spot. Size of the material depends upon the requirement and availability. Herbaceous small plant may be collected in 2-2, *i.e.*, with

roots also, but in woody plants 4-6 twigs are sufficient. One should not collect diseased, infected or inappropriate plant material. The collection should be given a field number. The species should have at least 4-6 specimens with same field number. The habit, habitat, flower colour, locality interesting features etc. should be noted down in the field note book. Some tools are rather important while collecting up plants for herbarium: A small knife, scissors, thorn-proof gloves and a small handy spade could be of great help. The collected specimens should be put into a strong bag made of cloth or polythene, the function of these containers being to protect plants from damage during your collection visit. If your excursion takes place in summer time or lasts for two or more days, it is better to bring a folder of approximately 45x30 cm or more. The folder must be made of cardboard or some other strong stuff, e.g. aluminum, and it must contain some old newspapers (the more plants you collect the more newspapers you need). The folder can be covered with cloth and it should be closed with straps or belts, and a handle or shoulder-belt should be added for easy carrying.

3.4.2 Field Note

After specimen collection, a field record is noted in small pocket sized notebook. Date of collection, location (name of place or distance from definite point)), collection number, if possible, name of the specimen, and description of the floral parts that may change after drying are noted down. The good quality specimens also become worst if it does not have good field record. The range, latitude and longitude as well as ecology of the plant need to be noted down by GPS (Global Positioning System) and eyesight vision. Likewise specimen's microhabitat; means associated species should be mentioned, at least five species. Finally the distribution status of plant also needs to be mentioned, either the collected species is rare, frequent, common, locally common or occasional. Duplicate specimens of one species that are collected on the same date and same locality should be given the same collection number.

3.4.3 Taking Pictures

Taking color pictures of each plant in its natural environment is also something which could substantially enrich the quality of herbarium. In that way the dried specimen can be placed together with one or more photographs, which are very helpful for bulky plants like trees or bushes, which obviously cannot be entirely included in a herbarium. Also the habitat of a plant can be well described with a photograph, taking care not to be too distant from the nearby bushes or trees.

The suggested equipment is a 35 mm. single lens reflex camera, with a standard lens and a macro-lens, the latter very useful for close-ups of flowers and other specific features. Also a tripod can be very important if many close-ups have to be made, allowing the camera to remain steady. A tripod can also alleviate the need for a flash, which may be used when taking pictures in low light, but has the disadvantage of giving quite unnatural looking images. The speed of print films can range from 64 - 100 ISO to 200 or 400 if pictures in the woods are planned.

Each photograph you take should be recorded in a note-book to provide further data for the classification and to include in the herbarium. Be careful that your camera and films are not damaged by rough handling and do not become wet.

3.4.4 Pressing

The specimens are kept gently within newspaper. Parts of flower are much carefully spread without overlapping in original shape. If the specimens are long, then it needs to be folded in V and N or Z shape.

Unnecessary overlapping of leaves and other parts must be avoided. Large leaf, if palmately compound, split in half lengthwise and one half is discarded. If pinnately compound, a branch is only kept. A few leaves may be turned over to show lower and upper view. If there is bulgy rhizome, needs to cut or dissect longitudinally by knife, so that moisture evaporates through there. Specimens should be of good quality with good field note. Collection numbers have also to be written in the flimsies (newspaper or blank newspaper). The standard size of the press is 30 x 45 cm.

If the specimen is gymnosperms, the specimens needs to dip in the glycerine before pressing. In case of flowers with gamopetalous corolla a few flowers should be pressed separately and some of these should be split open and spread. If flower is large, cotton padding is often helpful to dry quickly. The specimens thus kept inside flimsies, are covered on either side by blotters and then it is put in herbarium press. After press is filled or all the specimens are put in the press, the plant press is closed and pressure is applied by means of tightening the straps. Hard and dried fruits and cones need not to be preserved or pressed, but have to be kept in special boxes.

Fig. 3.1 Pressing of specimen in press board

Fig. 3.2 Steps of pressing

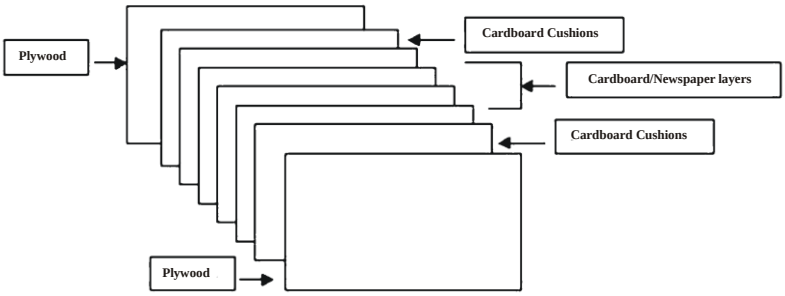

Fig. 3.3 Basic Structure of press

3.4.5 Drying

Drying techniques are of two types; those accomplished without heat, and those with the aid of artificial heat. Drying with the aid of artificial heat is the prevalent method. It is accomplished by means of heated dry air passing up and through the canal of the corrugate. Corrugates, often referred to as ventilators are used in presses when plants are dried by means of artificial heat. It is as sheet of pasteboard or thin aluminum metal, with fluted ducts. It provides air passages through the press for movement of dry heated air. The most common method of drying is without applying heat. Plants are placed in pressing papers between the blotters of the plant press. No corrugates are used. The press is locked up for about 24 hours. This is known as the sweating period. It is then opened, and as blotters are removed each pressing sheet is turned back, the specimens are examined, and parts rearranged as the situation demands.

After rearrangement the folder sheet is lifted on to a fresh dry blotter and covered by another dry blotter. The new pile of blotters and specimens is then locked up in the press and allowed to stand for another 24 to 36 hours, when the process of replacing wet blotters with dry ones is repeated. A third change of blotters follows usually after 2 to 3 days. Blotters must be changed 3-4 times; every wet blotter removed must be dried, usually by placing in the sun and reused. About a week is required for completion of drying. Dried specimens are packed with much care. Fungi as well as insects damage if proper care is not given till the permanent storage.

3.4.6 Poisoning

Precaution should be taken to protect herbarium specimens from damage by insect pests. The most destructive insects are herbarium beetle, cigarette beetle, booklice and silverfish. Insect repellants such as naphthalene ball or Para dichlorobenzene are sometimes placed in small quantities in herbarium cabinet. Although dangerous and hazardous to health, mercuric chloride is believed to be valuable because it provides long –term protection against insect attack. Besides the insect pest, the moulds and mildew are constant threat to material stored in damp condition or in areas of high humidity. Naphthalene and LPCP are believed to have fungicidal properties. However, thymol is quite effective as a fungicide.

3.4.7 Mounting

Mounting is the process by which a specimen is attached to a herbarium sheet and a label affixed at the lower right corner. Specimens are mounted on sheets of standard size herbarium paper (29 x 43 cm).

Most herbaria use a glue or paste to fasten specimens to the sheets. The specimen may be attached by various methods. A common method involves smearing a glass plate with a water-soluble paste, placing the specimen on the paste, and ten transferring the glued plant to the mounting sheet. Small paper envelopes called fragment packets are attached to the sheet to hold seeds, extra flowers, or any part of the specimen.

Fig. 3.4 Mounting of specimen

3.4.8 Label

Herbarium label is an important and essential part of permanent plant specimens. The size and shape of label may vary slightly but will usually be a rectangular and range between 10 x 15 cm (4 x 6 in.). The best position for the main label is generally thought to be the bottom right; this makes the label easier to read when kept in genus covers which open on the right hand side. Ideally a space should be left above the label to allow for the future attachment of determination slips. Generally herbarium label should contain the following information-

1. Heading- name of the institution in which the specimens originated /deposited.
2. Scientific name- Genus, specific epithet, author, or authors
3. Family-
4. Locality-
5. Range, latitude and longitude-
6. Habitat-
7. Date of collection-
8. Name of collector(s)-
9. Determined by-
10. Remarks-

3.4.9 Preservation of Specimens

Heating repellant and fumigants are used to check the attack of such destructive agents. The specimens may be treated by heating in a specially constructed cabinet at 60 ^{0}C for 6 hours, which kills larvae, eggs etc. A common process is-Ethylene dichloride mixed with one part of CCl_4 (carbon tetrachloride) used for fumigation in closed chamber, which is effective process. DDT (Dichloro Diphenyl Trichloroethane) is an important insecticide and it is dusted.

3.4.10 Problems in Management

In the current era of biotechnology and molecular biology the classical subjects like Taxonomy and Herbarium witnessed a great debacle. Herbaria contribute to the development of all biological disciplines. Today herbaria are ignored by so called modern biologists who have least knowledge of the significance of a herbarium.

Some herbaria developed over several decades of efforts of taxonomists are today at the verge of collapse due to wrong impression among the ruling biologists that herbaria are merely a storehouse of collections of dead plants which cannot contribute to the national development nor can generate funds for research forgetting that herbaria are simply a facility of a database on plants from which all biologists draw their basic information directly or indirectly about the plant species on which they carry out all advanced researches.

A national herbarium like the Central National Herbarium (CAL), Herbarium of the Forest Research Institute Dehradun, and the Herbarium of the National Botanical Research Institute, Lucknow are critically endangered due to lack of sufficient trained manpower facility.

Herbarium requires large building, curators, collection, tables for researchers and funds for continuous exploration. Funds are not provided for this subject now- a- days so it becomes very difficult to maintain. Policy makers must realize this and efforts should be made to maintain the important herbaria and Taxonomists should come up for exploration and maintenance of herbarium.

3.4.11 Index Herbariorum (IH)

For the past three centuries, scientists have documented the earth's plant and fungal diversity through dried reference specimens maintained in collections known as herbaria. There are approximately 3,990 herbaria in the world today, with approximately 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. *Index Herbariorum* is a guide to this crucial resource for biodiversity science and conservation.

The Index Herbariorum (IH) entry for an herbarium includes its physical location, Web address, contents (e.g., number and type of specimens), history, and names, contact information and areas of expertise of associated staff. Only those collections that are permanent scientific repositories are included in IH. New registrants must demonstrate that their collection is large

(usually 5,000 specimens minimum), accessible to scientists, and actively managed. Each institution is assigned a permanent unique identifier in the form of a four to eight letter code, a practice that dates from the founding of IH in 1935.

The first six editions of Index Herbariorum were published by the International Association for Plant Taxonomy in the Netherlands (1952-1974). Dr. Patricia Holmgren, then Director of the New York Botanical Garden (NYBG), served as co-editor of edition 6, and subsequently became the senior editor of IH. She oversaw the compilation of hard copy volumes 7 and 8, and Dr. Noel Holmgren, a scientist on the NYBG staff, oversaw the development of the IH database, which became available on-line in 1997.

3.4.12 Important Herbaria of India

S.NO	Name of Herbarium Places	No. of plants	Year of Specimens founding	Abbreviation
1	Central National Herbarium, Calcutta	2,500,00	1793	CAL
2	Forest Research Institute, Dehradun	3,000,00	1816	DD
3	Herbarium of the National Botanic Garden, Lucknow	1,00,000	1984	NBG
4	4. Botanical Survey of India, Dehradun Northern circle	60,000	1956	BSD

Important World's Herbaria

2	New York Botanical Garden	7,200,000	USA
4	Royal Botanic Gardens Kew	7,000,000	UK; Kew, England
6	Missouri Botanical Garden	5,870,000	USA; St. Louis, Missouri
7	British Museum of Natural History	5,200,000	UK; London, England

3.4.13 Steps For Herbarium Preparation

– Preparation of specimen
– Drying of specimen
– Preservation of specimen
– Mounting of the specimen
– Labeling of the specimen
– Filing of the specimen

Collection - Drying - Preservation - Mounting - Labeling – Filing

3.4.14 Functions of Herbarium

A modern Herbarium serves valuable functions or utility. The following are few important functions of a herbarium are:

1. It provides necessary information for verifying and identifying newly collected plants.
2. It is an invaluable conservatory of plant material and data.
3. It is storehouse of collections including the valuable type specimens. The herbaria greatly aid in all kinds of taxonomic researches.
4. Serves as a fundamental resource for identification of all plants of the world.
5. It serves as a source for collection of biodiversity. Most estimates on global biodiversity today are based on herbarium collection only.
6. It aids in biodiversity monitoring by carrying out security of herbarium collection to obtain quantitative baseline data on the distribution and abundance of keystone species is essential for all monitoring programmes.
7. It serves as a repository of voucher specimens on which various botanical researches are carried out.
8. Aids in assessment of conservation status of a taxon.
9. Vast collection of a particular species in a herbarium aids in assessing the diversity or variations exhibited by a species in its distributional range helping in population biology studies.
10. It serves as a source for search of new genetic material for improvement of cultivated stock.
11. It helps in development of computer database on plants and maintains active links to international networks of systematic resources and electronic database.
12. It provides research facilities to the students of taxonomic research.
13. It provides complete idea of vegetation and place of origin of plants.
14. The ecological, economical and ethnobotanical data may be obtained, and
15. It provides key for the preparation of modern system of classification.

The herbaria are classified as:

(a) Major or National Herbaria which cover the flora of the world and serve the purpose of research as well as identification.

(b) Minor Herbaria which include smaller herbaria such as Regional herbaria, local herbaria and College / University herbaria

3.5 BOTANICAL MUSEUMS

Institutions that collect, classify, preserve, and display botanical collections and also do scientific and educational work in botany. In 1969, there were more than 200 museums that disseminated botanical knowledge. In Great Britain, Indonesia, Norway, USA, France and other nations, botanical museums are usually divisions of botanical gardens, natural history museums, museums of local lore, and other museums. Thus, in the Museum of Natural History in Chicago, the botanical division consists of displays of plant life and plant raw materials and their uses. Plant groups are presented in biological groups that serve as a background for zoological exhibits. The collections of the Botanical Museum of the London Botanical Garden at Kew are kept in four buildings. Dicotyledons and various products from them are in the first building. Specimens of monocotyledons are in the second building. Collections of the varieties of trees in Great Britain and an exhibit of the methods of their industrial use are in the third building. A collection of drawings of plants from all continents of the world is in the fourth building, called the Miss North Gallery. In Vienna Natural History Museum Botany is represented in the so-called phytopaleontological division.

In the USSR there are botanical museums in Leningrad, Kiev, Baku, Dushanbe, and other cities. The largest specialized botanical museum is the museum of the V.L. Komarov Botanical Institute of the Academy of Sciences of the USSR (AN SSSR) in Leningrad. It was founded in 1823 as part of the Imperial Botanical Garden, on the basis of collections of specimens of dead plants, as well as everyday articles made from plants and products of plant origin collected by many generations of Russian botanists and travelers.

The possessions of the Botanical Museum — up to 70,000 specimens – are grouped in four sections. The collections of the economic botany section consists of objects of economic significance or those used for technical, pharmaceutical, and other purposes (fatty and volatile oils, resins, gums, samples of certain food products, fruits, seeds, types of tea, cocoa, coffee, various spices, medicines, and samples of fiber, narcotic, and sugar-containing plants.)

3.5.1 Definitions of Museum

It is necessary to begin with an understanding of what a museum is. This is vitally important, because most people think that a museum, in short, is a building which exhibits some old objects. There is some truth in the notion. However it sounds too scientific and dull. Similarly the Oxford Advance Learner's dictionary suggests that a museum is "a building in which objects of artistic, cultural, historical or scientific importance and interest are displayed" (Hornby, 1990). Needless to say, a dictionary describes the meaning of a word concisely, so the description is not always relevant to helping readers understand the whole meaning. The problem with these definitions is, firstly, a museum is not always in a building; secondly, it aims at educationally affecting the general public; and thirdly it also offers recreational opportunities to the public. In addition it is important to research.

There have been many definitions of a museum over time and throughout the world. For instance, George Brown Goode mentioned the definition at a general meeting of British museums in 1895.

"A museum is an institution for the preservation of those objects which best illustrate the phenomena of nature and the works of man, and the utilization of these for the increase in knowledge and for the culture and enlightenment of the people" (Burcaw, 1990).

This idea emphasizes the enlightenment of the people, and also does not insist that the institution is a building.

Nearly one century later Goode had defined a museum in 1989, as:

"a non-profit making, permanent institution in the service of society and of its development, and open to the public which acquires, conserves, researches, communicates and exhibits, for purposes of study, education and enjoyment, material evidence of people and their environment" (ICOM International Council of Museums – Statutes, 1990).

Also, the term "institution" is defined by ICOM as follows:

1. Natural, archaeological, ethnographic, historical monuments and sites.
2. Botanical and zoological gardens, aquaria and vivaria.
3. Science centres and planetaria.
4. Conservation institutes and exhibition galleries permanently maintained by libraries and archive centres.
5. Nature reserves.

This definition improves on that a George Brown Goode. It clearly describes the function of museums to:

a) exhibit to the public for their enjoyment.

b) include many types of institutes such as botanical, zoological gardens and aquaria.

The word "museum" comes from a *mouseion* in classical Greece (in Greek myth) which was a place of contemplation, a philosophical institution or a temple of the Muses (Lewis G. 1992) who are the nine goddesses, daughters of Zeus or Jupiter, who protected and encouraged poetry, music, dancing, history and other branches of art and literature (Hornby, 1990). That is to say, originally museums meant that the places for not only philosophical discussion but also for enjoyment such as dancing or singing. After the fifteenth century, the term began to be used to describe a collection in Renaissance Florence and then it carried with it connotations of comprehensiveness and encyclopedic knowledge (Lewis, 1992).

The ICOM definition seems to have accepted the original idea of a museum and developed it for public education and enjoyment.

The definition of a museum in each country differs slightly. According to the American Association of Museums in 1962:

"A museum is a non-profit permanent establishment, not existing primarily for the purpose of conducting temporary exhibitions, exempt from federal and state income taxes, open to the public and administered in the public interest, for the purpose of conserving and preserving, studying interpreting, assembling, and exhibiting to the public for its instruction and enjoyment objects and specimens of educational and cultural values, including artistic, scientific (whether animate or inanimate), historical, and technological material. Museums thus defined shall include botanical gardens, zoological parks, aquaria, planetaria, historical societies, and historic houses and sites which meet the requirements set forth in the preceding sentence" (Burcaw, 1990).

The Canadian Museums Association officially adapted this definition with minor changes. These definitions are quite similar to that of the ICOM. It particularly emphasizes.

1. Public benefit
2. The inclusion of a wide range of institutes

The Japanese definition is shorter than the above. However it states all the basic functions of a museum in one paragraph as follows:

A museum is an institution which collects and preserves material concerned with history, art, anthropology, industry, natural history, and so on, and exhibits them to the general public from a educational point of view, and carries out projects needed to contribute to the public education, study and recreation, and also it researches on the materials (Museum Law – translated by this author).

This definition does not mention the range of institutions exactly in the main paragraph. However if some institution follows this definition, it should be called a museum. It means that the range of museums is very wide. Also public benefit is regarded as the top priority.

Finally the English definition (adopted by MA-Museum Association) is as follows:

A museum is an institution which collects, documents, preserves, exhibits and interprets material evidence and associated information for the public benefit (Barbour 1992). This is particularly brief and concise, but in the same publication, each element (eg. Institution) is fully explored. This definition, too, complies with the significance of that from the ICOM. Especially this author feels that an important additional element of this definition is that "*Museums are the servants of society".*

3.5.2 Museum Mission Statements

Two major UK museums have the following mission statement:

1. *The Natural History Museum (NHM)*

The mission of the NHM is to promote the understanding and enjoyment of the variety of our natural world through high quality exhibitions, education and science (The Natural History Museum, 1992).

2. *The National Museum of Science and Industry (The Science Museum)*

The mission of this museum is to be the nation's leading centre for the public understanding of science by carrying for, presenting and interpreting the national collections of science, technology and medicine (quoted by Mazda X. 1993).

From above definitions and the nature of mission statements, author wants to summarize and reform it slightly to help develop new museology which is as follows:

A museum is a non-profit making, permanent institution which collects, preserves and researches material evidence of people and / or their environment, and exhibits them to the general public from an educational, point of view, and carries out projects needed to contribute to public education, study and recreation. It includes art galleries, botanical and zoological parks, aquaria, planetaria, historic houses and sites, and others which have the above characteristics. This ultimate objective is to facilitate the peaceful coexistence between human beings and the natural world.

Indian Museum is the largest and oldest museum in India and has rare collections of antiques, armour and ornaments, fossils, skeletons, mummies, and Mughal paintings. It was founded by the Asiatic Society of Bengal in Kolkata (Calcutta), India, in 1814. The founder curator was Dr. Nathaniel Wallich, a Danish botanist.

It has six sections comprising thirty five galleries of cultural and scientific artifacts namely Art, Archaeology, Anthropology, Geology, Zoology and Economic Botany. At present, it includes six cultural and scientific sections, viz. Art, Archaeology, Anthropology, geology, zoology and economic botany, with a number of galleries under each section. Many rare and unique specimens, both Indian and trans-Indian, relating to humanities and natural sciences, are preserved and displayed in the galleries of these sections. The administrative control of the Cultural sections, viz. Art, Archaeology and Anthropology rests with the Board of Trustees under its Directorate, and that of the three other science sections is with the Geological Survey of India, the Zoological Survey of India and the Botanical Survey of India. The Museum Directorate has eight co-coordinating service units: Education, preservation, publication, presentation, photography, medical, modeling and library. This multipurpose Institution with multidisciplinary activities is being included as an Institute of national importance in the seventh schedule of the Constitution of India. It is one of oldest museums in the world. This is an autonomous organization under Ministry of Culture, Government of India. The present Director of the Indian Museum is Dr. B. Venugopal. The museum was closed to visitors due to massive restoration and upgrades from 1 September 2013 to 3 February 2014. This great museum is relentlessly exploring the sea of knowledge seeking a new configuration of the vast meeting ground of the people coming from various cultural and social backgrounds.

The India Museum Ministry of Culture, Govt. of India

Botany Gallery:

The Botanical Gallery has a permanent exhibit display in 8 bays and various sections such as Indian timbers, Food products, Medicinal produces, Vegetable fibers, Oil and oilseeds, Dyes

and Tans and finally Gum and Resins. The gallery provides the first hand information on both wild and cultivated economical plants commonly used in India as well as its commercial perspectives.

The gallery has smaller display units on various economic products, such as 'Story of paddy', 'Story of Sugarcane', 'Story of Arrowroot', 'Tea story', 'Varieties of Paddy and Wheat', 'Common vegetables', 'Fruits of tropical region', under Food produces section.

'Crude drug', 'Crude drug products', 'Cinchona and its products', 'paper and paper materials', 'Shola products', 'Silk industry products', under Vegetative fiber section; sort of museum which situates on the border of the museum definition (this idea comes from Professor Tsuruta, a committee member of ICOM, on his lecture at Hosei University in Tokyo, 1988).

Finally, the ultimate objective of museums is "to facilitate the peaceful coexistence between human beings and the natural world'. This is his original idea, but basically this idea may have been a dormant element of museum philosophy, therefore he wants to bring it to light, and carry it out. Needless to say, this author believes that education is the most important task, as museums, as a subject will be highlighted and the evidence of the subject will be evaluated from various angles.

3.6 SUMMARY

In this unit Herbarium, Museum and Herbarium techniques were discussed. Herbarium is a collection of pressed and dried plant specimen mounted on appropriates sheets arranged to some known system of classification and kept in pigeon holes. The science of herbarium has been started by Luca Ghini. The function of Herbarium, classification of herbarium, tools for herbarium, techniques of collection, index herbarium, important herbarium of India were discussed. Institution that collect, preserve and display botanical collections and also do scientific and educational work in botany is known as museum. Definitions of Museum were also discussed in this unit.

3.7 GLOSSARY

Herbarium: dried plant material (specimen) on appropriate sheets
Major herbaria: cover the flora of world
Minor herbaria: smaller herbaria
Mounting: specimen attached to herbarium sheet
CNH: Central National Herbarium
FRI: Forest Research Institute
Museum: an institution for the preservation of those objects which best illustrate the phenomena of nature

3.8 SELF ASSESSMENT QUESTIONS

3.8.1 Fill in the blanks:

(i) Plant press is made up of ……..

(ii) A collection of plant material (after being dried) is called ……

(iii) Full form of CNH is …….

(iv) Creation of Herbarium was started by …….

(v) NHM (Natural History Museum) is situated at ……

(vi) Major herbarium covers the flora of …….

(vii) Standard size of herbarium sheet is ……..

(viii) DDT full form ……..

3.8.1 Answers:

(i) Wood / Iron, (ii) Herbarium, (iii) Central National Herbarium, (iv) Luca Gini, (v) London, (vi) World, (vii) 29 x 43 cm, (viii) Dichloro Diphenyl Trichloroethane.

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3.10 SUGGESTED READINGS

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3.11 TERMINAL QUESTIONS

3.11.1 Long answer questions:

(i) Describe Herbarium.

(ii) How museums are useful for plant preservation?

(iii) Describe plant collection in details.

(iv) Describe the steps for herbarium preparation.

UNIT-4 NORMAL AND ANOMALOUS GROWTH

4.1 Objectives
4.2 Introduction
4.3 Normal behaviour of cambium
4.4 Abnormal behaviour of cambium
    4.4.1 *Bougainvillea* stem
    4.4.2 *Nyctanthes* stem
    4.4.3 *Dracaena* stem
    4.4.4 *Ficus* root
    4.4.5 *Tinospora* stem
    4.4.6 Orchids
4.5 Activity of cork cambium
4.6 Summary
4.7 Glossary
4.8 Self Assessment Question
4.9 References
4.10 Suggested Readings
4.11 Terminal Questions

4.1 OBJECTIVES

After reading this unit, students will be able to understand:

- What is Secondary growth?
- About two types of tissue used during secondary growth: vascular cambium and cork cambium.
- What vascular cambium produces and what cork cambium produces?
- How does secondary growth occurs.
- How many types of wood are found in trees?
- How do we determine the age of the tree?
- What is the abnormal behaviour of cambium.

4.2 INTRODUCTION

Remember that all plant stem growth occurs at the meristems of the shoot system because this is where cell division occurs. There are two types of meristem in the plant stem: apical and lateral. As we just reviewed, primary growth occurs at the apical meristem and increases plant stem length. We have previously looked at the basic structures of the shoot system as well as primary growth of the stem. We will now look at another form of growth known as secondary growth of the stem. Before we do, let us review a few key components of the shoot system, which is the above ground structures of plants, including the leaves, buds, stems, flowers and fruits.

Primary growth occurs at the apical meristem and allows the plant stem to increase in length. However, some plants need more than just growth in the length of the stem. We will now look at this type of growth. Remember that all plant stem growth occurs at the meristems of the shoot system because this is where cell division occurs. There are two types of meristem in the plant stem: apical and lateral. As we just reviewed, primary growth occurs at the apical meristem and increases plant stem length. Primary growth occurs when plants grow toward the sunlight necessary for photosynthesis and also sink roots deep into the soil to anchor them and enable them to absorb water and nutrients. This 'up and down' growth is possible due to apical meristem, stem cell like tissue that, upon division, creates an undifferentiated cell that will become either a new root or shoot tip.

Secondary growth happens when stems or branches grow outward (get thicker) This type of growth is possible because some plants (like trees and shrubs) have lateral meristem, another stem cell like tissue. Instead of causing the plant to grow up or down, lateral meristematic tissue causes the plant to increase in girth by adding rings of growth. Now we know how a plant gets taller and its roots get longer. But what about being wider? Even a big tree with an enormous trunk starts out as a puny seedling. So when the width of a plant or its girth increases is called secondary growth and it arises from the lateral meristems in stems and roots.

As with apical meristems, lateral meristems are regions of high cell division activity. However, the cells they make grow outward rather than upward or downward. Dicots use lateral meristems to add to their width; monocots, however, do not experience secondary growth. We will come back to them later. The lateral meristems that produce secondary growth are called cambia, which just mean a tissue layer that adds to plant growth. The two important ones for secondary growth are the vascular cambium and the cork cambium**.** The vascular cambium produces more vascular tissue (xylem and phloem), which provide support for the shoot system in addition to transporting water and nutrients. Because the xylem and phloem that come from the vascular cambium replace the original (primary) xylem and phloem, and add to the width of the plant, they are called secondary xylem and secondary phloem**.**

Secondary growth is growth at the lateral meristem and increases the girth of the stem. This type of growth is only found in dicots and is not found in monocots. In order to understand why it does not occur in monocots, let us review the structure of vascular tissue in both types of flowering plants. There are two types of vascular tissue: xylem, which moves water and dissolved minerals, and phloem, which moves food in the plant stem. In monocots and dicots, these structures are organized a bit differently.

In monocots, the xylem and phloem are found in paired bundles and are scattered throughout the stem. Remember that monocots are simple flowering plants such as grasses. However, in dicots - which are more advanced flowering plants such as roses and apple trees - the xylem and phloem are found in rings with the xylem on the inside and the phloem on the outside. This organization allows for secondary growth of plant stems.

Cambium

Meristematic tissue responsible for lateral (outward) growth in plants is known as cambium. There are two kinds of cambium in woody plant stems, both of which increase the diameter of stems. First type of cambium is vascular cambium found in the center of the stem; its division produces the plant's secondary vascular tissue (xylem and phloem cells.) The outer ring or near the epidermis the bark of a woody plant also contains a cambium called secondary cambium or cork cambium, which creates cork cells of the outer layer and responsible to give rise the bark.

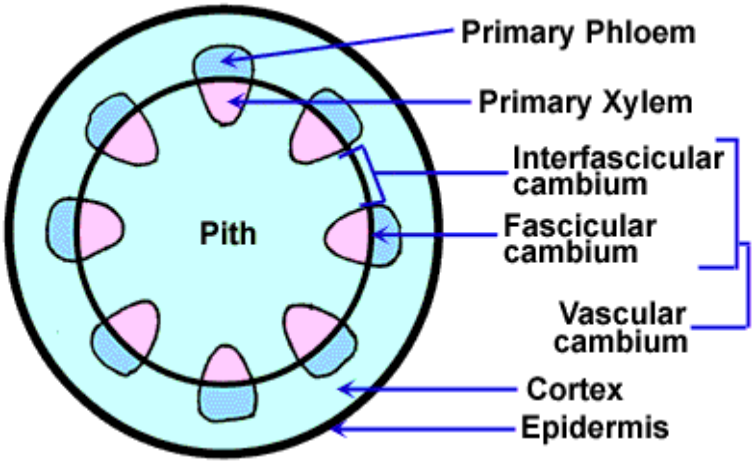


Fig. 4.1: Structure of cambium

The cambium layer consists of a single layer of cell and these cells divide in a direction parallel with epidermis. Each time it divides into two cells and one of the two new cells one remains meristematic and the other differentiates into permanent tissue. If the newly formed cell is near the xylem it will form secondary xylem and if newly formed cell is towards phloem it will develop in secondary phloem. The activity of cambium thus increases and the enlargement of stem takes place and the activity of cambium remains for a considerable long period of time (Fig. 4.1).

4.3 NORMAL BEHAVIOUR OF CAMBIUM

Cells of apical meristems divide, differentiate and develop to form primary tissues. As a result the plant grows in length this is called primary growth. While by the activity of secondary lateral meristems, increase in the circumference/girth of the plant organs due to the formation of secondary tissues in stelar and extra stelar regions, is called as secondary growth. Normally secondary growth takes place in roots and stem of dicots & Gymnosperms. Due to lack of cambium in monocots, secondary growth is absent. But exceptionally secondary, growth takes place in some monocots such as Palm, *Yucca*, *Dracaena*, *Smilax*, *Agave*, Coconut etc.

Secondary growth in dicot stem

Secondary growth in stelar region begins earlier than the extra stelar region. It starts from the development of cambial ring and the detailed activities occur during this is given below (Fig. 4.2, 4.3):

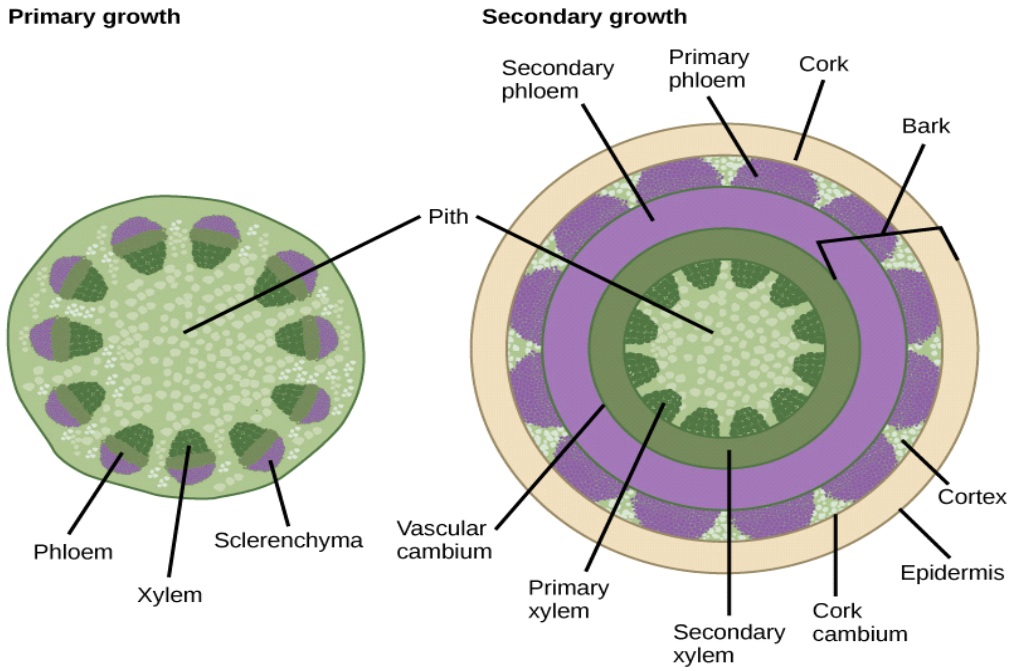


Fig. 4.2 Showing primary growth and secondary growth

Formation of ring of vascular cambium

Vascular bundle comprises xylem and phloem in a bundle and in case of dicot stem these are conjoint, collateral and open type i.e. cambium cells are present in between xylem and phloem cells. A cambium which is present inside the vascular bundle is called intrafascicular cambium. This is a type of primary meristem. When plants become mature then the secondary growth starts and the first step of secondary growth is the formation of cambial ring. For this first of all the cells of medullary rays present in between the vascular bundles become meristematic to form interfascicular cambium this is secondary lateral meristem. Interfascicular cambium is the meristematic cells present outside the vascular bundle and these cells are developed from the medullary cells. Intrafascicular and interfascicular cambia are collectively known as vascular cambial ring. Vascular cambium is formed in the form of a complete ring which is made up of single layer of cells. In dicot stem some part of vascular cambium is primary and some part is secondary. Two types of cells are found in the ring of this vascular cambium.

(i) Fusiform initials

(ii) Ray initials

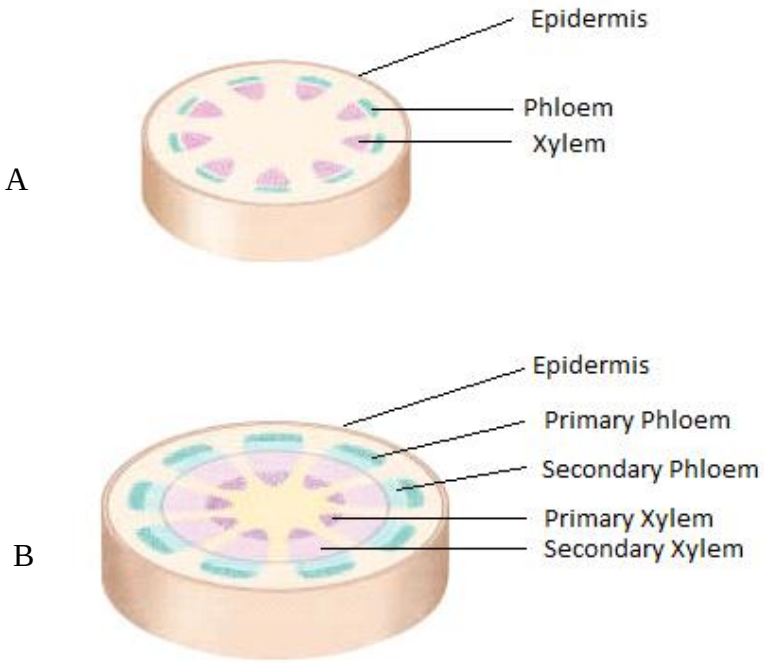


Fig. 4.3: A. T.S. of stem before secondary growth; B. T.S. of stem after secondary growth

Fusiform initials are long with pointed ends, while ray initials are spherical (oval). Amount of fusiform initials is more in vascular cambium. Continuous periclinal divisions or tangential division takes place in fusiform initials. The plane of division in periclinal divisions is parallel to longitudinal axis of a cell. Through this type of activity few cells are formed towards the radius (periphery) and these cells differentiate into secondary phloem or bast and some of the cells are formed towards the central axis and these cells are differentiated into secondary xylem or wood.

Now the complete cambial ring starts producing cells towards inside and outside by division. Normally more secondary xylem is formed as compared to secondary phloem due to unequal distribution of hormones. (secondary xylem is formed 8-10 times more as compared to secondary phloem). By the pressure of secondary phloem; primary phloem is pushed towards the outside and gets crushed. By the pressure of secondary xylem, all the primary tissues such as primary xylem, pith and old secondary xylem degenerates in the centre of the stem. Due to this central part of the stern becomes woody. These activities keep going on continuously in plants throughout.

Before secondary growth the sequences of cells from center towards outside remains pith, primary xylem, cambium, primary phloem, pericycle and endodermis. But due to secondary growth the sequence of the vascular bundle from center changes to primary xylem, secondary xylem, cambium, secondary phloem, primary phloem and then endodermis. Pith crushes due to the pressure created by the newly formed secondary xylem. Secondary xylem forms in the plant

regularly and primary tissues degenerate continuously. This new secondary xylem also degenerate the old secondary xylem.

Waste materials are formed in the stem such as lignin, suberin, tannin, resin-gums etc. due to degeneration of the cells. All these waste materials are filled in the lumen (cavity) of tracheids and vessels of secondary xylem. Because of this, wood in the central region of the stem becomes dark colored (Black brown). It is called heart wood or *Duramen*. The peripheral or outer wood which looks light in color is known as Sap wood or *Alburnum*. As a result of growing of secondary xylem, the diameter of heart wood increases. Physiologically active wood is sapwood and the main function of sap wood is water conduction. Heart wood provides maximum mechanical strength to stem.

Conduction of water is not carried by heart wood because:

- Cavities of tracheids and vessels are progressively filled by waste materials.
- The bladder like in growth of parenchyma cells which enter the lumen of vessels (mainly) and tracheids through the pits in their wall. Such bladder like in growth is called tyloses. Tyloses block the conduction of water.
- In Gymnosperms tylosoids are formed in place of tyloses.
- If the heart wood is destroyed in any stem, then there will be no effect on plants (any vital function is not effected), but if the sap wood is destroyed, then the plant will die because conduction of water will be blocked.
- Heart wood provides stiffness to the stem. The waste materials of heart wood are antiseptic in nature. Heart wood is resistant to bacteria and fungus. Heart wood has a power of repelling insects- so it is resistant to the termites and in rainy season it does not imbibe water. Thus it is the best quality of wood.
- Study of wood is known as xylotomy.
- If a wood is exposed freely in air then decomposition of sap wood takes place rapidly.
- Position of youngest layer of secondary phloem is just outside the vascular cambium.
- Position of oldest layer of secondary phloem is just inside the primary phloem.
- Position of youngest layer of secondary xylem is just inside the vascular cambium.
- Position of oldest layer of secondary xylem is just outside the primary xylem.
- If xylem is blocked then shoot will die first.

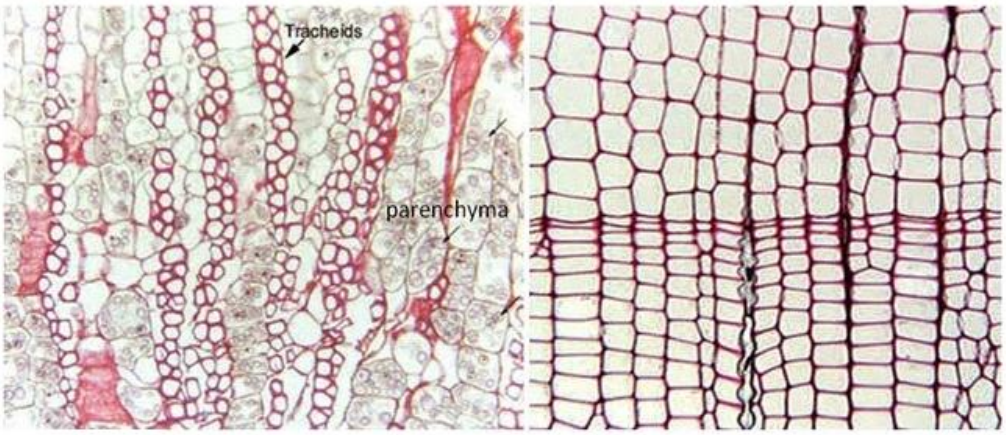
Classification of Wood

(A) On the basis of amount of parenchyma wood is classified into two groups:

1. **Manoxylic wood:** Such type of wood contains more living parenchyma. It is soft and loose wood e.g. *Cycas*. In this secondary vascular tissues with large amounts of softer storage

cells (*i.e.* parenchyma) mixed with the wood or xylem cells (e.g. tracheids). The stems of these plants are softer than the wood of trees we use for lumber. Examples of plants with manoxylic wood are sago palms or cycads, the spurs or short shoots of *Ginkgo* trees, as well as many extinct seed fern groups.

2. **Pycnoxylic wood:** Such wood contains less amount of living parenchyma. It is hard wood. Such types of wood are found in most of the plants and in these secondary vascular tissues with copious amount of xylem cells (e.g. tracheids) and little parenchyma. This wood is much stronger and durable. Examples of plants with pycnoxylic wood are conifers or cone-bearing trees, the long shoots of *Ginkgo*, and Angiosperms (Fig. 4.4).



A **B**

Fig. 4.4: A. Manoxylic wood; B. Pycnoxylic wood

These terms should not be confused with the terms "hard" versus "soft" woods. These terms are used by agro-foresters to make a distinction between conifer trees (soft wood) and angiosperm trees (hard wood). Conifers (mostly evergreen cone-bearing trees such as pines) have wood that is light-weight, light in color, and strong in tension, but weak in shear (along the grains). Therefore this is called "soft wood", which is usually cheaper and used for building inexpensive furniture or used for paper pulp. Flowering plants (mostly deciduous trees such as oak/maple) have wood that is darker in color, heavier in weight, and strong in compression, tension, and shear. Therefore this is called "hard wood", which is used to make durable furniture, flooring, and building structures

(B) On the basis of distribution of parenchyma wood is classified into three groups:

1. **Apotracheal:** In this type of wood parenchyma is in scattered form e.g. Gymnosperms
2. **Paratracheal wood:** In this wood parenchyma is arranged or distributed in the form of masses or groups e.g. Dicot plants.
3. **Syntracheal wood:** In this wood parenchyma is collected around the vessels e.g. *Terminalia arjuna*.

C) Classification based on vessels:

On the 'basis of presence or absence of vessels, wood is classified in two categories

1. Non-porous soft wood: Vessels are absent in such type of wood e.g. Gymnosperms

2. Porous wood: Vessels are present in such type of wood. On the basis of arrangement of vessels porous wood is divided into two groups.

(a) Ring porous wood: Vessels are arranged in the form of a ring in this type of wood. Such wood conducts water more efficiently e.g. in temperate region as in *Dalbergia*

(b) Diffused porous wood: Asystematical distribution of vessels is found in this type of wood in tropical region as in *Azadirachta.*

Formation of Annual rings:

Fig. 4.5: Annual rings

Annual rings are formed due to unequal activity of vascular cambium. The activity of cambium does not remain same; it is changeable in the whole year. Activity of vascular cambium is affected by physiological and environmental factors. In winter or autumn season the activity of the cambium is less and the secondary xylem or wood formed is not extensive through the vascular cambium. Cells formed during this period are small thick walled and have narrow lumens. This is called autumn wood or late wood. The vascular cambium is highly active in spring or summer season and secondary xylem formed during this period is extensive and cells of secondary xylem are larger, thin walled and have wider lumen. This wood is known as spring wood or early wood. The spring wood is lighter in color and exhibits low density where as the autumn (or winter) wood is darker and has higher density (Fig. 4.5).

The autumn and spring wood is formed in the form of rings. The ring of any type of wood is called growth ring. Thus two growth rings are formed in one year. A ring of autumn wood and a ring of spring wood are collectively/known as annual ring. Thus are annual ring consists of two growth rings. The number of annual rings, formed in a tree gives the idea of the age of the tree. The study of determination of age of the plant by these techniques is called **Dendrochronology**.

The annual rings are counted from the base of the stem because basal part has maximum annual rings and upper part has less. Therefore, counting from the basal region can give the correct idea. A piece is taken from the stem up to central region from the base of stem with the help of increment borer instrument. The annual rings are counted from that piece and again inserted (fitted) into the same stem at the same place (Fig.4.6).

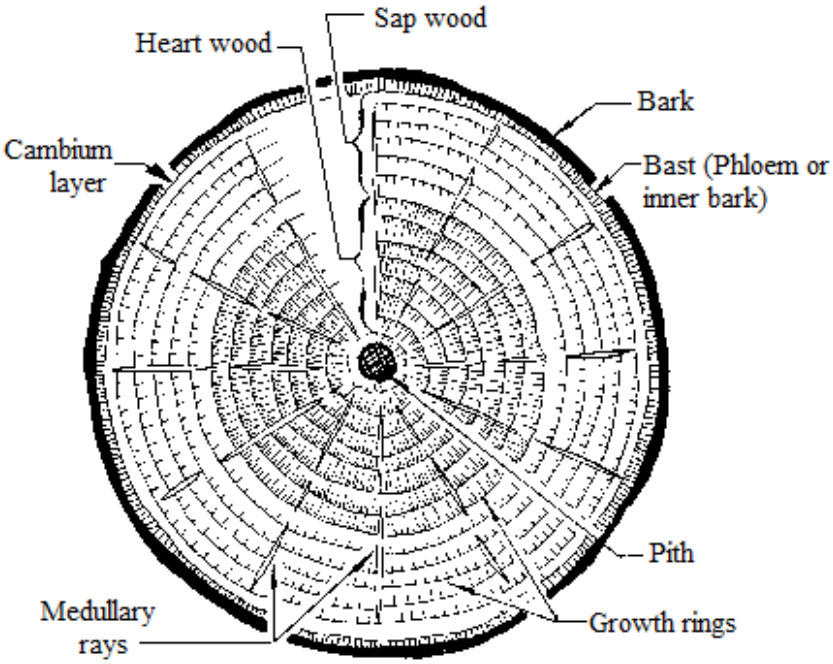


Fig. 4.6: A portion of stem showing annual rings

More distinct annual rings are formed in those regions where climatic variations are sharp, as in temperate plants. Distinct annual rings are not formed in tropical plants. Distinct annual rings are not formed in India except Himalayan regions. Least distinct annual rings are formed in seashore regions because the climate remains same throughout the year. One more thing more clear annual rings are formed in deciduous plants as compared to evergreen plants. Similarly in deserts annual rings are less distinct. Annual rings are bands of secondary xylem and xylem rays. Sometimes drought conditions prevail during the middle of a growing season resulting in formation of more than one annual ring these are called pseudo annual rings.

Secondary Growth in Dicot Root

In dicot roots the vascular bundles are of radial type and in this condition the xylem and the phloem are present in different radii. So there are no cambial cells in between xylem and phloem as in the case of stem. So for the secondary growth in roots first of all, conjunctive tissue becomes meristematic during the secondary growth in a dicot root and form separate curved strips of vascular cambium below phloem bundles. Then after, the cells of pericycle lying opposite to protoxylem also become meristematic to form additional strips of cambium. So the cells present at the base of phloem and the top of xylem first of all become meristematic. Very soon the cells present near to these cells also attain the meristematic behaviour and in this

way a complete ring of vascular cambium is formed. The portion of vascular cambium formed by pericycle is less. The main portion of vascular cambium is formed by conjunctive tissue.

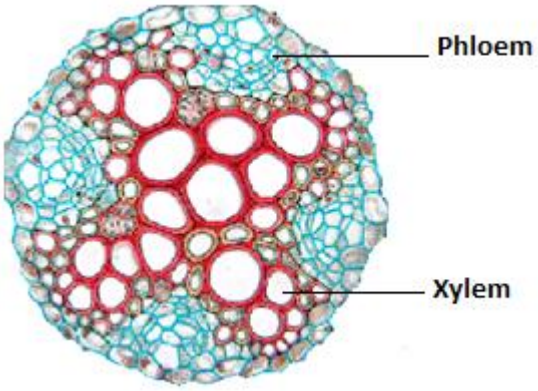


Fig. 4.7: Xylem and Phloem in root

The shape of ring of vascular cambium is wavy in the beginning, but later on it becomes circular due to the pressure of secondary xylem. The portion of vascular cambium formed by conjunctive tissue becomes meristematic first and forms the secondary xylem towards the center. Ultimately the ring becomes circular by the pressure of secondary xylem (pushing outwards). The activity of vascular cambium of root is the same as the activity of vascular cambium of stem. Secondary xylem is formed towards the inner side and secondary phloem is formed towards the outer side by vascular cambium. The portion of vascular cambium which is formed by pericycle is responsible for the formation of pith rays. These are made up of parenchyma. These pith rays are known as primary medullary rays (multiseriate). A few medullary or pith rays are also formed from remaining vascular cambium. These are called secondary medullary rays (uniseriate). Thus two types of medullary rays are found in the secondary structure of roots. The presence of two types of medullary rays is basic characteristic feature of roots. Only secondary medullary rays are found in stem after the secondary growth. Both of them conduct water and food in radial direction (Fig.4.7).

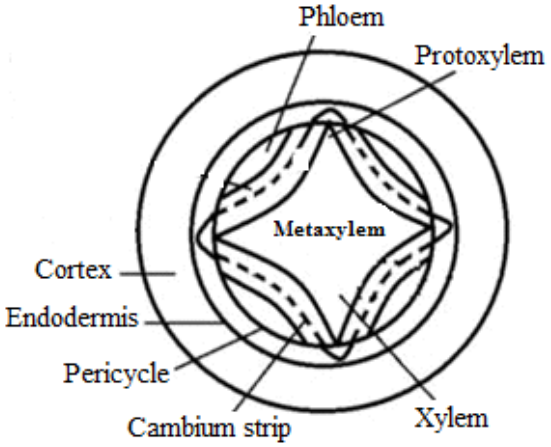


Fig. 4.8 Dicot root

Cork cambium is developed from the pericycle in roots. Cork is formed towards the outside and secondary cortex is formed towards the inner side by the cork cambium. Lenticels are also found in roots but less in number as compared to stem. Cortex completely degenerates in roots after the secondary growth of one or two years. This falls down due to the pressure of cork, whereas in stem, it degenerates after the long duration. Secondary growth is essential in roots to provide strength to the growing aerial parts of the plants and fulfill the requirement of water and minerals. Annual rings are not formed in roots because these are not affected by the changes of environment. Secondary growth is not found in monocot roots (Fig. 4.8).

Functions of Secondary Meristem

1. Healing of wounds

When any plant part gets injured wound is formed there. Boundary of the wound is raised outside and composed of similar type of living cells (parenchyma) called callus. Living cells of wound are responsible to form a cambium. This is called wound cambium. It is also called inducible cambium. This newly formed cambium forms cork towards the outside. This cork covers the wound entirely. Wound cambium is a secondary lateral meristem.

2. Abscission

Falling of any plant organ is called as abscission. Abscission takes place due to formation of abscission layer at the base of plant organ and it is composed of parenchyma. Middle lamella is dissolved in abscission layer during abscission and primary walls also dissolve partially or completely. Sign of leaf fall on stem is called leaf scar and it is a type of wound. The living cells of leaf scar are responsible to form cork cambium, which produce cork. Cork covers the wound. At the site of abscission protective layer is found which is suberized.

3. Knots

Knot is formed when branches are embedded inside the main stem. In most cases knots are caused by the natural growth of the tree, though the specific circumstances under which they form determines how they will appear. As a tree grows and increases the circumference of its trunk, the growing trunk begins to overtake the branches that grow out from it. Knots form around these branches, building up trunk material as the tree continues to expand. The wood of the knot is typically tougher than the surrounding wood and may form a bulge around the branch emerging from its center and known as tight knot. If a branch becomes injured or otherwise dies while still attached to the tree, a loose knot forms as the trunk grows larger. Loose knots are similar to tight knots, but instead of having living wood in the center of the knot there is only a dark plug of dead or decaying material.

4.4 ABNORMAL BEHAVIOUR OF CAMBIUM

The word anomalous means deviating from the general or common order or type. Thus, the term, anomalous growth reflects a **growth condition** which is not commonly seen and which is present in a limited number of families or genera. Plants showing anomalous secondary growth can be studied in two main groups.

(1) Those in which cambium of normal type is present and persists but by peculiarity or irregularity in its activity develop vascular tissues of unusual arrangement.
(2) Those in which the normal cambium either does not develop or is soon replaced by another cambium. This abnormal cambium may either develop from cortex or pericycle and shows abnormal activity.

Several dicots show secondary growth that deviates considerably from the normal secondary growth. The deviating methods of secondary thickenings are called *abnormal* or *anomalous,* although the normal and abnormal forms of growth are not sharply separated from one another. These anomalies may be enlisted as follows:

(a) Anomalous secondary growth in Dicots may be due to following reasons:
  (i) Anomalous position of cambium
  (ii) Abnormal behaviour of normal cambium
  (iii)Accessory cambium formation and its activity
  (iv) Extrastelar cambium
  (v) Interxylary phloem
(b) Absence of vessels in the xylem
(c) Scattered vascular bundles in dicots
(d) Presence of exclusive phloem and xylem bundles
(e) Presence of medullary bundles
(f) Presence of cortical bundles
(g) Intraxylary phloem
(h) Vascular bundles arranged in a ring in monocots

(a) Anomalous secondary growth in Dicots in Dicots may be due to following reasons-

(i) Anomalous/abnormal position of vascular cambium: Normally vascular cambium is circular, but it is folded in stem of some plants. Later on these folds break and separate from each other. Each fold is responsible to form a complete vascular bundle. Many vascular bundles are formed in stem e.g. *Thinouia, Serjania, Bauhinia*.

(ii) Abnormal Activity of vascular cambium: Generally xylem and phloem is formed from the maximum part of the vascular cambium and medullary rays are formed from the few parts of vascular cambium. But in some plants parenchyma (Medullary rays) is formed from the maximum part of the vascular cambium and rarely in some places xylem and phloem are formed e.g. *Aristolochia, Vitis vinifera* (Grape).

(iii) Sequential or successive ring of vascular cambium: In some of the plants, a new ring of vascular cambium is formed each year. This is formed outside the previous ring e.g. *Mirabilis, Boerhaavia, Bougainvillea* etc.

(iv) Formation of vascular cambium from pericycle: Vascular cambium is formed from the pericycle in plants of Amaranthaceae and Chenopodiaceae families. A complete ring of vascular cambium is formed from the pericycle.

(v) Interxylary phloem: This is also called internal phloem. It occurs usually in the form of strands or as a continuous band around the pith. The origin of intraxylary phloem in most plants is primary. The internal phloem develops after the development of external primary phloem. The bundles are treated as bicollateral because of presence of the internal phloem. This type of development is found in Solanaceae, Apocynaceae, Lathyraceae etc.

(b) Absence of vessels in the xylem: Vessels are mainly conducting channels for water but in some species like *Zygozynum, Belliolum, Drimys* and in some aquatic plants like *Elodea, Utricularia, Ceratophyllum* and *Hydrilla* etc. vessels are absent. In these taxa trachieds are the main conducting channels like Gymnosperms.

(c) Scattered vascular bundles in dicotyledons: Vascular bundles are normally arranged in a ring in dicots but in some taxa such as *Thalictrum, Piper, Peperomia, Podophyllum, Papaver, Nymphaea* etc. vascular bundles are scattered. Scattered vascular bundles in dicots recall the arrangement of vascular bundles in monocots.

(d) Presence of exclusive phloem and xylem bundles: Sometimes vascular bundles are incomplete i.e. a bundle is represented either exclusively by xylem or phloem strand. In *Paeonia,* in addition to normal vascular bundle incomplete bundles are also present which are exclusively represented by xylem. Similarly *in Cuscuta, Boerhaavia diffusa, Ricinus communis,* and *Antigonon leptopus* only phloem bundles are present.

(e) Presence of medullary bundles: In some dicots vascular bundles are present in pith and then they are known as medullary bundles. These bundles show a limited amount of secondary growth. These are found in Ranunculaceae, Amaranthaceae, Acanthaceae, Cactaceae and Chenopodiaceae. Their number varies from one to many but they do not supply to the lateral organs like leaf and branch. Their presence is only because of increased needs of translocation and also to the mechanical role in lianas.

(f) Presence of cortical bundles: In some dicots in addition to the normal ring of stelar bundles some vascular bundles are also present in the cortex known as cortical bundles. Morphologically these bundles are leaf traces which traverse through the cortical region of the stem before entering into the petiole. *Casuarina* has a ring of normally oriented cortical bundles below the ridges whereas in *Limonium vulgare* there are numerous irregularly scattered vascular bundles.

(g) Intraxylary phloem: Phloem situated in the inner side of the vascular bundles is known as intraxylary phloem. As it is located in the periphery of the pith it is also known as medullary phloem. It occurs either in the form of a ring (*Asclepias, Convolvulus, Eucalyptus* etc.) or in isolated patches (*Solanum, Capsicum, Calotropis* etc). The internal phloem develops from the provascular tissue. It resembles the external phloem except that fibres are less conspicuous or lacking and sieve tubes and companion cells are in small groups surrounded by parenchyma.

(h) Vascular bundles arranged in a ring in monocots: In monocots the vascular bundles are scattered in the ground tissue. But in some cases as in *Tamus communis* the vascular bundles are arranged in two rings around the pith; the outer ring has only two small bundles which are embedded in the sclerenchymatous pericycle and the inner ring has several large vascular inside the pericycle. In the tubular stems of some of the grasses as *Triticum, Hordeum, Oryza* etc the vascular bundles are arranged in two or more definite rings.

4.4.1 *Bougainvillea* stem

Bougainvillea is a member of the Nyctaginaceae and is an example of a dicotyledonous stem which displays anomalous secondary growth. In the T.S. of *Bougainvillea*, near the centre of the stem, you will see some primary vascular bundles embedded in lignified pith parenchyma. Move the slide towards the outer regions, and you will notice that there has been fairly extensive production of secondary vascular tissue. Secondary phloem and secondary xylem lie on either side of it. The secondary xylem is composed of tracheids, fibers and narrow-diameter vessels. Interspersed with the secondary xylem you will be able to see small pockets of phloem and look like large-diameter metaxylem vessels. These are reminiscent of the primary bundles towards the centre of the stem. These are in fact primary vascular bundles embedded within the secondary xylem, hence the use of the term, anomalous growth in this instance.

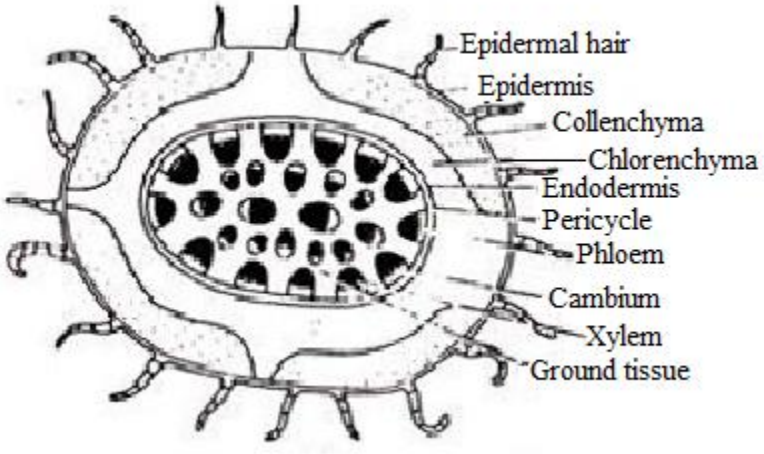


Fig. 4.9: T.S. of *Bougainvillea* stem

The phloem is described as being included phloem, which by definition is phloem tissue which lies between regions of secondary xylem. Whilst the physiological advantage of the formation

of included phloem has not yet been studied, one could speculate that in this instance, the included phloem would be well-protected from predators and pests and, of course, be well-supplied with water and nutrient. The anomalous growth results as a result of differential cambial activity. Newly-produced vascular cambia result in the outer lateral meristem becoming quiescent and this cambium returns to activity only when the internal vascular cambium (which produces the individual embedded bundles) becomes less active. Vascular cambia are said to not produce rays in Nyctaginaceae (lateral meristems do), but do produce vessels and associated, axial parenchyma and sometimes fibers to the inside and variable secondary phloem to the outside (Fig. 4.9).

4.4.2 *Nyctanthes* stem

In *Nyctanthes arbor-tristis* stem which is a dicot plant, apart from normal vascular bundles which occur in a ring in the central region, there are four inversely oriented vascular bundles at the four ridges of stem. These cortical bundles are collateral and open. So in addition to the normal ring of stelar bundle some vascular bundles are also present in the cortex, they are known as cortical bundles. Morphologically these are the leaf traces which traverse through the cortical region of the stem before entering into the petiole. These types of vascular bundles are also found in family Crassulaceae, Casuarinaceae and Oleaceae. These cortical bundles are equally active producing cells and helping in secondary growth of the plant (Fig. 4.10).

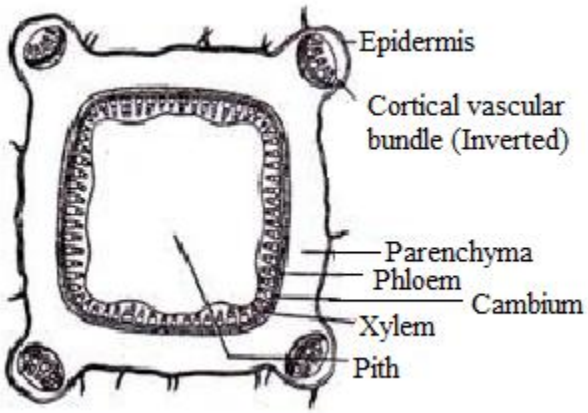


Fig. 4.10: T.S. of *Nyctanthes* stem

4.4.3 *Dracaena* stem

Palm trees are monocots that grow quite tall and thick, yet they lack "normal" secondary growth. *Dracaena* is a monocot but not a true palm, as palms lack the peripheral secondary thickening meristem such as is found in *Dracaena* and *Cordyline*. *Dracaena* is an unusual plant, in that the vascular bundles are surrounded by very prominent fiber bundles. In this sense, *Dracaena* is not anomalous. The stems undergo a specialized secondary growth, which manifests itself in the production of additional parenchymatous elements. Their later growth

pattern is termed diffuse secondary growth, and consists mostly of a proliferation of ground parenchyma cells and additional vascular bundles near the periphery.

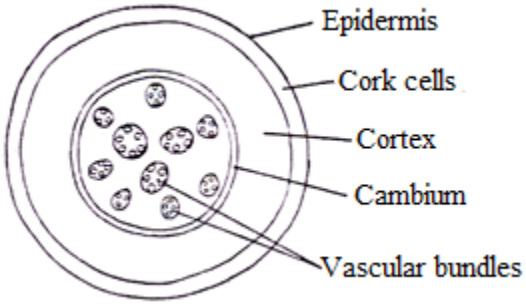


Fig. 4.10: T.S. of *Dracaena* stem

The young *Dracaena* stem has typical structure i.e. epidermis is followed by sclerenchymatous hypodermis. A large number of closed collateral bundles are scattered in ground tissue. One of the outer layers of cells from the ground tissue becomes meristematic and functions as cambium. The cambium formed in the region which has ceased elongating. The activity of this cambium is more on the inner side and very little on the outside where it forms only parenchyma. On the inner side it forms xylem and parenchyma in alternate patches. The inner parenchymatous cells are called conjunctive tissue. After a short while the activity of cambium on inner side changes and above the xylem it starts forming phloem and then again xylem. Thus phloem becomes encircled by xylem and ring of leptocentric (amphivasal) vascular bundle is formed. The xylem formed earlier has bigger vessels and around each vascular bundle is developed a sclerenchymatous sheath. The cambium after sometime alter its activity and forms xylem on the inner side, at those places where it was previously forming the parenchyma and parenchyma in place of xylem. Similar to earlier case again by change in activity it forms a ring of vascular bundles. Activity of cambium goes on changing regularly and more rings of vascular bundles are formed. The last one or two rings of vascular bundles lie in conjunctive tissue. Cork cambium is formed below hypodermis and forms cork and cork cambium in normal fashion (Fig. 4.11).

4.4.4 *Ficus* root

Ficus is a pantropical genus of trees, shrubs and vines occupying a wide variety of ecological niches; most are evergreen, but some deciduous species are endemic to areas outside of the tropics and to higher elevations. Fig species are characterized by their unique inflorescence and distinctive pollination syndrome, which utilizes wasp species belonging to the Agaonidae family for pollination.

In this furrows of secondary phloem are present in the cylinder of secondary xylem. A peculiar secondary growth takes place due to development of unidirectional and bidirectional arcs of cambium. Unidirectional arc of cambium is that portion of the cambium which produces little or no xylem but extensive amount of phloem, bidirectional arc if cambium produces as much or

more xylem then phloem. In the initial stages cambial cylinder produces secondary vascular tissues that have a cylindrical configuration. But subsequently four grooves or furrows of phloem are formed. Other portion of the cambial cylinder except for these four arcs show bicambial activity i.e. they produce as much or more xylem then the phloem. As secondary growth continues furrows of phloem become truncated and the unidirectional and bidirectional arcs of cambium become separated. Initially four furrows of phloem are formed but in the older stems additional furrows may be formed (Fig. 4.12).

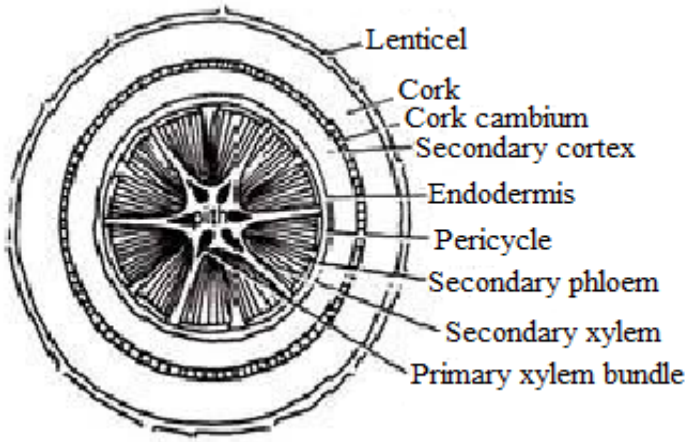


Fig. 4.11: T.S. of *Ficus* root

4.4.5 *Tinospora* stem

Tinospora cordifolia commonly known as Guduchi is an Indian medicinal plant and has been used in Ayurvedic preparations for the treatment of various ailments throughout the centuries. It is a glabrous, succulent, woody climbing shrub native to India. It thrives well in the tropical region, often attains a great height, and climbs up the trunks of large trees. The stem is gray or creamy - white, deeply cleft spirally and longitudinally with the space between spotted with large rosette - like lenticels. The wood is white, soft, and porous, and the freshly cut surface quickly assumes a yellow tint when exposed to air.

Vascular zone is composed of discrete vascular strands with 10 to 12 or more wedge shaped strips of xylem, externally surrounded by semi circular strips of phloem alternating with wide medullary rays; phloem parenchyma contain calcium oxalate crystals; cambium is of 1-2 layers; xylem consists of vessel elements, tracheids, parenchyma and fibres. Vessel elements cylindrical in shape bearing bordered pits. Medullary rays 15 to 20 cells wide. Pith mostly made up of large thin walled cells containing starch grains.

The presence of discrete vascular strands in the mature stem of *Tinospora cordifolia* is one of the anomalous secondary structures found in Menispermaceae. The cambium forms secondary vascular tissue only in the fascicular region, whereas in the interfascicular areas parenchyma is produced. Thus in the old stem the xylem becomes fissured due to the development broad

parenchymatous rays. In such stem parenchyma acts like a shock absorber. It also enables the stem to resist the pulling and compression due to the pressure of high winds. This anomaly is thus an adaptation to the climbing habit of the plant (Fig. 4.13).

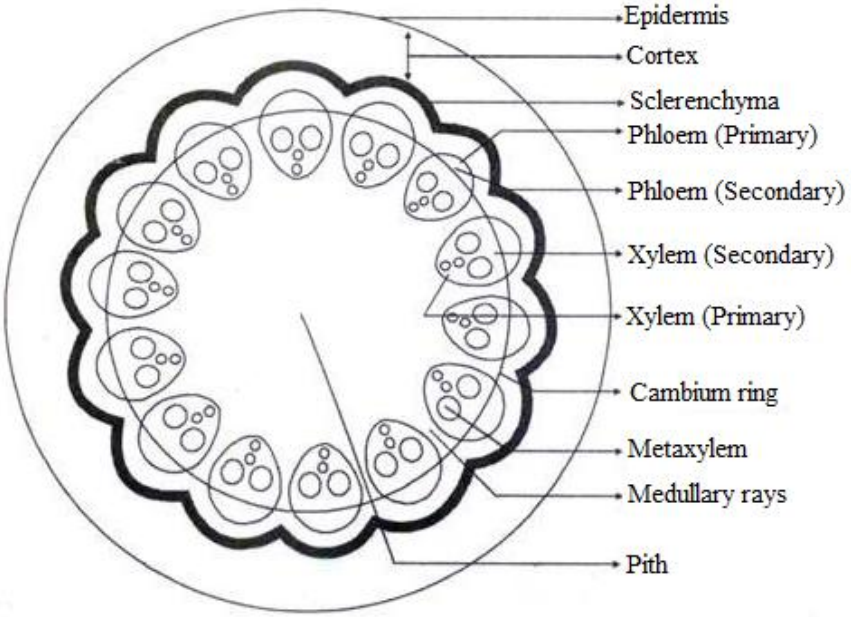


Fig. 4.12: T.S. of *Tinospora* stem

4.5 ACTIVITY OF CORK CAMBIUM

Primary growth in plants yields an outer layer known as the epidermis. In plants that do not have lateral growth, this layer is enough to help protect the inner tissues. When a stem gets thicker, however, this epidermis splits and falls off. The plant would be susceptible to disease and water loss if it weren't for cork cambium. Secondary growth takes place in extra stelar region due to the activity of cork cambium. Cork cambium is also known as phellogen or extra stelar cambium. (The cells of the cork cambium are rectangular). In contrast to vascular cambium the phellogen is relatively simple in structure and composed of one type of cell. Cork cambium arises from the hypodermis or from the outer layer of cortex because they become meristematic. At the time of their development the first phellogen arises in the subepidermal region. Cork cambium is also formed in the form of a single layered ring.

Cork cambium is a tissue found in many vascular plants as part of the periderm. The cork cambium is a lateral meristem and is responsible for secondary growth that replaces the epidermis in roots and stems. It is found in woody and many herbaceous dicots, Gymnosperms and some monocots, which usually lack secondary growth. Cork cambium is one of the meristems - the series of tissues consisting of embryonic (incompletely differentiated) cells from which the plant grows. It is one of the many layers of bark between the cork and

primary phloem. The function of cork cambium is to produce the cork (a tough protective material).

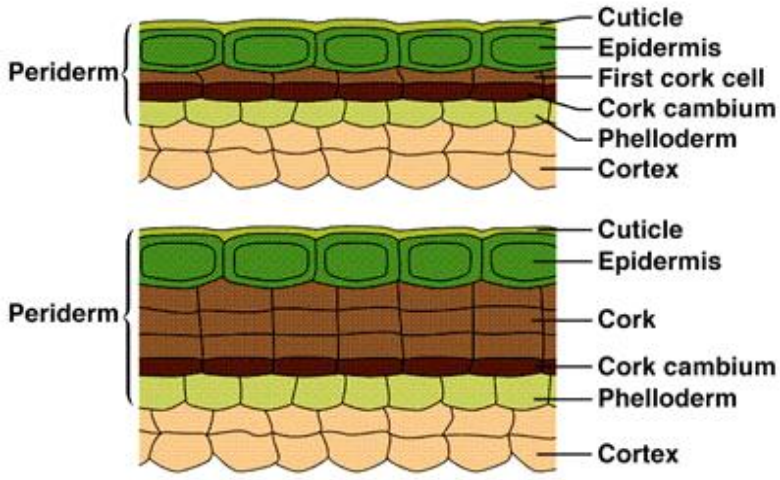


Fig. 4.13: Activity of cork cambium

Phellogen or cork cambium after repeated division gives rise to new cells similar to that of cambial ring. Cork cambium also divides periclinally and it forms some cells towards the outside (epidermis) and some cells towards the inside (cortex). Those cells formed towards outside, their middle lamella is suberized so that these cells become dead and known as Cork or Phellem. Those cell formed towards the inside are differentiated into parenchyma and may contain chloroplasts and these are called secondary cortex or Phelloderm (Fig. 4.13).

Phellogen, phellem and phelloderm are collectively known as periderm. It means the entire secondary tissue in the cortex is known as periderm.

Phellogen + Phellem (cork) + Phelloderm = Periderm

Phellem or cork is formed in high quantity and they are like phellogen cells. They are polygonal and uniform in shape with no intercellular spaces. The phelloderm or secondary cortex is in less quantity because activity of cork, cambium is more towards outside. These cells are living with cellulose walls. Their shape is similar to that of phellogen cell as well. They may be distinguished from cortical cells by their arrangement in radial series.

The periderm thus consists of three different layers:

- phelloderm - inside of cork cambium; composed of living parenchyma cells
- phellogen (cork cambium) - meristem that gives rise to periderm
- phellem (cork) - dead at maturity; air-filled protective tissue on the outside

Growth and development of cork cambium is very variable between different species, and is also highly dependent on age, growth conditions, etc. as can be observed from the different surfaces of bark like smooth, fissured, scaly, flaking off etc.

The **periderm** is the secondary protective (dermal) tissue that replaces the epidermis during growth in thickness of stems and roots of Gymnosperms and dicots (i.e. secondary growth). Unlike typical epidermis, the periderm is a multilayered tissue system, the bulk of which usually constitutes the cork, or **phellem**. There are, however, some exceptions to this in as much as some other structures (*e.g.* potato skin and apple peel) are also periderm. Phellem (the cork) consists of cells that are dead at maturity, and their primary walls become covered from the inside by the secondary wall which consists of parallel suberin lamellae alternating with wax layers. The lateral meristem, (cork cambium or **phellogen**), is one cell layer thick and encircles the stem. It produces periderm centrifugally. The layer of cork cells formed is impermeable for water and gases, but is interrupted at certain points by **lenticels** which function to some extent similar to stomata in the epidermis, and permit gas diffusion.

In some cases parenchyma cells are produced centripetally (i.e. to the inside of the stem or root) by the phellogen as a part of the periderm. These persistent living cells are called **phelloderm** and structurally appear similar to cells of the cortex. The number of layers of cork and phelloderm varies greatly among different species; some plants produce no phelloderm. The most important function of the periderm is to reduce the loss of water and solutes from interior tissues and to protect a plant from unfavorable environmental conditions.

Cork cambium in most stems arises from an outer (subepidermal) layer of the cortex, but in some plants it originates by the periclinal division of the epidermal cells or, alternatively, fairly deeply inside the stem, such as in the primary phloem. In roots, it arises in the pericycle. In woody plants, with the growth of the main stem in thickness, new layers of cork cambium, and accordingly sequential periderm formed in the secondary phloem, cutting off old non-functional phloem tissues. As a result, **rhytidome** or outer bark, is formed consisting entirely of dead cells.

It should be emphasized that bark is not wood. Wood refers only to the secondary xylem. Bark is generally accepted to include all tissues of a plant exterior to the vascular cambium. It can be divided into **inner bark** and **outer bark**. The inner bark includes the region from the vascular cambium to the innermost cork cambium (or phellogen), that is going from one secondary meristem to a second secondary meristem. The outer bark is composed of all tissues outside of the cork cambium (which are dead) and includes phellem, old secondary phloem, crushed primary phloem, crushed cortex, crushed epidermis and any prior periderms.

It is worth considering the differences between the phellogen (cork cambium) and the vascular cambium. It can be said that the phellogen:

- is not derived from any previous meristem, such as procambium.
- is initially derived from permanent tissues, mostly from the subepidermal layer of the
- cortex.
- may repeatedly originate progressively in the deeper layers of the stem.
- typically owes its origin to dedifferentiation and redifferentiation into meristematic cells.

- produces its derivatives mainly (or only) to the outside (generally only cork cells are produced).
- lacks intercellular spaces except where lenticels are present.
- produces a single kind of initial that is rectangular in cross-section, and wider tangentially
- than radially. The cork cells produced have the same shape as the phellogen cells.

As indicated above, phellem cells are dead at maturity, and appear in brick-like rows having their primary walls impregnated with suberin. The plasmodesmata are blocked and usually the contents are filled with tannins or resins, or possibly just air filled as in the case of bottle cork. Some cells, called **phelloids**, have non-cork construction - not suberized but being thin-walled, sclerified or lignified. The highest activity of cork cambium is in winter (autumn) season. Ring of cork cambium remains living only for one year. Each year, a new cambium is formed below the previous cambium. This new cambium is derived from the secondary cortex or phelloderm.

Lenticels: Most of the cells of phellem are dead but at some places living cells are also found. Suberin is not deposited in these places and these loosely arranged cells are called lenticels. Lenticels appear on the outer surface of the plant either in small points or in the form of areas of protuberance. Lenticels are made up of scattered group of living cells. Usually they are formed below the stomata. These cells are known as complementary cells/complementary tissue. The main function of lenticels is exchange of gases between plant and atmosphere. Rows (vertical or longitudinal) of lenticels may occur opposite the medullary rays, facilitating the free exchange of gases. Transpiration also takes place through the lenticels known as lenticular transpiration. Adventitious roots on cutting originate from the living cells of lenticels in vegetative reproduction.

Lenticels are found in most of the woody trees but absent in woody climbers. Lenticels are mainly found on wood stems and they are never found on leaves. Lenticels are present all over the plant body and they are also present on fruits. If lenticels are blocked then root will die first due to lack of food. All the tissues which occur outside the cork cambium are collectively termed as rhytidome. Rhytidome includes cork and tissues which become dead due to the pressure of cork.

Kinds of bark

1. Ring Bark: Continuous bark of equal thickening is called ring bark. It is formed around the stem in the form of a complete ring. In ring bark cork cambium is continuous. A complete distinct ring bark is formed in this plant. Its bark was used as a writing material as a paper in ancient period. Example: Bhojpatra (*Betula utilis*) and it is also formed in *Eucalyptus*.

2. Scaly Bark: Discontinuous bark of unequal thickening is called scaly bark. This bark is formed around the stem in the form of pieces or fragments. In scaly bark the ring of cork cambium is not continuous. Highly obvious scaly bark is formed in *Psidium guajava*.

Besides this scaly bark is also formed in Neem (*Azadirachta indica*), Mango (*Mangifera indica*) and Imli (*Tamarindus indica*) etc.

4.6 SUMMARY

In plant science, secondary growth refers to the growth that results from cell division in the cambia or lateral meristems and that causes the stems and roots to thicken, while primary growth is growth that occurs as a result of cell division at the tips of stems and roots, causing them to elongate, and gives rise to primary tissue. Secondary growth occurs in most seed plants, but monocots usually lack secondary growth. If they do have secondary growth, it differs from the typical pattern of other seed plants.

In many vascular plants, secondary growth is the result of the activity of the two lateral meristems, the cork cambium and vascular cambium. Arising from *lateral* meristems, secondary growth increases the girth of the plant root or stem, rather than its length. As long as the lateral meristems continue to produce new cells, the stem or root will continue to grow in diameter. In woody plants, this process produces wood, and shapes the plant into a tree with a thickened trunk.

Because this growth usually ruptures the epidermis of the stems or roots, plants with secondary growth usually also develop a cork cambium. The cork cambium gives rise to thickened cork cells to protect the surface of the plant and reduce water loss. If this is kept up over many years, this process may produce a layer of cork. In the case of the cork oak it will yield harvestable cork. Secondary growth also occurs in many non-woody plants e.g. tomato, potato tuber, carrot taproot and sweet potato tuberous root. A few long-lived leaves also have secondary growth.

Abnormal secondary growth does not follow the pattern of a single vascular cambium producing xylem to the inside and phloem to the outside. Some dicots have anomalous secondary growth e.g. in *Bougainvillea* a series of cambia arises outside the oldest phloem. Most monocots either have no secondary growth or else anomalous secondary growth of some type. For example, palm trees increase their trunk diameter due to division and enlargement of parenchyma cells, which is termed diffuse secondary growth. In some other monocot stems with anomalous secondary growth, a cambium forms, but it produces vascular bundles and parenchyma internally and just parenchyma externally. Some monocot stems increase in diameter due to the activity of a primary thickening meristem, which is derived from the apical meristem.

4.7 GLOSSARY

Apical meristem: Embryonic, totipotent tissue in the tips of the roots and shoots of plants

Cambium: A lateral meristem that produces secondary growth

Collenchyma: Tissue composed of unevenly thickened cell walls; collenchyma cells are flexible and support young parts of the plant without hindering growth; collenchyma cells are composed of cellulose

Cork: A plant tissue composed of cells whose walls are impregnated with suberin and are non-living at maturity; cork is produced by the cork cambium

Cork cambium: A narrow cylindrical sheath of meristematic cells that produces cork cells to replace the epidermis during secondary growth (growth in width)

Cuticle: An impermeable layer of cutin on the outer walls of epidermal cells

Ectophloic: Having phloem only on the outer side of the stele; compare to amphiophloic

Endarch: A type of xylem maturation in which protoxylem is internal to metaxylem and development proceeds centrifugally (from the inside out)

Epidermis: The exterior tissue, usually on cell thick, of leaves and young stems and roots

Exarch: A type of xylem maturation in which protoxylem is external to metaxylem and development proceeds centripetally (from the outside in)

Fiber: A long-walled plant cell which is often dead at maturity; fibers impart elasticity, flexibility and tensile strength to plant structure

Ground tissue: A tissue consisting mostly of parenchyma cells that makes up the bulk of a young plant

Manoxylic wood: Wood type that contains abundant parenchyma; typical of cycads

Mesarch: A type of xylem maturation in which the protoxylem is embedded in the metaxylem and development proceeds both centripetally (from the outside in) and centrifugally (from the inside out); compare to endarch and exarch

Mesophyll: Parenchyma tissue between the upper and lower epidermis of a leaf

Metaxylem: A type of primary xylem that differentiates and matures later than the protoxylem; generally metaxylem tracheids are longer than protoxylem

Periderm: A tissue primarily consisting of cork cells; outer bark

Phloem: Photosynthate conducting tissue of vascular plants

Pith: The central parenchymatous tissue in a vascular plant axis

Polystelic: Having more than one stele

Primary growth: Growth in length, controlled by the apical meristem

Procambium: The primary meristematic tissue that gives rise to primary xylem and primary phloem; procambia are found in apical as well as intercalary meristems

Protoxylem: The first primary xylem to differentiate and mature, usually before and during elongation of the axis; protoxylem cells are generally smaller in diameter than metaxylem

Pycnoxylic wood: Dense wood that contains little parenchyma; typical of *Archeopteris* conifers

Secondary growth: Growth in width initiated and maintained by the vascular cambium and cork cambium

Secondary xylem: Xylem produced by the vascular cambium

Siphonostele: A type of stele that consists of a ring of vascular tissue surrounding pith

Stele: The central vascular cylinder in stems and roots where the vascular tissue is located

Tracheid: A water conducting and supportive cell type of xylem composed of long, thin cells with tapered ends and walls hardened with lignin

Vascular bundle: A strand of tissue composed mostly of xylem and phloem

Vascular cambium: A lateral meristem that produces secondary vascular tissue in stems and roots

4.8 SELF ASSESSMENT QUESTION

4.8.1 Multiple choice questions:

1. Cork is formed from:

(a) Cork cambium (phellogen) (b) Vascular cambium

(c) Phloem (d) Xylem

2. What is true about a monocot leaf:

(a) Reticulate venation

(b) Absence of bulliform cells from epidermis

(c) Mesophyll not differentiated into palisade and spongy tissues

(d) Well differentiated mesophyll

3. Vascular cambium produces:

(a) Primary xylem and primary phloem (b) Secondary xylem and secondary phloem

(c) Primary xylem and secondary phloem (d) Secondary xylem and primary phloem

4. A bicollateral vascular bundle is characterized by:

(a) Phloem being sandwiched between xylem (b) Transverse splitting of vascular bundle

(c) Longitudinal splitting of vascular bundle (d) Xylem being sandwiched between phloem

5**.** Abnormal/anomalous secondary growth occurs in:

(a) *Dracaena* (b) Ginger

(c) Wheat (d) Sunflower

6**.** Which exposed wood will decay faster?

(a) Sap wood (b) Soft wood

(c) Wood with lot of fibers (d) Heart wood.

7. A narrow layer of thin walled cells found between phloem/bark and wood of a dicot is :

(a) Cork cambium (b) Vascular cambium

(c) Endodermis (d) Pericycle.

8. Periderm is produced by:
(a) Vascular cambium (b) Fascicular cambium
(c) Phellogen (d) Intrafascicular cambium.

9. Casparian strip occurs in a:
(a) Endodermis (b) Exodermis
(c) Pericycle (d) Epidermis.

10. Vascular bundles in a dicot stem are :
(a) Open, collateral, exarch (b) Closed, collateral, endarch
(c) Closed, collateral, exarch (d) Open, collateral, endarch

11. Annual rings are distinct in plants growing in :
(a) Temperate regions (b) Tropical regions
(c) Grasslands (d) Arctic region

12. The lateral roots generally originate in :
(a) Cork cambium (b) Cortex
(c) Pericycle cells lying against protoxylem (d) Endodermal cells lying against protoxylem

13. The best method to determine the age of tree is:
(a) To count the number of leaves (b) To count the number of annual rings
(c) To measure it's diameter (d) To find out the number of branches

14. The bark of a tree comprises:
(a) All the tissues outside the cork cambium (b) All the tissues outside the vascular cambium
(c) Only the cork (d) Just inside the cork cambium

15. Which of the following give rise to the cork tissue?
(a) Phellogen (b) Periblem
(c) Periderm (d) Phelloderm

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

4.9 REFERENCES

- Cutler, Botha and Stevenson, Plant Anatomy, an Applied Approach and Raven, Evert and Eichhorn, *Biology of Plants* (6th or later edition) i**s** highly recommende**d** for additional background information.

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4.10 SUGGESTED READINGS

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- Pandey. B.P. (2012). Plant Anatomy. S. Chand & Company Ltd., New Delhi
- Integrative Plant Anatomy, 26 Apr 2000, by William C. Dickison Academic Press Inc.
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- Esau's Plant Anatomy: Meristems, Cells, and Tissues of the Plant Body: Their Structure, Function, and Development, 3rd Edition by Ray F. Evert (Author), Susan E. Eichhorn ISBN-13: 978-0471738435
- *Plant Anatomy: Tissue* by Dr. Manisha Majumdar, Book Rix Edition

4.11 TERMINAL QUESTIONS

4.11.1: Answer the following questions in two or three sentences:

i. Name two plants which possess interxylary phloem?
ii. What are the changes involved in formation of heart wood?
iii. What is ring bark and scale bark? Give one example each.
iv. Differentiate between soft wood and hard wood.
v. Name any two monocot plants in which secondary growth is seen?
vi. Name two unusual structure found in the stem of *Boerhaavia*?
vii. Why annual rings are prominent in the wood of temperate region?
viii. Differentiate between growth and annual rings?
ix. What cells give rise to the interfascicular cambium?
x. How accessory cambial rings are found?

4.11.2 Answer the following questions in about 100 words.

i. Cork cambium forms tissues that form the cork. Do you agree with this statement?
ii. Explain the process of secondary growth in the roots of woody Angiosperms.
iii. Define anomalous secondary growth in *Dracaena* stem.
iv. What is periderm? How does periderm formation take place in the dicot stems?
v. What are cortical bundles and how do they arise?

4.11.3 Answer the following questions in about 200 words.

i. Explain the process of secondary growth in the stems of woody Angiosperms with the help of schematic diagrams. What is its significance?
ii. What are the various regions of anomalous secondary growth in dicot? Describe the secondary growth in *Boerhaavia*.
iii. What are the differences in the secondary growth of stem and root?
iv. Give an account of origin, structure and function of periderm?

BLOCK -2 FAMILIES

UNIT-5 RANUNCULACEAE, CARYOPHYLLACEAE AND RUTACEAE

5.1- Objectives
5.2-Introduction
5.3-Ranunculaceae
    5.3.1-Systematics
    5.3.2-General characters
    5.3.3-Important Genera
    5.3.4-Economic importance
5.4- Caryophyllaceae
    5.4.1-Systematics
    5.4.2-General characters
    5.4.3-Important Genera
    5.4.4-Economic importance
5.5- Rutaceae
    5.5.1-Systematics
    5.5.2-General characters
    5.5.3-Important Genera
    5.5.4-Economic importance
5.6-Summary
5.7-Glossary
5.8-Self Assessment Questions
5.9-References
5.10-Suggested Readings
5.11-Terminal Questions

5.1 OBJECTIVES

In the present unit students will be able -

- to become familiar with the general distribution, systematics, General characters, Important genera and economic importance etc. of families Ranunculaceae, Caryophyllaceae and Rutaceae.
- to know the phylogenetic and evolutionary relations of the families. Some of the important genera of the concerning families are also mentioned here to let you familiar with them.

5.2 INTRODUCTION

Student must be knowing different types of classification for angiospermic plants in your previous units. The classification used in Indian subcontinent is that proposed by Bentham and Hooker. They discussed 163 families under dicotyledons in their *Genera Plantarum*. Economic importance of each family is also discussed in some detail.

The dicotyledons include all those angiosperms in which the embryo possess two cotyledons, leaves with reticulate venation and vascular bundles are open and arranged in one or more rings. These plants have secondary thickenings in the stems. Due to the presence of the cambium. These plants may be either woody or herbaceous, having pentamerous flowers. They posses persistent primary root that develop into tap root.

Families Ranunculaceae, Caryophyllaceae and Rutaceae belong to Polypetalae (Petals are free and flower with Calyx and Corolla) group. Of them Family Ranunculaceae and Caryophyllacee belong to SeriesThalamiflorae (Polysepalous, petals hypogynous) while family Rutaceae belongs to Disciflorae (Thalamus expanded into a disc , ovary superior).

The members of the subclass Polypetalae contain flowers with free petals and their perianth is usually in two whorls i.e. calyx and corolla . Polypetalae have been divided into 3 series viz, Thalamiflorae, Disciflorae and Calyciflorae.

Series Thalamiflorae is characterized by (i) Usually distinct sepals free from ovary (ii) presence of many stamens (iii) Hypogynous flowers (iv) superior ovary and (v)Absence of disc . Thalamiflorae includes 6 cohorts (= orders) and 34 orders (= families)

Series Disciflorae is characterized by (i) distinct or united sepals free or adnate to ovary (ii) stamens hypogynous, usually definite flowers (iv)superior ovary and (v) presence of disc. Disciflorae includes 4 cohorts (= orders) and 23 orders (= families)

Series Calyciflorae is charactrised by (i) Usually inferior ovary (ii) united or usually free sepals and flowers perigynous or epigynous. It includes 5 cohorts (= orders) and 27 orders (= families)

Table 5.1 Generalized Systematic position of families mentioned in your syllabi

	Dicotyledons					**Monocotyledons**
Subclass	**Polypetalae**			**Gamopetalae**		
Series	Thalamiflorae	Disciflorae	Calyciflorae	Inferae	Bicarpellatae	
Families	Ranunculaceae, Caryophyllaceae	Rutaceae	Rosaceae Fabaceae		Asclepediaceae Solanaceae Lamiaceae	Orcidaceae Liliaceae Poaceae

5.3 FAMILY: RANUNCULACEAE

Bentham & Hooker included family Ranunculaceae under Ranales, one of the 8 orders (families). It is commonly known as **Buttercup family**. According to Dr John David, (2010) the Ranuculaceae are combined with the Eupteleaceae, Lardizabalaceae, Menispermaceae, Berberidaceae, and Papaveraceae in the Ranunculales, the only order in the superorder Ranunculanae. This follows the work of the Angiosperm Phylogeny Group.

Takhtajan 1997 includes the Ranunculaceae as the only family in the Ranunculales which he placed in a subclass, the Ranunculidae, instead of a superorder. Previously, Thorn 1992 placed the Ranunculaceae in the Berberidales, an order within the Superorder Magnolianae. Earlier Cronquist in 1981 included the Ranunculaceae along with seven other families in the Rancunculales which was included in the Magnoliidae, which he regarded as a subclass.

Diagnostic characteristics - Herbaceous, leaves palmately divided, flowers with many stamens, gynoecium of many simple pistils, fruit an aggregate of achenes or follicles.

Distribution pattern

It is a large family and includes 50 genera and 1900 species. It is mostly distributed in the temperate regions of the Northern Hemisphere. In India this family is represented by 20 genera and 165 species, mostly confined to the Himalayan region of Pakistan and India.

5.3.1 Systematics

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledons
Polypetalae	Archichlamydeae	Herbaceae
Thalamiflorae	Ranales	Ranales

Ranales	Ranunculaceae	Ranunculaceae
Ranunculaceae		

5.3.2 General Characteristics

Habit: Annual or perennial herbs, rarely shrubs or vines (*Clematis*). Some species are aquatic herbs (*Rannunculas aquatilis*). The perennial species usually develop rhizome and tuberous root (*Aconitum* and *Ranunculus*)

Roots: Tap as well as adventitious root, Tuberous root (*Aconitum)*

Stem: Herbaceous (*Rannunculas*), woody (*Paeonia*) or climbing (*Clematis*) stem, develops rhizome

Leaves: Usually basal and cauline, Petiolate. Usually exstipulate but stipulate in *Ranunculus* Alternate rarely opposite (*Clematis*). Simple, pinnately compound (*Clematis*), decompound (*Thalictrum*) some aquatic species show heterotrophy, reticulate venation. The leaves are modified into tendrils in *Clematis aphylla* and photosynthesis is carried out by the stem.

Inflorescence: Inflorescence is variable. Dichasial Cyme (*Rannunculas sp.*), sometimes raceme (*Aconitum*), axillary (*Clematis*), solitary and terminal (*Nigella*)

Flower: Pedicillate, ebracteate rarely bractate, hermaphrodite, unisexual in *Thalictrum* actinomorphic (*Rannunculas sp.*) rarely zygomorphic (*Delphium*), hypogynous, complete, pentamerous, Regular.The floral parts are arranged spirally on the elongated receptacle. An involucres of leaves is present outside the calyx.

Calyx: Sepals 5-8 which are distinct and usually deciduous, free, In Delphinium and *Aconitum* the sepals are petaloid and the posterior sepal is spurred. Aestivation is imbricate

Corolla: 5 or more petals or sometimes petals may be absent, polypetalous, variously colored, Sometimes, petals are changed into nectaries, In *Delphinium* the posterior pair of petals forms spur which projects into the spur of the sepal, another pair of the petal if present is very much reduced (*Aconitum*). In *Clematis* petals are altogether absent and sepals become petaloid.

Androecium: Stamens are numerous, polyandrous. Spirally arranged on the thalamus, In some genera (*Nigella* ansd *Aquilegia*) the stamens are arranged in definite rings, anthers adnate, dithecous, extrose, dehiscing longitudinally.

Gynoecium: Numerous free carpels (Polycarpellary) arranged spirally on a distinct thalamus (one to three carpels in *Delphinium*), apocarpous rarely syncarpous (*Nigella*), ovary superior, one to several ovules in each ovary. Placentation basal or marginal.style and stigma one.

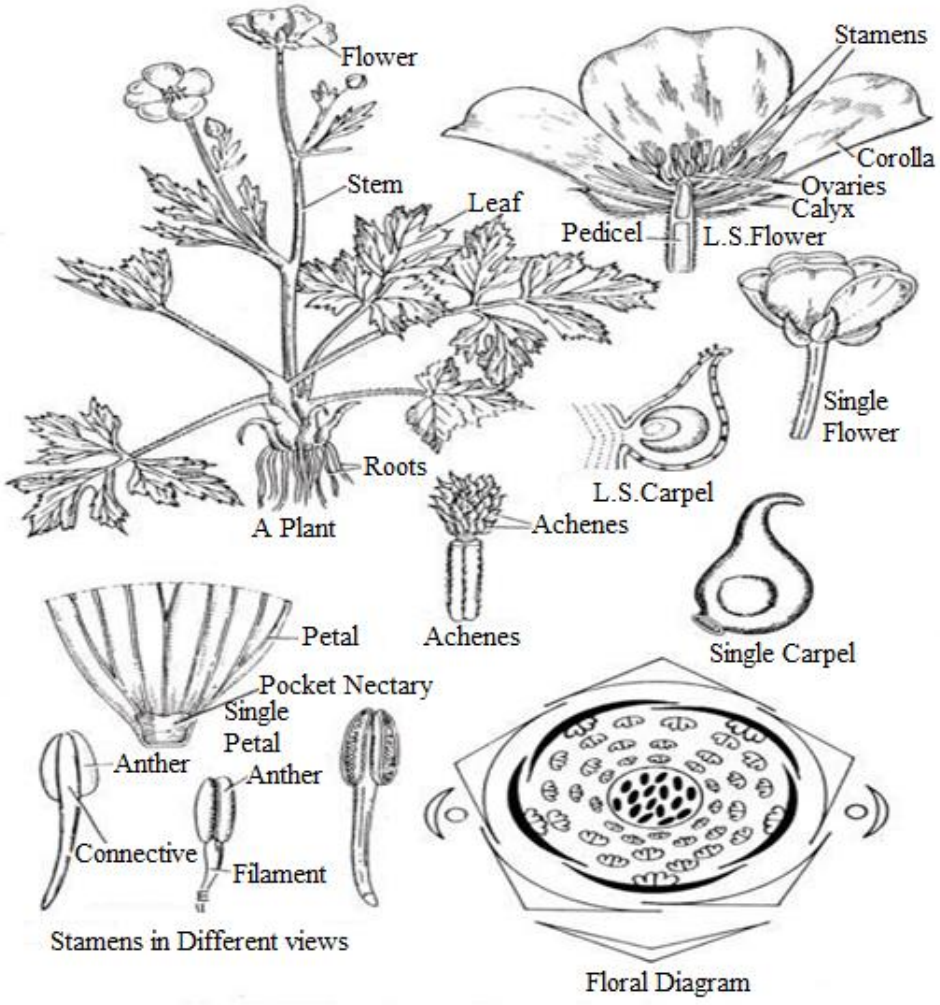

Fig. 5.1 ***Ranunculus sceleratus***

Fruits: An etaerio of achenes or follicles**,** sometimes berry or capsule.

Seed: Small**,** endospermic seed

Pollination: Generally entomophilous

Floral formula

Ranunculus	**Br**	Brl	⊕	♂♀	$K_5\ C_5\ A\alpha\ \underline{G}\alpha$
Delphinium	**Br**	Brl	⊕	♂♀	$K_5\ C_4\ A_{15}\ \underline{G}_1$

Nigella	**Ebr**		⊕	♂♀	$K_5\ C_0\ A\ \alpha\ \underline{G}_{(5\text{-}12)}$
Clematis	**Br**	Brl	⊕	♂♀	$K_5\ C_5\ A\alpha\ \underline{G}\alpha$

5.3.3. Important Genera

The familiar examples of the family are *Delphinium* (Larkspur) *Thalictrum* (Meadow-rue) (*Ranunculus* (Butter-cup) *Nigella* (Kala-jeera), *Anemone* (Wind flower), *Aconitum* (Aconite)

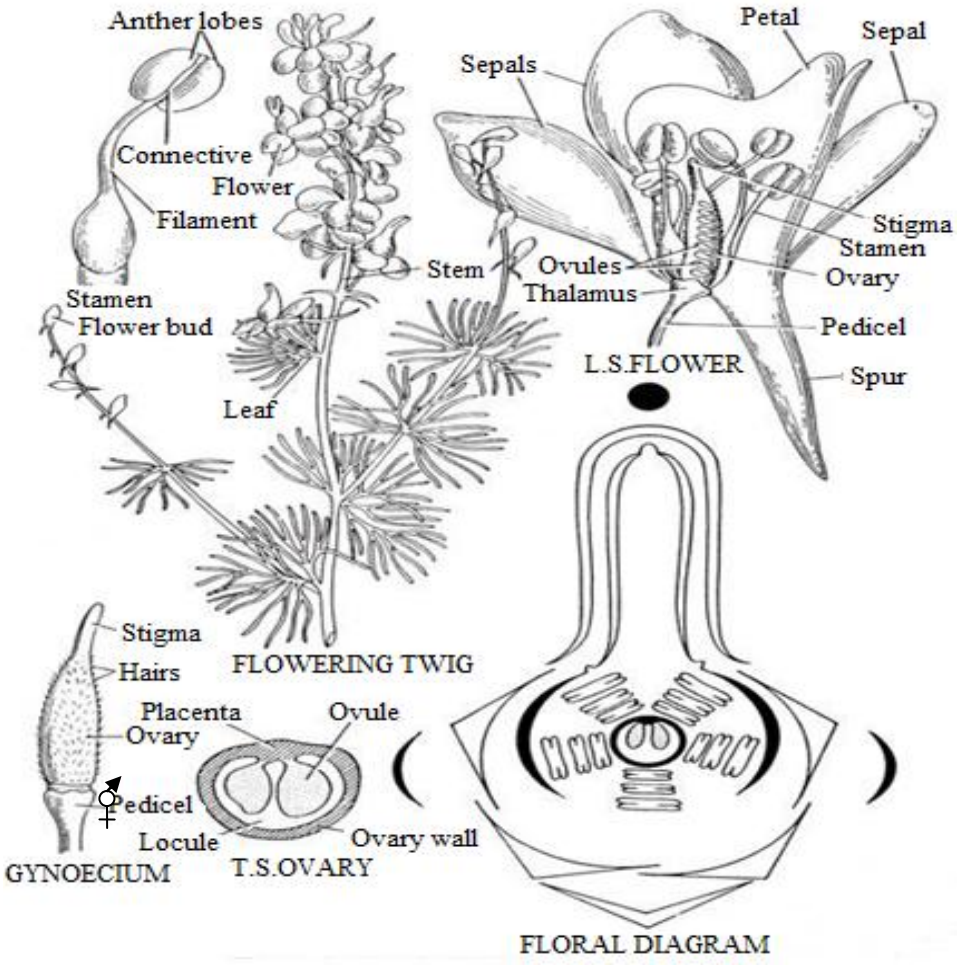

Fig. 5.2 ***Delphinium ajacis***

5.3.4 Economic importance

1-Ornamental plants: Most plants are cultivated for their beautiful flowers like *Ranunculus* (Buttercup), *Thalictrum, Clematis etc*.

2-Medicinal plants: Some members are used as medicinal plants. *Aconitum napellus* yields an alkaloid **aconite used for rheumatism and as nerve sedative.** *Thallicirom* yields **mamira.** It is used in the treatment of ophthalmia. Some species of *Clematis* are used as a remedy for leprosy and blood diseases. Juice of some sp, of ranunculus used for intermittent fever. Roots of *Hydrastis canadensis* are used as antidote of snake bite.

3-Condiments: Some members are used as condiments for flavoring. Seeds of *Nigella* (Black fennel, Kala jeera) are used as drug for bronchial asthma, fever and cough

4-Importance for honey: Most members of this family have nectaries. Flower nectaries have great importance for honey bees for honey production.

5-Poisonous species: Some members of this family produce acrid juice. It is highly poisonous.

5.4 FAMILY- CARYOPHYLLACEAE

Caryophyllaceae commonly known as the pink, or carnation family of flowering plants. According to Bentham and Hooker it belongs to order Caryophyllales. Currently Amaranthaceae and Caryophyllaceae are sister groups and considered closely related.

Formerly, Caryophyllaceae was considered the sister family to all of the remaining members of the suborder Caryophyllinae because they have anthocyanins, and not betalin pigments. However, cladistic analyses indicate Caryophyllaceae evolved from ancestors that contained betalin, reinforcing betalin as an accurate synapomorphy of the suborder. This family is traditionally divided in three subfamilies:

Alsinoidae: no stipules, petals not united
Silenoideae: no stipules, petals united
Paronychioideae: fleshy stipules, petals separate or united

Diagnostic characteristics: The members are diverse in appearance and habitat; most of them have swollen leaf and stem joints. They have five sepals and five petals, but it is thought that the latter are in origin modified stamens. There are usually 5 or 10 stamens, with an ovary borne above them. The ovules are borne in the centre of the ovary, and there are usually no walls dividing up the ovary cavity.

Distribution: Caryophyllaceae comprising some 86 genera and 2,200 species of herbaceous annuals and perennials, mainly of north temperate distribution. The members of this family are commonly found in the temperate regions of the Northern hemisphere. Certain genera are found in the Southern hemisphere and few are found in the mountains of tropical regions. In our country the plants of this family are either found in the hilly tracts or they grow in the plains during winter season, e.g., *Stellaria, Spergula, Dianthus*, etc.

5.4.1 Systematics

Bentham & Hooker	Engler& Prantl	Hutchinson
Dicotyledons	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Herbaceae
Thalamiflorae	Centrospermae	Caryophyllales
Caryophyllinaeae	Caryophyllaceae	Caryophyllaceae
Caryophyllaceae		

5.4.2 General Characteristics

Habit: Most of them are annual, while some of them are perennial herbs. Certain small shrubs, e.g., some species of *Acanthophyllum* are also found in the warmer parts of the world. Some species of *Stellaria* (*S. aquatica*)

Stem: The stem is erect, branched, green, herbaceous, solid and mostly swollen at the nodes.

Leaves: The leaves are simple, opposite decussate (rarely alternate), entire and exstipulate. The leaves sometimes possess shortly connate perfoliate base, e.g., in *Dianthus*. linear to lanceolate in shape. At each node one leaf develops earlier than the other. The stipules are usually absent but scarious stipules are present in some genera (*Spergula*). This leaf bears in its axil a more vigorous bud than on the other side and frequently it is only this bud which develops later.

Inflorescence: The inflorescence is cymose. Usually it is a dichasium which later on becomes a dichasial cyme ending in a scorpoid monochasial cyme. This is known as cincinnus or caryophyllous type inflorescence which is characteristic of the family. In certain cases the flowers are arranged in racemes or solitary (*Arenaria*).

Flower: The flowers are pedicellate, actinomorphic, usually hermaphrodite and pentamerous (but rarely unisexual or tetramerous *Sagina*). They are regular, complete and hypogynous slightly perigynous in *Arenaria.*

Calyx: It is composed of five and very rarely of four sepals (*Sagina*). The sepals may be free or united together into a tube. They are usually persistent with membranous margins. The aestivation is imbricate (quincuncial).

Corolla: It is composed of five and rarely of four petals. They are always free and usually differentiated into lomb and claw. The petals are mostly notched (*Cerasrium*) sometimes deeply bifid, e.g *Stellaria media*.In Dianthus aligulate outgrowth is present on the adaxial side of the petal forming the corona. Occasionaly the petals are minute or absent (*Sagina*). Usually the aestivation is imbricate.

Androecium: Stamens are usually twice the number of petals (ten or eight) in two equal and alternate whorls. Sometimes the number of stamens reduces to eight, five, four, three or even one. They are polyandrous, obdiplostemonous, i.e., the stamens are arranged in two whorls of five each, the stamens of the outer whorl are seen to be opposite the petals and of inner whorl alternating the petals (*Stellaria*). In caryophyllaceae the obdiplostemony is not real but apparent as it has been brought about as a result of mechanical pushing of the stamens of inner whorl outwards. The filaments are distinct or slightly connate at the base. The anthers are dithecous, introrse and dehiscing longitudinally.

Gynoecium: It consists of two (*Dianthus*) or three to five (*Cerastium, Spergula and Stellaria*) carpels; syncarpous. The styles are free. The ovary is superior (slightly inferior in *Arenaria*) and unilocular; Occasionaly in *Vaccaria*, the ovary becomes chambered in the basal region due to the formation of the septa the ovules are many, campylotropous and arranged on a central column.

The placentation is free-central which is most characteristic of the family. The number of carpels corresponds to the number of styles and stigmas. In *Stellaria* the number of carpels is reduced to three. A disc is present at the base of the stamens which is annular or divided into glands.

Fruit: Generally the fruit is an unilocular capsule, e.g., *Stellaria, Arenaria, Spergula*, etc. In some cases the fruit, may be an achene or a nut, e.g., *Herniaria, Dysphania, Scleranthus*, etc.

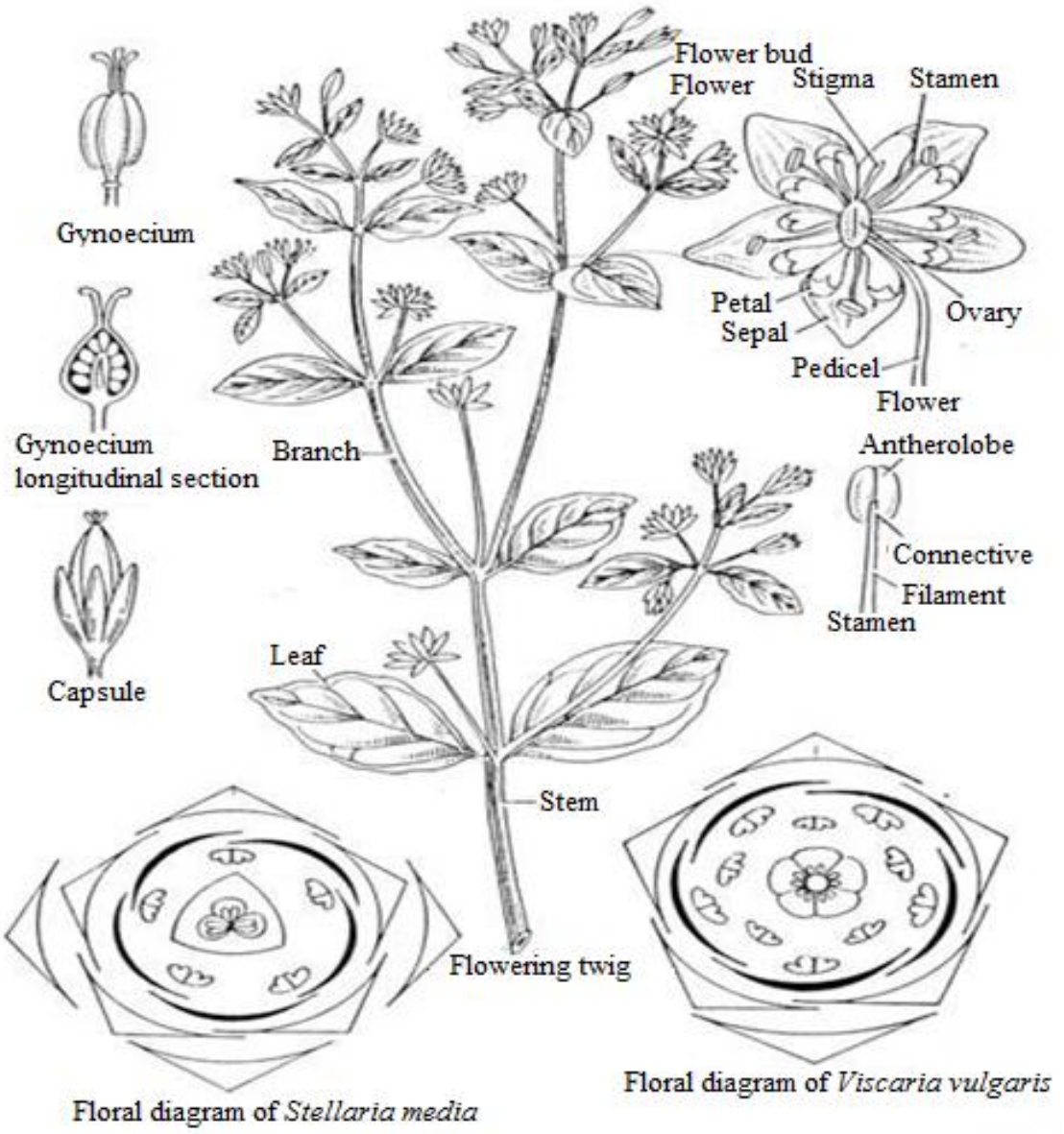

Fig.5.3 *Stellaria media*

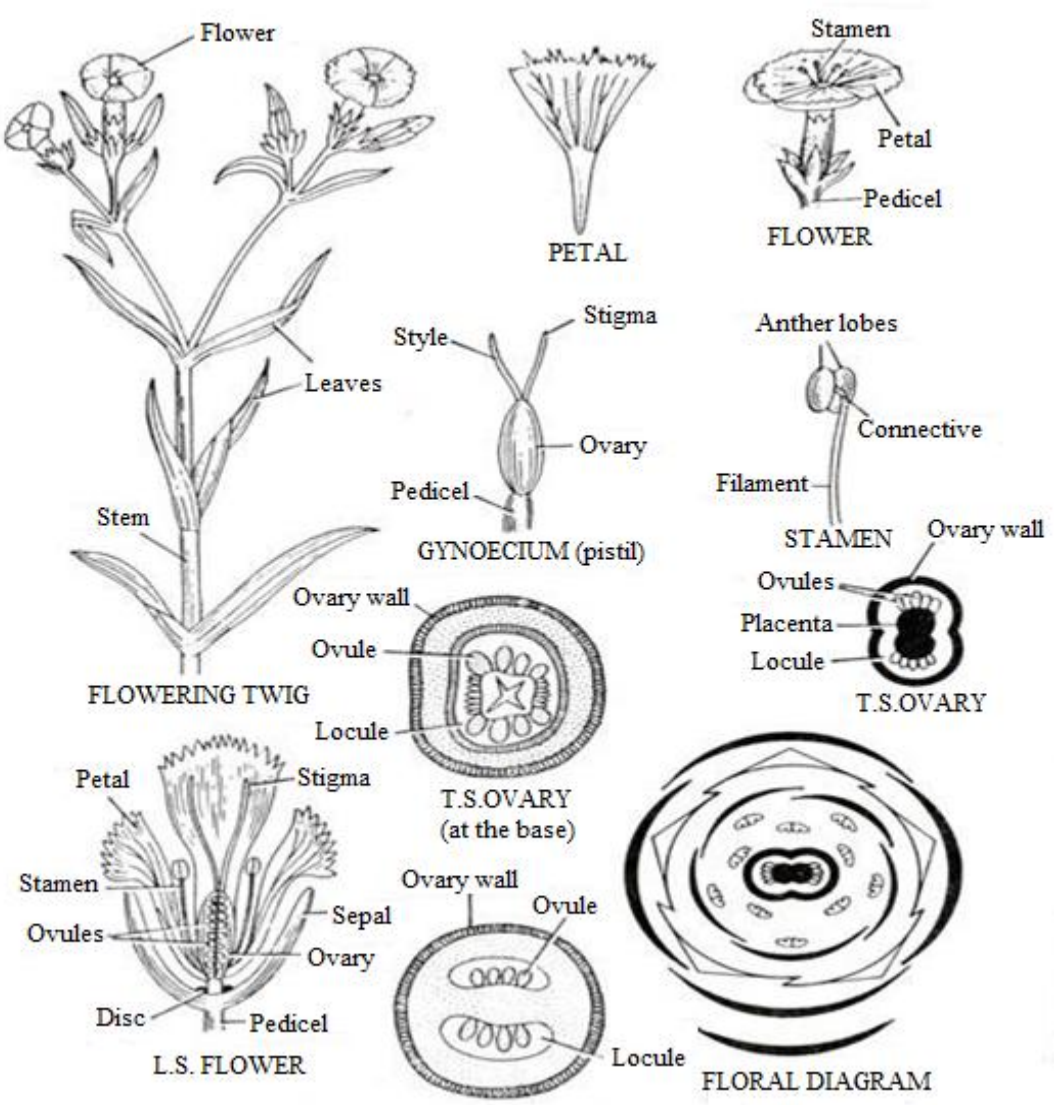

Fig 5.4 ***Dianthus***

Seeds: The seeds are small and endospermic. The embryo is curved in the endosperm. Sometimes the funicle is conspicuous. They are dispersed by censor mechanism.

Pollination: It usually takes place by means of insects (i.e., entomophily).

Floral formula: Generalized for family ⊕ ♀♂ $K_5\ C_5\ A_{5+5}\ \underline{G}_{(2-5)}$

Stellaria media	**Br**	Brl	⊕	♀♂ $K_5\ C_5\ A_{5+5}\ \underline{G}_{(3)}$
Spergula arvensis	**Br**	Brl	⊕	♀♂ $K_5\ C_5\ A_5\ \underline{G}_{(3\text{ or }5)}$

Dianthus caryophyllatus	⊕	♂ ♀	Epi	K_{2+2} $K_5\ C_0\ A\ \alpha\ \underline{G}_{(5-12)}$
Silene conoides	⊕	♂ ♀		$K_5\ C_5\ A_{5+5}\ \underline{G}_{(3)}$

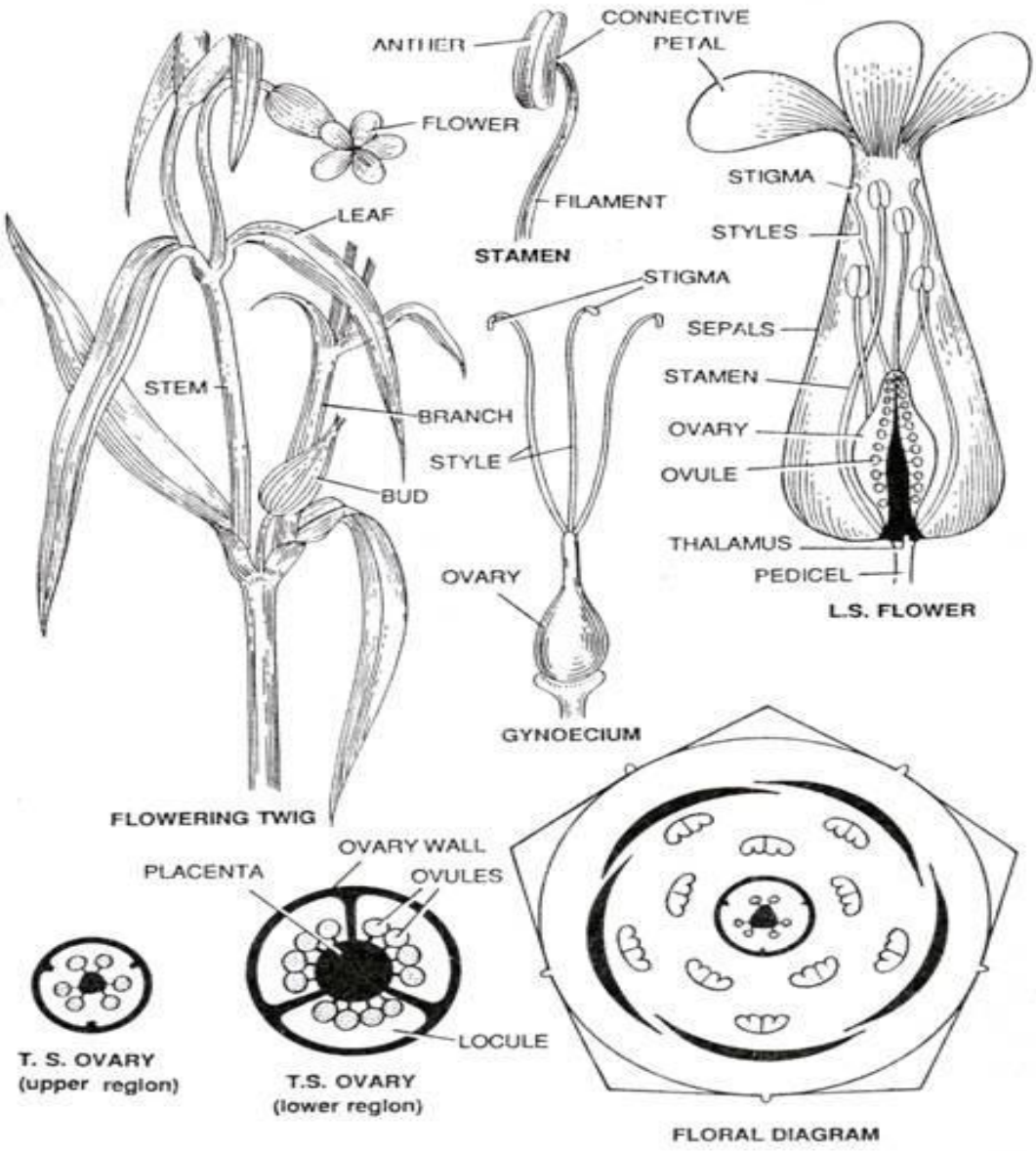

Fig 5.5 *Silene*

5.4.3. Important Genera

Among the important genera are *Stellaria, Cerastium, Arenaria, Silene* , *Lychnis, Gypsophila* and *Saponaria* . The most valued horticulturally is *Dianthus,* which includes the carnation, commonly cultivated by florists and also grown in Europe for use in perfumes.

5.4.4 Economic Importance of Family

The members of the family are important as ornamentals and as the source of medicines

(I) Ornamentals

Dianthus barbatus, Dianthus caryophyllatus, Dianthus chinensis,. Arenaria sp, Cerastium sp, Saponaria vaccaria, Silene armeria, Gypsophila sp. etc. are grown as an ornamental.

(II) Medicinal

- Alcoholic extract of the whole plant of *Stellaria semivestita* shows anti- cancer activity
- Decoction of *Stellaria vestita* relieves bone ache and rheumatic pain
- Seeds of *Spergula arvensis are* employed against pulmonary tuberculosis

(III) Other uses

- The plant juice of *Saponaria vaccaria, Lychnis* etc. are used as a substitute of soap.
- The shoots of *Stellaria aquatica* (Eng.-Chick weed; Verna.-Badeola) are eaten as vegetable.
- *Spergula arvensis* is used as fodder. It is diuretic.

5.5 FAMILY RUTACEAE

Rutaceae commonly known as citrus family usually with strong scents. They range in form and size from herbs to shrubs and small trees.

Distribution: Consists of 160 genera and 1,700 species distributed throughout the world, especially in warm temperate and tropical regions. The largest numbers are found in Africa and Australia, often in semiarid woodlands. In India the family is represented by 23 genera and over 80 species occurring mostly in tropical and subtropical Himalayas and the western peninsular India.

5.5.1 Systematics

Bentham & Hooker	**Engler& Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Lignosae
Disciflorae	Geraniales	Rutales
Geraniales	Rutaceae	Rutaceae

Rutaceae		

The family is closely related to Sapindaceae, Simaroubaceae and Meliaceae, and all are usually placed into the same order, although some systems separate that order into Rutales and Sapindales. The families Flindersiaceae and Plaeroxylaceae are sometimes kept separate, but nowadays generally placed in Rutaceae, as are the former Cneoraceae. The subfamilial organization has not been fully resolved, but the subfamily Aurantioideae (=Citroideae) is well supported; the placement of several genera remains unclear.

5.5.2. Generalized characters

Habit: Mostly perennial trees (*Citrus*), some shrubs (*Murrya paniculata*), a few are herbs (*Boenning hausenia)*, frequently aromatic with glands on the leaves, sometimes with thorns

Roots: Fibrous tap root

Stem: Woody; spiny; Cylindrical

Leaves: Petiolate; Leave alternate or opposite simple (*Citrus*) or compound (pinnately compound in *Murraya* and digitate compound in *Aegle*, exstipulate; reticulate venation. Pellucid glands, a type of oil gland, are found in the leaves responsible for the aromatic smell of the family's members. In citrus leaves are unifoliate with a joint at the junction of the blade and winged petiole. The stipules are absent.

Inflorescence: Terminal or axillary cymes or panicle solitary or in cyme, rarely form raceme as in *Dictamnus.* In some species of *Citrus* the flowers are axillary solitary.

Flower: Flowers are Pedicilate; bracteate or ebracteate; usually hermaphrodite, unisexual and polygamous (*Zanthoxylum*), actinomorphic (rarely zygomorphic in *Dictamnus*), Regular, complete pentamerous (tetramerous in some species of *Ruta*), hypogynous. A fleshy nectariferous disc is present between the stamens and ovary.

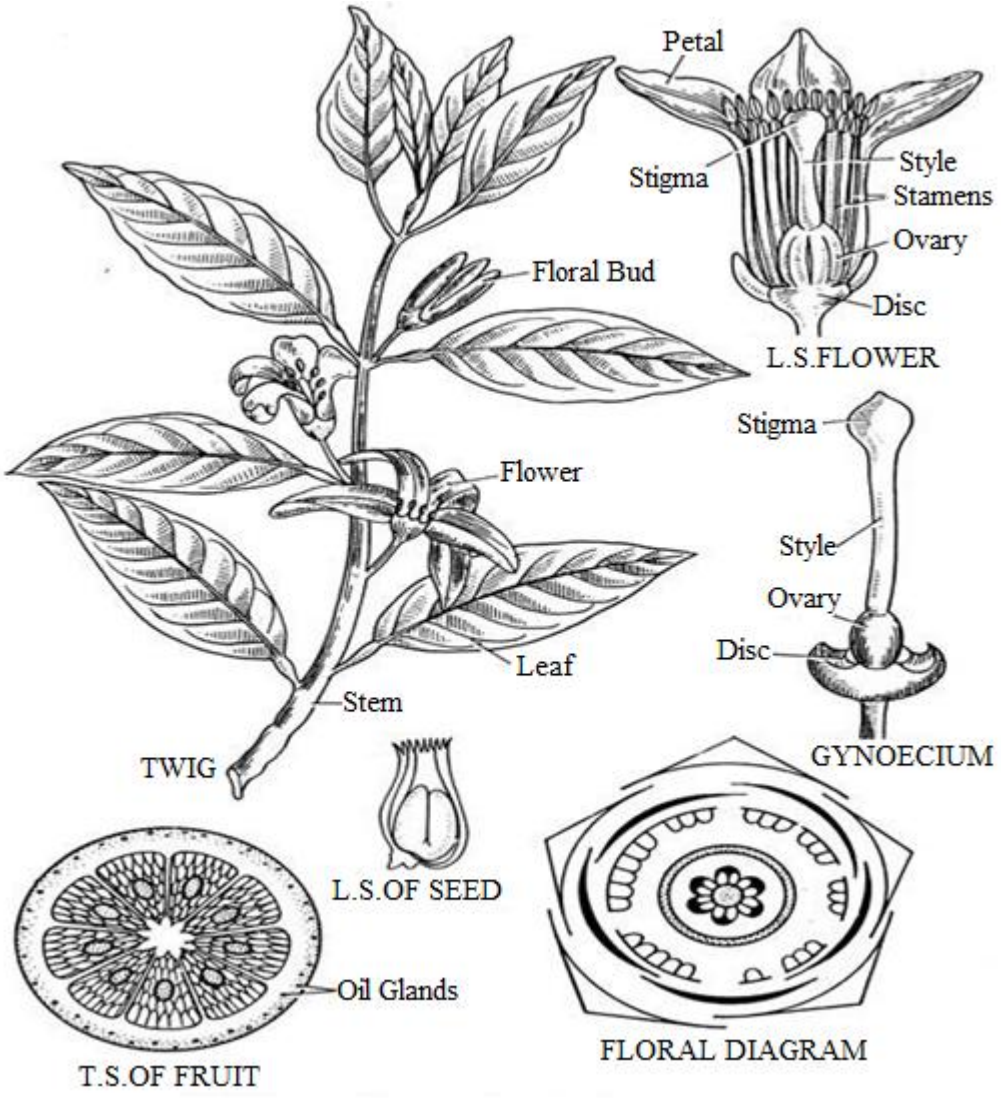

Fig. 5.6 *Citrus aurantium* Linn. Orange Verna, Narangi

Calyx: 4 or 5 sepals which are free or more often show various degrees of connation**. In citrus the** calyx is copular or urceolate imbricate aestivation in bud; green. Rarely sepals are absent (*Zanthoxylum*), In *Peganum* the sepals are foliaceous, pinnatifid and persistent.

Corolla: 4 or 5 petals, free, valvate or imbricate aestivation in bud. In *Dictamnus*, where the corolla is zygomorphic, the four petals are in pairs and are ascending, whereas the lower one is declinate.

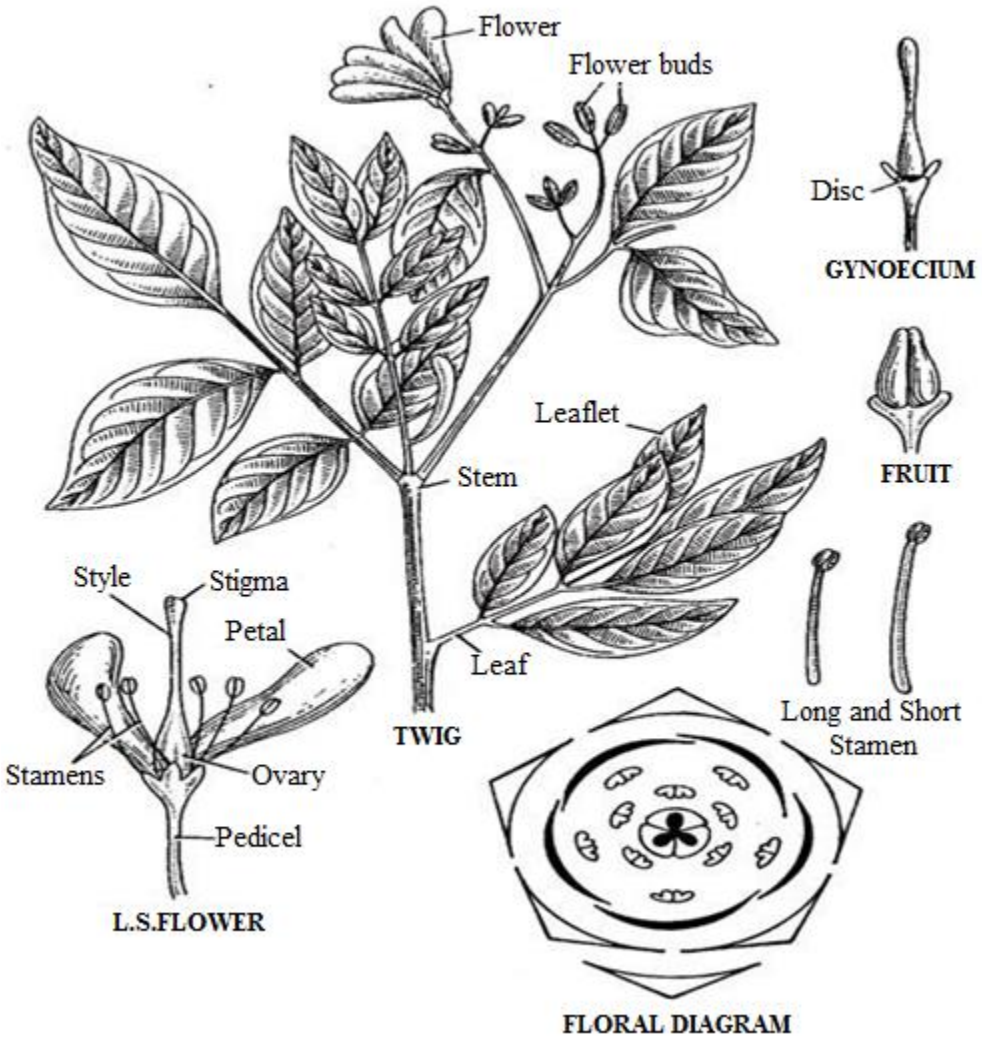

Fig.5.7 *Murraya exotica* Spreng.

Androecium: Stamens are as many as or twice the number of petals or sometimes numerous (*Citrus*) five in *Skimmia*. When the stamens are equal to the number of petals they are arranged in an antesepalous whorl (*Zanthoxylum*). More frequently the stamens are double the number of petals then they are obdiplostemonous. The filaments are usually free or but in *Citrus* they are united in several bundles (polyadelphous condition); the anthers are dithecous, introrse and dehiscing longitudinally basifixed.

Gynoecium: 2 to 5carpels, which are completely united or free towards the base and the ovary is deeply lobed as in *Peganum, Dictamus* and other related genera. The ovary has as many locules as the number of carpel with two to many sometimes one anatropus ovule in each

locule ; superior ovary, axile placentation, . The styles are as many as the carpels, free or variously united. The stigmas are terminal and lobed

Fruits: The fruits of the family are various, Capsule (*Ruta*), follicles (*Zanthoxylum*), drupes (*Amyris*), berries (*Triphasia*), samaras (hop tree), and schizocarps (*Helietta*). Hesperidium of citrus fruit is actually a modified berry.

Pollination: mainly pollinated by insects

Seed: non-endospermic seed.

Floral formula ⊕ ♂♀ $K_{5or(5)}\ C_5\ A_{10}\ \underline{G}_{(3-5)}$

Citrus	**Br**	Brl	⊕	♂♀ $K_{(5)\text{ or }(4)}C_{(5)\text{ or }(4)}\ A_{\alpha\ (polyadel)}\ \underline{G}_{(\alpha)}$
Murraya	**Br**	Brl	⊕	♂♀ $K_{(5)}\ C_5\ A_{5+5}\ \underline{G}_{(2-3)}$
Aegle marmelos		**Br**	⊕	♂♀ $K_5\ C_5\ A_\alpha\ \underline{G}_{(\alpha)}$

5.5.3 Important Genera: The well known examples of the family are Lemon (*Citrus lemon*), Malta or sweet orange (*C. sinensis*), Bael fruit (*Aegle marmelos*), Kamini or orange jasmine *(Murraya paniculata*), Lime *(Citrus acida)* and Citron (*Citrus medica).*

5.5.4 Economic Importance

1. **Fruits**: This family is important for citrus fruits like orange (Santra; *Citrus reticulata*) lemons, Chakotra (*Citrus maxima syn. Citrus decumana*). This family is ranked third in food production. Besides these, fruits of Bael and *Feronia* are also edible. The aromatic pulp of large globose fruits of *Aegle marmelos* is eaten and very good remedy for dysentery and other stomach troubles. The root and stem bark is used in intermittent fever. The pulp of ripe fruit *of Feronia limoni (*wood apple) is eaten and also used in chutney and sharbat.

2. **Medicinal plants**: Most of the plants of this family have medicinal importance. Their fruits are rich in vitamins and minerals. Most of vitamin C is extracted from these fruits. *Aegle* gives tannic acid. Leaves of *Murraya paniculata* are used in flavouring. The twigs of *Zanthoxylum armatum* (Tejpat) is carminative, stomachic and anti-helminthic and are used in soap making and dental cream preparations. The root bark of *Toddalia asiatica* is a potent antimalarial drug . It is also used in cough and influenza. Oil of lemon is used in the

preparation of mosquito oil. The leaves of *Murraya koenigii* (Meetha-neem) are aromatic which are used for flavouring curries , especially in South India.

3. **Ornamental plants:** The following species are used as ornamentals:
   Murraya paniculata (Orange jasmine)
   Skimmia arborescens
   Ruta graveolens (Comman Rue)
   Glycosmis pentaphylla

4. **Uses in perfumes**: The large white fragrant flowers and fruits are used in perfumery.

5.6 SUMMARY

Now you can sum up the important criteria of the families student studied in this Unit.
Ranunculaceae show combination of primitive and advanced characters. The Ranunculaceae is considered primitive in the presence of predominantly herbaceous habit, bisexual and actinomorphic flower, numerous free and spirally arranged stamens and capels, follicular fruit. They are advanced in the presence of unisexualiuty, few and whorled appendages, zygomorphy, connation in the gynoecium and achenial fruit.

Family Caryophyllaceae is considered to have been derived form the order Ranunculales or from ranalian ancestors. It belongs to order Caryophyllinae where flowers are actionomorphic ,stamens usually the twice as many as the petals , ovary unilocular with free central placentation. The diagnostic features of the this family are herbs with opposite and simple leaves, inflorescence dichasial cyme ending into monochasial cyme, flowers actionomorphic, pentamerous, hypogynous , sepals 4-5, Petals 4-5,stamens usually the petals and obdiplostemonous, ovary unilocular with free central placentation , capsule 2-6 valved.

Family Rutaceae belongs to order Geraniales of Series Disciflorae in which carpels are several, syncarpous, ovules 1 or 2 in each locule, ascending and pendulous , raphae ventral.
Salient features of Rutaceae are trees and shrubs with usually compound and exstipulate, pellucid punctuate leaves , flowers bi- or unisexual, sepals 4-5, imbricate, petals 4-5 imbricate or valvate, stamens usually definite, carpels 4-5, free or connate.ovules1-many in each locule, fruit usually berry.

5.7 GLOSSARY

Actinomorphic- A flower having radial symmetry
Adnate – Grown together or fused, used only to describe unlike parts. For comparison, connate.

Adventitious – Arising from an unusual or irregular position

Alternate – Arrangement of leaves or parts one at a node, as leaves on a stem. For comparison, opposite and whorled

Angiosperm – Having seeds borne within a pericarp. For comparison, **gymnosperm**.

Anther – Pollen-bearing part of a stamen, borne at the top of a filament.

Apex – The tip or terminal end.

Apocarpous-Carpels in flower free from each other *e.g. Ranunculus, Nigella, Clematis* etc.

Axillary – Borne or carried in the axil.

Basifixed- Fixed to the filament at the base

Berry – A fleshy, indehiscent, pulpy, multi-seeded fruit resulting from a single pistil, e.g. tomato.

Bipinnate – Twice pinnate, the primary leaflets being again divided into secondary leaflets.

Bract – A much-reduced leaf, often scale-like and usually associated with a flower or inflorescence

Bracteole- Secondary bract at the base of individual flower

Calyx – The outer whorl of perianth, composed of the sepals, usually green in color and smaller than the inner set.

Capsule – A dry dehiscent fruit produced from a compound pistil, e.g. fruit of a tobacco, *Catalpa*, *Dianthus*.

Complete. The flower with all the four whorls i.e. calyx, corolla,androecium and gynoecium

Compound leaf – A leaf of two or more leaflets.

Corolla – Inner whorl of the perianth, between the calyx and the stamens; a collective term for the petals of a flower.

Cotyledon – The primary leaves of the embryo, present in the seed. One of the first leaves to appear after germination (there may be more than 1).

Cyme – A more or less flat-topped determinate inflorescence whose outer flowers open last, e.g. *Sambucus*, elderberry.

Decompound – Leaf having more than one compound.

Dioecious – Having unisexual flowers, each sex confined to a separate plant, said of species.

Dithecous- Two - celled anther

Drupe – A fleshy, indehiscent fruit whose seed is enclosed in a stony endocarp, e.g. date, cherry.

Dissected - Leaf divided into very fine, somewhat indistinct segments

Dorsifixed -Filament attached to the dorsal side of the anther

Extrorse- Facing outward from the centre of flower referred for anthers

Hermaphrodite (bisexual)- The flower having both male and female reproductive organs
Hypogynous- situated below the gynoecium or ovary referring to stamens, petals and sepals
Imbricated – Overlapping, as shingles on a roof.
Inferior – Beneath, below; said of an ovary when situated below the apparent point of attachment of stamens and perianth.
Inflorescence – The arrangement of flowers on the axis.
Introrse- Facing inward from the centre of flower referred for anthers
Involucre – One or more whorls or series of small leaves or bracts that are close underneath a flower or inflorescence.
Lanceolate – Much longer than wide, broadest below the middle and tapering to the apex.
Linear – Long and very narrow, as in blades of grass.
Nectary- A nectar-secreting gland
Obdiplostemonous - the stamens are arranged in two whorls of five each, the stamens of the outer whorl are seen to be opposite the petals and of inner whorl alternating the petals
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.
Orthotropus - An straight ovule with the micropyle opposite to chalaza
Palmately compound - like the fingers on your hand
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. **Perfect** – Having both functional stamens and pistils (not imperfect); a unisexual flower.
Perianth – A collective term embracing both the **corolla** and the **calyx**.
Petaloid- Coloured resembling petals
Pollination-Transference of pollen grain from anthers to stigma
Polyandrous-Androecium that consists of free stamens
Polyadelphous- Stamens united in many bundles
Raceme – A simple indeterminate inflorescence, having a single long axis, with pedicelled flowers.
Sepal – A single segment of a divided calyx.
Sepaloid- Green resembling to sepal
Stamen – Male or pollen-bearing organ of a flower, composed of filaments and anthers.
Syncarpous- United carpels, compound ovary *e.g. Citrus*
Tendril - modified leaf or stem

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.
Valvate – (1) dehiscing by valves; (2) meeting at the edges without overlapping, as leaves or petals in the bud.
Venation- The arrangement of veins in a leaf
Whorl – Arrangement of three or more structures arising from a single node.
Zygomorphic-Asymmetrical, irregular

5.8 SELF ASSESSMENT QUESTIONS

5.8.1 Multiple Choice Questions:

1. Which one of the following has deeply bifid petals
(i) *Citrus* (ii) *Ranunculus*
(iii) *Stellaria* (iv) *Nigella*

2. Which one of the following is commonly known as Pink family
(i) Ranunculaceae (ii) Caryophyllaceae
(iii) Rutaceae (iv) Fabaceae

3. Which one of the following is more primitive than others
(i) Ranunculaceae (ii) Caryophyllaceae
(iii) Rutaceae (iv) Fabaceae

4. Aconite**,** an alkaloid **is** present in
(i) *Thalictrum* (ii) *Aconitum napellus*
(iii) *Clematis* (iv) *Ranunculus*

5. Botanical name of *Kari-patta* (Meetha- Neem) is
(i) *Azadirachta indica* (ii)*Murraya koenigii*
(iii) *Clematis* (iv) *Ranunculus*

6. Members (plants) of family Rutaceae are generally good source of
(i) Vitamin –A (ii) Vitamin -B
(iii) Vitamin –C (iv) Vitamin –D

7. Obdiplostemonous condition of stamens is general criterion of which one of the following families
(i) Ranunculaceae (ii) Caryophyllaceae

(iii) Rutaceae (iv) Fabaceae

8. Which one of the following families belongs to series Disciflorae as proposed by Bentham & Hooker

(i) Ranunculaceae (ii) Caryophyllaceae
(iii) Rutaceae (iv) Malvaceae

9. Botanical name of the *Bael* fruit

(i) *Citrus lemon* (ii) *Murraya paniculata*
(iii) *Citrus medica* (iv) *Aegle marmelos*

10. Tejpat (*Zanthoxylum armatum*) belongs to family

(i) Ranunculaceae (ii) Caryophyllaceae
(iii) Rutaceae (iv) Fabaceae

5.8.1. Answer Keys:

1- iii	2- ii	3- i	4- ii	5- ii
6- iii	7- ii	8 -iii	9- iv	10- iii

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5.10 SUGGESTED READINGS

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5.11 TERMINAL QUESTIONS

1. What is Cincinus or Caryophyllus type of inflorescence.
2. Give medicinal and condiment uses of family Ranunculaceae.
3. Give distribution pattern of family Rutaceae.
4. Draw obdiplostemonous condition of the stamen.
5. Give characteristic floral features of family Caryophyllaceae .
6. Write taxonomical characteristics of citrus family.
7. Write floral formulae of the following plants:
    (a) *Ranunculus*
    (b) *Nigella*
    (c) *Citrus*
    (d) *Stellaria media*
8. Give comparative account of taxomnomic characters of family Ranunculaceae and Rutaceae.

UNIT-6 ROSACEAE, FABACEAE AND ASCLEPIADACEAE

6.1- Objectives
6.2-Introduction
6.3-Rosaceae
    6.3.1-Systematics
    6.3.2-General characters
    6.3.3-Important Genera
    6.3.4-Economic importance
6.4- Fabaceae
    6.4.1-Systematics
    6.4.2-General characters
    6.4.3-Important Genera
    6.4.4-Economic importance
6.5- Asclepiadaceae
    6.5.1-Systematics
    6.5.2-General characters
    6.5.3-Important Genera
    6.5.4-Economic importance
6.6-Summary
6.7-Glossary
6.8-Self Assessment Questions
6.9-References
6.10-Suggested Readings
6.11-Terminal Questions

6.1 OBJECTIVES

In the present unit students will be able -

- to become familiar with Order: Rosales of Series: Calyciflorae of Division-Polypetalae including family Rosaceae and Fabaceae. While Family Asclepiadaceae will be studied under Order Gentianales of Series Bicarpellatae under Division- Gamopetalae (According to Bentham and Hooker).
- to know Detailed description of the general distribution, General characters, Important genera and Economic Importance *etc.* of families **Rosaceae,** Fabaceae and Asclepiadaceae. Moreover 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.

6.2 INTRODUCTION

Student have already studied characteristic features of division Polypetalae and its series Thalamiflorae (Family- Ranunculaceae and Caryophyllaceae) and Disciflorae (Family - Rutaceae) in Unit -5. This unit introduces you with series Calyciflorae (Order Rosales; Family Rosaceae and Fabaceae) of Division-Polypetalae and series Bicarpellatae (Order Gentianales Family Asclepiadaceae) under Division- Gamopetalae.

Series Calyciflorae is characterized by its perigynous or epigynous flower a disc rarely present at the base of ovary,sub- inferior or inferior ovary. It consists of seven orders namely- Rosales, Myrtales, Passiflorales, Ficoidales and Umbellales.

Order Rosales having bisexual flower, regular or zygomorphic flower, gynoecium with 1 or more carpels, styles usually distinct *e,g,* Family Rosaceae and Fabaceae

Division-Gamopetalae is having corolla of united petals. It is divided into three series

(i) Inferae (ovary inferior)- consists of three orders namely Rubiales, Asterales, Companulales

(ii) Heteromerae (ovary usually superior, stamens as many as or twice the corolla segments, carpels more than two) – contains three orders Ericales, Primulales and Ebenales

(iii) Bicarpellatae (ovary superior, stamens as many or fewer than the corolla, carpels usually two)- consists of four orders Gentianales, Polemoniales, Personales and Lamiales

Order Gentianales includes plants having Flower regular, stamens as many as the corolla lobes, leaves opposite (Family Apocynaceae and Asclepiadaceae)

6.3 FAMILY ROSACEAE

The **Rosaceae** (rose family) family is a medium-sized family of flowering plants, including about 2,950 known species belonging to 100 genera.

The name is derived from the type genus *Rosa*. The Rosaceae family includes herbs, shrubs, and trees. Most species are deciduous, but some are evergreen. Among the most species-rich genera are *Alchemilla , Sorbus , Crataegus ,Cotoneaster , Rubus, Prunus* (plums, cherries, peaches, apricots, and almonds) with about 200 species. They have a worldwide range, but are most diverse in the Northern Hemisphere.

Several economically important products come from the Rosaceae, including many edible fruits (such as apples, pears, quinces, apricots, plums, cherries, peaches, raspberries, loquats, and strawberries), almonds, and ornamental trees and shrubs (such as roses, meadow sweets).

Diagnostic characteristics – Herbs, shrubs or trees with simple or compound stipulate leaves, Flowers regular and bisexual, sepals and petals 5 each, stamens many, distinct, gynoecium of 1 or more free or connate carpels, ovules 1-2 in each carpel, fruits various.

Distribution pattern

The Rosaceae have a cosmopolitan distribution (found nearly everywhere except for Antarctica), but are primarily concentrated in the Northern Hemisphere in regions that are not desert or tropical forestland hawthorns.In India they are represented by over 25 genera and 215 species mainly confined to Himalaya ascending upto to about 6000 meters . The familiar examples of the family are Rose (*Rosa spp*.), Apple (*Pyrus malus*), Peach (*Prunus persica*), Strawberry (*Fragaria vesca*), Brambles (*Rubus spp*.) and Cinquefoil (*Potentilla spp*.)

6.3.1 Systematics

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledons
Polypetalae	Archichlamydeae	Lignosae
Calyciflorae	Rosales	Rosales
Rosales	Rosaceae	Rosaceae
Rosaceae		

Subfamily Rosoideae: Traditionally composed of those genera bearing aggregate fruits that are made up of small achenes or drupelets, and often the fleshy part of the fruit (e.g. strawberry) is the receptacle or the stalk bearing the carpels. The circumscription is now narrowed (excluding, for example, the Dryadoideae), but it still remains a diverse group containing five or six tribes

and 20 or more genera, including rose, *Rubus* (blackberry, raspberry), *Fragaria* (strawberry), *Potentilla*, and *Geum*.

Subfamily Amygdaloideae: Within this group remains an identified clade with a pome fruit, traditionally known as subfamily Maloideae (or Pyroideae) which included genera such as apple, *Cotoneaster*, and *Crataegus* (hawthorn). To separate it at the subfamily level would leave the remaining genera as a paraphyletic group, so it has been expanded to include the former Spiraeoideae and Amygdaloideae. The subfamily has sometimes been referred to by the name "Spiraeoideae", but this is not permitted by the International Code of Nomenclature for algae, fungi, and plants.

Subfamily Dryadoideae: Fruits are achenes with hairy styles, and includes five genera (*Dryas, Cercocarpus, Chamaebatia, Cowania*, and *Purshia*), most species of which form root nodules which host the nitrogen-fixing bacteria *Frankia* spp.

6.3.2 General Characteristics

Habit and Vegetative Characters

Perennial herbs (*Fragaria* and *Potentilla*), shrubs (*Spiraea* and *Prinsepia*), and trees (*Pyrus, Prunus and Eriobotrya*). Several species of *Rubus* and *Rosa* scramble over the surrounding vegetation with prickles. Sometimes plants are armed with sharp spines, which are modified branches (*Crataegus* and *Prinsepia*).

Vegetative reproduction takes place in several ways for example by runners **(*Fragaria*),** by suckers (***Rubus***) and leafy buds are formed on the roots of some species *Pyrus* and *Prunus*

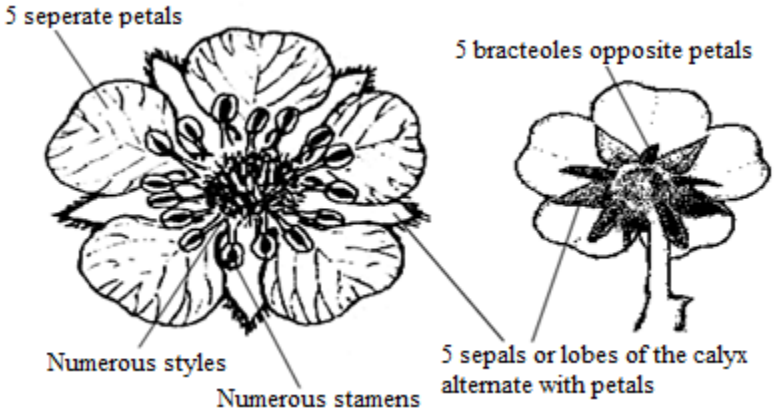

Fig 6.1 Structure of typical Rose Flower

Leaves: Petiolate; alternate, stipulate and simple (*e.g. Pyrus and Prunus*) or pinnately (*Rubus* and *Rosa*) or palmately compound (*Fragaria* and *Potentilla*): Stipules are small and caducousin *Pyrus, Prunus* and *Pygeum* but more commonly they are persistent and adnate to the petiole.

Inflorescence: commonly arranged in various types of definite or indefinite inflorescences Racemes (*Pygeum*), Corymbs (*Rubus*) or thyrsoid panicles (*Eriobotrya*). In *Prinsepia* short racemes are borne on the sides of spines rarely solitary (some species of *Rubus* and *Rosa*.

Flower: Pedicellate; bracteate, Regular; complete, actinomorphic (zygomorphic in *Parinarium*), hermaphrodite (unisexual in Pygeum) or sometimes polygamous, pentamerous, hypogynous (e.g.*Prunus*) or perigynous (*Rosa*). Sometimes epigynous (*Pyrus*).

Calyx: Five petals which are basally connate: the calyx tube is free or adnate to ovary, aestivation is imbricate or valvate. In some species (*Rosa*) sepals become foliaceous. In some (e.g. *Fragaria* and *Potentilla*) an epicalyx of small green leaves is present outside and alternating with the sepals.

Corolla: Five or multiple of five petals. In cultivated species of *Rosa* there are numerous petals usually imbricate in bud. Sometimes they are absent (*Alchemilla*) or very small (*Neurada*).

Stamens: number of stamens varies considerably. In some species of *Agrimonia* there is a single whorl of stamens alternating with the sepal lobes. One to four in *Alchemilla* (two unilateral stamen

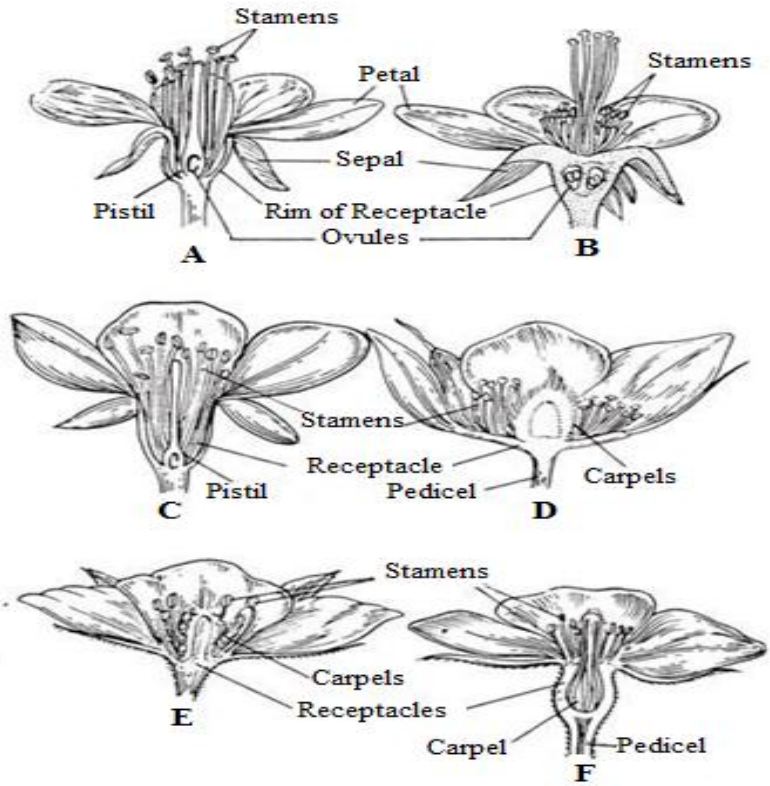

Fig.6.2 A-F Floral variations in Rosaceae. A- *Prunus sp*. B-*Malus sylvestris* C- *Prunus avium* D-*Rubus sp*. E- *Fragaria vesca* F- *Rosa* sp.

in *Parastemon*). Usually the stamens are two, three or four times as many as petals or indefinite. In *Pyrus* there is an outer whorl of ten stamens in five antesepalous pairs. They are followed by second whorl of five antepetalous stamens and a third whorl of five antesepalous stamens.
In *Prunus* outer whorl of ten stamens followed by second whorl of ten stamens alternating with those of the first whorl. A third whorl of stamens is sometimes also present alternating with those of the second. In several genera the stamens are usually many (*Fragaria*) to numerous (*Geum*). The stamens are usually bent in the bud. The anthers are dithecous and introrse. A cushion shaped or ring like nectar secreting disc is present between the stamens and carpel.

Gynoecium: It shows much variation. The number of carpels is one to many, the gynoecium consists of either one compound carpel (syncarpous) or many simple carpels (apocarpous) The carpels are usually situated within the hypanthium or the hypanthium remains

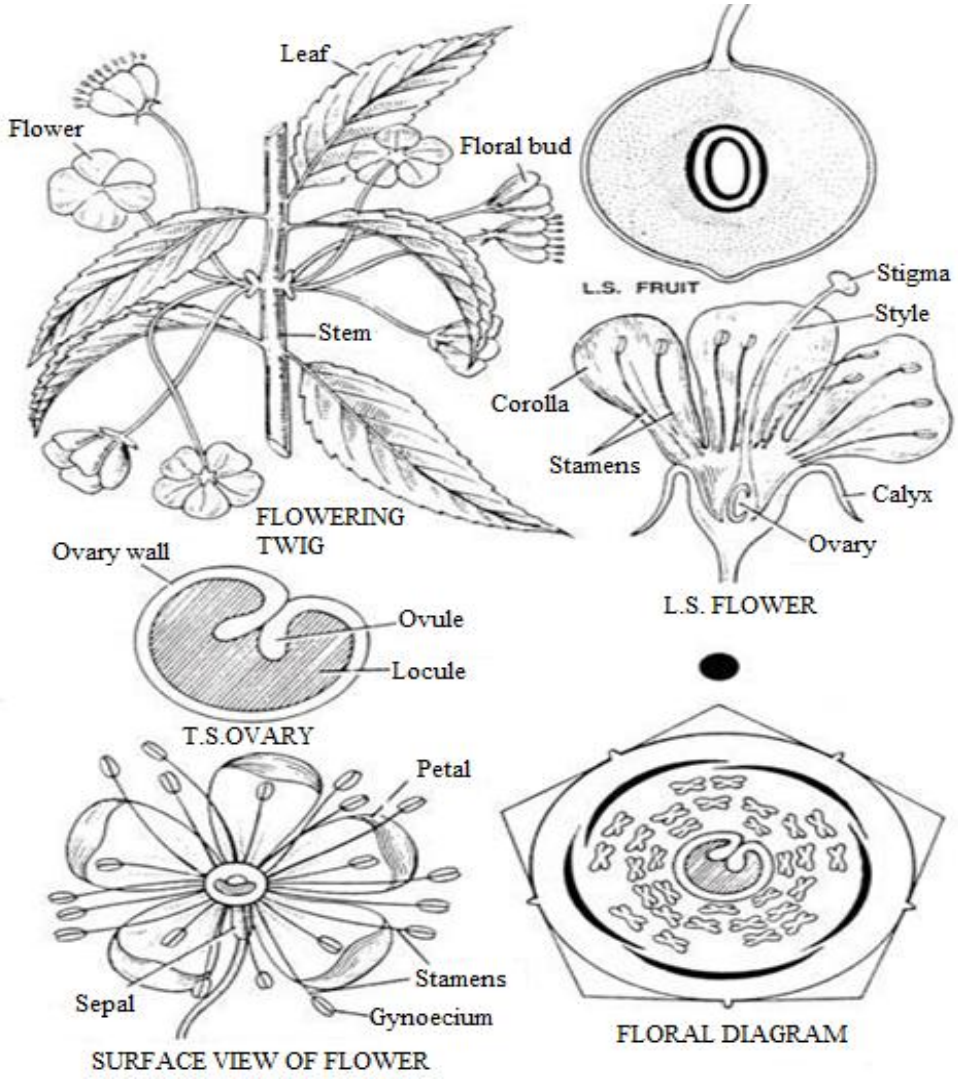

Fig.6.3 *Prunus persica* Verna. Aru

adnate to the compound ovary arranged in cyclic or spiral manner the ovary is either superior or inferior or half superior half inferior (i.e., perigynous condition. Monocarpellary (*Alchemilla, Prunus*) or pentacarpellary and apocapous (*Spiraea*) or multicarpellary and apocarpous (*Fragaria, Rosa, Rubus*) or five carpels fused only in the basal region or capels united completely with each other as well as with the floral cup (*Pyrus*), if the receptacle is convex or dome shaped, the ovary is superior (*Fragaria, Potentilla. Rubus*), if the receptacle is cup shaped and the carpels are developing on the inner surface , the ovary is half inferior (*Prunus, Rosa, Spiraea*) and if carpels are fused with one another and also with the floral cup (Pyrus) the ovary is inferior, placentation is marginal or axile.

Styles and stigmas as many as carpel number. The style is free or connate; the stigma is simple, lobed or capitate. when syncarpous, 2-5 locules are found, placentation basal or axile, the placentation is axile, and the stigmatic lobes are as many as the number of carpels. The placentation is basal when one carpel is present (apocarpous); the ovules are one to many in each carpel.

Seed: non-endospermic seed

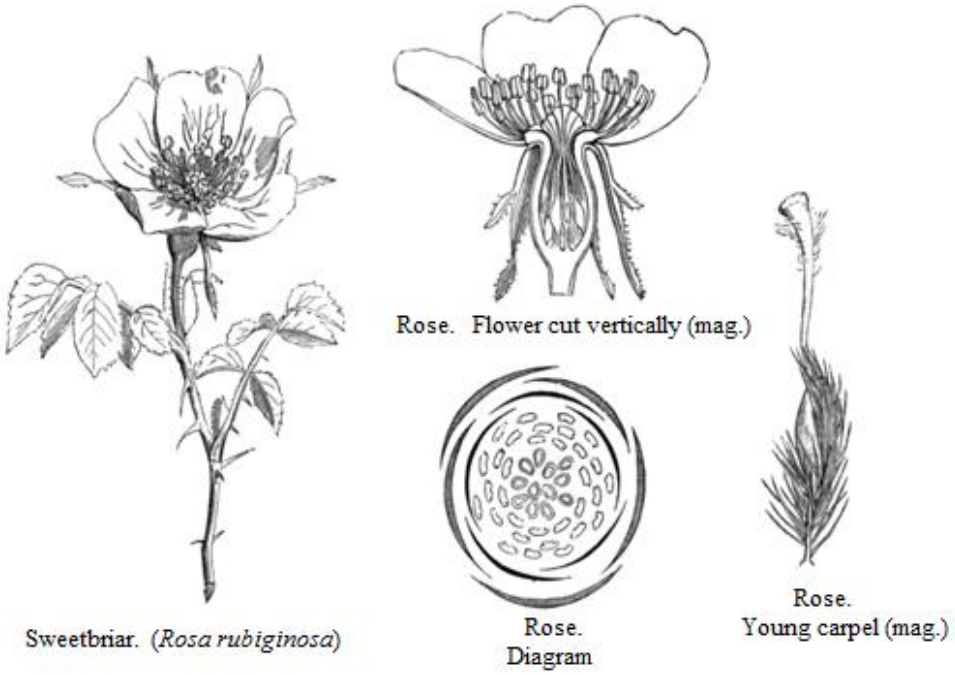

Fig. 6.4 Floral parts of *Rosa*

General Floral Formula

$$\text{Br} \quad \oplus \quad ♀ \quad K_{5 \text{ or } (5)}\ C_5\ A_{\alpha}\ \underline{G}_{1-\alpha} \text{ or } G_{1-\alpha}\ \overline{\text{or}}\ G_{(\alpha)}$$

Prunus	**Br**	⊕	♂♀	$K_{(5)}\ C_{(5)\text{ or }(4)}\ A_{\alpha}\ \underline{G_1}$
Eriobotrya	**Br**	⊕	♂♀	$K_{(5)}\ C_5\ A_{\alpha}\ \overline{G_{(2-5)}}$
Potentilla	**Ebr**	⊕	♂♀	$K_{(5)}\ C_5\ A_{\alpha}\ \underline{G_{(\alpha)}}$

6.3.3 Important Genera: The well known examples of the family are *Rosa indica* (rose), *Pyrus malus* (apple), *Prunus persica* (peach) , *Fragaria vesca* (Strawberry) *Eriobotrya japonica* (loquat) , *Prunus persica* (Aru)

6.3.4. Economic Importance

This family has a great economic importance for mankind. It has great importance in temperate (cold) region. This family is ranked third in the flowering families for commercial importance in the temperate zone.

1- Fruits: Many fruits are obtained from the plants of this family. A list of some important plants is given here:

Prunus persica Eng.-Peach; Verna-Aru- The fruits are edible and rich in vitamins; the oil is obtained from the seeds which is used for cooking and other purposes.

Prunus domestica Syn. *Prunus communis var. insititia*; Eng.-Plum; Verna- Alucha, Alu-bokhara- The fruits are edible.

Prunus amygdalus Eng.-Almond; Verna. Badam-This is a tree yielding edible seeds. There are two varieties of almonds, i.e., sweet and bitter. The oil obtained from the seeds of both the varieties is used in perfumery and medicinal purposes.

Prunus armenica Eng. Apricot; Verna.-Khubani, Zardalu.. The fruits are edible and rich in vitamins.

Prunus cerasoides Eng. Wild Himalayan cherry ; Verna. Paddam- They are commonly found in the temperate Himalayas from Garhwal to Sikkim and also in Nilgiris. The wood is used for walking sticks.

Eriobotrya japonica Eng.-Loquat; Verna.-Lokat. This is a small tree. Fruits.are edible

Fragaria chiloensis Eng. Garden strawberry. Used as edible fruits

Pyrus communis; Eng.-Pear; Verna.-Nakh,-This is a small tree. It is native of Eurasia but now cultivated in Kashmir, Kulu, Kumaon and Himachal Pradesh. The fruits are edible.

Pyrus malus Eng.-Apple; Verna-Seb.- The fruits are edible, delicious, rich in iron and vitamins.

Pyrus pyrifolia var. culta; Eng.-Chinese pear; Verna.-Nashpati- Used as edible fruits.

Rubus ellipticus Eng. Himalayan yellow raspberry; Verna.-Lal anchu, Hisalu-This is a shrub found in the Western Himalayas, South India, the Western ghats and the Khasia hills. The fruits are edible.

2-Ornamental Plants: A large number of plants of this family are ornamental. They are grown in gardens for their beautiful and scented flowers. The genus *Rosa* is widely cultivated for decorative purpose. *Rosa damascena. Rosa centifolia, Rosa chinensis* and *Rosa alba* have been in cultivation since ancient times.. Many other genera such as *Spiraea corymbosa* and *Spiraea cantoniensis* are also grown in gardens and parks for beautiful flowers.

3- Wood: The branches of *Crataegus* are used as walking sticks and wood. The wood of P*ints pactia* is used for making tobacco pipes. *Cotoneaster acuminata*; Verna-Riu-This is a shrub found in Himalayas.

4-Commercial and medicinal uses

The petals of some common roses are called **gulabs** in many Asian countries like Pakistan. These petals are used for making **gulkand**. Petals of rose are used tor extraction of **rose oil.** This oil is used in perfumes. The petals give **Ark-Gulab** on distillation with water. This Ark-Gulab is used tbr curing eye disease and for many other purposes. *Potentilla nepalensis*-this is medicinal plant; used as a remedy for burns. *Potentilla reptans*-The infusion of the herb is used as a remedy of diarrhoea.

6.4 FAMILY: FABACEAE

This is the third largest family of the flowering plants. It is represented by 600 genera and 12000 species, annual or perennial herbs, shrubs, vines, or trees, fibrous tap root often develops nodules in herbs. Nitrogen fixing bacteria live in these nodules, herbaceous or woody; cylindrical, tendril climbers, leaves petiolate; alternate: compound of pinnate type, stipulate, stipules may be modified into leaves or thrones, parallel venation. Inflorescence: Racemose or cymose, the flowers are clustered in heads. Flower: Pedecillate; bracteate: actinomorphic or zygomorphic; regular: complete; hermaphrodite; pentamerous; hypogynous but slightly perigynous, Calyx: 5 or sometime 4 sepals: free or fused green S. Corolla: 5 sometimes 4 petals; free or united, coloured. Androecium: 10 or numerous stamens; polyandrous, in some cases diadelphous, anther basifixed. Gynoecium: monocarpillary: ovary superior, placentation marginal. Fruits: Legume or sometimes lomentum, Seed: Non-endospermic seed.

6.4.1 Systematics

Bentham & Hooker	Engler & Prantl	Hutchinson

Dicotyledones	Dicotyledoneae	Dicotyledons
Polypetalae	Archichlamydeae	Lignosae
Calyciflorae	Rosales	Rosales
Rosales	Fabaceae	Fabaceae
Fabaceae		

Traditional approach is to treat all legumes as one large, somewhat heterogenous family, the Fabaceae (Leguminosae). Bentham and Hooker divided the family into three subfamilies: Papilionaceae, Caesalpinieae and Mimosaceae. Most of the recent taxonomist treats them as three distinct families, Papilionaceae, Caesalpiniaceae and Mimosaceae respectively. The three subfamilies of Bentham and Hooker, which differ in several characters, are described here separately

Description of the Sub–families

6.4.2. (A) General characteristics of Papilionaceae or Papilionoideae (Pea family)

This sub-family has about 500 genera and 10000 species. The members of this family occur all over the world except Arctic regions. Largely represented in temperate regions of Northern and Southern Hemisphere. Over 100 genera and 800 species have so far been reported from India

Habit: Mostly herbs, however shrubs (*Crotolaria*), trees (*Dalbergia, Pterocarpus*), In some climbers (*Clitoria*) twinning stem while in *Vicia* leaf tendrils are found.

Root: Lateral roots of most of the plants have nodules which contain nitrogen fixing bacteria (*Rhizobium*) which convert atmospheric nitrogen into nitrogenous material.

Stem: It may be herbaceous, woody or climber with tendrils. Tendrils are wiry, coiled and thread like structures.

Leaves: Alternate and stipulate leaves.They may pinnately (*Sesbania*, *Abrus*, *Dalbergia)* or digitately compound (*Trifolium*), rarely simple (*Crotalaria*), The stipules are mostly leafy. Sometimes, these leaves are partially or completely modified into tendrils. The leaf base is usually pulvinous. Leaves of several genera (*Desmodium*, etc) perform sleep movements.

Inflorescence: It is commonly an axillary, leaf opposed or terminal Raceme, sometimes panicle (*Dalbergia*), axillary head (*Trifolium*), solitary axillary (*Lathyrus*).

Flowers: Bracteate, sometimes bracteolate (*Sesbania*) , complete, bisexual. zygomorphic, pedicellate, perigynous, pentamerous and papilionaceous.

Calyx: They have usually 5 sepals. These petals are mostly united to form tube. These are hairy. Aestivation is valvate or imbricate. The odd sepal is usually anterior.

Corolla: Five petals, very unequal and papilionaceous corolla. These petals are not similar, clawed and show bilateral symmetry. The upper (posterior) one is largest and conspicuous called

Standard or Vexillum, two lateral free petals which are slightly curved **known** as **Wings** and two anterior most petals united to form a boat- shaped structure called the **Keel** or **Carina** which enclose the stamens and carpels. The petals show descending imbricate aestivation. In *Amorpha* wings and keel are absent and in *Lespedeza* flowers are apetalous.

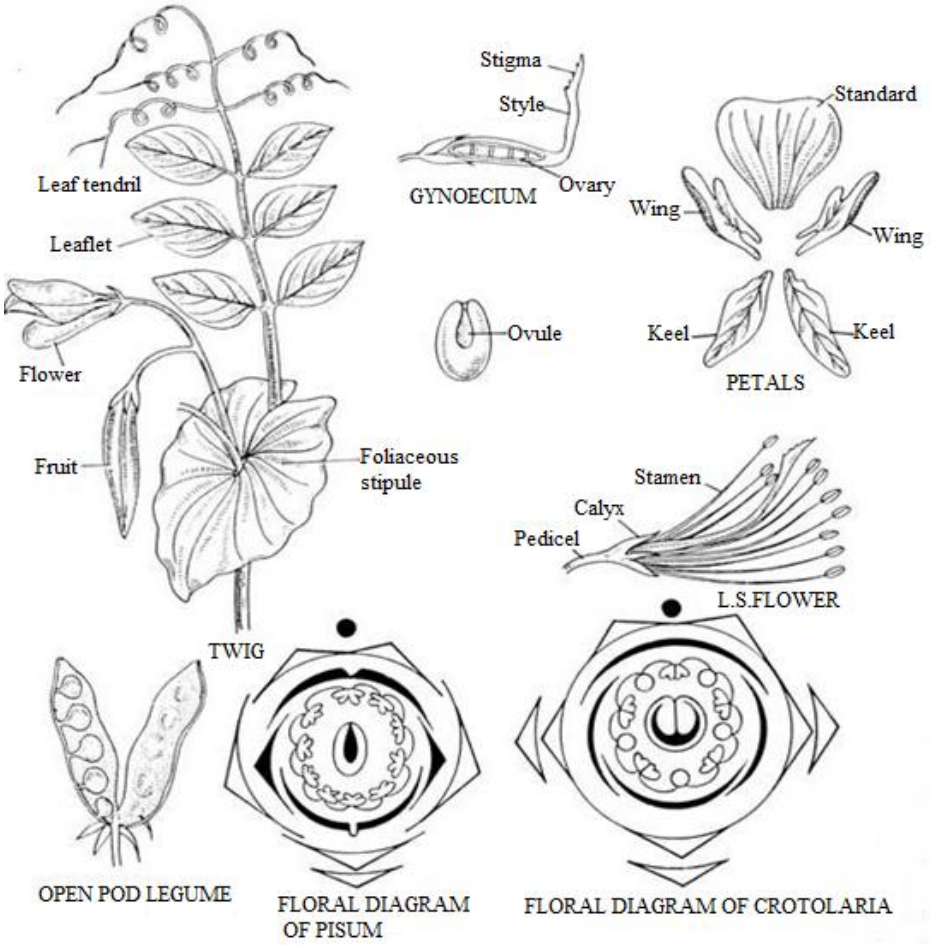

Fig. 6.5 Floral details of *Pisum sativum*

Androecium: 10 stamens, mostly diadelphous stamens, usually 9+1 or sometimes 5+5. In case of 9+1 arrangement, the 9 stamens fused to form a sheath around the pistil and the posterior stamen is free which is often sterile or absent (*Arachis hypogea, Dalbergia sissoo*). Anthers are dithecous, introrse and dehisce by longitudinal slits, rarely all the 10 stamens are free (*Sophora*).

Gynoecium: It has simple pistil. This pistil has single carpel (monocarpellary) with single locule, the ovary is superior. Ovules many to several on the ventral suture, marginal placentation, style is long bent at its base, stigma capitate and lobed.

Fruit: Fruit is usually a legume or pod dehiscing by one or both the sutures into two valves or it is indehiscent (*Dalbergia*). Fruits of *Arachis hypogea* (Groundnut) develop underground.

General Floral Formula

$$Br \quad brl \quad \% \quad \female \quad K_{(5)}\ C_{1+(2)+2}\ A_{(9)+1}\ \underline{G}_{1}$$

6.4.3. (A) Important Genera of Papilionaceae

Astragalus is the largest genus of this subfamily, *Lathyrus odoratus* (Sweet pea) *Arachis hypogea* (Peanut), *Cicer arietinum* (Chick pea) *Dalbergia sissoo* (Shisham), *Trifolium* (Clover), *Medicago sativa* (Alfalfa) *Indigofera, Crotolaria, Vigna* are common genera and speceis found in India.

6.4.4. (A) Economic Importance of Papilionaceae

This family is of great economic importance and provides food stuffs, fodder, fatty oils, fibers, timbers, dyes, gums and ornamentals.

Pulses: Most of the important pulses are belonged to this family. These pulses are used as food. Pulses are rich in proteins. The common species of pulses are *Pisum sativum* (Pea; Matar), *Cicer arietinum* (Gram; Chick pea), *Glycine max* (Soybean), *Cajanus cajan* (pigeon pea, Arhar), *Lens culinaris* (Lentil; Masur), *Vigna radiata* (Green gram; Moong) *Vigna mungo* (Black gram;Urd), etc.

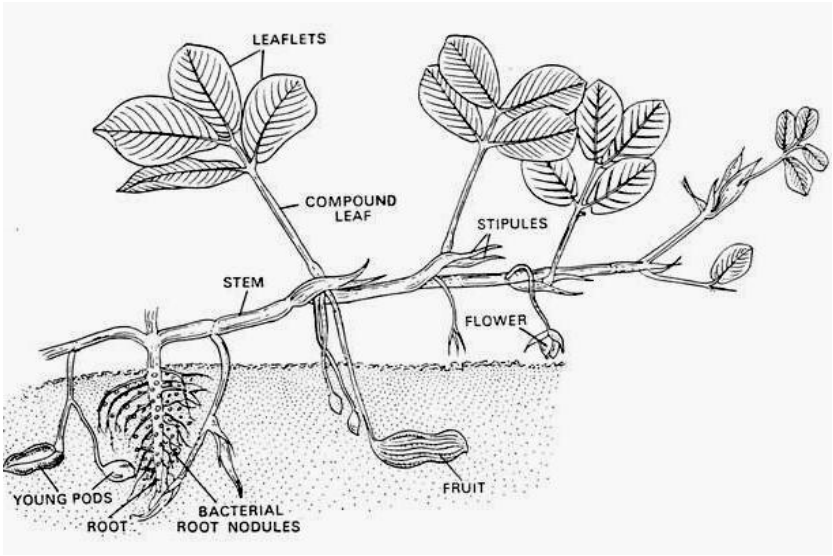

Fig. 6.6 Fruit formation in *Arachis hypogea*

Vegetables: *Vigna unguiculata* (Cow pea, Lobia), *Phaseolus vulgaris* (Kidney bean,French bean, etc.

Fodders*: Medicago sativa* (Alfalfa) is one of the best forage crops. Several species of clover (*Trifolium*) are also cultivated as main fodder crops.

Timber: Many trees of this family provide timber for building furniture and fuel. Main timber plants are *Dalbergia sisso* (Shisham), *Pterocarpus, Butea* etc.

Vegetable oil: The seeds of *Arachis hypogea* (peanut) are edible. They are also used for extraction of peanut oil. This peanut oil is hydrogenated and used as vegetable oil. Soyabean oil is obtained from *Glycine max*.

Dyes: *Indigofera tinctoria* (Indigo) and its other species are source of indigo dye. *Pterocarpus santalinus* (Red Sandalwood) give yellow and orange dyes.

Medicinal plants: Many plants of this family are used as medicines. *Glycorrhiza glabra* (Lquorice) is used for cough and cold. *Clitoria ternata* is used against snake bite. Decoction of leaves and roots of *Abrus precatorius* (Rati) is used for cough and cold.

Ornamental plants: Some important ornamental plants are *Lathyrus* (sweet pea), *Lupinus*, *Clitoria*, *Butea*, *Erythrina*, etc.

Subfamily: Caesalpiniaceae

6.4.2. (B) General characteristics of Caesalpiniaceae (Cassia family)

This family has **152** genera and **2800** species distributed both in subtropical and tropical regions of the world. It has 23 genera and **80** species in India.

Habit: They are mostly trees (*Tamarindus indica*) or shrubs (*Parkinsonia*) or rarely herbs (*Cassia tora*) occasionally woody climber (*Buahinia*)

Stem: It is erect, woody, herbaceous or climbing.

Leaves: The leaves are alternate, stipulate, compound (rarely simple e.g. *Bauhinia*), and unipinnate (*Cassia*) or bipinnate (*Tamarindus).*leaf base often swollen

Inflorescence: It may be axillary **or terminal raceme** or panicles, rarely cymose.

Flower: Flower is mostly large and showy, bractate, complete, bisexual, zygomorphic, pentamerous and hypogynous

Calyx: Sepals are 5. Basally connate or short or long tube. Odd sepal is usually anterior. They are often coloured (*Saraca*).

Corolla: usually 5 free petals, alternate with sepal, aestivation ascending imbricate

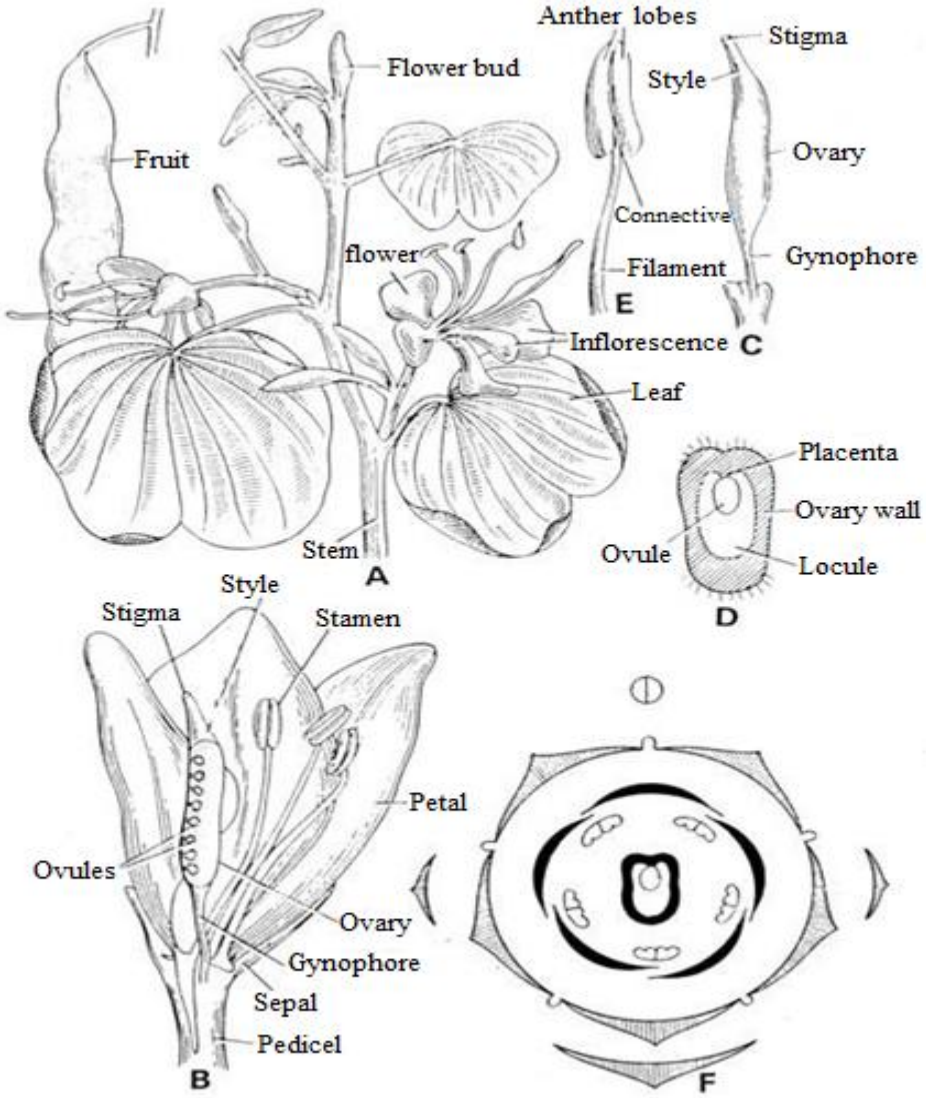

Fig. 6.7 Floral details of *Bauhinia varigata*

Androecium: Stamen are 10 or less (rarely numerous) but often some of the stamens reduced to staminodes or altogether absent (*e.g*. In *Cassia* five to seven, *Bauhinia* three to five are perfect rest are staminodes. Anthers are dithecous, introrse and dehisce by longitudinal slits

Gynoecium: The pistil has single carpel (monocarpellary) with single locule., ovary superior, two rows of ovules on the marginal placentation . The style is simple with capitate stigma.

Fruit: Fruit is usually a legume or pod, often becomes transversely septate (*Cassia*)

General Floral Formula

$$Br \quad \% \; ♂♀ \quad K_{(5)} \; C_5 \; A_{5+5} \; \underline{G}_1$$

6.4.3. (A) Important Genera of Caesalpiniaceae

Tamarindus indica (Imili), *Bauhinia* (Kachnar), *Cassia* (Senna), *Parkinsonia, Saraca* (Ashok tree), *Cassia fistula* (Amaltas), *Delonix regia* (Gulmohar) are some of the important genera and species found in India

6.4.4. (B) Economic Importance of Caesalpiniaceae

Medicinal importance: The leaves of *Cassia alata* are used to cure ringworm and skin diseases. The leaves of *Cassia senna* and *Cassia obovata* are used in making drug called Senna. This oil is applied externally for skin diseases.

Vegetables and fruits: The leaves and flower bud of *Bauhinia variegata* are used as vegetable. The acidic fruit of *Tamarindus indica* are edible. It is rich in tartaric acid.

Tanning and dyes: The bark of *Buahinia* and *Tamarindus* indica is used in tanning. Heart wood of *Haematoxylon campechianum* provide red-orange dye

Ornamental plants: *Bauhinia variegata* (kuchnar), *Cassia***,** *Delonix regia, Caesalpinia pulcherrima* are used as ornamentals.

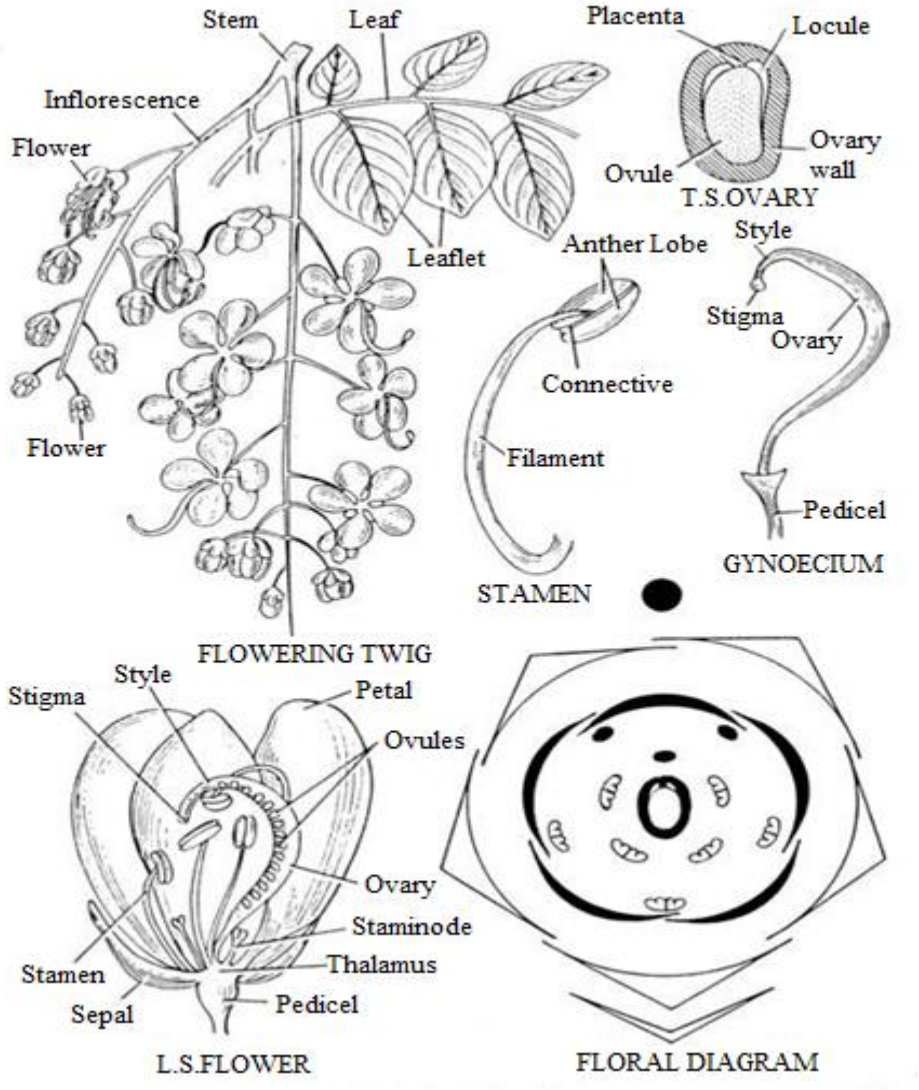

Fig. 6.8 Floral details of *Cassia fistula*

Subfamily-Mimosaceae

6.4.2. (C) General characteristics of Mimosaceae (Acacia family)

This famiy has 56 genera and about 2800 species, widely distributed in subtropical and tropical regions of the world. It has 15 genera and **72** species in India.

Habit: Mosly trees (*Acacia, Albizzia*) or shrubs. Rarely climbers or herbs (*Neptunia*) or woody climbers with most of them are xerophytes.

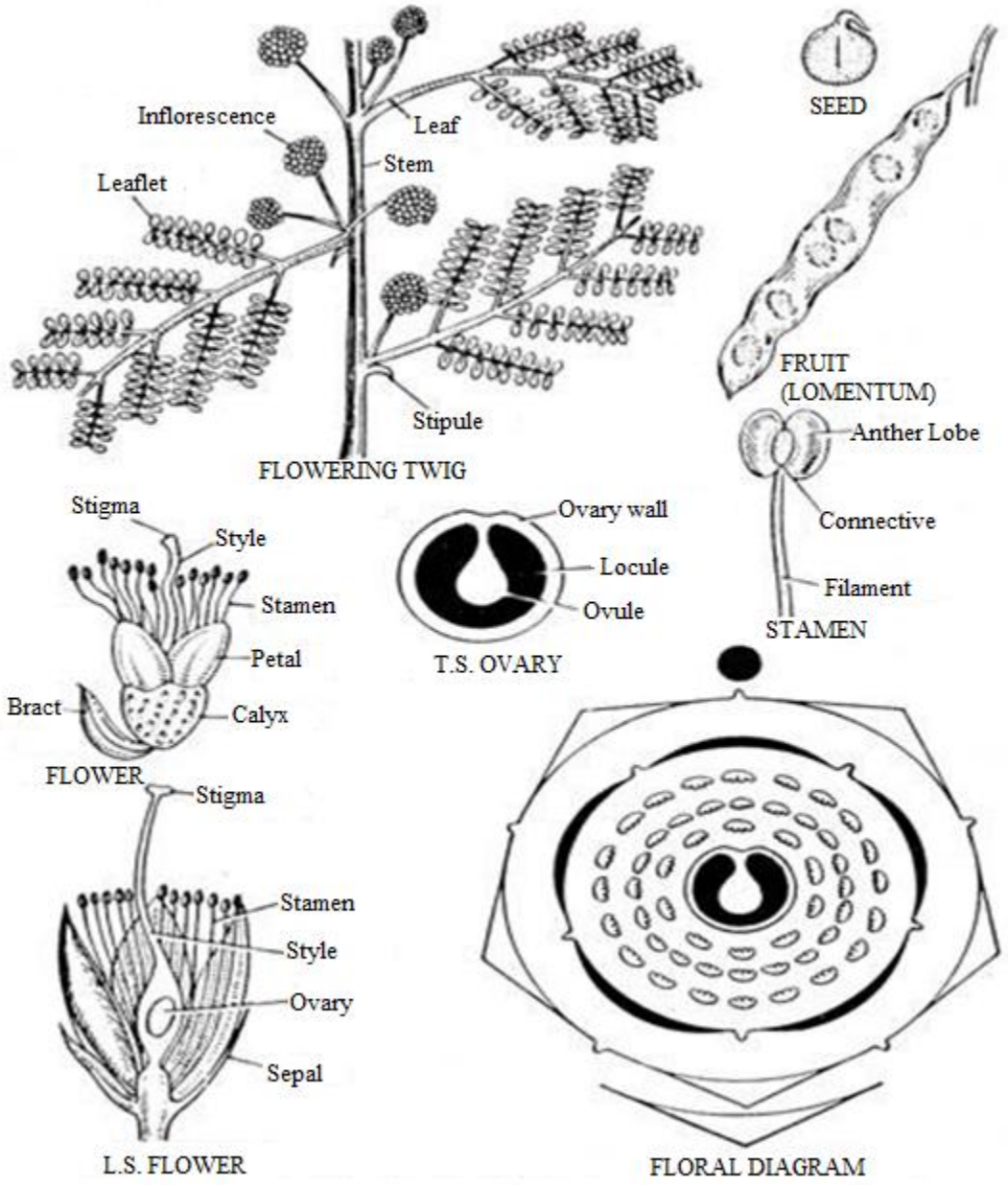

Fig. 6.9 Floral details of *Acacia nilotica*

Stem: Mostly woody, Tannin sac and gum passage are common in the pith and medullary rays

Leaves: Alternate and stipulate leaves, they are bipinnate (unipinnate in *Inga*) compound,. The stipules are modified into thrones (Acacia). Leaves of *Mimosa pudica* and *Neptunia* are sensitive to touch and assume sleep position.

Inflorescence: Minute flowers are condensed in spike-like or head or umbel. It is rarely racemose or globose umbel.

Flowers: The flower is bisexual, actinomorphic, hypogynous to slightly perigynous and bracteate.

Calyx: They have 4-5 sepals. These sepals are fused to tube, toothed or lobed. Aestivation is valvate to imbricate

Corolla: They have 4-5 petals. petals may be free or united tube. Aestivation is valvate

Androecium: The number and cohesion of stamens show much variation. In *Acacia* numerous stamens which are free, whereas in *Albizzia* indefinite stamens are monoadelphous at the base. In several genera (*Prosopis*) stamens are twice the number of petals, free, sometimes as many as the petals (*Mimosa*), the filaments are long, filiform and often exerted. Anthers are dithecous, introrse and dehiscing by longitudinal slits

Gynoecium: The pistil has single carpel (monocarpellary) with single locule., ovary superior and unilocular with several ovules along with ventral suture on the marginal placentation . The style and stigma one.

Fruit: Fruit is usually a legume or pod, indehiscent. In several species of *Acacia* it is lomentum.

General Floral Formula

$$\text{Br} \quad \oplus \quad \text{♀♂} \; K_{(4) \text{ or } (5)} \; C_{4 \text{ or } 5} \; A_{\alpha} \; \underline{G}_{1}$$

6.4.3. (C) Important Genera of Mimoseae

Acacia nilotica (Babul), *Acacia catechu* (Khair), *Albizzia lebbek* (Siris),*Mimosa pudica* (sensitive plant), *Prosopis glandulosa, Prosopis cineraria*, *Leucaena leucophloea*(White popinae) are some of the important genera and species found in India.

6.4.4. (C) Economic Importance of Mimoseae

Wood: Many trees of this family provide commercially important wood, for example many species of Acacia (*A. nilotica*), *Albizzia* (*A. lebbek, A. procera*) and *Xylia*. Their wood is used for construction, for furniture and for fuel.

Gum: Gum is obtained from *Acacia nilotica* and *Acacia senegal* used in medicine and confectionary and as a sizing material in textile industry.

Dye: A dye catechu (Katha) is obtained from *Acacia catechu* used in industries and betel.

Medicinal plants: The tender leaves of *Acacia nilotica* are used as blood purifier.

Ornamental plants: Some common plants are grown for their beautiful flowers. Some of these are *Mimosa pudica* and *Acacia melanoxylon.*

Tannins: It is mostly obtained from the bark of *Acacia nilotica* (Babul), *Acacia catechu* (Khair) and *A. leucophloea.*

As Wind breakers: A few species of *Prosopis* are planted in the arid zone for breaking the wind pressure e.g. *Prosopis glandulosa, Prosopis cineraria.*

6.5 FAMILY 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* (milkweeds).

6.5.1 Systematics

Bentham & Hooker	Engler & Prantl	Hutchinson
Dicotyledones	Dicotyledoneae	Dicotyledons
Gamopetalae	Sympetalae	Lignosae
Bicarpellattae	Contortae	Apocynales
Gentianales	Asclepiadaceae	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 succulent stem 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. They are mainly located in the tropics to subtropics, especially in Africa and South America. Most common species is *Calotropis procera* and *Crptostegia grandiflora* is cultivated in gardens.

6.5.2 General Characteristics

Habit: The members are Herbs (*Asclepias*) or shrubs *Calotropis*, or rarely trees or woody climbers (lianas) *e.g.* laticiferous. 'Normal' plants, or switch-plants, or plants of very peculiar vegetative form; sometimes (e.g. *Stapelia*) 'cactoid', succulent, *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, Stephanotis*).

Root: They have 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 semiamplexicaule in *Calotropis*, pulvinous in C*ryptostegia grandifolia.*

Inflorescence: It is usually dichasial cyme, arising from leaf axil or flowers aggregated, racemose or umbelliform (*Asclepias* and *Calotropis*).

Flower: Flowers are bractate, usually bracteolate, perfect pentamerous and bi-sexual, cyclic, They have succulent flowers. Their symmetry is mostly actinomorphic, zygomorphic 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.

Corolla: 5 gamopetalous (the tube short) usually rotate or 5-lobed but sometimes campanulate (*Gymnema*) or funnelform (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 Periploceae, the filaments are free. The anthers are coherent and apprised 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 with it coherent (via the filaments, forming a short sheath around the style (by contrast with *Periplocaceae*). 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. The short filaments are ornamented with necteriferos corona which varies in form in different genera.

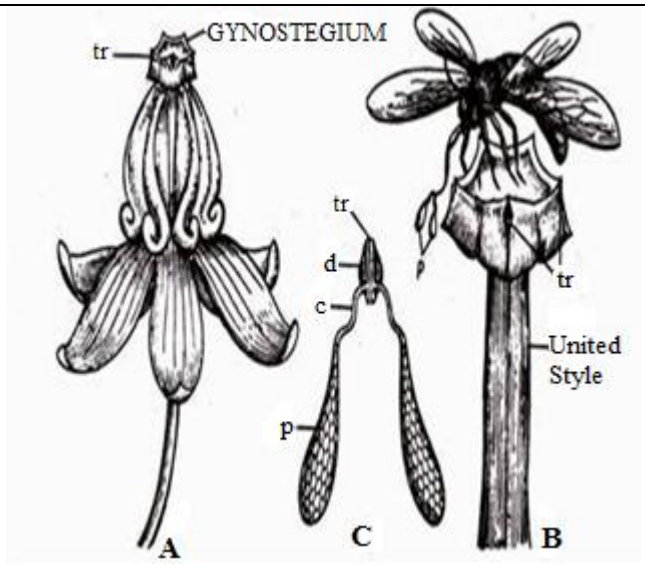

Fig 6.10 Pollination mechanism in *Calotropis gigantea*
A- A Flower , B- A bee removing a pair of pollinia from the gynostegium, C- A pair of pollinia
tr=translator locating paired pollinia d=disc, c=caudicle, p= pollinia

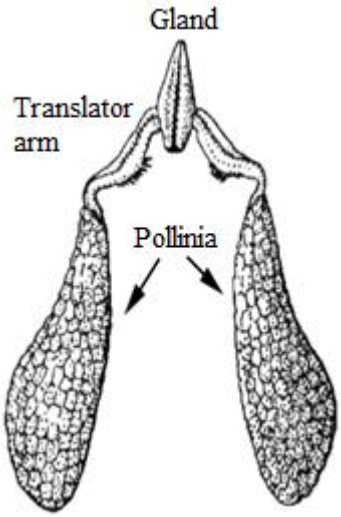

Fig.6.11 A pair of pollinia

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. Styles short.

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

General Floral Formula

$$Br \quad \oplus \quad \varphi \quad K_{(5)\text{ or }5}\ \overset{\frown}{C_{(5)}\ A_{(5)}}\ \underline{G}_{(2)}$$

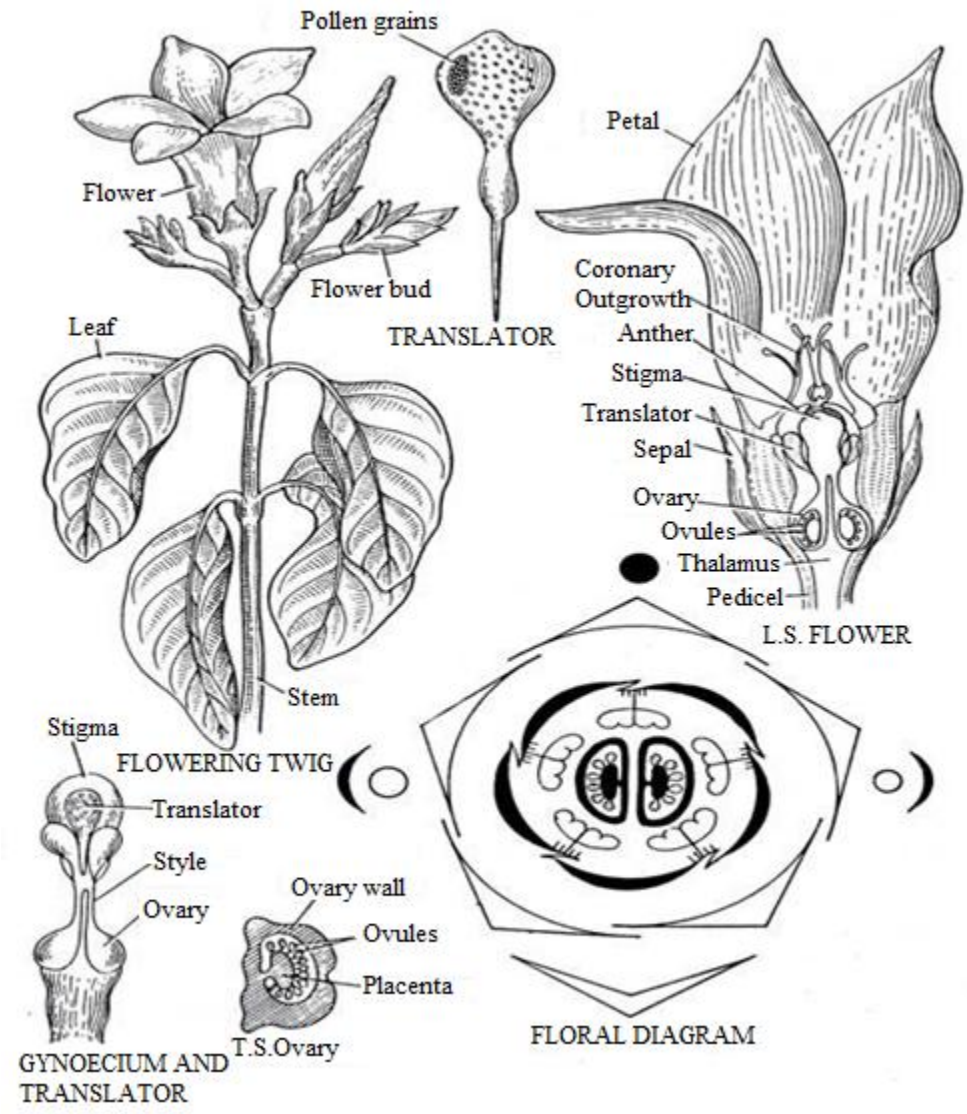

Fig. 6.12 ***Cryptostegia grandiflora***

6.5.3. Important Genera

Asclepias curassavica (Milkweed), *Oxystelma esculentum*, *Calotropis procera (*Madar), *C. gigantea*, *Stapelia variegata*, *Hoya longifolia*, *Daemia extensa*, *Cryptostegia grandiflora*.

6.5.4 Economic Importance

The family is important for ornamental and drug plants

Ornamentals: Species of *Asclepias curassavica* (Milkweed), *Stapelia variegata*, *Cryptostegia grandiflora* (Rubber vine) are grown for ornamental purpose.

Medicinal: Roots of *Tylophora indica* (Indian ipecacuanha) 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 sylvestris* 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 tanning industry for deodorizing hair and imparting yellow colour to hides. The latex of *Cryptostegia grandiflora* is commercial source of rubber.

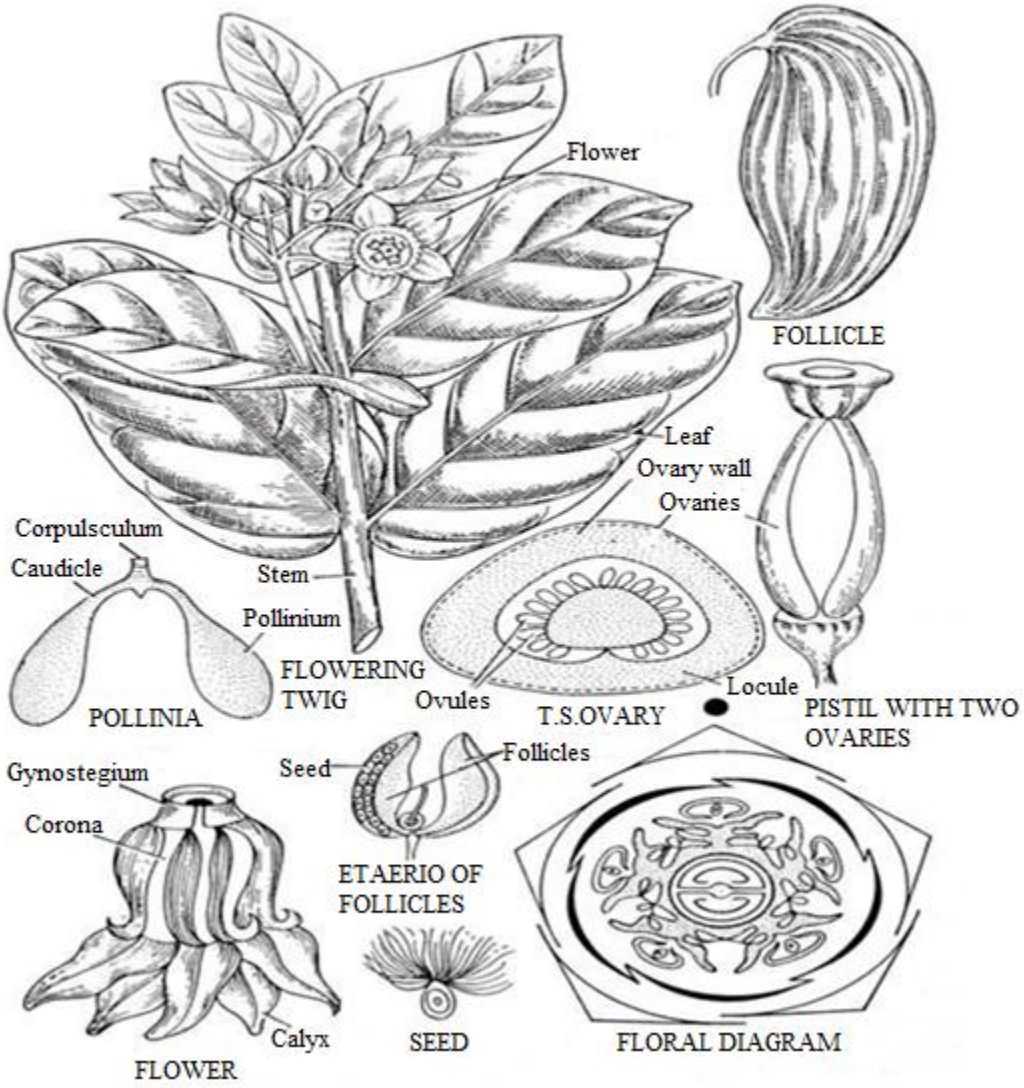

Fig. 6.13 Floral details of *Calotropis procera*

6.6 SUMMARY

Now student can sum up the important criteria of the families studied in this unit.
The Rosaceae are an assemblage of fairly advanced and primitive characters, they are included in order Rosales by most of the botanists. Although Rosaceae are more natural assemblage, most of the tribes (subfamilies) are treated as independent families.

The Fabaceae are included in the order Rosales by Bentham and Hooker, Engler and Prantl, etc. divided the family into three subfamilies. Papilionaceae, Caesalpinieae and Mimoseae. Most of the recent taxonomist treat them as three distinct families, Papilionaceae, Caesalpiniaceae and Mimosaceae respectively, include them in single order Leguminales (Hutchinson, 1959,1969) or Fabales (Takhtajan,1969, 1980). Of the three families (Hutchinson, 1969) b considered caesalpinaceae as the most primitive family. According to him it is closer to Rosaceae and seems to be derived from the rosaceous stock.

According to APG II, the Asclepiadaceae is a former plant family now treated as a subfamily (subfamily Asclepiadoideae) in the Apocynaceae (Bruyns 2000). Bentham and Hooker divided the family into two subfamilies.

In the subfamily Periploceae (*Hemidesmus, Cryptostegia*), the filaments are free. The anthers are coherent and apprised 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.This subfamily has been raised to the status of separate family Periplocaceae by some botanists. (Hutchinson, 1959, 1969)

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 shapes to a gland (Corpusculum) which lie on the stigma.

The Asclepiadaceae is considered as closely related and advanced over the Apocynaceae and usually included in order Gentianales along with Apocynaceae.

6.7 GLOSSARY

Bipinnate – Twice pinnate, the primary leaflets being again divided into secondary leaflets.
Caducous – Falling off very early as compared to similar structures in other plants.
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.
Extrorse- Facing outward from the centre of flower referred for anthers
Hairy – Pubescent with long hairs.
Hermaphrodite (bisexual)- The flower having both male and female reproductive organs
Hypanthium-Fused basal portion of sepals, petals or stamens around ovary
Inferior – Beneath, below; said of an ovary when situated below the apparent point of attachment of stamens and perianth.
Milky sap – Whitish in color, often thicker than water.
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.
Papilionaceous- pea-flowered; flowers which are zygomorphic with imbricate petals, one broad upper one, two narrower lateral ones and two narrower lower ones, the latter usually coherent or connate by their margins; the flowers of Papilionaceae
Pedicel – Stalk of a single flower in an inflorescence.
Peduncle – Stalk of a flower or inflorescence.
Pinnate – Compound, with leaflets or pinnae arranged feather-like on either side of a common axis or rachis.
Polygamous – Bearing unisexual and bisexual flowers on the same plant.
Pome – A type of fleshy, indehiscent fruit represented by the apple, pear and related genera, resulting from a compound ovary.
Prickle – An excrescence of bark that is small, weak, and spine-like.
Pollination-Transference of pollen grain from anthers to stigma
Raceme – A simple indeterminate inflorescence, having a single long axis, with pedicelled flowers.
Schizocarp – A dry dehiscent fruit that splits into two halves, e.g. *Acer* (maple).
Syncarpous- United carpels, compound ovary *e.g. Citrus*
Staminode- Sterile stamen with reduced anther
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.
Pubescent- downy; covered with short, soft, erect hairs
Zygomorphic-Asymmetrical, irregular

6.8 SELF ASSESSMENT QUESTIONS

6.8.1 Multiple Choice Questions:

1. Pulses are group of plants belonging to family (or sub-family)
(i) Caesalpinaceae (ii) Rosaceae
(iii) Papilionaceae (iv) Asclepiadaceae

2. In Papilionaceae the placentation is
(i) Parietal (ii) Axile
(iii) Marginal (iv) Free central

3. Which one of the following is known as Milkweed family
(i) Caesalpinaceae (ii) Rosaceae
(iii) Papilionaceae (iv) Asclepiadaceae

4. Pome type of fruit is characteristic of family
(i) Caesalpinaceae (ii) Rosaceae
(iii) Papilionaceae (iv) Asclepiadaceae

5. Botanical name of Soybean is
(i) *Vicia faba* (ii*) Glycine max*
(iii) *Vigna mungo* (iv) *Pisum sativum*

6. Translator mechanism is found in which of the following families
(i) Caesalpinaceae (ii) Rosaceae
(iii) Papilionaceae (iv) Asclepiadaceae

7. Descending imbricate condition of corolla is general criterion of which one of the following families
(i) Ranunculaceae (ii) Caryophyllaceae
(iii) Rutaceae (iv) Fabacea (Papilionaceae)

8. Which one of the following families belongs to series Bicarpellatae of Gamopetalae as proposed by Bentham & Hooker-

(i) Asclepiadaceae (ii) Rosaceae
(iii) Caryophyllaceae (iv) Rutaceae

9. Botanical name of the Shisham is

(i) *Pterocarpous* (ii) *Dalbergia sissoo*
(iii) *Shorea robusta* (iv) *Aegle marmelos*

10 Gynostegium is found in

(i) Rutaceae (ii) Rosaceae
(iii) Asclepiadaceae (iv) Caryophyllaceae

6.8.1 Answers Key:

1- iii	2- iii	3- iv	4- ii	5- ii
6- iv	7- iv	8 -i	9- ii	10- iii

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6.11 TERMINAL QUESTIONS

1. What do you understand by papilionaceous corolla.
2. Give economic importance of family Fabaceae.
3. Write descriptive note on floral variation of Rosaceae.
4. Give characteristic floral feature of family Asclepiadaceae.
5. Write short notes on the following:
   (i) Pollinia (ii) Gynostegium (iii) Pome (iv) Follicle (v) Lomentum (vi) Legume
6. Write about Economic importance of Rosaceae.
7. Give comparative account of taxonomic characters of different subfamilies of family Fabaceae (Leguminosae).

UNIT-7 SOLANACEAE, ACANTHACEAE AND LAMIACEAE

7.1- Objectives
7.2-Introduction
7.3- Solanaceae
    7.3.1-Systematics
    7.3.2-General characters
    7.3.3-Important Genera
    7.3.4-Economic importance
7.4- Acanthaceae
    7.4.1-Systematics
    7.4.2-General characters
    7.4.3-Important Genera
    7.4.4-Economic importance
7.5- Lamiaceae
    7.5.1-Systematics
    7.5.2-General characters
    7.5.3-Important Genera
    7.5.4-Economic importance
7.6-Summary
7.7-Glossary
7.8-Self Assessment Questions
7.9-References
7.10-Suggested Readings
7.11-Terminal Questions

7.1 OBJECTIVES

In the present unit students will be able -

- to introduced themselves with families -Solanaceae, Acanthaceae and Lamiaceae. According to Bentham and Hooker all these families come under Division- Gamopetalae, Series -Bicarpellatae with different orders. Solanaceae belongs to Order Polemoniales, Acanthaceae to Personales while Lamiaceae comes under order Lamiales.
- to know the Detailed description of the General distribution, Systematics, General characters, Important genera and Economic Importance *etc.* of families Solanaceae, Acanthaceae and Lamiaceae.
- to understand the phylogenetic and evolutionary relations of the families.

Figures of some of the important genera of the concerning families are also given here for correlating this text to the surrounding nature.

7.2 INTRODUCTION

Student has already studied characteristic features of division Gamopetalae and its series Bicarpellatae. In this unit (Unit-7) you will be familiar with three families *i.e.* Solanaceae, Acanthaceae and Lamiaceae of their concerning orders *viz.* Polemoniales, Personales and Lamiales respectively.

Division Gamopetalae and its Series Bicarpellatae

Division- Gamopetalae is characterized by having corolla of united petals. It is divided into three series

(i) Inferae (ovary inferior), (ii) Heteromerae (ovary usually superior, stamens as many or twice of the corolla segments, carpels more than two), (iii) Bicarpellatae (ovary superior, stamens as many or fewer than the corolla, carpels usually two)

It consists of four orders:

Gentianales- Already studied in Unit-6 (Family Asclepiadaceae)

Polemoniales-Leaves generally alternate and exstipulate, flowers regular, stamens as many a corolla lobes.(Family Solanaceae)

Personales- Flowers usually zygomorphic, corolla often billipped, stamens generally fewer than corolla lobes, ovules many in each locule. (Family Acanthaceae)

Lamiales- Corolla usually billipped, stamens usually didynamous or sometimes 2, ovary 2-4 locular with usually 1 ovule in each locule, fruit a drupe or nutlets. (Family Lamiaceae)

7.3 FAMILY- SOLANACEAE (POTATO FAMILY)

The **Solanaceae**, or **nightshades**, are an economically important family of flowering plants. The family ranges from annual and perennial herbs to vines, lianas, epiphytes, shrubs, and trees. It includes a number of important agricultural crops, medicinal plants, spices, weeds, and ornamentals. Many members of the family contain potent alkaloids, and some are highly toxic,

Diagnostic characteristics: Herbs or shrubs with usually alternate, simple and exstipulate leaves, flowers solitary or cymes, calyx often persistent and enlarged, 5-cleft corolla or corolla lobes 5, plaited or valvate in bud, stamens 5 on corolla tube, anthers conniving, sometimes open by pore, ovary bilocular with many ovules in each locule, placentae swollen and septum oblique, fruit a berry or capsule

Distribution pattern: The family has a worldwide distribution, being present on all continents except Antarctica. The greatest diversity in species is found in South America and Central America. Solanaceae commonly called 'Brinjal family'. It includes about 90 genera and 2000 species.. There are around 15 genera and 90 species found in India occurring chiefly in the Himalayas and Southern and Eastern parts of India

Well known examples are mostly cultivated species such as *Solanum tuberosum* (Potato) *Nicotiana tabacum* (Tobacco), *Lycopersicon esculentum* (Tomato), *Capsicum frutescens* (Red pepper), *Solanum melongena* (egg plant or brinjal).

7.3.1 Systematics

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledons
Gamopetalae	Sympetalae	Herbaceae
Bicarpellatae	Tubiflorae	Solanales
Polemoniales	Solanaceae	Solanaceae
Solanaceae		

According to Bentham and Hooker the Polemoniales consists of five families, they are Polemoniaceae, Hydrophyllaceae, Boragineae, Convolvulaceae and Solanaceae. Engler and Prantl have placed all these families in order Tubiflorae into small groups (orders). He placed Solanaceae Convolvulaceae and Solanaceae in the order Solanales. Hutchinson has also shown the close systematic relationship of the Geraniales with the Convolvulaceae.

7.3.2 General Characteristics

Habit: Mostly annual herbs (*Solanum nigrum*), undershrubs (*Solanum melongena*). Some are shrubs (*Solanum torvum*) rarely trees (*Solanum grandiflorum*) and climbers (*Solanum seaforthianum*).

Root: Fibrous or tuberous Taproot, branched.

Stem: In most species stem is Herbaceous or woody, smooth and branched but sometimes it is prickly or spinous. The spines are modified branches, In *Solanum tuberosum* underground stem tubers are formed.

Leaves: Simple, Petiolate, exstipulate, alternate or opposite, entire (*Petunia*), simple, lobed or pinnatifid (*Solanum*), They are pinnately compound in *Lycopersicon* and *Solanum tuberosum.* In the inflorescence portion the leaves often become sub-opposite or opposite.

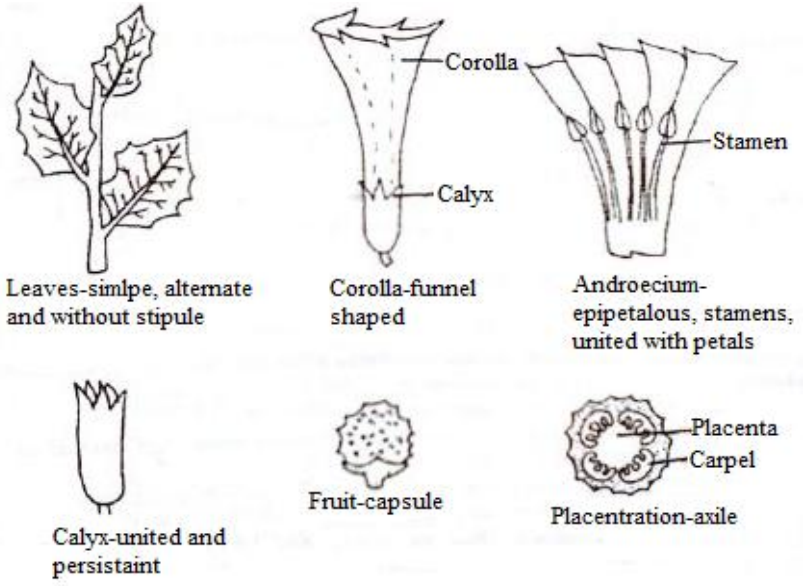


Fig. 7.1 Vegetative and floral parts of Solanaceous plant

Inflorescence: The flowers are often borne in Cymes which are lateral, axillary or terminal. In some species of *Solanum* the cymes are extra-axillary appearing to rise from the middle of an internode. The flowers are solitary and axillary in *Datura* and clustered in *Withania*..

Flower: The flowers are ebracteate, actinomorphic (Zygomorphic in *Salpiglossis*), bisexual (unisexual in *Withania coagulans*), pedicellate, pentamerous and hypogynous.

Calyx: Sepals 5, gamosepalous (five-lobbed or five partite), persistent (in the fruit condition also) green; often much enlarged in the fruit, valvate aestivation in bud.

Corolla: Petals 5, gamopetalous, rotate or companulate (*Physalis*)) or infundibuliform (*Petunia*) trumpet- shaped (*Datura*). The limb is usually five-lobed or rarely ten-lobed as in *Datura* Twisted or valvate aestivation.Sometimes the corolla is strongly zygomorphic and may become bilabiate (*Schizanthus*).

Androecium: The stamens are usually 5, polyandrous and epipetalous on the corolla tube and alternate with the lobes. They are commonly of unequal height. In Zygomorphic forms there are only four in *Salpiglossis* or two *Schizanthus* fertile stamens and remaining are represented by staminodes. The anthers are often conniving (*Solanum*), dithecous, introrse and dehiscing by longitudinal slits or by apical pore free or united, basifixed.

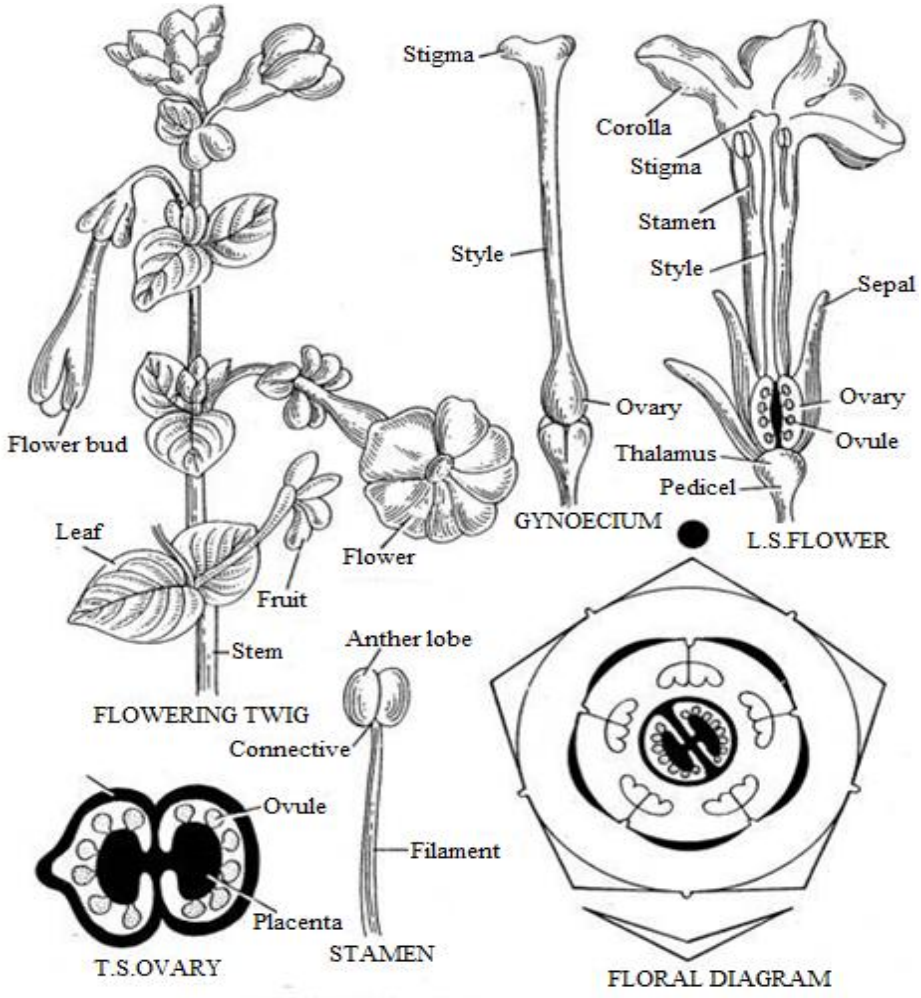


Fig.7.2 Floral details of *Petunia nyctaginifolia*

Gynoecium: Bicarpellary (the number of carpels often increase in *Lycopersicon* and *Capsicum* , syncarpous, The ovary is superior and bilocular (sometimes in *Datura* and *Nicandra* the number of locules increases to three to five by formation of pseudoseptum (false septum) with numerous

ovules in each locule (few in *Cestrum*) on axile placentation.. The placentae are often swollen and the septum is oblique. In *Capsicum* the ovary becomes unilocular in the upper region by receding of placentae and appears to be parietal. The style is linear and the stigma is capitate or shortly lobed. A hypogynous nectariferous disc is usually present at the base of the ovary.

Fruit: Fruit is a berry which is sometimes (*Physalis*) enclosed within an inflated bladder-like calyx or it is capsule which dehisces by valves (*Datura*) or circumcise above the middle.

Seed: Numerous, compressed, discoid or subreniform, endospermic with curved or straight embryo.

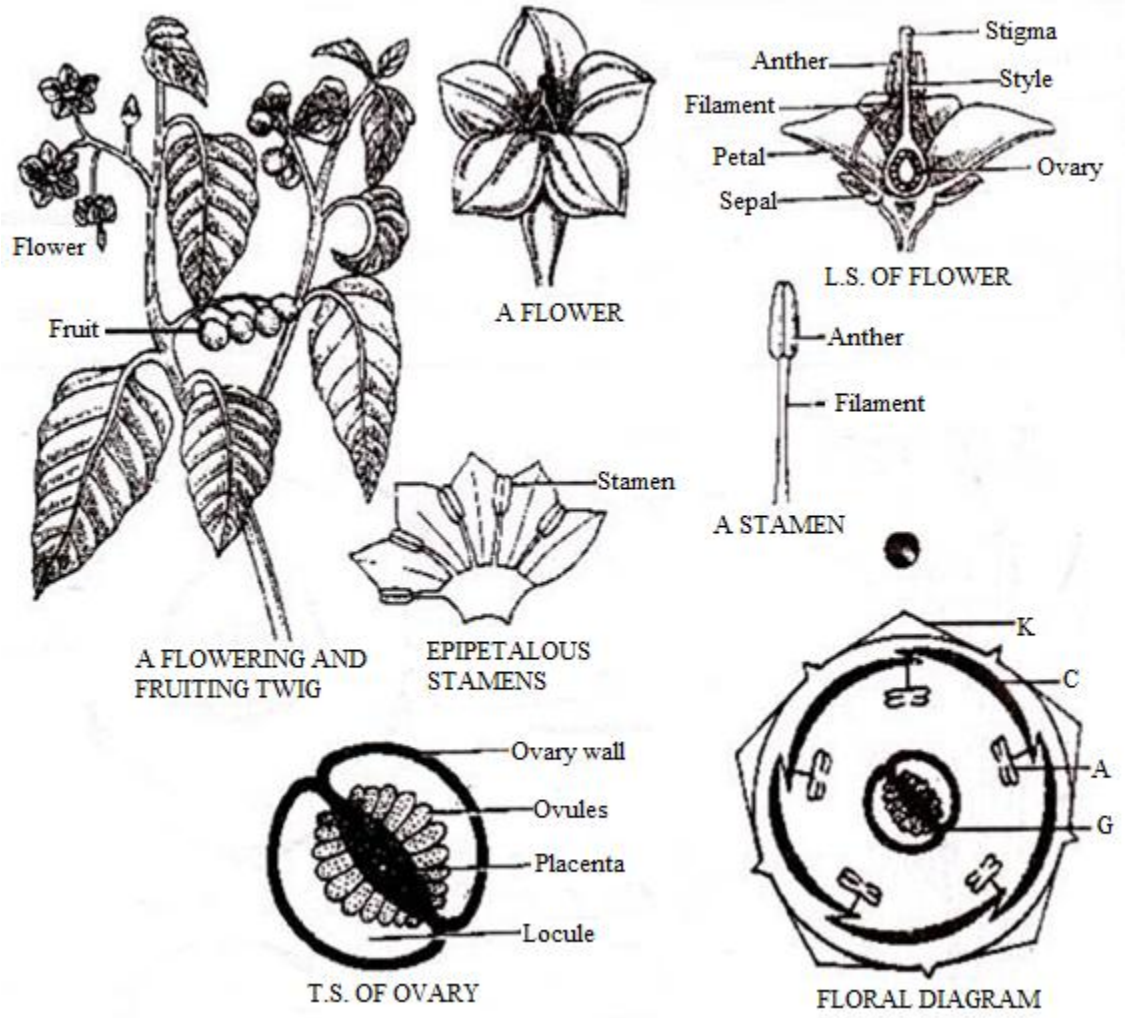


Fig.7.3 Floral details of *Solanum nigrum*

Pollination: Usuallty conspicuous flowers of the solanaceae are visited by insects for nector secreted by a hypogynous disc. In *Solanum tuberosum* usually self pollination occurs.

Floral formula

Solanum	**Ebr**	⊕	♂♀	$K_{(5)}\ \overline{C_{(5)}}\ A_5\ \underline{G}_{(2)}$
Salpiglossis	**Ebr**	%	♂♀	$K_{(5)}\ \overline{C_{(5)}}\ A_4\ \underline{G}_{(2)}$

7.3.3 Important genera: *Solanum tuberosum* (Potato), *Nicotiana tabacum* (Tobacco), *Lycopersicon esculentum* (Tomato), *Capsicum frutescens* (Red pepper) *Solanum melangena* (egg plant or brinjal), *Solanum nigrum* (Makoi), *Cestrum nocturum* (Rat-ki-rani), *Hyoscyamus niger* (henbane), *Cestrum nocturnum, Withania somnifera* (Ashwagandha).

7.3.4 Economic importance

The solanaceae are of great economic importance. They yield food, drugs, tobacco and many ornamentals.

1- As food stuff: Genus *Solanum*, which contains the potato *S. tuberosum*, in fact, another common name of the family is the "potato family", the tomato (*S. lycopersicum syn. Lycopersicon esculentum*), and the eggplant or aubergine (*S. melongena*).

Another important genus, *Capsicum*, produces both chili peppers and bell peppers. The dried fruits of *Capsicum annum* (Chillies or red pepper, Mirch) are the principal source of chilli powder of commerce used as spice in India. *C. frutescens* is used in making hot sauces and as a vegetable.

Fruits of *Physalis* produce the so-called ground cherries, *Physalis (4-jet-Ground-Cherry), it produces an edible fruit. This fruit is enclosed in a bladder like calyx called husk. So it is called husk tomato.*

2- Tobacco: Nicotiana tabacum (tobacco) has great commercial value. It leaves are dried and made into tobacco. This tobacco is used for making cigarettes.

3- As Medicinal plants: *Many members of this family produce powerful alkaloids e.g. Atropa belladona (Belladona) which are the source of atropine. It is* used for making belladona plasters. Atropine is a medicinal extract. *These are used in many medicines such as overcoming spasm of involuntary muscles, dilating pupils and relieving pain. It is valuable antidote in case of poisoning by opium.*

The dried leaves and flowering tops of Datura stramonium (Dhatura) are source of drug stramonium used chiefly in spasm of the bronchioles in asthma and in treatment of parkinsonism.

It contains alkaloids daturines and atropine. One of the chief ingredients of the Ayurvedic preparation, *Kanaka Asava* used as sedative and intoxicant.

The dried leaves and flowering tops of Hyoscyamus niger (henbane) used as sedative in nervous affections and irritable condition of asthma and whooping cough.

The fruits of *Withania somnifera* (Ashwagandha) constitute the Ayurvedic drug Ashwagandha prescribed for hiccup, female disorders, cough and rheumatism. Another species *Withania coagulans* (Indian rennett) is used in asthma, chronic complaints of lever, colic and as blood purifier.

4- Ornamental Plants: Many plants are cultivated in the gardens for their beautiful flowers. Such as *Petunia, Nicotiana alata, Cestrum nocturnum* (Rat-ki-rani, night queen or night jasmine), *Cestrum diurnum* (Din- ka-raja or day jasmine), *Salpiglossis and Solanum* etc.

7.4 FAMILY- ACANTHACEAE (ACANTHUS FAMILY)

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)

Diagnostic characteristics: Plants in this family have simple, opposite, decussate leaves with entire (or sometimes toothed, lobed, or spiny) margins, and without stipules simple leaves arranged in opposite pairs, with cystoliths (enlarged cells containing crystals of calcium carbonate) 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.

Distribution pattern: This family of dicotyledonous flowering plants has 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. A species well-known to temperate gardeners is bear's breeches (*Acanthus mollis*), a herbaceous perennial plant with big leaves and flower spikes up to 2 m tall. Tropical genera familiar to gardeners include *Thunbergia* and *Justicia*.

7.4.1 Systematics

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledons
Gamopetalae	Sympetalae	Herbaceae
Bicarpellatae	Tubiflorae	Personales
Personales	Acanthaceae	Acanthaceae
Acanthaceae		

Sometimes the genera *Mendoncia* and *Gilletiella*, and *Thunbergia*, *Pseudocalyx*, *Meyenia* and *Pounguia* are placed in separate families, Mendonciaceae and Thunbergiaceae respectively (Airy Shaw, 1973). The family is generally considered to have been derived from the Scrophulariaceae or stocks ancestral to them.

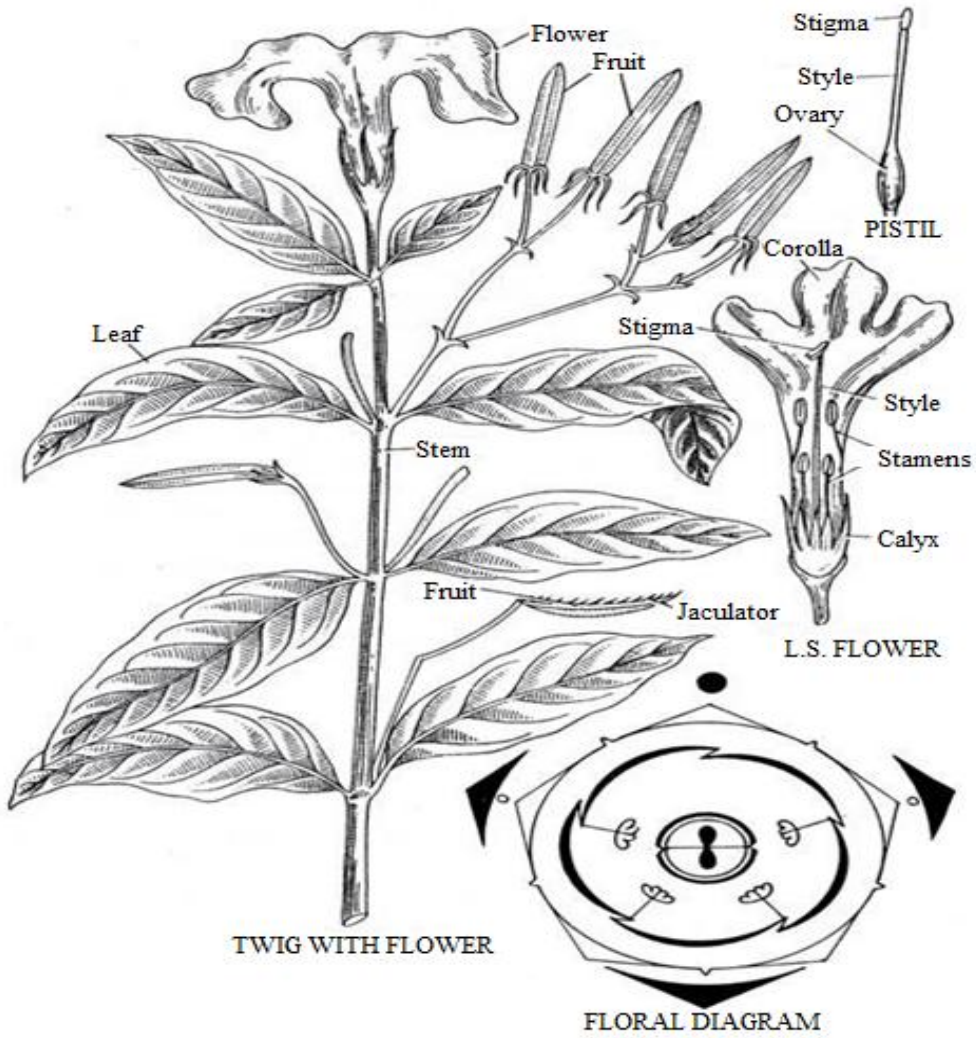


Fig.7.4 Floral details of *Ruellia prostrata*

7.4.2 General Characteristics

Habit: They are mostly annual or perennial herbs, undershrubs or shrubs or sometimes climbing as species of *Thunbergia* and *Mendonica Justicia*. Hydrophytic, or helophytic (including a few mangroves), or mesophytic (many in damp places in tropical forests), or xerophytic (*Barleria*), trees (rarely, but including a few mangroves).

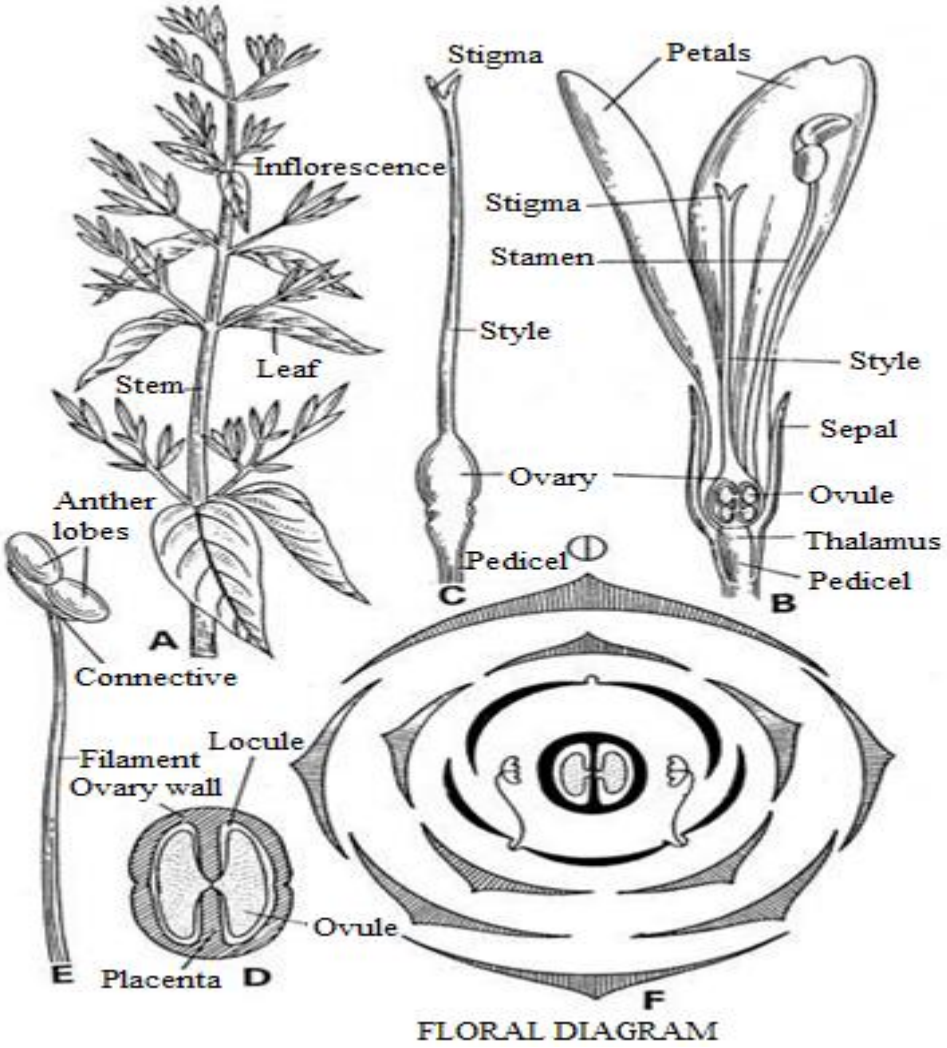


Fig. 7.5 Floral details of *Peristrophe bicalyculata*

Stem: well developed (usually), or much reduced. The herbs annual to perennial, there is basal aggregation of leaves, or without conspicuous aggregations 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 characterstic and are useful in distinguishing various genera and tribes.

Leaves: Leaves opposite decussate, simple exstipulate. Lamina margins entire

Inflorescence: Inflorescences 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 bracteates, 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.

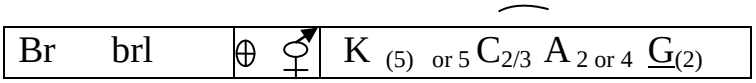
Androecium: The stamens are more often four and didynamous and frequently two as in *Blepharis, Acanthus* and *Justicia*. The one to three missing stamens are frequently staminodes. In *Pentstemonacanthus* all the stamens are fertile (rarely), inserted near the base of the corolla tube, or midway down 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

General Floral Formula



7.4.3 Important Genera: *Acanthus ilicifolius*-A mangrove plant with prickly and handsome flowers, *Barleria*- A medicinal shrub bearing two long thorns at each node., *Adathoda vesica* (syn. *Justicia adathoda*), *Ernathemum, Peristrophe, Rueliia, Thunbergia* are some common plants of family Acanthaceae found in our country.

7.4.4 Economic Importance: Species of several genera are cultivated as garden ornamentals and medicines

Ornamentals*:* A number of species are used as ornamentals of the garden. These include:
Thunbergia (clock-vine) - *T. grandiflora, T. alata, T. coccinefra*
Ernanthemum- E. nervosum, E.bicolor, E.reticulata
Barleria- B. polytrichia, B. cristata
Justicia gendarusa
Peristrophe,
Ruellia ruberosa

Medicines: A few species provide some well known drugs used in indigenous system of medicine. The leaves and roots of *Adhatoda vasica* (Vasaka) provide a well known drug used for bronchitis, asthma and cough.

The roots and leaves of *Hygrophila spinosa* are used for jaundice and rheumatism.

The leaves and roots of several species of *Barleria* such as *B.bauxifolia, B.cristata, B.longifolia, B.prionitis (kalabansa) and B.strigosa* are used for cough and inflammations.

Peristrophe bicalyculata is used as antidote of snake bite.

Rungia parviflora- The juice of its leaves is given to children in small-pox.

7.5 FAMILY- LAMIACEAE (MINT FAMILY)

The original family name is **Labiatae**, so given because the flowers typically have petals fused into an upper lip and a lower lip (*labia* in Latin). **Labiatae** (the **mint** or **deadnettle** family) are a family of flowering plants. The plants are frequently aromatic in all parts and include many widely used culinary herbs, such as basil, mint, rosemary, sage, savory, marjoram, oregano, hyssop, thyme, lavender.

Diagnostic characteristics: The flowers are bilaterally symmetrical with 5 united petals, 5 united sepals. They are usually bisexual and verticillastrate (a flower cluster that looks like a whorl of flowers but actually consists of two crowded clusters). Although this is still considered an acceptable alternative name, most botanists now use the name "Lamiaceae" in referring to this family. The leaves emerge oppositely, each pair at right angles to the previous one (called decussate) or whorled. The stems are frequently square in cross section, but this is not found in all members of the family, and is sometimes found in other plant families.

Distribution pattern

The mint family is rather large containing **180 genera and 3500 species** of worldwide distribution. The Mediterranean region is the chief centre of distribution. In India the family is

represented by about **64 genera and 380 species** occurring chiefly in comparatively dry areas and moderate altitudes. The two chief centers of distribution are South India and North Western India. The familiar examples include Mentha *(Mentha spicata*), Holy basil (*Ocimum sanctum)* and Sage *(Salvia spp).*

7.5.1 Systematics

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledons
Gamopetalae	Sympetalae	Herbaceae
Bicarpellatae	Tubiflorae	Solanales
Polemoniales	Solanaceae	Solanaceae
Solanaceae		

Bentham and Hooker have included five families in order Lamiales. They are Myoporineae, Selagineae, Verbenaceae, Labiatae and Plantagineae. Engler and Prantl have included (excluding Selagineae) in order Tubiflorae. Hutchinson has included the families Myoporaceae, Selagineae, Globulariaceae and Labiatae in the order Lamiales and the Verbenaceae in the Verbenales.

7.5.2 General Characteristics

Habit: They are mostly annual or perennial herbs, sometimes shrubs (as some species of *Ocimum* and *Orthosiphon*) or rarely small trees as *Leucosceptrum*. Species of *Mentha* and *Lycopus* are marsh plants which persist by perennial rhizomes. *Rosamarinus* and some other taxa are xerophytic.

Roots: Tap root

Stem: The stems of the herbaceous species are often quadrangular.

Leaves: The leaves are Petiolate, opposite and decussate (Whorled in *Dysophyla*) simple, exstipulate and the blade is from entire to finely multisect in some species of *Salvia*. They are abundately loaded with epidermal glands secreting volatile aromatic oils. Which impart characterstics odour.

Inflorescence: The inflorescence is usually a dichasial cyme which often becomes cincinal in its later branching. These cymes occur in the leaf axils and often form a whorl of flower at each node. This type of inflorescence is often called Verticillaster (opposite axillary cymes). Rarely the flowers are solitary in the axils of leaves or bracts and form a racemose inflorescence *(Scutellaria*). Each flower is usually subtended by a bract and a pair of bracteoles.

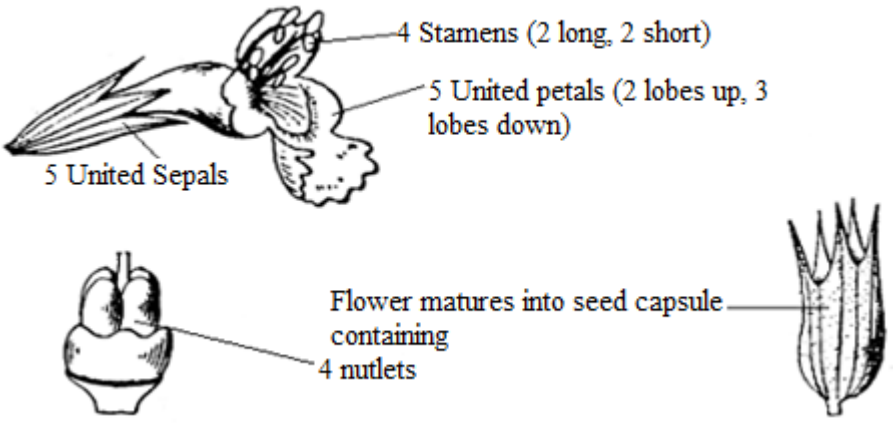


Fig. 7.6 Floral structure of Lamiaceae (Typical mint flower)

Flower: The flowers are bracteates, perfect, hermaphrodite, zygomorphic (rarely actinimorphic as in *Mentha*) Pedicillate, complete. Pentamerous, hypogynous.

Calyx: composed of 4 or 5(usually) sepals, persistent fused, show various degree of union, tubular or funnel-shaped, sometimes as in *Salvia*, *Ocimum* and several other taxa, it is two-lipped. The aestivation is valvate or rarely imbricate.

Corolla: 4 or 5 petals, gamopetalous and is differentiated into a tube and a limb. The tube is straight or bent and often widens upward. The limb is usually two-lipped **(**bilabiate). In the lower lip of *Lamium* the median lobe is most developed. In *Ocimum* and related genera such as *Salvia* the upper lip is composed of two posterior petals, while the remaining three form lip which is four-fid formed by four petals while the remaining fifth anterior petal forms the lower lip which is hardly longer than the upper lip. In *Teucrium* the limb is one-lipped as all the five lobes are pushed on the lower side. The corolla lobes are contorted or imbricate in the bud.

Stamens: The stamens are usually four, stamens didynamous and inserted on the corolla tube . The anterior pair of stamen is usually longer. The fifth (posterior) stamen is sometimes represented by staminode but it is usually suppressed. In *Lycopus, Salvia, Mosla* and some other genera only two stamens (anterior pair) are fertile whereas the other two (posterior pair) are reduced to staminodes. The filaments are usually free but they are connate in *Coleus*. The anthers are dithecous, introrse and dehisce lengthwise. In *Salvia* the two anther cells are separated by the development. The posterior cell alone is fertile epipetalous, basifixed.

Gynoecium: The gynoecium is bicarpellary and syncarpous. The ovary is superior, deeply four lobed, bilocular or apparently becoming four-lobed by the formation of false septa. There are two anatropous ovules in each locule (only one ovary is tetra-locular). The style is very characterstic of the family. It arises from the base of ovary in between the four locules and is known as **gynobasic style.** The stigmatic papillae of bilobed stigma are situated at the tip of the style arms.

The placentation is axile. A hypogynous disc is present at the base of ovary. It is usually four-lobed and the anterior pair of lobes which are more developed secrete nectar.

Fruits: The fruit is of four one-seeded nutlets enclosed by the persistent calyx.

Seed: Non-endospermic.

Pollination: Entomophilous

General Floral Formula

%	♀♂	$K_{(5)}\ \overset{\frown}{C_5}\ A_4$ or $2\ \underline{G}_{(2)}$

Ocimum	**Br**	%	♀♂	$K_{(1/4)}\ \overset{\frown}{C}_{(4/1)}\ A_{2+2}\ \underline{G}_{(2)}$
Salvia	**Br**	%	♀♂	$K_{(3/2)}\ \overset{\frown}{C}_{(2/3)}\ A_2\ \underline{G}_{(2)}$

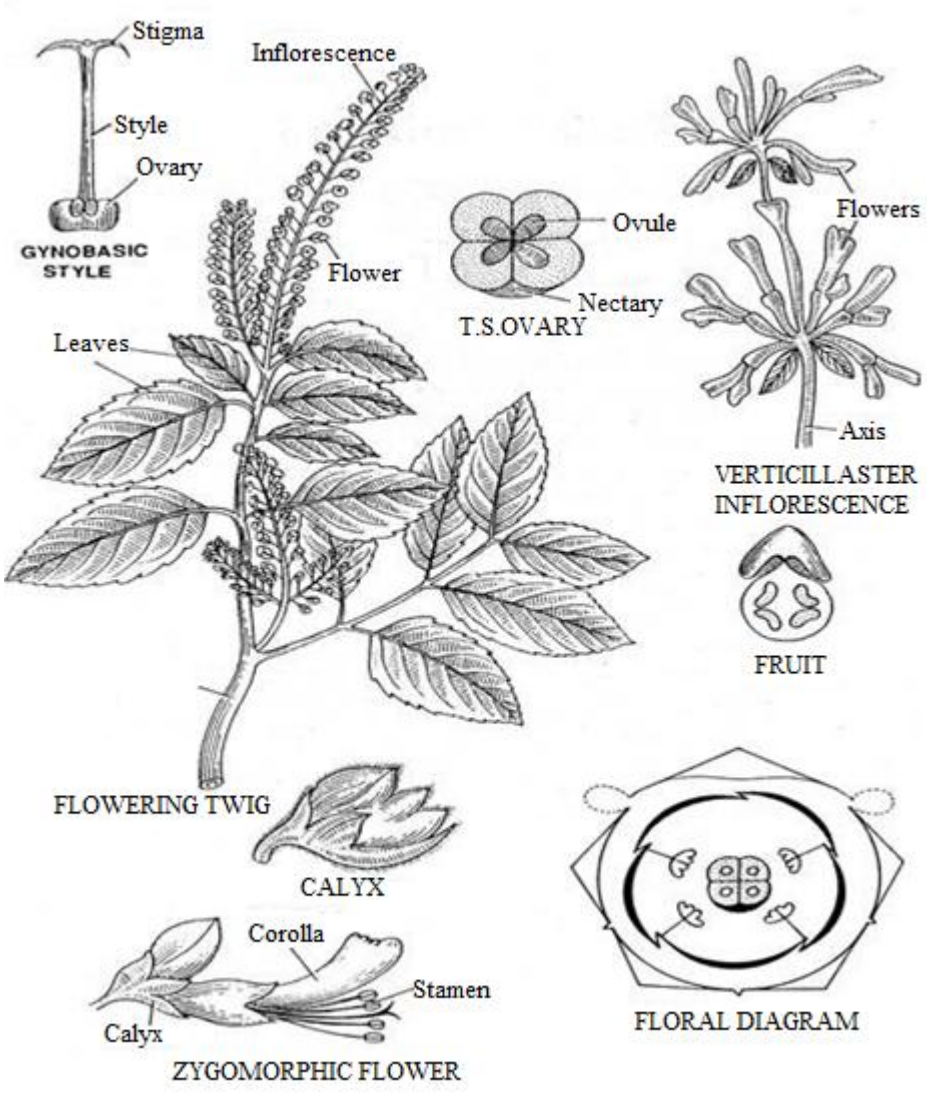


Fig 7.7 Floral details of *Ocimum sanctum*

7.5.3 Important species: *O.americanum syn. O.canum* (Ram tulsi), *O. gratissimum* (Shrubby basil), *O. basilicum* (sweet basil, Kali basil), *O. sanctum* (Holy basil, tulsi). *Mentha piperata* (Vilayati pudina), *M. arvensis* (Field mint), *M. spicata* (pahari pudina), *Ocimum kilimandscharicum, Lavandula officinalis* (Lavandula), *Rosmarinus officinalis* (Rosemarry), *Salvia splendens* (Scarlet sage), *S. leucantha, S. coccinea, S. officinal*is and *Coleus blumei* are common plants grown in India.

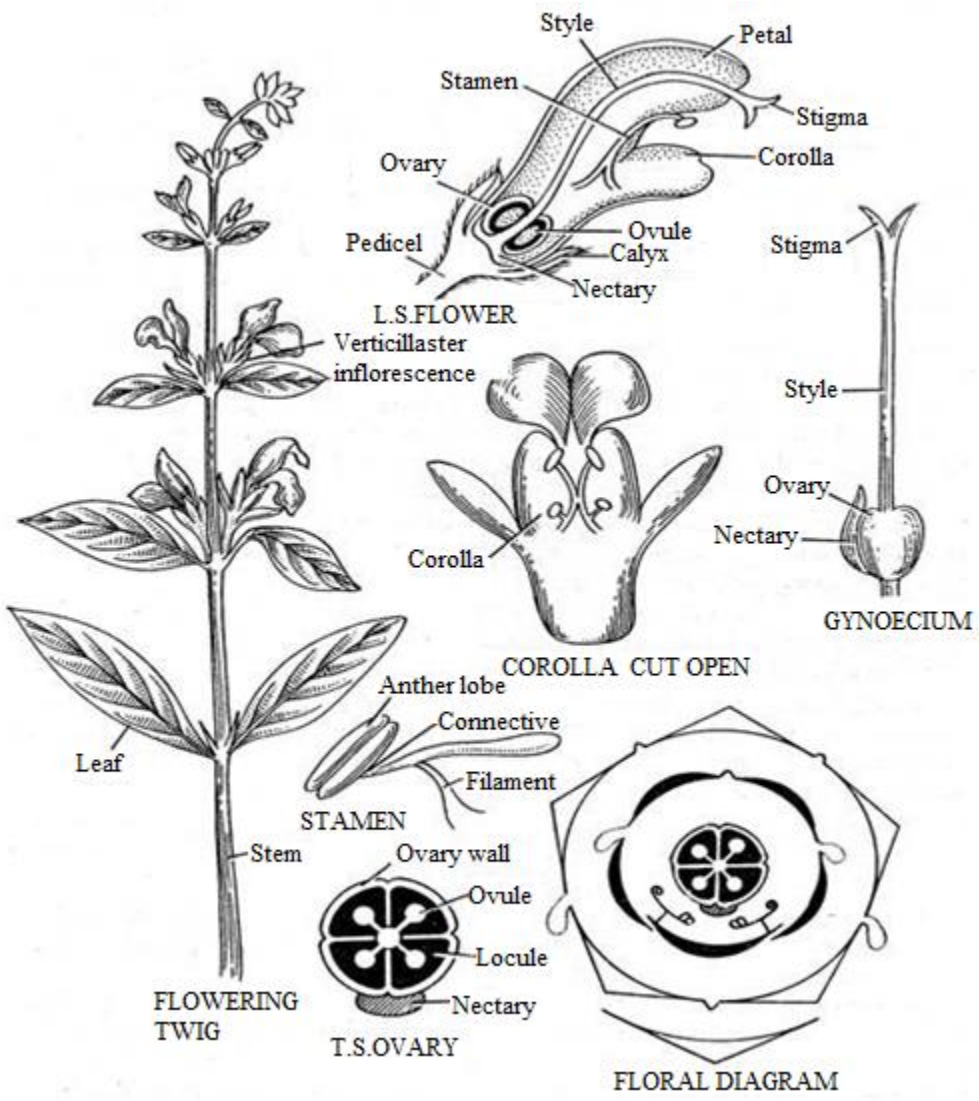


Fig.7.8 *Salvia officinalis* Linn.

7.5.4 Economic Importance:

The lamiaceae are valuable chiefly as a source of volatile essential oils which are used for flavouring for perfumery and for medicines and as garden ornamentals.

Medicinal plants: Many plants of this family give drugs. Several species of *Ocimum* (Basil) such as *O.americanum syn. O.canum* (Ram tulsi), *O. gratissimum* (Shrubby basil), *O. basilicum* (sweet basil, Kali basil) and *O. sanctum* (Holy basil, tulsi) yield essential oils used in medicines and perfumery.

Peppermint is obtained from *Mentha piperata.* It is used in perfumery and the oil obtained from its leaves used medicinally as stimulant, carminative. *M. arvensis* (Field mint) and *M. spicata* (pahari pudina) are used in flavouring food products.

O. sanctum (Holy basil, tulsi) is used as remedy for cold and cough. *Ocimum kilimandscharicum* contains camphor.

Perfumes: Many plants contain abundant volatile aromatic oils like *Lavandula officinalis* yields lavender oil, *Rosmarinus officinalis* yields rosemary oil.

Condiments: *Mentha* and *Ocimum* are used as condiments.They are used in digestive disorders and as stomachic problems

Beverages: *Ocimum canum* gives mucilaginous seeds. These are used in beverages as tukhmalanga.

Ornamental plants: Several species of *Salvia* (Sage) – *S. splendens* (Scarlet sage), *S. leucantha, S. coccinea, S. officinali*s and *Coleus blumei* are cultivated for their beautiful flowers.

7.6 SUMMARY

Now student can sum up the important criteria of the families studied in this unit (Unit-7). In the present unit student were introduced with families Solanaceae, Acanthaceae and Lamiaceae. According to Bentham and Hooker all these families come under Division- Gamopetalae and Series Bicarpellatae with different orders. Solanaceae belongs to Order Polemoniales, Acanthaceae of Personales while Lamiaceae comes under Lamiales.

The **Solanaceae**, or **nightshades**, are an economically important family of flowering plants. The family ranges from annual and perennial herbs to vines, lianas, epiphytes, shrubs, and trees, and includes a number of important agricultural crops, medicinal plants, spices, weeds, and ornamentals. Many members of the family contain potent alkaloids, and some are highly toxic, but many cultures eat nightshades, in some cases as staple foods. The family belongs to the order Solanales in the asterid group dicotyledons (Magnoliopsida). The Solanaceae consists of about 98 genera and some 2,700 species, with a great diversity of habitat, morphology and ecology.

Another family Acanthaceae is varyingly placed under 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. Subfamilies Mendoncioideae and Thunbergioideae are intermediate between Bignoniaceae and Acanthaceae and are usually

considered as independent families). Plants in this family have simple, opposite, decussate leaves with entire (or sometimes toothed, lobed, or spiny) margins, and without stipules. Simple leaves arranged in opposite pairs, with cystoliths (enlarged cells containing crystals of calcium carbonate) 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.

The last family of this unit is Lamiaceae also well known as Labiatae. The flowers are bilaterally symmetrical with 5 united petals, 5 united sepals. They are usually bisexual and verticillastrate (a flower cluster that looks like a whorl of flowers but actually consists of two crowded clusters). Although this is still considered an acceptable alternative name, most botanists now use the name "Lamiaceae" in referring to this family. The leaves emerge oppositely, each pair at right angles to the previous one (called decussate) or whorled. The stems are frequently square in cross section, but this is not found in all members of the family, and is sometimes found in other plant families. The style is very characterstic of the family. It arises from the base of ovary in between the four locules and known as gynobasic style. The stigmatic papillae of bilobed stigma are situated at the tip of the style arms. The placentation is axile.

7.7 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 developingf from single carpel or more commonly from a syncarpous pistil with axile or parietal placentation e.g. tomato
Bilabiate: Two lipped zygomorphic gamopetalous corolla, *e.g. Justicia, Ocimum, Salvia*
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.
Monochasial (Uniparous) cyme: Having a cymose inflorescence with one axis at each branching
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 borne on the petals or corolla tube *e.g. Justicia, Solanum*
Extrorse- Facing outward from the centre of flower referred for anthers
Gamosepalous: With coherent sepals
Imbricate: A mode of aestivation in 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
Jaculator: Structural modification of the funiculus develops into a hook like structure on which the seeds rest.
Locule: Chambers, the ovary may be unilocular (*Ranunculus*), bilocular (*Solanum*), trilocular (*Allium*), tetralocular (*Ocimum*), Pentalocular (*Hibiscus*) or multilocular (*Citrus*)
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.
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 grains from anthers to stigma
Raceme – A simple indeterminate inflorescence, having a single long axis, with pedicelled flowers.
Syncarpous- United carpels, compound ovary
Staminode- Sterile stamen with reduced anther
Verticillaster: Much condensed cymes occur in the leaf axils and often form a whorl of flower at each node. This type of inflorescence is often called Verticillaster (opposite axillary cymes) characterstic of Labiatae.

7.8 SELF ASSESSMENT QUESTIONS

7.8.1 Multiple Choice Questions:

1. In Labiateae (Lamiaceae) the fruits are usually
(i) Follicle (ii) Nutlets
(iii) Capsule (iv) Achene

2. Botanical name of Chilli (Red hot pepper) is
(i) *Solanum tuberosum* (ii) *Lycopersicon esculentum*

(iii) *Capsicum frutescens* (iv) *Nicotiana tabacum*

3. Gynobasic style is the characteristic of the family
(i) Lamiaceae (ii) Acanthaceae
(iii) Solanaceae (iv) Poaceae

4. Persistent calyx (in fruit) is characteristic feature of which one of the following families
(i) Lamiaceae (ii) Acanthaceae
(iii) Solanaceae (iv) Poaceae

5. *Withania somnifera* is commonly called as
(i) Sarpgandha (ii) Ashvagandha
(iii) Rajnigandha (iv) Rat-ki- rani

6. *Adathoda vasica* belongs to which one of the following families
(i) Lamiaceae (ii) Acanthaceae
(iii) Solanaceae (iv) Poaceae

7. Berry or septicidal fruit is charactersic feature of family
(i) Lamiaceae (ii) Acanthaceae
(iii) Solanaceae (iv)Poaceae

8. Epipetalous and didynamous stamens and presence of staminode is characterstic feature of which one of the following families
(i) Lamiaceae (ii) Acanthaceae
(iii) Solanaceae (iv) Poaceae

9. A hook like projection known as 'jaculator'in which the seed rest is found in
(i) Lamiaceae (ii) Acanthaceae
(iii) Solanaceae (iv) Poaceae

10. Botanical name of Pudina is
(i) *Salvia officinals* (ii) *Ocimum sanctum*
(iii) *Coleus bruni* (iv) *Mentha arvensis*

7.8.1 Answers Key:

1- ii	2- iii	3- i	4- iii	5- ii
6- ii	7- iii	8 -ii	9- ii	10- iv

7.9 REFERENCES

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7.11 TERMINAL QUESTIONS

Q1. What do you understand by verticillaster inflorescence.
Q2. Describe economic importance of family Solanaceae.
Q3. Write descriptive note on floral features of Acanthaceae.
Q4. Give characteristic features of family Lamiaceae.
Q5. Write short notes on the following:
(i) Jaculator (ii) Gynobasic style (iii) Capsule (iv) Bi-lipped corolla (v) Economic importance of genera *Solanum* (iv) Berry
Q6. Describe family Solanaceae in semi-technical taxonomic language.
Q7. Give comparative account of taxonomic characters of families Acanthaceae and Lamiaceae.

UNIT-8 ORCHIDACEAE, LILIACEAE AND POACEAE

8.1- Objectives
8.2-Introduction
8.3- Orchidaceae
    8.3.1-Systematics
    8.3.2-General characters
    8.3.3-Important Genera
    8.3.4-Economic importance
8.4- Liliaceae
    8.4.1-Systematics
    8.4.2-General characters
    8.4.3-Important Genera
    8.4.4-Economic importance
8.5- Poaceae
    8.5.1- Systematics
    8.5.2-General characters
    8.5.3- Important Genera
    8.5.4-Economic importance
8.6-Summary
8.7-Glossary
8.8-Self Assessment Questions
8.9-References
8.10-Suggested Readings
8.11-Terminal Questions

8.1 OBJECTIVES

After reading this unit student will be able-

- to know introductory account on monocotyledons and its three families *Viz.* Orchidaceae, Liliaceae and Poaceae.
- to know Detailed description on General distribution, their Systematics, General characters, Important genera and Economic Importance *etc.* of families Orchidaceae, Liliaceae and Poaceae will be studied.
- to give 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.

8.2 INTRODUCTION

In previous units student have already studied characteristic features of dicotyledons. Now, student will get familiar with three monocotyledon families i.e. Orchidaceae, Liliaceae 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 while Poaceae is 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 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 locule and seeds with abundant and starchy endosperm. It includes 5 families. e.g. Poaceae.

8.3 FAMILY- ORCHIDACEAE (ORCHID FAMILY)

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 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.

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 Eastern Himalaya, Western Himalaya and Western ghats.

8.3.1 Systematics

Bentham and Hooker	**Engler & Prantl**	**Hutchinson**
Monocotyledons	Monocotyledoneae	Monocotyledoneae
Microspermae	Microspermae	Orchidales
Orchidaceae	Orchidaceae	Orchidaceae

Orchidaceae is treated as family by Bentham and Hooker. 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.

8.3.2 General Characteristics

Habit: They are perennial, terrestrial, succulent, scapose herbs; many are epiphytic or saprophytic, sometimes climbers *e.g.*, *Vanilla*. The tropical species are mostly epiphytes while those occurring in the temperate zone are largely terrestrial.

The terrestrial forms (*Orchis*) are sympoidal. In most of them the internodes are often swollen which serve as storage reservoir of food. Other develop thick or fleshy adventitious roots forming a large tuber acting as perrenating body.

The epiphytic forms (*Cypripedium*, *Cymbidium*) are mostly sympoidal 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 on fleshy pseudo-bulb each year. Those not having pseudobulb 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.

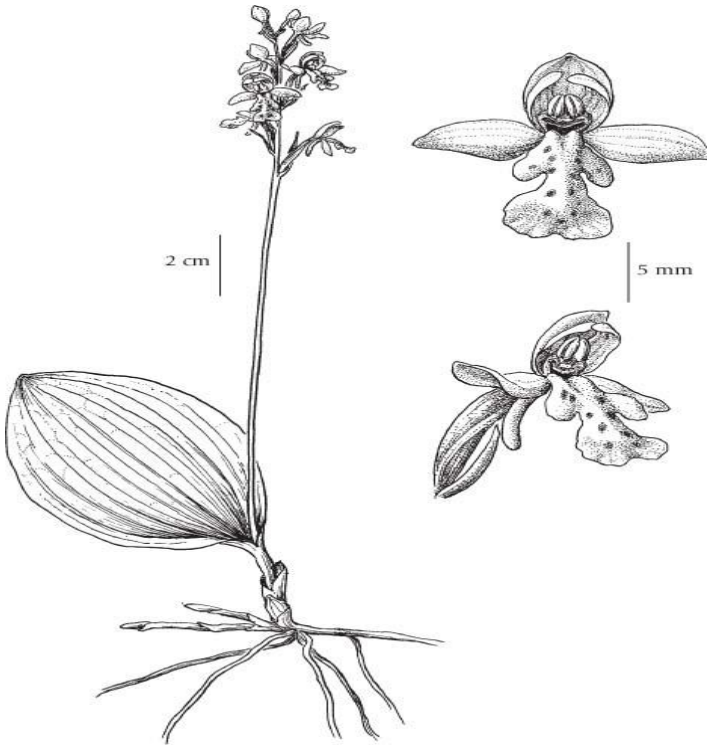

Fig 8.1 *Amerorchis rotundifolia*

Stem: Erect sometimes climbing or trailing, annual in terrestrial forms, perennial in epiphytic forms; generally thickened into rhizomes or pseudobulbs (*Phajus*, *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 raceme or panicle (*Oncidium*).

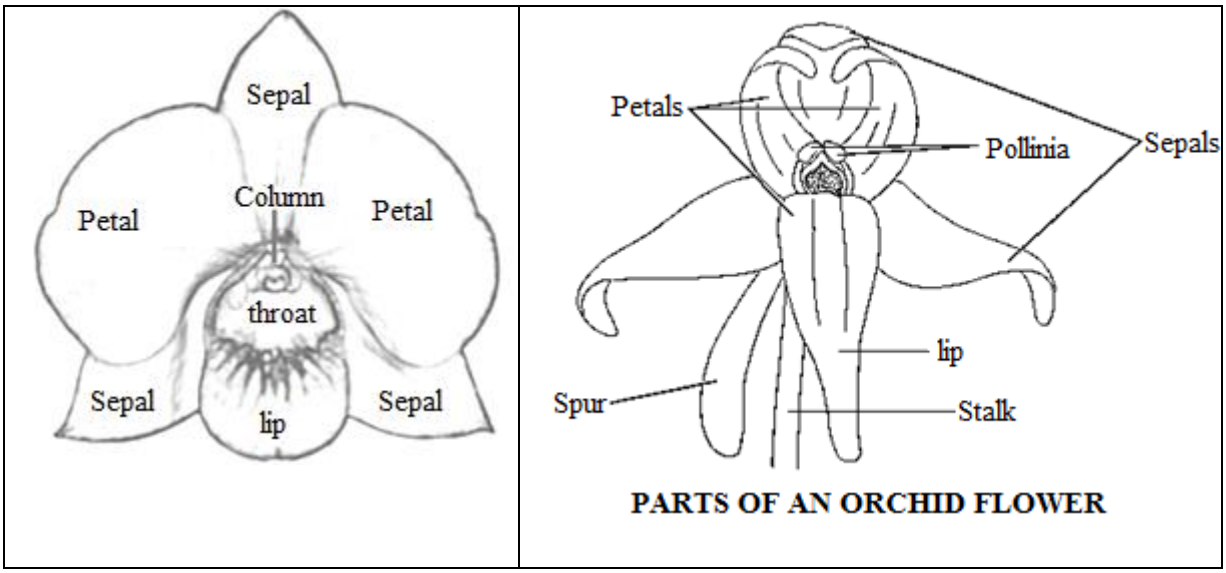

Fig. 8.2 Floral details of typical Orchidaceae flower

Flower: Flowers are of variable and peculiar shape, size and beautifully coloured, often showy, bracteates, 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 tepals are alike in appearance. They are imbricate or subvalvate in bud. Inner three tepals coloured (representing corolla), dissimilar- the 2 lateral or wings alike, the third posterior tepal 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 orchids).

The most characterstic 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 an 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 they are lateral to the column. The median 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 dithecous, 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, occupyning 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*); stigmas 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 represents 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 tree stigmas are simple and fertile.

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.

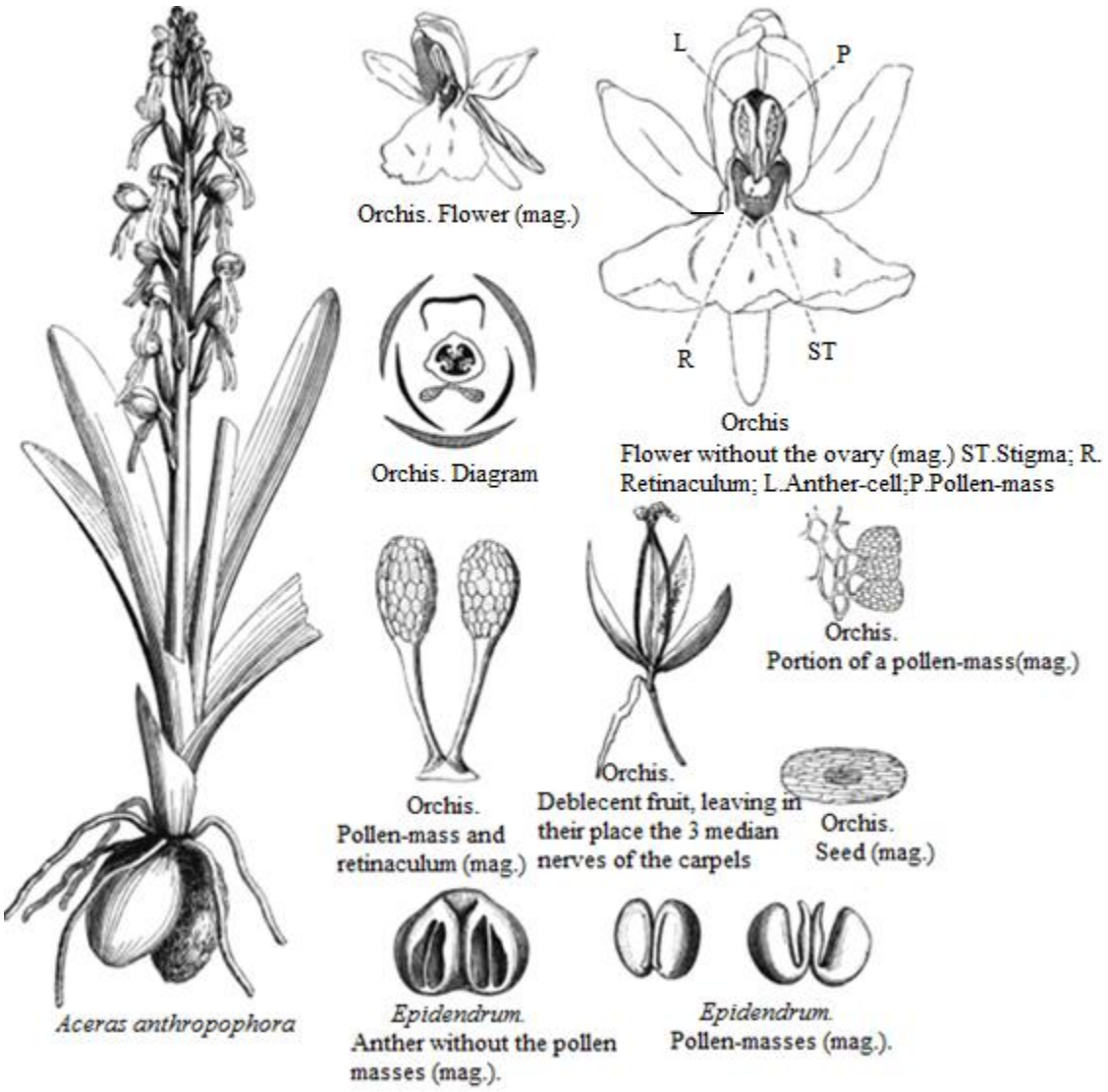

Fig 8.3 Floral details of some orchids

General Floral Formula

$$Br \quad \% \quad \male\!\!\female \quad P_{3+3}\, A_{1-2}\, \underline{G_{(3)}}$$

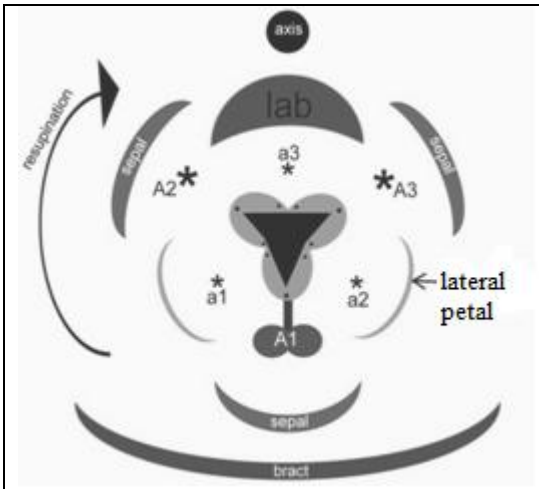

Fig 8.4 Floral Diagram of Monandrous orchid

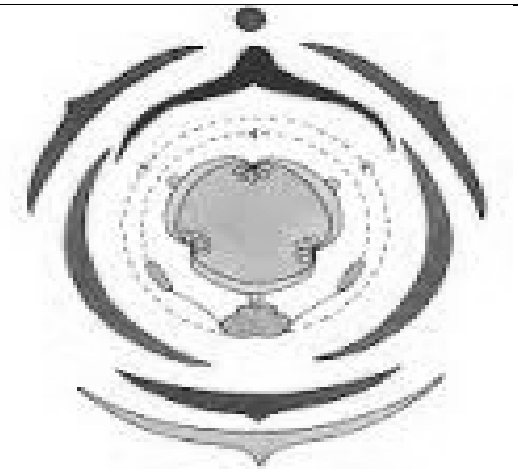

Fig 8.5 Floral Diagram of Diandrous orchid

8.3.3. Important Genera

The familiar examples are Ladyslipper (*Cypripedium sp*,), Vein orchid (*Habenaria* spp), Vanda (*Vanda* spp.) *Epidendrum* (Green fly orchid), *Oncidium* (butterfly orchid), *Odontoglossum* (lady orchid).and *Cattleya spp.* are one of the most popular florist orchids.

8.3.4 Economic Importance: Orchidaceae are important for their ornamental values chiefly. Beside this they are also valuable for flavouring and as medicines.

1-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 they are 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*, *Vanilla*, *Odontoglossum* (lady orchid).

2-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.

3-Flavour-The capsules of *Vanilla planifolia*, *V. fragrans* yield commercial "Vanilla" a flavouring agent for chocolate and confectionary.

4- Medicinal- The root-stocks of *Eulophia epidendraeas* are used as vermifuge.

5- Dyes- The leaves of *Calanthe veratrifolia* contain a glycoside "indicant", which on hydrolysis yields "indigo blue".

8.4 FAMILY- LILIACEAE

It is commonly called "Lily Family". Liliaceae is regarded as a typical monocot family and represents the basic monocot stock from which many families have arisen.

Diagnostic characteristics: Herbs rarely shrubs, stem underground rhizome, corn or bulb; leaves alternate, flowers actinomorphic, trimerous, hypogynous, perianth segments 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.

Distribution: A large family, cosmopolitian in distribution. They are abundantely found in temperate and tropical regions. It includes 250 genera and 4000 species, which are worldwide in distribution. In India it is represented by 169 species. The plants are usually annual and perennial herbs. In our country it chiefly occurs in Himalayas. The familiar examples are Onion (*Allium cepa*), Lily (*Lilium spp*.), Dracaena *(Dracaena spp*.), Asparagus (*Asparagus spp.*).

8.4.1 Systematics

Bentham and Hooker	Engler & Prantl	Hutchinson
Monocotyledons	Monocotyledoneae	Monocotyledons
Coronarieae	Liliflorae	Corolliferae
Liliaceae	Liliaceae	Liliales
		Liliaceae

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 in petaloid perianth. The family on account of marked variability in cytological, embryological, and anatomical structures appears to be polyphyletic in origin.

8.4.2 General Characteristics

Habit: Mostly herbs (*Asphodelus*), Perennating by rhizome (*Aloe*), bulbs (*Lilium*, *Tulipa*, *Allium*), tree (*Dracena*), 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 *Dracena*.

Leaves: Alternate, opposite or whorled, basal (*Allium* and *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 (*Allium* and *Smilax*), solitary axillary (*Gloriosa*).

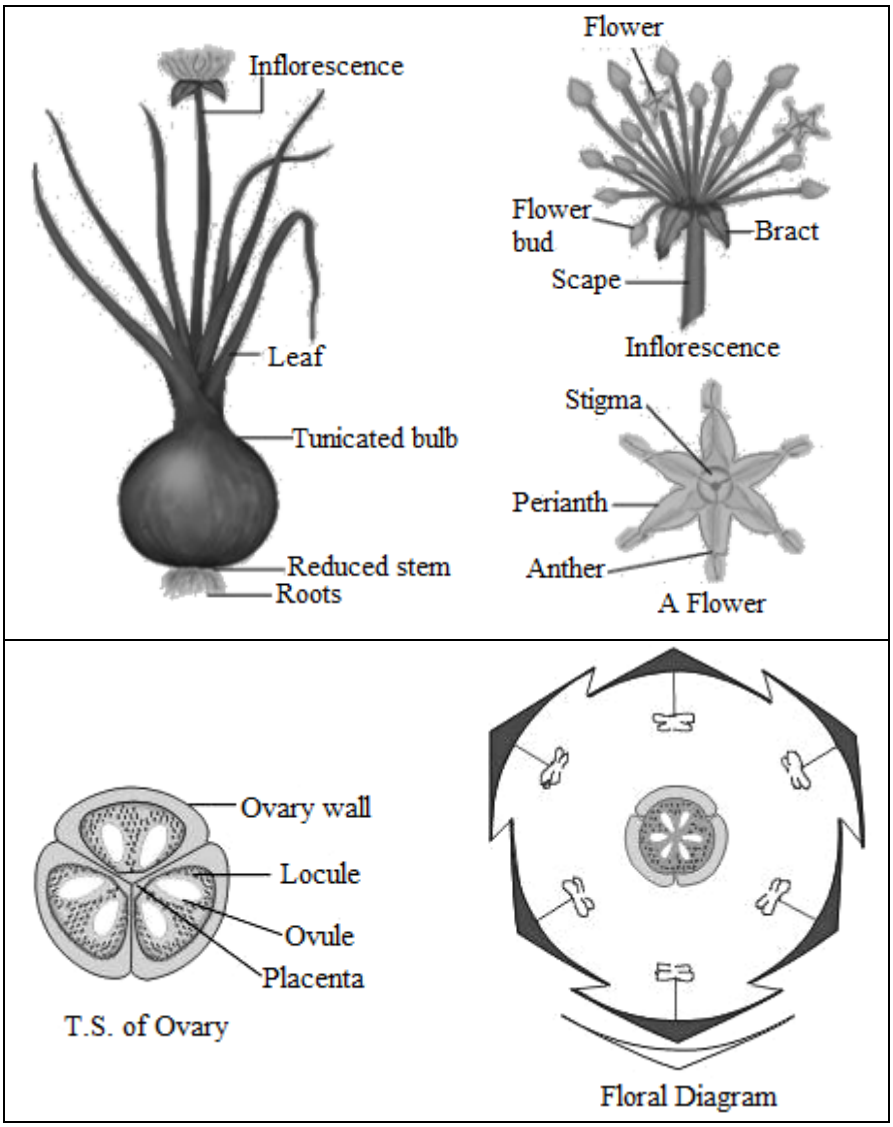

Fig 8.6 Floral details of *Allium cepa* (Onion)

Flower: Pedicellate, bracteate actinomorphic, or zygomorphic (*Lillium*, *Hemerocallis*), hermaphrodite or unisexual in *Smilax*, *Ruscus*; hypogynous, complete or incomplete (in unisexual flowers), trimerous rarely 2 or 4- merous (*Maianthemum*, *Paris*)

Perianth: 6 tepals arranged in two whorls of three each, polyphyllous (*Lilium*, *Tulipa*) or gamophyllous (*Aloe*, *Asparagus*) and of various shapes, petaloid or sepaloid, imbricate in bud, usually valvate in aestivation , perianth may be scarious or membranous.

Androecium: Stamens usually 6 arranged in two alternate whorl of three members each. They are always opposite to the tepals and sometimes adnate to perianth or 3 (*Ruscus*), 8 in *Paris*; polyandrous, epiphyllous, filaments 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.

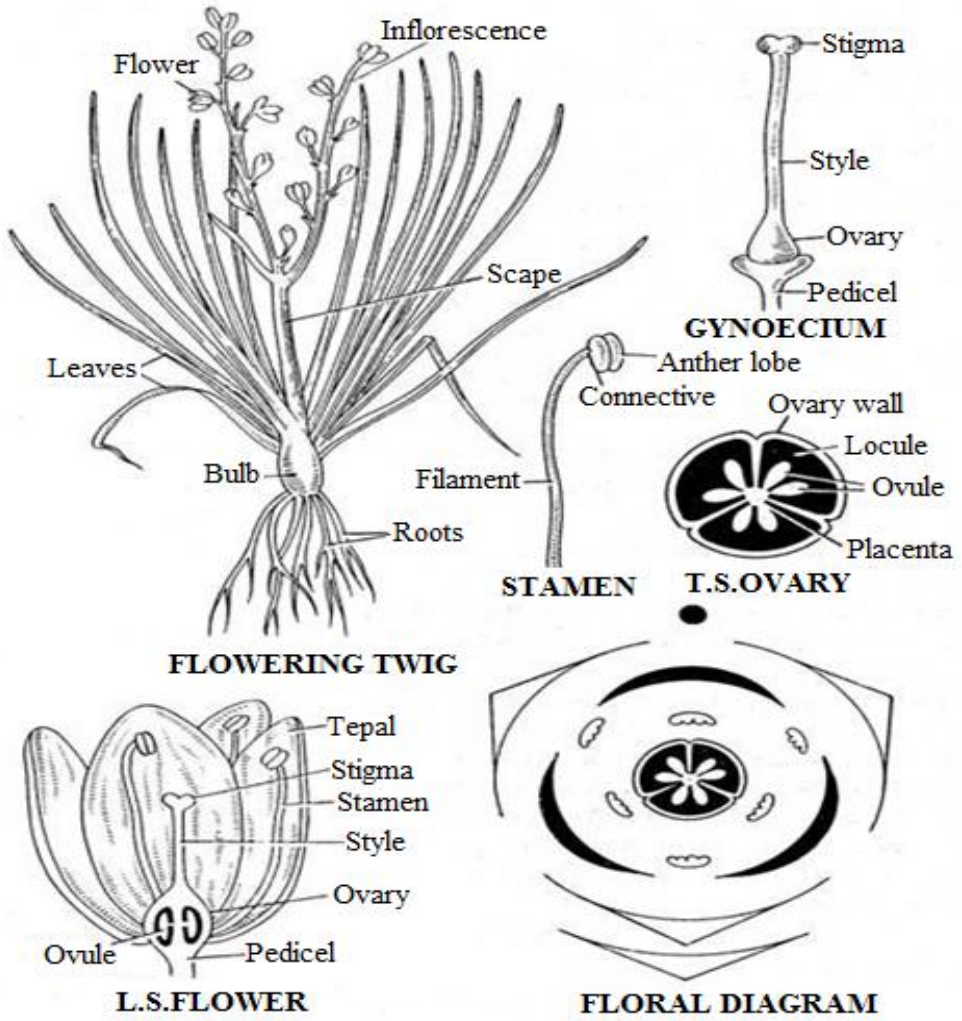

Fig. 8.7 *Asphodelus tenufolius* Cav. Verna.-Piazi

Fruit: Usually a loculicidal or septicicidal capsule (*Asphodelus*) or a berry (*Asparagus*, *Smilax*)

Seed: Endospermic; endosperm horny or cartilaginous.

Pollination: Entomophilous rarely self-pollination.

General Floral Formula

$$Br \quad \oplus \quad \varphi \quad P_{3+3 \text{ or } (3+3)} \; A_{3+3} \; \underline{G}_{(3)}$$

8.4.3 Important Genera

The familiar examples are Onion (*Alium cepa*), Lily (*Lilium spp*.), Dracaena *(Dracaena spp*.), Asparagus (*Asparagus spp.*).

8.4.4 Economic Importance: Family Liliaceae provides food, drugs, fibre and plants of ornamental values.

1-Edibles- *Allium cepa* (Onion) is popular as vegetable and also for flavoring and pickling. The fresh juice possesses bactericidal properties, *Allium sativum* (Garlic) is largely cultivated as an important spice and condiment crop. It is used as tonic, stimulant to stomach, as vermifuge and good for heart. Fleshy shoots of *Asparagus officinalis* are used as vegetable.

2- Medicinal- *Smilax, Aloe, Gloriosa, Veratrum, Colchicum, Scilla,* and *Urginea* yield useful drugs. Rat poison is obtained from *Urgine* and the bulbs of *Scilla*. *Aloe vera* yields "Aloin" used in treatment of piles and fissure. The roots of *Asparagus racemosus* yields a tonic. Corms and seeds of *Colchicum luteum* are useful in rheumatism and liver diseases. An alkaloid 'Cochicine' is obtained used to induce polyploidy in plant breeding.

3-Fibres- *Yucca* and *Phormium tenax* yield fibre of commerce used in cordage

4-Resin-*Dracaena* and *Xanthorrhoea* yield resin. From the acrid resin of *Xanthorrhoea* sealing wax is prepared.

5-Ornamentals-The common cultivated garden plants are *Tulipa, Lillium, Gloriosa, Aloe, Ruscus, Dracaena, Asparagus, Yucca, Hemerocallis etc.*

8.5 FAMILY- POACEAE (THE GRASS FAMILY)

The Poaceae or Gramineae is the large and nearly ubiquitous family of monocotyledonous flowering plants known as grasses. The Poaceae includes the cereal grasses, bamboos and the grasses of natural grasslands and cultivated lawns (turf) and pastures. 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.

Diagnostic characteristics

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 scales (**lodicules**), stamens 3 , versatile, carpel one, styles 2 or 3, stigma feathery, basal placentation, fruit caryopsis, testa fused with pericarp.

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 3 ecological types as hydrophytes, xerophytes and mesophytes. Around 900 species are present in India.

8.5.1 Systematics

Bentham and Hooker	**Engler & Prantl**	**Hutchinson**
Monocotyledons	Monocotyledoneae	Monocotyledons
Glumaceae	Glumiflorae	Glumiflorae
Poaceae	Poaceae	Poaceae

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. Hutchinson (1964) and other modern botanists placed the family 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 .

8.5.2 General Characteristics

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 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.

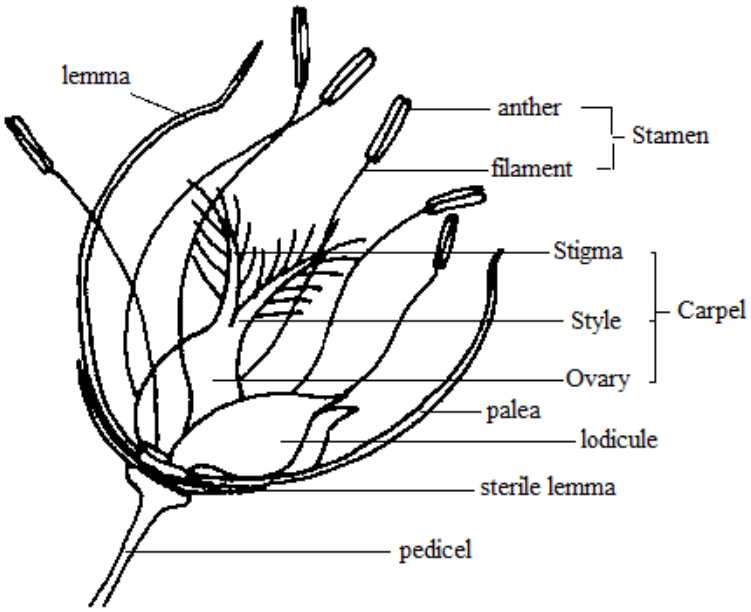

Fig 8.8 Typical spikelet of family Poaceae

Inflorescence: The inflorescence terminates the culm and its branches. The basic unit of inflorescence is called spikelet. The spikelets are sessile or pedicelled few to several and 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 stalks 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 glume. The sterile glumes are followed by a variable number (1-50) of **fertile or flowering glumes 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 bikeeled structure is present in between the fertile glume and the rachilla the structure 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.

Flower: Small, inconspicuous, bracteate, bracteolate, sessile, incomplete, bisexual or unisexual (*Zea mays*), irregular, zygomorphic, hypogynous, cyclic.

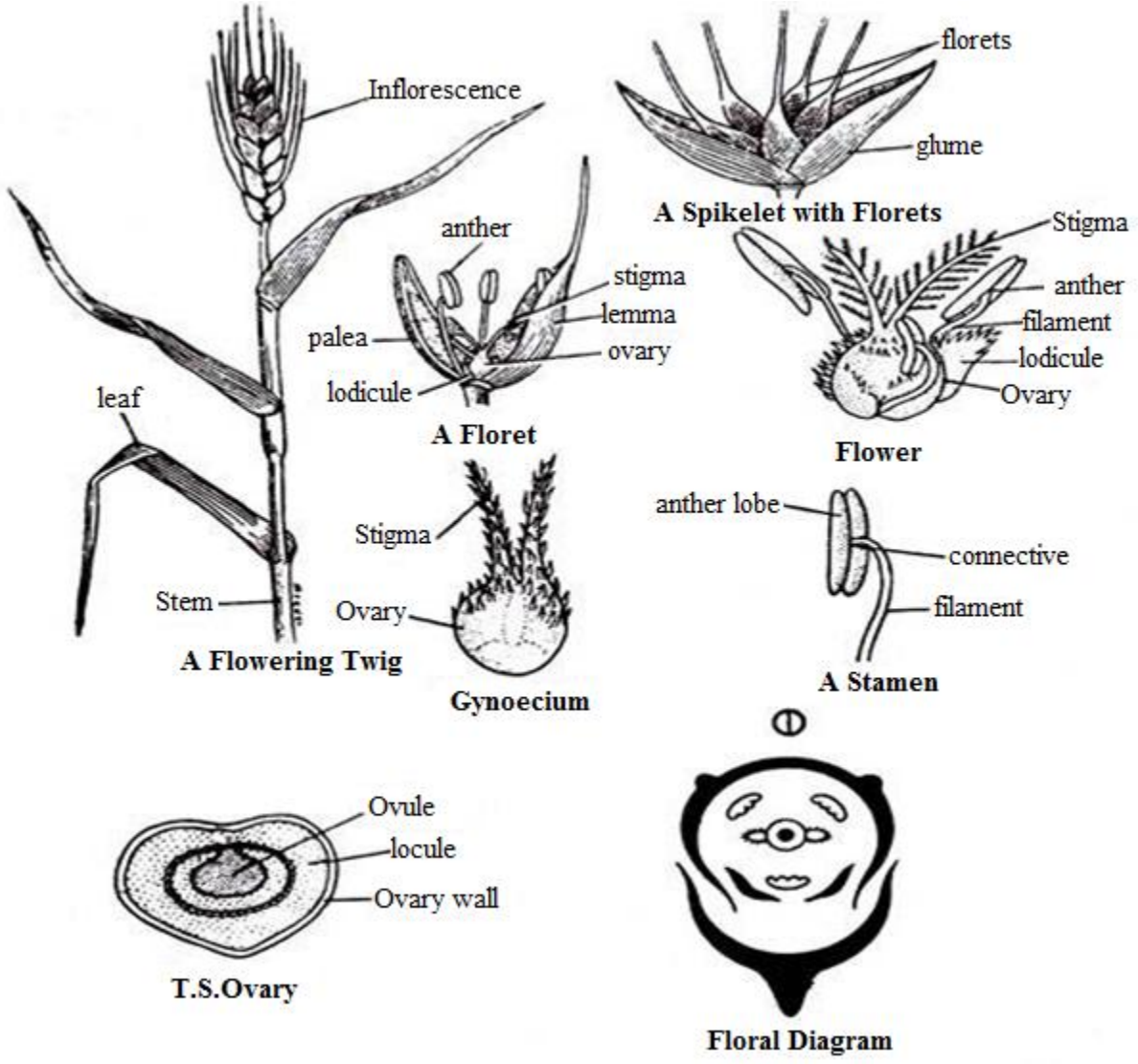

Fig 8.9 Floral details of *Triticum aestivum* (Wheat) *Verna.* Gehun

Perianth: It is highly modified and much reduced and usually represented by two minute or fleshy and hyaline membranous scale-like structures 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 stamens (*Pariana*) Polyandrous, filaments are long and free, basifixed, anthers dithecous, versatile and linear, extrorse, pollen grains dry.

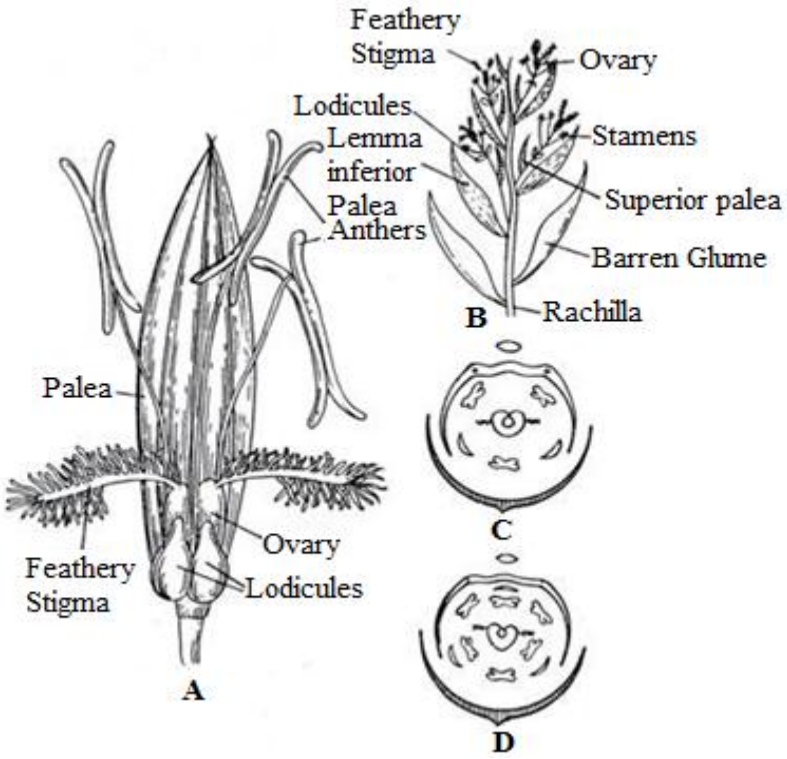

Fig. 8.10 A- Spikelet of *Festuca* sp.; B- spikelet of grass; C- Floral diagram of grass; D- floral diagram of *Bambusa*

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.

General Floral Formula

$$\% \ \female \ \ P_{0 \text{ or } 2 \text{ (Lodicules)}} \ A_{3 \text{ or } 6} \ \underline{G}_{1}$$

8.5.3 Important Genera

Triticum aestivum (wheat), *Zea mays* (corn), *Avena sativa*, *Oryza sativa* (rice), *Bambusa* (bamboo), *Saccharam officinarum* (Sugarcane), *Hordeum vulgare* (Barley), *Secale*

cereale (rye), *Sorghum vulgare* (Jowar), *Pennisetum typhoides* (Bajra), *Cynodon dactylon, Panicum, Cymbopogon, Poa*

8.5.4 Economic Importance

Family Poaceae stands first and foremost in respect of economic importance in whole of angiosperms. The staple food grain of the population of world is derived from *Oryza sativa* (Rice) and *Triticum aestivum* (Wheat). They are cultivated from time immemorial. 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 *Triticum sp* (Wheat). *Avena sativa* (Oats), *Zea mays* (Corn), *Oryza sativa* (Rice). *Hordeum vulgare* (Barley), *Scale cereale* (rye), *Sorghum vulgare* (Jowar), *Pennisetum typhoides* (Bajra), *Setaria italica* (Italian millet), *Panicum miliaceum (*commom millet), *Eleusine coracana* (Finger millet, Ragi)

Fodder plants: Most of the fodder of the animals belongs to this family. Many grasses such as *Cynodon dactylon, Panicum, Cymbopogon* and *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 oil which are used in perfumery viz. *Vetiveria zizaniodes* (Khus-khus) yield vetiver oil from the roots, *Andopogon odoratus* (Ginger grass), *Cymbopogon citratus* (Lemon grass) and *Cymbopogon martinii* also yield aromatic oil. *Cymbopogon throws* (lemon grass) gives lemon grass 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 paper.

Alcohol and beverages: Ethyl alcohol and many other beverages are prepared form cereals. For example, wine is prepared from rye, corn and rum from molasses of sugar cane.

Ropes: Fibre is obtained from the leaves of *Saccharum munjo*. This fibre is used for making ropes.

Uses of Bamboo: *Bambusa* (bamboo) is used as building material. Bamboos are used for thatching huts, making boats, carts, pipes etc. Their spilt stems are woven into mats, fans, hats and ‘course umbrella’. Their leaves are given to horses for curing cough and cold.

8.6 SUMMARY

Monocotyledons are usually characterized by the presence of one cotyledon, fibrous and adventitious root arising from the base of stem , narrow leaves with parallel veins, herbaceous stem, irregular distribution of the vascular bundles in the stem, trimerous flower and perianth often not clearly divisible into calyx and corolla.Family Orchidaceae comes under Series- Microspermae, Liliaceae under Series- Coronarieae while Poaceae is included under Series- Glumaceae.

Family 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 represents the basic monocot stock from which many families have arisen. Herbs rarely shrubs, stem underground rhizome, corm or bulb; leaves alternate, flowers actinomorphic, trimerous, hypogynous, perianth 6 in two whorls of 3 each, free or fused; stamens 3+3, epiphyllous, antiphyllous; gynoecium tricarpellary, syncarpous, ovary superior, axile placentation, two to many ovules per loculus; fruits capsule or berry; seeds endospermic.

The family Liliaceae 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.

The Poaceae (Gramineae) are 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 scales (**lodicules**), stamens 3, versatile, carpel one, styles 2 or 3, stigma feathery, basal placentation, fruit caryopsis, testa fused with pericarp.

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. Hutchinson (1964) and other modern botanists placed the family 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.

8.7 GLOSSARY

Achene- Small, dry, indehiscent, one-seeded fruit seed separating from 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 or corymb

Parallel venation- Veins run parallel to each other Compound inflorescence, stem branches two or more

Radicle- leaf borne on reduced stem and appears to come from root

Ramal- Leaf borne on the branches

Sheath- basal portion of grass or sedage 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 parts in one plane only.

8.8 SELF ASSESSMENT QUESTION

8.8.1 Multiple Choice Questions:

1. In Poaceae the fruits are usually

(i) Follicle (ii) Nutlets

(iii) Capsule (iv) Caryopsis

2. Botanical name of onion is

(i) *Solanum tuberosum* (ii) *Lycopersicon esculentum*

(iii) *Allium cepa* (iv) *Nicotiana tabacum*

3. Resupination *i.e.* twisting to 180^0 or upside down is characterstic feature of which one of the following families

(i) Liliaceae (ii) Acanthaceae

(iii) Orchidaceae (iv) Poaceae

4. A plant that belongs to Liliaceae in which stipules are modified into tendrils is

(i) *Gloriosa* (ii) *Yucca*

(iii) *Lilium* (iv) *Smilax*

5. The inflorescence of Paddy is

(i) racemose (ii) catkin

(iii) panicle (iv) verticillaster

6. In Poaceae the Lodicules are

(i) petals (ii) perianth leaves

(iii) sepals (iv) bracts

7. Genus *Colchicum* belongs to which one of the following family

(i) Lilaceae (ii) Acanthaceae

(iii) Orchidaceae (iv) Poaceae

8. The highly modified tepal of orchidaceous flower is called

(i) lip or labellum (ii) standard

(iii) spur (iv) wings

9. Gynandrium or column, which is the most characteristic part of orchid flower is formed by

(i) Stamen (ii) Style and stigma

(iii) Perianth (iv) by adnation of stamen, style and stigma

10. Which one of the following family stands first and foremost in respect of food and fodder

(i) Asteraceae (ii) Poaceae

(iii) Liliaceae (iv) Brassicaceae

8.8.1 Answer Key:

1- iv	2- iii	3- iii	4- iv	5- iii
6- ii	7- i	8 -i	9- iv	10- ii

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8.11 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. Give characteristic features of family Poaceaae.
5. Write short notes on the following:
   (i) Lodicules (ii) Gynostegium (iii) Labellum (iv) Lemma and Palea (v) Resupination
6. Describe family Liliaceae in semi-technical taxonomic language.
7. Give comparative account of Monandrous and diandrous types of orchids

BLOCK-3 BIODIVERSITY AND CONSERVATION

UNIT-9 BIODIVERSITY-BASIC CONCEPT

9.1- Objectives
9.2-Introduction
9.3-Basic concept
9.4-Biodiversity at global level
9.5- Biodiversity at national level
9.6-Threats to biodiversity
9.7-Summary
9.8-Glossary
9.9-Self Assessment Questions
9.10-References
9.11-Suggested Readings
9.12-Terminal Questions

9.1 OBJECTIVES

After reading this unit students will be able-

- to know about the concepts of the biodiversity conservation
- acquaint with the biodiversity profile at national as well as global
- learn about the various threats to the biodiversity

9.2 INTRODUCTION

Life on Earth is diverse at many levels, beginning with genes and extending to the wealth and complexity of species, life forms, and functional roles, organized in spatial patterns from biological communities to ecosystems, regions, and beyond. The study of biodiversity encompasses the discovery, description, and analysis of the elements that underline these patterns as well as the patterns themselves. The challenge of quantifying patterns of diversity at the species level, even when the organisms are known to science, is complicated by the problem of detecting rare species and the underlying complexity of the environmental template.
The term ‘‘biodiversity’’ was first used in its long version (biological diversity) by (Lovejoy, 1980) and is most commonly used to describe the number of species.

From hot arid deserts of the Sahara, through the lush green rainforests of the Amazon, to the ocean depths and bright corals, our natural world is a marvel of different landscapes, materials, colours and textures. The land, air and seas of our planet are home to the tiniest insects and the largest animals, which make up a rich tapestry of interconnecting and interdependent forces.

Biodiversity found on Earth today consists of many millions of distinct biological species, the product of four billion years of evolution.

E. O. Wilson first used the term biodiversity in the literature in, the concept of biological diversity from which it arose had been developing since the nineteenth century and continues to be widely used.

Biodiversity encompasses the variety of life, at all levels of organization, classified both by evolutionary (phylogenetic) and ecological (functional) criteria.

The most acceptable definition of the biodiversity is the one held by the CBD which was signed by the more than 180 nations on June 5, 1992 at Rio-De-Janerio. But, there are at least 12 formal definitions. The CBD states that Biological Diversity means the variability among living organisms from all sources, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complex of which they are part, this includes diversity within species, between species and of ecosystems.

In other words Biodiversity is the variety of life in all many manifestations. It encompasses all forms, levels and combinations of natural variations.

The actual definitions as per the conventions: the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and technologies and by appropriate funding.

But another definition as per the WCMC (1992) in their edited book {Global Biodiversity} is "Diversity is a concept which refers to the range of variation or differences among some sets of entities: biological diversity thus refers to variety within the living world. Thus the term is often used to describe the number and variability of living organisms".

Several definitions framed by the different scientists from time to time are given below for correct and better understanding of the term Biodiversity:

1. As per D.L. Perlman and G. Andelson (1997) Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur.
2. Fidler and Jain (1992) defined Biological diversity as full range of variety and variability within and among the living organisms, their associations and habitat-oriented ecological complexes.
3. The International Council for Bird Preservation (1992) defined it as "Biodiversity is the total variety of life on earth. It includes all genes, species and ecosystems and the ecological processes of which that are the part".
4. Hunter (1996) states biodiversity as the diversity of life in all its forms, and at all levels of organizations. All levels of organizations indicate that biodiversity refers to the diversity of genes and ecosystems, as well as species diversity.
5. Mc Neely *et al*., (1990) define biodiversity as an umbrella term for the degree of nature's victory. It encompasses all species of plants, animals and micro-organisms and the ecosystems and ecological processes of which they are the part.
   Thus, the biodiversity can be seen as the measure of nature and its diversity, rather than an entity in itself, and is usually measured at three levels- genes, species and ecosystems.

   U.S. National Research Council (1992) defines it as "Biological diversity refers to the variety and variability among the living organisms and the ecological complexes in which they occur".

Ecosystem Diversity ----------BIODIVERSITY---------- Genetic Diversity

Species Diversity

However, the word "Biodiversity" is relatively new, and is thought to have first been coined as a contraction of the term "biological diversity" in 1985 and then popularised by a number of authors (Nematology: Advances and Perspectives, Vol. 1 By Z. X. Chen, S. Y. Chen, Donald Ward Dickson p 439)

Biodiversity is the variety of life on Earth, it includes all organisms, species, and populations; the genetic variation among these; and their complex assemblages of communities and ecosystems.

It also refers to the interrelatedness of genes, species, and ecosystems and in turn, their interactions with the environment. Three levels of biodiversity are commonly discussed — **genetic, species and ecosystem diversity.**

1. **Genetic diversity** is all the different genes contained in all the living species, including individual plants, animals, fungi, and microorganisms.
2. **Species diversity** is all the different species, as well as the differences within and between different species.
3. **Ecosystem diversity** is all the different habitats, biological communities and ecological processes, as well as variation within individual ecosystems.

9.3 BASIC CONCEPT

"Without knowing it, we utilize hundreds of products each day that owe their origin to wild animals and plants. Indeed our welfare is intimately tied up with the welfare of wildlife. Well many conservationists proclaim that by saving the lives of wild species, we may be saving our own."

Norman Myers

Biodiversity is a shorthand way of saying biological diversity. Biodiversity includes all of the various forms of life on Earth. You might also know it as "the web of life". This web of life is divided into three parts to help simplify a very complex concept:

- Genes
- Species
- Ecosystems

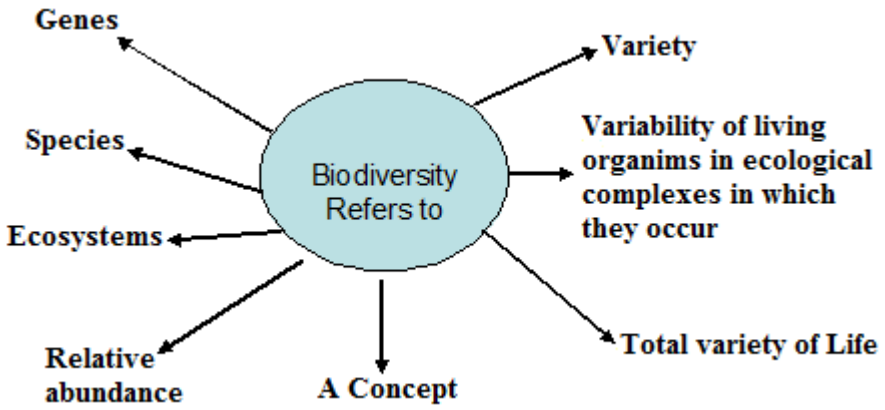

Fig.9.1 Biodiversity: Further Concepts

(Source: Modified from Biodiversity by D.L. Perlman and G. Andelson, 1997)

Michael J. Jeffries (1997) has elaborated biodiversity concept in Biodiversity and Conservation which directly and indirectly touches all areas of human lives. The concept of biodiversity also covers the following:

Evolution: Ecological processes have evolutionary consequence. They interact with genetic diversity via adaptation, micro-evolution and specialization.

Diversification of Genes: Selection and maintenance of genetic diversity.

Specialization of Diversity: There are three components to biodiversity: genetic, organizational and ecological. It covers conservation of genetic diversity, species variation and ecosystem diversity.

Table 1. Major themes within biodiversity. The presence of six main themes in texts from the conceptual origin of biodiversity in 1980 prior to the 1992 UN Convention on Biodiversity

Paper or Publication	**Lovejoy 1980**	**Norse and Mc Manus 1980**	**Norse et al., 1986**	**Biodiversity 1988**	**National Science Board 1989**	**Biological Diversity developing countries 1991**
Theme						
1. Inventory	Definition Global Sp. Total	Definition Global Sp. Total	Definition Global Sp. Total	Definition Global Sp. Total Habitat specific totals	Definition Global Sp. Total Gaps in Knowledge	Definition Global Sp. Total
2. Loss rates	Estimated losses due to forest destruction	Causes (settlement transport, fragmentation, agriculture, forestry, over exploitation, introduction of new species)		Global and habitat specific estimates, Geological patterns	Causes (human population growth, habitat loss, ecosystem function loss)	Habitat causes (development, market failure, interventions, habitat loss, over exploitations)
3. Value	Potential uses	Potential uses (food, energy, chemicals, raw materials, medicines)	Products (actual and poential). Ecosystem services, forestry, psychological	Medicine, Industry, food, Potential	Uses of organisms and plants	Use and non use values potential, habit examples

			well being			
4. Economics	Valuation of ecosystem function		Timber production	Market failure to price biodiversity new economic approaches, pricing biodiversity	Economics of utilization (clothes, food, medicine and shelter)	Economic approaches to value biodiversity
5. Conservation		Gene banks, botanical gardens, species specific schemes, ecosystem management, legislation	Concepts, Conservation and management of forests and rare species and laws	Priorities, case studies, technologies reintroductions	Recommendations for research on inventories, education training and functioning in developing countries	Aid policy procedures for priorities, habitat examples, criteria
6. Attitude		Philosophica, psychological affinity to life, right to exist	Ethics and stewardship	Green movement, society links to ecosystem morals, religion		Ethical value of biodiversity

9.4 BIODIVERSITY AT GLOBAL LEVEL

Conservative estimates of the existing biodiversity is ten million species, but if estimates for insects are correct then it could be around 30 million species, we have till now enlisted about 1.4 million species. It includes among others about 98% birds, 95% reptiles and amphibians, 90% fish and about 85% higher plants known to exist on this Earth (source: http://www.yourarticlelibrary.com/uncategorized/biodiversity-at-global-national-and-local-levels-explained-with-diagram/28262/). Floral and faunal diversity at global level are presented in Tables 2 and 3.

Table 2. Biodiversity Profile: World: Plant Kingdom

Group	**No. of species**
Bacteria	4,000
Viruses	4,000
Algae	40,000
Fungi	72,000
Lichens	17,000
Bryophyta	16,000
Pteridophyta	13,000
Gymnosperms	750
Angiosperms	2,50,000

Table 3. Biodiversity Profile: World: Animal Kingdom

Group	**No. of species**
Protista	31,259
Mollusca	66,535
Arthropoda	9,87,949
Other Invertebrates	87,121
Protochordata	2,106
Pisces	21,723
Amphibia	5,150

Reptilia	5,817
Aves	9,026
Mamalia	4,629

9.5 BIODIVERSITY AT NATIONAL LEVEL

India, with 2.4% of the world's area, has over 8% of the world's total biodiversity, making it one of the 12 mega-diverse 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. This diversity can be attributed to the vast variety of landforms and climates, resulting in 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. Being a predominantly agricultural country, India also has a mix of wild and cultivated habitats, giving rise to very specialized biodiversity, which is specific to the confluence of two or more habitats.

Natural Ecosystems

Biogeographic Zones of India

Rodgers *et al*., (2002) recognizes ten biogeographic zones divided into twenty-six biotic provinces in India. Biogeographic zones of India and their spatial extent is presented in Table 4.

Table -4 Biogeographic zones of India and their spatial extent

S.No.	Zone	Area	% of India's land area
1	Trans-Himalaya	184823	5.62
2	Himalaya	210662	6.41
3	Desert	215757	6.56
4	Semi-Arid	545850	16.60
5	Western Ghats	132606	4.03
6	Deccan Peninsula	1380380	41.99

7	Gangetic Plain	354782	10.79
8	Coasts	82813	2.52
9	Northeast	171341	5.21
10	Islands	8249	0.25
	Grand Total	**3287263**	**100.00**

Natural Terrestrial Ecosystems

India, due to its varied physical features and its geographical location, experiences almost all kinds of climate, from tropical to alpine and from desert to humid. On the basis of temperature, the landmass of India can be broadly classified into four zones: a. *Tropical zone*, which is very hot round the year and does not have a winter, b. *Sub-tropical zone*, which is hot for most of the year but with a cool winter, c. *Temperate zone*, which has a warm summer and a pronounced winter, and, *Arctic or Alpine zone*, which has a short summer and a long and severe winter d. *Natural terrestrial ecosystems* are of the following broad kinds: forests, grasslands, deserts and permanently snow-bound areas (Source: Natural Terrestrial Ecosystems Thematic BSAP 2002).

Forests

According to FSI (2002), forest cover has been assessed to be 20.55% of the country's geographical area. Of this, dense forest areas cover 4,16,809 sq km (12.68 %) and open forests cover 2,58,729 sq km (7.87%) (MoEF & Kalpavriksh.2004). There have been various approaches to classifying forest ecosystems. One of the most comprehensive and detailed classifications of forests has been by Champion and Seth (1968), which is still in vogue in India. They have ecognised five major forest types: a) Tropical forests, b) Montane sub-tropical forests, c) Montane temperate forests, d) Sub-alpine forests, and, e) Alpine scrub. These are in turn classified into 16 major forest-type groups and 221 minor forest-type groups (Table 5). Besides this In India we have recorded forest areas classified as Reserve Forests (55%), Protected Forests (29%) and Unclassed Forests (16%).

Table -5. Forest Types As Classified By Champion and Seth (1968)

S.No.	Vegetation Type	Area (Million ha)	% of forest area
1	Tropical wet evergreen forest	4.5	5.8
2	Tropical semi-evergreen forest	1.9	2.5
3	Tropical moist deciduous forest	23.3	30.3

4	Littoral and swamp forest	0.7	0.9
5	Tropical dry deciduous forest	29.4	38.2
6	Tropical thorn forest	5.2	6.7
7	Tropical dry evergreen forest	0.1	0.1
8	Sub-tropical broad leaved forest	0.3	0.4
9	Sub-tropical pine forest	3.7	5.0
10	Sub-tropical dry evergreen forest	0.2	0.2
11	Montane wet temperate forest	1.6	2.0
12	Himalayan moist temperate forest	2.6	3.4
13	Himalayan dry temperate forest	0.2	0.2
14	Sub-alpine	3.3	4.3
15	Moist alpine forest	-	-
16	Alpine forest	-	-
	Total	**77**	**100**

Grasslands

Grasslands, variously called steppes, prairies, cerrados, pampas, savannahs, velds and rangelands in different parts of the world, are vegetation types with predominance of grass and grass-like species. In India, high-altitude grasslands of the Himalaya have been referred to as marg or bugiyal, and in Ladakh as tsang. Grasslands are plant communities with a more or less continuous layer of graminoids (grasses and grass-like plants), with or without a discontinuous layer of trees or shrubs. Grasslands are often associated with marked seasonality in precipitation, occurrence of fire and grazing by ungulates. Bamboo forests, though technically dominated by grasses, are not included under grasslands as they physically and in other respects resemble forests, and are usually mixed with a significant number of trees. Some research on this ecosystem was done by various workers (Singh and Gupta, 1993; Pandey and Singh, 1991; Melkania and Singh, 1989; and Singh *et al*., 1983). The grassland community builds an entirely different type of soil as compared to a forest, even when both start with the same parent material. Since grass-plants are short-lived as compared to trees, a large amount of organic matter is added to the soil. The first phase of decay is rapid, resulting in little litter, but much humus. Humification is rapid but mineralization is slow.

Consequently grassland soils may contain 5-10 times as much humus as forest soils (Odum, 1971). As of 1992, the grassland coverage of the earth's terrestrial area was about 27% (Groombridge, 1992). For India, Olson *et. al*., (1983) put the cover of grassland and shrubland at 12% of the total landmass; however, the Planning Commission (PC 1988) estimates (MoEF & Kalpavriksh.2004) grassland coverage at 3.7%, and scientists at the Indian Grasslands and Fodder Research Institute, Jhansi, give an estimate of 3.9%, or about 120 lakh (12 million) hectares (Singh and Misri, 1993). The distribution of grasslands in India is quite uneven. For instance, in the western region, Rajasthan and Gujarat have 5.4% and 3.5% respectively of their land area under grasslands. In the eastern region, grasslands and pastures comprise less than 1% of the area, except in Sikkim, where they cover 13.3% of the land. The grasslands include such dissimilar ecosystems as the semi-arid pastures of the western part of the Deccan peninsula, the humid, semi-waterlogged tall grassland of the Terai belt, the rolling shola grasslands of the Western Ghats, hilltops, and the high-altitude alpine pastures of the Himalayas.

In India, grasses form the largest family of flowering plants. Out of an estimated 17500 species of flowering plants, about 1200 are grasses. About 360 grass taxa (almost 30%), are endemic to India. 172 endemics occur in the peninsular region, 56 in the north-east, 30 in the north-west, 5 in the western arid regions, 12 in the lower Gangetic plain, 4 in the Andaman and Nicobar Islands, and 50 endemics are spread over more than one of the above regions.

Deserts

Deserts (as distinct from desertified areas) are natural ecosystems characterized by very low rainfall (<600mm) arid and sparse presence of vegetation. Though appearing to be lifeless at first glance, deserts can harbour an astonishing and unique diversity of species, and biological communities of high conservation value. India broadly has three kinds of deserts: sandy warm desert in the far western region of Rajasthan; salt desert in the western region of Gujarat; and cold desert in the trans-Himalayan region of Ladakh in Jammu and Kashmir and Lahaul-Spiti in Himachal Pradesh.

The Great Indian Thar Desert is an important bio-region of Rajasthan comprising about 61 percent of the state's total geographical area. It is one of the most biologically and culturally diverse deserts of the world, and houses distinct and unique ecosystems, landscapes and species of plants and animals. It is characterised by geomorphic forms and landscapes such as dunes, magras, dhands and bhakars, each with a distinct ecology of its own. It is an extension of the Sahara desert, through the Arabian and Persian deserts. It extends from Punjab through Haryana and Rajasthan to Gujarat. The desert results from the dryness of the prevailing monsoon winds, which do not bring sufficient rain to keep the region moist. The desert presents an undulating surface, with high and low sand dunes separated by sandy plains and low, barren hills, or bhakars, which rise abruptly from the surrounding plains.

The Salt Desert or the Rann of Kachchh is distinguished from the Thar desert by its exceptional salinity (Rann in the local language means salt desert), caused by seasonal

inundation by the sea into a vast area inland. The extraordinary intermingling of saline, marshy and coastal desert ecosystems found in the Rann is perhaps the only one of its kind in the world. The Great Rann of Kachchh and the Little Rann of Kachchh, with an area of about 16780 sq km and 5180 sq km respectively, constitute the entire Rann of Kachchh. The average altitude is about 15 m above mean sea level, and it thus appears like a table-top surface. Ecologically, it represents one of the largest seasonal saline wetland areas, having water depth ranging from 0.5 to 1.5 m. The Little Rann of Kachchh is world famous for the last remaining population of the endemic Wild Ass, and almost the entire Little Rann is covered under WAS to protect this species.

The Cold Desert, sprawled over a vast area north of the Himalayan ranges, is an ecosystem of exceptionally low temperatures (down to -75°C) and rainfall (500-800 mm annually). It forms a plateau at a height of 4,500 to 6,000 meters above mean sea level, and is encompassed by the Trans-Himalayan Biogeographic Zone (Rodgers and Panwar, 1988). This zone extends into the Tibetan plateau, to cover an area of 2.6 million sq km, from which originated the great river systems of the Indus, Sutlej, Brahmaputra and Yangtze. In India, cold deserts cover a vast area of 1, 09, 990 sq km, about 87,780 sq km in Ladakh (Kashmir), and 22,210 sq km in Lahaul-Spiti (Himachal Pradesh). Lahaul and Spiti is delimited by the Pir Panjal range, the Great Himalayan range, and the Zanskar range. The Great Himalayan range with a mean elevation of 5,500 m extends from Kunzam range to Baralacha and Pin Parvati range, separating the Chamba-Beas basin from the Sutlej-Spiti basin around Pooh, and pierced by the Sutlej at Kalpa. The Zanskar is distinguished by highly evolved life forms, including a variety of aromatic and medicinal plants, several wild relatives of domesticated plants (barley, gooseberry, garlic) and animals (four species of wild sheep and goats) and a charismatic mega-fauna, still preserved in its entirety, unlike in most other parts of the world.

Natural Aquatic Ecosystems

India has a rich variety of wetland and aquatic habitats, ranging from small streams and village ponds through large lakes and reservoirs, some of the longest rivers in the world, coastal lagoons, estuaries and backwaters, the unique Rann of Kachchh, coral reefs and mangroves, to open coastal and oceanic waters. India's wetlands can be grouped, based on salinity, into two major categories marine, and brackish or freshwater, within each of which there are several different ecosystems.

Marine Ecosystems

India has a long coastline, estimated to range between about 8000 km (Ramakrishna and Venkataraman, 2002) and 8130 km (CMFRI, 1998-99). India occupies the tenth place in terms of coastline length of all maritime countries and seventh place in terms of the extent of the Exclusive Economic Zone (2.02 million sq km) adjoining the continental region and the offshore islands. The long coastline and the tropical climate favour a multitude of coastal and offshore marine ecosystems.

Fresh and Brackish water Systems (Wetlands)

The Ramsar Convention (Ramsar, 1993) defines wetlands as 'areas of submerged or water saturated lands, both natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish, or salty including area of marine water, the depth of which at low tide does not exceed six meters' (IUCN, 1971). The freshwater ecosystems encompass a wide spectrum of habitats covering both lentic and lotic water bodies. The former includes either temporary or permanent ponds, lakes, floodplain marshes and swamps while the latter relate to rivers and streams.

Brackish water ecosystems like the estuaries and coastal lagoons are also classified as wetlands. The natural freshwater wetlands can be broadly classified into three major categories with 15 predominant wetland types (Table 6).

Table-6. Categories of Natural Freshwater Wetlands (Source: Scott 1989; Dugan 1990)

Type	Nature of flow	Sub type
Riverine	Perennial	i. Permanent rivers and streams, including waterfalls
		ii. Inland deltas
	Temporary	i. Seasonal and irregular rivers and streams
		ii. Riverine floodplains, including river flats, flooded river basins, seasonally flooded grasslands
Lacustrine	Permanent	i. Permanent freshwater lakes (>8 ha), including shores subject to seasonal or irregular inundation
		ii. Permanent freshwater ponds (<8 ha)
	Seasonal	i. Seasonal freshwater lakes (>8 ha), including floodplain lakes
Palustrine	Emergent	i. Permanent freshwater marshes and swamps on inorganic soil with emergent vegetation whose bases lie below the water table for at least most of the growing season
		ii. . Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by *Papyrus* or *Typha*
		iii. Seasonal freshwater marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes, and dambos
		iv. Peatlands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub

		vegetation, and fends of all types
		v. Alpine and polar wetlands, including seasonally flooded meadows moistened by temporary waters from snowmelt
		vi. Volcanic fumaroles continually moistened by emerging and condensing water vapour
	Forested	i. Shrub swamps, including shrub-dominated fresh-water marsh, shrub carr and thickets, on inorganic soils
		ii. Freshwater swamp forest, including seasonally flooded forest, Wooded swamps on inorganic soils
		iii. Forested peat lands, including peat swamp forest

Floristic diversity in different groups

About 45,000-47,000 plant species are reported from India, representing 11% of the known world flora (Mudgal and Hajra, 1999; Singh and Karthikeyan 2000 and 2001). About 33% flowering plant species and 29% of the total Indian flora are endemic. Indian flora shows affinity with the flora of several countries and regions, due to the continuity of the northern part of India's landmass with the Middle East, the former USSR, Central Asia, China and east Asia. Some elements in Indian flora belong to distant places like Africa and Australia and thus show discontinuous distribution. Besides, the flora of north-eastern India has rich admixture of floristic elements of Malaysian, Burmese, Sino Tibetan, Japanese and, to a lesser degree, even of Australian region. Similarly, certain floristic elements of Western India and the Ghats of the peninsular region are common with Sri Lanka and eastern parts of South Africa. The flora of the Andaman group of islands has more in common with the flora of Myanmar, while the flora of the Nicobar group of Islands show affinity with the flora of Indonesia and Malaysia (Jain and Sastry, 1983). Comparative account of floristic diversity of India is presented in table 7.

Table-7. Floral diversity of India

Group	**No. of species**	**% of India to World**
Bacteria	850	21.25
Viruses	Unknown	---------
Algae	6500	16.25
Fungi	14,500	20.14
Lichens	2000	11.80
Bryophyta	2850	17.80

Pteridophyta	1100	8.46
Gymnosperms	64	8.53
Angiosperms	17500	7

Distribution of wild relatives in different crop groups

India is one of the world's 12 Vavilovian Centres of origin and diversification of cultivated plants, known as the 'Hindustan Centre of Origin of Crop Plants' (Vavilov, 1951). These wild relatives of crop plants (WRCPs) constitute a rich reservoir of genetic variation (MoEF & Kalpavriksh. 2004). About 320 species of these wild relatives (116 genera and 48 families) are known to have originated in India (Arora and Nayar, 1984). The distribution of these crop groups is presented in **Table** 8.

Table -8. Wild relatives of some crops in India

Crop	**No. of wild relatives**
Millets	51
Fruits	104
Spices & condiments	27
Vegetables & pulses	55
Fibre crops	24
Oil seed, tea, coffee, tobacco & sugarcane	12
Medicinal Plants	3000

Threatened floral species in India by threat category (2002 Red List)

Despite the migration of floristic elements from other contiguous or neighbouring regions, India has a very high number of endemic elements. About 33% of the Indian flowering plants (5725 species, 146 genera, 47 families) are regarded as endemic; they are mainly located in 24 centers of the country (Nayar, 1996). Besides endemics, nearly 10% of flowering plants are assessed under various categories of threatened species. The Red Data Book of Indian Plants listed 620 threatened species. Of these, 28 are presumed extinct, 124 endangered, 81 vulnerable, 160 rare and 34 insufficiently known (Nayar and Sastry, 1987, 1988).

Wild Animal (Including Protozoan) Diversity

India has a very rich range of fauna, which is still far from completely documented. Nearly 90,000 species of fauna have been reported from India, a little over 7% of the world's reported animal diversity. Faunal diversity, degree of endemism and list of threatened species is presented in table 9.

Table- 9. Faunal diversity of India

Group	No. of species
Protista	2577
Mollusca	5070
Arthropoda	68389
Other Invertebrates	8329
Protochordata	119
Pisces	2546
Amphibia	209
Reptilia	456
Aves	1232
Mammalia	390

Micro-Organisms

Micro-organisms are ubiquitous in distribution. They represent the earliest life-forms and have been around for 3.6 to 4.0 billion years on the earth. Fossil evidence of microbial life has been found in rocks containing diverse prokaryotes (simple unicellular organisms without a defined nucleus). The origin of eukaryotic (complex, multicellular organisms with a well defined nucleus) life has also stemmed from the fundamental contributions of bacteria, in the form of chloroplasts and mitochondria (Micro-organic Diversity Thematic BSAP) The number of microbial cells is estimated to be about 4-6x1030, containing nearly half the total carbon and 90% of the nitrogen and phosphate on this planet. It may be noted that micro-organisms are the only living forms which are present under the most difficult habitats and extreme environments like Bore water, deep sea vents, salt pans, the interiors of rocks, acid mine drainage, extreme cold environments and almost all other conceivable conditions harbour micro-organisms. Unlike animals and plant species that are restricted in terms of geographical areas due to the climate and natural borders between the continents, most micro-organisms (especially bacteria and archaea) are found across the continents and are truly cosmopolitan. It is estimated that over 1.3 million endophytic microbes await discovery. Diversity of microbes in different ecosystems is important not only in isolated species but in consortia as well. In addition, human-made habitats also contain diverse types of microbes. It has been estimated that out of the microbial diversity worldwide, only about 5-10% is known based on the analysis of culturable microbes (MoEF & Kalpavriksh, 2004).

Agricultural Ecosystems

Agroclimatic Zones of India

From the desert ecosystem of Rajasthan in the West to the flood plain systems of Bengal in the East, from the mountain agriculture of the Himalayas to the wetland ecosystems of Kerala, from the semi-arid rainfed ecosystems in the Deccan plateau to the highly developed terraces of Northeast, the wide-ranging agro-ecosystems in India offer a mind-boggling variety. They also represent a fascinating array of practices which embody a vast expanse of agriculture-related knowledge systems of local rural communities. As per Murthy and Pandey (1978) there are eight broad agricultural zones in India: 1. Humid Western Himalaya, 2. Humid Bengal-Assam, 3. Humid Eastern Himalayan Region and Bay Islands (MoEF & Kalpavriksh, 2004), 4. Sub-Humid Satluj Ganga Alluvial Plains, 5. Sub-Humid to Humid Eastern and South-Eastern Uplands, 6. Arid Western Plains, 7. Semi-Arid Lava Plateaus and Central Highlands, 8. Humid to Semi-Arid Western Ghats and Karnataka Plateaus but as per the Planning Commission of India, (1985-1990), 15 broad agro-climatic zones are (based on physiography and climate): 1. West Himalayan Region, 2. East Himalayan Region, 3. Lower Gangetic Plains Region, 4. Middle Gangetic Plains Region, 5. Upper Gangetic Plains Region, 6. Trans-Gangetic Plains Region, 7. Eastern Plateau and Hill Region, 8. Central Plateau and Hill Region, 9. Western Plateau and Hill Region, 10. Southern Plateau and Hill Region, 11. East Coast Plains and Hill Region, 12. West Coast Plains and Ghats Region, 13. Gujarat Plains and Hill Region, 14. Western Dry Region, and 15. The Island Region.

But as per the National Bureau of Soil Survey and Land Use Planning of the Indian Council for Agricultural Research, a set of 21 agro-ecological regions has been delineated based on physiography, soil types, bioclimate, and length of crop-growing period (Sehgal *et. al.*, 1990), which are 1. Western Himalayas: Cold arid ecoregion with shallow skeletal soils, Length of growing period (LGP) < 90 days, 2. Western Plain and Kutch Peninsula: Hot arid ecoregion with desert and saline soils. LGP < 90 days, 3. Deccan Plateau: Hot arid ecoregion, with mixed red and black soils, LGP < 90 days, 4. Northern Plain and Central Highlands: Hot semi-arid ecoregion with alluvium derived soils. LGP 90-150 days. Central (Malwa) Highlands and Kathiawar Peninsula: Hot semi-arid ecoregion with medium and deep black soils. LGP 90-150 days. 5. 6. Deccan Plateau: Hot semi-arid ecoregion with shallow and medium (inclusion of deep) black soils. LGP 90-150 days, 7. Deccan Plateau and Eastern Ghats: Hot semi-arid ecoregion with red and black soils, LGP 90-150 days (MoEF & Kalpavriksh, 2004), 8. Eastern Ghats (Tamil Nadu uplands and Deccan Plateau: Hot semi-arid ecoregion with red loamy soils, LGP 90-150 days, 9. Northern Plain: Hot sub-humid ecoregion with alluvium-derived soils. LGP 150-180 days, 10. Central Highlands (Malwa and Bundelkhand): Hot sub-humid ecoregion with medium and deep black soils, LGP 90-150 days. Deccan Plateau and Central and Highlands (Bundelkhand): Hot sub-humid ecoregion with mixed red and black soils. LGP 150-180 days, 11. 12. Eastern Plateau (Chhattisgarh): Hot sub-humid ecoregion with red and yellow soils, LGP 150-180 days, 13. Eastern (Chhota Nagpur) Plateau and Eastern Ghats: Hot sub-humid ecoregion with red loamy soils, LGP 150180 days, 14. Eastern Plain: Hot sub-humid ecoregion with alluvium-derived soils. LGP

180-210 days, 15. Western Himalayas: Warm sub-humid (inclusion humid) ecoregion with brown forest and podzolic soils, LGP 180-210 days, 16. Assam and Bengal Plains: Hot humid ecoregion with alluvium-derived soils, LGP > 210 days, 17. Eastern Himalayas: Warm perhumid ecoregion with brown and red hill soils, LGP > 210 days, 18. Northern Eastern Hills (Purvanchal): Warm perhumid ecoregion with red and lateritic soil, LGP > 210 days, 19. Eastern Coastal Plains: Hot sub-humid ecoregion with alluvium-derived soils, LGP 150-210 days, 20. Western Ghats and Coastal Plains: Hot humid perhumid ecoregion with red, lateritic and alluvium soil, LGP >210 days, and 21. Islands of Andaman and Nicobar and Lakshadweep: Hot perhumid ecoregion with red loamy and sandy soils. LGP > 210 days.

9.6 THREATS TO BIODIVERSITY

Human civilization and economic activity put pressure on aspects of biodiversity. The present rate of extinction is believed to be much higher than can be explained totally by natural causes. We must be careful to balance our needs with those of other species. There are many threats to our natural world, which include:

a. Habitat loss and destruction
b. Alteration in ecosystem composition
c. Invasive alien species
d. Over exploitation
e. Population and contamination and
f. Global climate change

What's happening?

Fast isn't always good. Species are becoming extinct at the fastest rate known in geological history, and most of these extinctions are tied to human activity. Some conservation organizations estimate species are heading towards extinction at a rate of about one every 20 minutes (Conservation International http://www.conservation.org/act/ get involved/ Pages/ stoptheclock.aspx). One figure frequently cited is that the rapid loss of species we are seeing today is estimated to be between 1,000 and 10,000 times higher than the natural extinction rate. Experts calculate that between 0.01 and 0.1 per cent of all species will continue to become extinct each year, if we carry on with business as usual. That may not sound like very much, but consider that if there are 100 million species on Earth as some estimates suggest, then between 10,000 and 100,000 species are becoming extinct each year. Looking at recent assessments we know that more than one third of species assessed in a 2009 major international biodiversity study are threatened with extinction. Of the 47,677 species in the IUCN Red List of Threatened Species of 2009, 17,291 are deemed to be at serious risk (http://cms.iucn.org/ about/work/programmes/ species/ red_list/about_the_red_list/). The list reveals that 21 per cent of all known mammals, 30 per cent of all known amphibians, 12 per cent of all known birds, 28 per cent of reptiles, 37 per cent of freshwater fishes, 70 per cent of plants and 35 per cent of invertebrates assessed so far, are under threat.

9.7 SUMMARY

This Module provides a global overview of the different definitions of biodiversity proposed by different workers from time to time, various concepts behind the Conservation of Biological Diversity in general and particular as per the Convention of Biological Diversity (CBD), and various types of ecosystems and their percentage share of faunal and floral diversity of the globe as well as India. Further, various levels of biodiversity, further concept and major themes within the biodiversity were also discussed for the better understanding of the students. Also an attempt has been made to discuss various ecosystem diversity of the India including Agricultural Ecosystem and their share in Indian Biodiversity. Further, threats also pose a serious problem in the conservation of the biodiversity therefore different kinds of threats responsible for the depletion of the biodiversity was also discussed. Current hypothesis with all clarifications regarding the loss of biodiversity was also presented in this module.

9.8 GLOSSARY

CBD=Convention on Biological Diversity

WCMC=World Conservation Monitoring Centre

Genes: The basic biological unit of heredity. Genes of an individual belonging to the same species are similar and genes control the characteristics of particular species.

Species= A species is often defined as a group of individuals that actually or potentially interbreed in nature. In this sense, a species is the biggest gene pool possible under natural conditions.

Ecosystem=An ecosystem includes all of the living things (plants, animals, and microorganisms in a given area, interacting with each other, and also with their non-living environments

FSI=Forest Survey of India

MoE&F=Ministry of Environment and Forests

WAS=Wild Ass Sanctuary

IUCN=International Union for Conservation of Nature and Natural Resources

9.9 SELF ASSESSMENT QUESTIONS

9.9.1 Objective type questions:

1- Who coined the term biodiversity?

(i) Lovejoy (ii) E.P. Odum

(iii) S.K. Jain (iv) E.O. Wilson

2- How many levels Biodiversity have?

(i) Four (ii) Five
(iii) Three (iv) Two

3- India constitutes …….. % of world's flora?
(i) 2.4 (ii) 3.4
(iii) 4.4 (iv) 1.4

4- How many Biogeographic zones we have in India?
(i) 11 (ii) 12
(iii) 10 (iv) 5

5- How many forest types we have in India?
(i) 10 (ii) 16
(iii) 14 (iv) 6

6- The Great Indian Thar Desert is an important bio-region of ……?
(i) Uttar Pradesh (ii) Rajasthan
(iii) Uttarakhand (iv) Jammu and Kashmir

7- The Ramsar Convention is for……
(i) Wetlands (ii) Forests
(iii) Grasslands (iv) Alpine regions

8. ……..% flora of India is endemic?
(i) 35 (ii) 29
(iii) 46 (iv) 28

9.9.1 Answers Key:

1-(i); 2-(iii); 3-(i); 4-(iii); 5-(ii); 6-(ii); 7-(i); 8-(ii)

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9.12 TERMINAL QUESTIONS

1. Define biodiversity. Explain the interrelationship between natural vegetation, wildlife and micro-organisms.

2 What are the main causes of loss of biodiversity? State any four.

3 Describe biodiversity profile at global and national level with suitable examples.

4. Justify the need for conservation of natural vegetation, wildlife and microorganisms with suitable reasons.

5. Categorize the following statements into narrowly utilitarian, broadly utilitarian and ethical reason and justify your categorization also.

i) Every species in biodiversity has an intrinsic value even if it is not of value to us.

ii) Human beings device a number of economic benefits like food, fibre etc from Biodiversity.

iii) Biodiversity provides ecosystem services which cannot be given price tag.

6. What are the various threats to the biodiversity? Discuss the causes of loss of biodiversity.

7. Why Biodiversity does not have political boundaries?

UNIT-10 BIODIVERSITY CONSERVATION - *IN SITU* AND *EX SITU*

10.1- Objectives
10.2-Introduction
10.3-Biodiversity conservation
    10.3.1-In situ conservation (National park, Sanctuaries and Biosphere reserves)
    10.3.2-Ex situ conservation
10.4-Gene bank
10.5-NBPGR
10.6-Summary
10.7-Glossary
10.8-Self Assessment Questions
10.9-References
10.10-Suggested Readings
10.11-Terminal Questions

10.1 OBJECTIVES

After reading this unit students will be able-

- to know about the concepts behind conservation
- various methods of conservation i. in-situ and ii. ex-situ with suitable examples
- issues/concerns related to the conservation
- to know about the Indian scenario of germplasm collection and National Institute involved in the germplasm collection

10.2 INTRODUCTION

Conservation of biodiversity is of utmost importance in ensuring the protection of healthy environment over the globe and also for meeting the basic needs of food, nutrition, health care, clothing and many more. At the Earth Summit in Rio de Janeiro, June 1992, a biodiversity convention was signed by more than 150 countries. The signatories committed to "conserve the variety of animals and plants within their jurisdiction."

Conservation is the protection, preservation, management, or restoration of wildlife and natural resources such as forests and water. Through the conservation of biodiversity and the survival of many species and habitats which are threatened due to human activities can be ensured. There is an urgent need, not only to manage and conserve the biotic wealth, but also restore the degraded ecosystems.

Why we should all value the biodiversity of the earth:

1) Moral reasons. A culture that encourages respect and stewardship for wildlife and landscapes is preferable to a culture which does not take these things seriously.

2) Aesthetic reasons. Landscapes and species should all be conserved because they are beautiful and enrich the lives of humans.

3) Providing important natural functions. Ecosystems serve humans because they provide natural functions. For example, the microbes in an ecosystem are vital in the breakdown of dead plant and animal remains and in the recycling of nutrients.

4) Biodiversity provides actual and potential material and economic benefits to people.

5) Continuance of evolutionary processes.

6**) Insurance.** No one knows what humans may need in the future. If species have become extinct, humans can never benefit from them.

Generally, Conservation is defined as the management of human use of the biosphere so that it may yield the sustainable benefit to the present generations, while maintaining its potential to meet the needs and aspirations of future generations. Now, it has become clear that biodiversity is the cornerstone of our existence on Earth. It is also important to conserve biodiversity for the sake of our own curiosity and aesthetic appreciation.

Issues/concerns related to the conservation

There are a number of issues and concerns related to the conservation of biodiversity which are summarized below:

1. Inventorization and proper documentation
2. Patenting of indigenous knowledge through products, novelties, processes and techniques
3. Value addition
4. Several threats to biodiversity
5. Excessive collection of plant genetic resources and it's over exploitation, poisoning by peptides/pollutants, exotic taxa etc.
6. Passport data and their evaluation data of germplasm
7. Urged need for exploration of some more wild varieties, landraces to fill the gap
8. Building partnership in conservation of biodiversity in between ICAR, NBPGR, NDRI and several national and regional stations
9. Human Resource Development and training at National and International level of organizations, directly associated with conservation programme
10. Promote and strengthen and generate awareness or conservation of genetic resources among the common populace

10.3 BIODIVERSITY CONSERVATION

Generally, there are two basic strategies involved for the conservation purposes like in-situ and ex-situ.

10.3.1 In-situ conservation (National parks, Sanctuaries and Biosphere reserves)

In-situ conservation, the conservation of species in their natural habitats, is considered the most appropriate way of conserving biodiversity.

Conserving the areas where populations of species exist naturally is an underlying condition for the conservation of biodiversity. That's why protected areas form a central element of any national strategy to conserve biodiversity. It aims at conserving biota in their natural habitats on a holistic basis more as a system than as separate individuals. The aim is to conserve an integrated system (ecosystem) of plants, animals (wildlife) and microorganisms with its particular atmosphere, hydrosphere and lithosphere under such conditions, there are opportunities for mutualism, co-adaption and co-evolution together with the processes like

mutation, recombination and natural selection which work unfettered leading to the survival of the fittest.

The most commonly referred in-situ conservation sites include:
1-Sanctuary
2-National Park
3- Biosphere reserve
4- Conservation Reserve
5- Community Reserve

1-Sanctuaries

Sanctuary is an area which is of adequate ecological, faunal, floral, geomorphological, natural or zoological significance. The Sanctuary is declared for the purpose of protecting, propagating or developing wildlife or its environment. Certain rights of people living inside the Sanctuary could be permitted. Further, during the settlement of claims, before finally notifying the Sanctuary, the Collector may, in consultation with the Chief Wildlife Warden, allow the continuation of any right of any person in or over any land within the limits of the Sanctuary (Source: http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf).

2-National Parks

National Park is an area having adequate ecological, faunal, floral, geomorphological, natural or zoological significance. The National Park is declared for the purpose of protecting, propagating or developing wildlife or its environment, like that of a Sanctuary. The difference between a Sanctuary and a National Park mainly lies in the vesting of rights of people living inside. Unlike a Sanctuary, where certain rights can be allowed, in a National Park, no rights are allowed. No grazing of any livestock shall also be permitted inside a National Park while in a Sanctuary, the Chief Wildlife Warden may regulate, control or prohibit it. In addition, while any removal or exploitation of wildlife or forest produce from a Sanctuary requires the recommendation of the State Board for Wildlife, removal etc., from a National Park requires recommendation of the National Board for Wildlife (However, as per orders of Hon'ble Supreme Court dated 9th May 2002 in Writ Petition (Civil) No. 337 of 1995, such removal/ exploitation from a Sanctuary also requires recommendation of the Standing Committee of National Board for Wildlife) (Source: http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf).

3-Biosphere Reserves

Biosphere reserves are areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. They are internationally recognized, nominated by national governments and remain under sovereign jurisdiction of the states where they are located. Biosphere reserves serve in some ways as 'living

laboratories' for testing out and demonstrating integrated management of land, water and biodiversity. Collectively, biosphere reserves form a world network: the World Network of Biosphere Reserves (WNBR). Within this network, exchanges of information, experience and personnel are facilitated. There are over 500 biosphere reserves in over 100 countries (Source: http://www.unesco.org/mab/doc/faq/brs.pdf).

4-Conservation Reserves

Conservation Reserves can be declared by the State Governments in any area owned by the Government, particularly the areas adjacent to National Parks and Sanctuaries and those areas which link one Protected Area with another. Such declaration should be made after having consultations with the local communities. Conservation Reserves are declared for the purpose of protecting landscapes, seascapes, flora and fauna and their habitat. The rights of people living inside a Conservation Reserve are not affected ((Source: http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf).

5-Community Reserves

Community Reserves can be declared by the State Government in any private or community land, not comprised within a National Park, Sanctuary or a Conservation Reserve, where an individual or a community has volunteered to conserve wildlife and its habitat. Community Reserves are declared for the purpose of protecting fauna, flora and traditional or cultural conservation values and practices. As in the case of a Conservation Reserve, the rights of people living inside a Community Reserve are not affected (Source: http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf).

Table 1. State-wise details of the Protected Areas Network of the country

S.No.	State/UT	National Parks	Wildlife Sanctuaries	Conservation Reserves	Community Reserves
1	Andhra Pradesh	6	21	0	0
2	Arunachal Pradesh	2	11	0	0
3	Assam	5	18	0	0
4	Bihar	1	12	0	0
5	Chhatisgarh	3	11	0	0
6	Goa	1	6	0	0
7	Gujarat	4	23	1	0
8	Haryana	2	8	2	0
9	Himachal Pradesh	5	32	0	0
10	Jammu &Kashmir	4	15	34	0
11	Jharkhand	1	11	0	0
12	Karnataka	5	22	2	1
13	Kerala	6	16	0	1

14	Madhya Pradesh	9	25	0	0
15	Maharashtra	6	35	1	0
16	Manipur	1	1	0	0
17	Meghalaya	2	3	0	0
18	Mizoram	2	8	0	0
19	Nagaland	1	3	0	0
20	Orissa	2	18	0	0
21	Punjab	0	12	1	2
22	Rajasthan	5	25	3	0
23	Sikkim	1	7	0	0
24	Tamil Nadu	5	21	1	0
25	Tripura	2	4	0	0
26	Uttar Pradesh	1	23	0	0
27	Uttaranchal	6	6	2	0
28	West Bengal	5	15	0	0
29	Andaman & Nicobar	9	96	0	0
30	Chandigarh	0	2	0	0
31	Dadar & Nagar Haweli	0	1	0	0
32	Lakshadweep	0	1	0	0
33	Daman & Diu	0	1	0	0
34	Delhi	0	1	0	0
35	Pondicherry	0	1	0	0
	TOTAL	**102**	**515**	**47**	**4**

(Source: http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf).

Table 2. List of Biosphere Reserves, their area and location

S.No.	**Name of the Biosphere Reserve & total geographical area (Km^2)**	**Location in the State (s)/Union Territory**
1	Nilgiri (5520)	Part of Wynad, Nagarhole, Bandipur and Madumalai, Nilambur, Silent Valley and Siruvani hills in Tamil Nadu, Kerala and Karnataka.
2	Nanda Devi (5860.69)	Part of Chamoli, Pithoragarh and Almora districts in Uttarakhand.
3	Nokrek (820)	Part of East, West and South Garo Hill districts in Meghalaya.
4	Manas (2837)	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamprup and Darang districts in Assam.
5	Sunderban (9630)	Part of delta of Ganges & Brahamaputra river

		system in West Bengal.
6	Gulf of Mannar (10500)	India part of Gulf of Mannar extending from Rameswaram island in the North to Kanyakumari in the South of Tamil Nadu.
7	Great Nicobar (885)	Southern most island of Andaman and Nicobar Islands.
8	Similipal (4374)	Part of Mayurbhanj district in Orissa.
9	Dibru-Saikhova (765)	Part of Dibrugarh and Tinsukia districts in Assam.
10	Dehang-Dibang (5111.5)	Part of Upper Siang, West Siang and Dibang Valley districts in Arunachal Pradesh.
11	Pachmarhi (4981.72)	Part of Betul, Hoshangabad and Chhindwara districts in Madhya Pradesh.
12	Khangchendzonga (2931.12)	Part of North and West districts in Sikkim.
13	Agasthyamalai (3500.36)	Part of Thirunelveli and Kanyakumari districts in Tamil Nadu and Thiruvanthapuram, Kollam and Pathanmthitta districts in Kerala.
14	Achanakmar- Amarkantak (3,835. 51)	Part of Anuppur and Dindori districts of Madhya Pradesh and Bilaspur district of Chattisgarh.
15	Kachchh (12,454)	Part of Kachchh, Rajkot, Surendranagar and Patan districts in Gujarat.
16	Cold Desert (7,770)	Pin Valley National Park and surroundings; Chandratal & Sarchu; and Kibber Wildlife sanctuary in Himachal Pradesh.
17	Seshachalam (4755.997)	Seshachalam hill ranges in Eastern Ghats encompassing part of Chittoor and Kadapa districts in Andhra Pradesh.
18	Panna (2998.98)	Part of Panna and Chhattarpur districts in Madhya Pradesh

10.3.2-Ex-situ conservation

The ex-situ conservation approaches require collection and systematic long term storage of germ plasm outside the natural habitats of species. Normally, the following components constitute the ex-situ conservation sites.

1. Seed banks maintained at sub-freezing temperature (-20 ^{0}C),
2. Cryobanks under liquid nitrogen (-165 to -196 ^{0}C),
3. In-vitro tissue culture banks at varying degrees of temperature regimes (4 to 25 ^{0}C) and sub-culture intervals (4-24 months) depending upon individual species, DNA Banks,
4. Filed repositories,
5. Botanical Gardens,

6. Arboreta etc.

Ex-situ conservation measures can be complementary to in-situ methods as they provide an "insurance policy" against extinction. These measures also have a valuable role to play in recovery programmes for endangered species. The Kew Seed Bank in England has 1.5 per cent of the world's flora - about 4,000 species - on deposit (Source: http://www.jamaicachm.org.jm/BHS/conservation.htm)

Ex-situ conservation provides excellent research opportunities on the components of biological diversity. Some of these institutions also play a central role in public education and awareness raising by bringing members of the public into contact with plants and animals they may not normally come in contact with. It is estimated that worldwide, over 600 million people visit zoos every year.

10.4 GENE BANK

Conserving the genetic diversity of our crops, landraces and related wild species is essential to ensure future plant breeders can access this variation, especially in view of increased food demand by a growing world population and climate change.

Gene banks are repositories where biological material is collected, stored, catalogued and made available for redistribution. The main role of gene banks is to preserve genetic diversity, in the form of seeds or cuttings in the case of plants reproduced vegetatively, and subsequently make this material, together with associated information, available for future use in research and plant breeding.

Gene banks are sometimes also referred to as an ex-situ conservation facility (because biological materials are conserved outside their natural habitat). An important part of the work at gene banks is to ensure the seed collection remains alive: seeds need to be periodically checked for viability and the material regenerated to replenish the collection with fresh seed and planting materials.

Gene bank- guidelines

By now it is clear that conservation of genetic recourses is a high priority in the national or international context, as a global plan of action activity or a convention on biological diversity requirement. The National Plant Genetic Resources Programme in India has already developed elaborate guidelines for sending germplasm for long-term conservation in its gene bank, which maintains international standards and also ensure long term viability of the material conserved after due processing. It has been suggested that the following points should be check-listed after sending seeds for ex-situ conservation. The seed should be:

a. well developed and physiologically mature,
b. free from insects, weeds and disease,

c. clean and free from undesired, shriveled, immature and discolored seeds,
d. properly labeled and packed to avoid damage during transit,
e. untreated with chemicals,
f. sent to Genebank at the earliest possible (soon after harvest),
g. accompanied with minimum passport data such as name of crop, location of collection, its original identification number/name, evaluation data, other special attributes (diseases/stress resistance quality), month and year of seed harvest etc. and
h. sent in sufficient numbers.

Primarily it is suggested that the sample should contain at least 3000 seeds for conservation in case of self-pollinated crop species, which are genetically homogenous and how little morphological variation. On the other hand, 6000 seeds of cross pollinated crop species, being genetically heterogeneous, should be provided so as to give an adequate representative outlook to the accession in respect of its original population, including morphological variation of the seed lot. Seeds of landraces, wild or weedy forms and rare plant species may be provided in smaller quantities depending upon availability.

Plant genetic resource conservation in gene banks and the Indian Status

Over 2.7 million crop accessions are held in germplasm collections globally, including over 1.3 million accessions of cereals 3, 70,000 accessions of food legumes; 2,20,000 accessions of forage legumes and grasses; 1,38,000 accessions of vegetables and 74, 000 clones of root crops. Crops of major economic importance that are backed by Agricultural Research Programmes are best represented in gene banks. Keeping in view the national needs, the Department of Agricultural Research and Education and Indian Council of Agricultural Research has provided umbrella to the ex-situ and on-farm conservation of biodiversity especially agro-biodiversity. Germplasm holding of various crop plant species at different IARCs and some National gene banks are presented in Table 3 and germ plasm of Indian originated stored in different international gene banks are presented in Table 4 and 5.

Table 3. Germ Germplasm holding of various crop plant species at different IARCs and some National gene banks

Institute/Country/Gene Bank	Holdings	Institute/Country/Gene Bank	Holdings
Wheat VIR	74500	Chickpea IRCRISAT	14361
USDA	39000	ICARDA	5585
CIMMYT	31144	USA	3396
Italy	26000	India	2000
Rice IRRI	82000	Groundnut ICRISAT	11641
NSSL (USA)	18063	INDIA	6274
USDA	11230	POTATO VIR	9435
INDIA MAIZE VIR	19858	CIP	6500

CIMMYT	12500	USA	2375
NSSL (USA)	12500	INDIA MUNGBEAN	5483
YUGOSLAVIA	8000	CHINA	5483
INDIA UPLB LOS BANOS, PHILIPPINES	2500	INDIA	1850; 5736

Source: (Gautam et al., 1998)

Table 4. Germplasm of Indian-origin conserved in CGIAR gene-banks

S. No.	CGIAR Genebank	Total no. of accessions	Accessions of Indian origin	
			No.	%
1	International Crop Research Institute for the Semi-Arid Tropics, India	119,524	37,470	35.54
2	International Rice Research Institute, The Philippines	131,862	17,824	16.81
3	International Centre for Agricultural Research in Dry Areas, Syria	147,118	3,747	3.53
4	International Institute of Tropical Agriculture, Nigeria	27,232	2,276	8.36
5	International Livestock Research Institute, Ethiopia	20,229	501	2.48
6	Centro Internacional de Agricultura Tropical, Colombia	64,721	422	0.65
7	Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico	164,320	318	0.19
8	West African Rice Development Association, Ivory Coast	26,098	299	1.15
9	*Musa* International Transit Centre, Diversity International, Belgium	1,529	54	3.53
10	Centro Internacional de la Papa, Peru	16,061	9	0.06
11	Information and Communication Division, International Center for Research in Agroforestry, Kenya	2,005	0	0
	Total	**720,699**	**62,920**	**8.73**

Table 5. Germplasm of Indian-origin conserved in major national gene-banks

S. No.	International Genebank	Total no. of accessions	Accessions of Indian-origin	
			No.	%
1	USDA Genebanks, USA	625,112	22,582	3.61
2	N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry, Russia	346,415	8,145	2.35
3	Asian Vegetable Research and Development Center, Taiwan	60,883	4,729	7.77
4	Leibniz Institute of Plant Genetics and Crop Plant Research, Germany	137,010	2,233	1.63
5	Department of Applied Genetics, John Innes Centre, Norwich Research Park, UK	26,669	1,714	6.43
6	Plant Breeding and Acclimatization Institute, Poland	67,980	428	0.62
7	Millennium Seed Bank Project, Seed Conservation Department, Royal Botanic Garden, Kew, UK	46,689	335	0.72
8	Division of Genetics and Plant Breeding, Research Institute of Crop Production, Czech Republic			

(**Source**: Indian Plant Germplasm on the Global Platter: An Analysis Sherry R. Jacob,[1] Vandana Tyagi,[2] Anuradha Agrawal,[3] Shyamal K. Chakrabarty,[4] and Rishi K. Tyagi[1,*] LoS One. 2015; 10(5): e0126634. Published online 2015 May 14.doi: 10.1371/journal.pone.0126634.)

10.5 NATIONAL BUREAU OF PLANT GENETIC RESOURCES

History

Indian interest and abiding concern in the collection and utilization of plant genetic resources dates back to the early decades of this century (Howard and Howard, 1910), though botanical accounts on available flora and the economic plants/products had been documented much earlier (Hooker, 1872-97; Watt, 1889-93). However, it was late Dr. B.P. Pal who truly focused attention on the use of germplasm variability in crop improvement in national context. The publication of his paper, 'The search for new genes', in fact, paved the way for augmenting genetic diversity for use in plant breeding (Pal, 1937; Pal and Singh, 1943). It was primarily due to his foresight and wisdom that a nucleus Plant Exploration and Collection Unit was established in 1946 in the Division of Botany at the Indian Agricultural

Research Institute, New Delhi. This unit became a regular wing in 1956 that was raised to the status of a Division of Plant Introduction in 1961. The late Dr. Harbhajan Singh dedicated his entire services to operate and boost these activities from the beginning and particularly so during the 1960s-1970s. (Singh and Hardas, 1970; Singh, 1970). Dr. M.S. Swaminathan and Dr. A.B. Joshi further strengthened the foundations of these activities. To serve the needs of the ICAR Crop Research Institutes, All India Coordinated Crop Improvement Projects and State Agricultural Universities, the Indian Council of Agricultural Research created a separate organization named as National Bureau of Plant Genetic Resources (NBPGR) in 1976 along with two other Bureaus concerned with animal and fish genetic resources.

NBGPR and its activities

NBPGR's activities have grown rapidly since 1976. It is a service-oriented national institute with a component of basic research for improving quality and efficiency of its services. It has five major Divisions, namely, Division of Plant Exploration and Collection, Division of Germplasm Exchange, Division of Plant Quarantine, Division of Germplasm Evaluation and Division of Germplasm Conservation. In addition, there is a DBT funded National Facility for Plant Tissue Culture Repository. The Bureau also has 12 Regional Stations/Base Centres/Quarantine Stations/Experimental Farms located in different agro-climatic zones. In addition, several All India Coordinated Crop Improvement Projects on Medicinal and Aromatic Plants, cluster bean, and under-utilized and under-exploited plants are also located at the Bureau. Primary objectives of the Bureau are to:

1. Organize and conduct plant exploration and germplasm collection activities in India and abroad.
2. Undertake and coordinate the supply/introduction/exchange of plant genetic resources for research purpose within India and abroad.
3. Conduct plant quarantine examination of plant materials introduced by the Bureau for pests and pathogens; treat and salvage infested/infected material and carry out research on plant quarantine/seed-health problems.
4. Conduct, monitor and coordinate all activities concerning germplasm conservation in national base and active collections.
5. Characterize, evaluate and document available germplasm collections and coordinate these activities at the Regional Stations and other collaborating Institutes with a view to preparing proper inventories and catalogues of such resources.
6. Develop and operate the National PGR Database for documentation and retrieval of information on plant genetic resources held by the Bureau and all other collaborating institutes/centres.
7. Conduct training programmes on different aspects of genetic resources activities at national and international levels.
8. Develop and implement work-plans concerning PGR activities based on memoranda of understanding under bilateral and international agreements.

In order to fulfill its national mandate, the Bureau maintains links with all crop-based institutes/national research centres of the Indian Council of Agricultural Research, State Agricultural Universities and the network of All India Co-ordinated Crop Improvement Projects. In addition, the Bureau maintains effective links with more than seventy countries as well as different crop-based international institutes under the CGIAR system including, the IBPGR.

The Exploration Division of NBPGR develops advance perspective plans for germplasm collection in collaboration with other cooperating institutes/centres. More than 80,000 accessions of indigenous cultivars and their wild relatives have already been collected through over 300 crop-specific and region-specific explorations (Table 6). These represent wide variability in crops like wheat, maize, rice, minor millets, cucurbits, okra, eggplant, tuber crops, jute, cotton, ginger, sugarcane, mango, banana, jujube, citrus, black pepper, turmeric, medicinal plants and forages, besides many others. The areas already explored include the North-eastern region, North-Western Himalayas, drier western plains, central India and the eastern and western peninsular tracts. Indigenous collections have been further enriched by importing over 9, 00,000 samples from more than 70 countries through specific requests and exchange (Table 7). Diverse germplasm has thus been introduced from different international crop-based institutes/centres like IRRI, Philippines; CIMMYT, Mexico; ICARDA, Syria; CIP, Peru; CSIRO, Australia; VIR, USSR; USDA, USA; AVRDC, Taiwan; INTSOY, USA; ICRISAT, India, besides, the FAO and IBPGR.

Table 6. Germplasm collecting activities at NBPGR

Year	**No. of explorations undertaken**	**No. of germplasm samples collected**		
		Cultivated	**Wild**	**Total**
1976	4	1,987	138	2,125
1977	6	5,099	24	5,123
1978	7	938	11	949
1979	11	4,256	54	4,310
1980	7	4,559	22	4,581
1981	16	6,031	271	6,302
1982	9	3,575	-	3,575
1983	9	3,000	-	3,000
1984	10	3,525	-	3,525
1985	25	8,008	55	8,063
1986	43	8,391	97	8,488
1987	44	7,115	178	7,293
1988	52	7,646	154	7,800
1989	59	11,278	925	12,203
1990	42	5,071	751	5,822
Total	**344**	**80,479**	**2680**	**83,159**

Table 7. Exchange of plant germplasm

Year	No. of samples		National supply
	Import	Export	
1976	85,872	70,551	3,284
1977	74,835	10,686	2,397
1978	1,17,279	8,697	2,059
1979	1,30,194	5,287	2,976
1980	51,906	1,917	6,558
1981	53,264	2,260	6,889
1982	42,663	1,748	5,681
1983	49,268	2,683	6,213
1984	38,992	3,843	3,701
1985	85,117	1,355	5,867
1986	52,767	5,535	12,726
1987	52,642	2,260	10,578
1988	53,629	2,168	11,828
1989	50,536	3,310	17,250
1990	49,521	1,195	12,680
Total	**9,88485**	**1,23,495**	**1,10,687**

Plant quarantine facility at the Bureau has helped in ensuring that insect pests, pathogens and obnoxious weeds do not enter the country along with seed and other propagating materials. Well equipped laboratories of Plant Pathology, Virology, Nematology and Entomology work hand-in-hand to salvage the infected/infested materials using techniques, such as mechanical cleaning, washing, fumigation, X-ray radiography, hot water treatment, acid seed treatment, pesticidal seed treatment, dips and sprays, etc. A large number of important exotic plant pests, nematodes and pathogens have been intercepted. A recent case is that of the groundnut stripe virus intercepted by the Hyderabad Station of NBPGR in collaboration with ICRISAT.

The Seed Repository of the National Gene Bank at NBPGR Headquarters, New Delhi, conserves genetic resources of orthodox (desiccation-tolerant) agri-horticultural crop plants in the form of seed under controlled conditions of temperature and seed moisture. Two types of cold storage vaults are available: (i) medium-term storage facility kept at + 4° C and 35 percent RH, and (ii) long-term storage vaults (2 units of 100 m^2 each and 2 of 176 m^2 each) maintained at-20° C. The repository has a fully equipped seed testing laboratory and other ancillary facilities. Over 1, 35, 000 accessions of various crop plants are currently stored in the repository (Table 8) and its present storage capacity is about two lakh (0.2 million)

accessions. Protocols have also been developed for making the plant germplasm collections disease-free through tissue culture techniques and ensuring their safety under *in-vitro* storage. Work has been in progress on crops, such as yams, *Coleus*, ginger, *Musa* and citrus. Experimental work has also progressed for storing seeds at -196°C in cryopreservation tanks using liquid nitrogen.

Table 8. National gene bank in operation at NBPGR (germplasm kept in long-term storage

Crop groups	**No. of accessions**
Cereals	34,697
Pulses	21,510
Millets and minor millets	12,850
Oilseeds	12,621
Vegetables	3,635
Fibre crops	2,609
Narcotics	665
Medicinal and aromatic plants	138
Pseudo cereals (miscellaneous crops)	653
Improved (named) varieties	302
Voucher specimens of exotics	19,178
Reference samples of indigenous collection	27,000
Total holdings	**1,35,858**

The Bureau is also the lead institute to impart training in all facets of PGR activities. It has organized international/regional training programmes for the South and South-East Asia region with IBPGR support. It has also conducted regular short duration trainings at the national level and a Summer Institute sponsored by ICAR. This activity has been further accelerated now (from 1990) with national training programmes conducted by NBPGR in plant exploration and collection, tissue culture and cryopreservation techniques, medium and long-term storage of seed materials, exchange of germplasm and plant quarantine methods, and computer appreciation related to PGR documentation. The emphasis is on training of the concerned PGR scientists from ICAR crop institutes and other interested research centres in public institutions and universities with a view to producing more resource personnel in this field. The NBPGR is also the information dissemination organization on PGR activities. It regularly publishes Research Highlights, Annual Reports, Newsletter (quarterly) and the Plant Introduction Reporter (quarterly). It has so far published well over 400 research papers,

reports, brochures, bulletins, inventories, catalogues, books, proceedings of seminar/ symposia, etc. with bearing on conservation and scientific management of plant genetic resources. This has helped in creating awareness and know-how among the scientific community as well as public and private organizations. The list of active germ plams collections at NGPGR is presented in table 9.

Table 9. Active germplasm collections at NBPGR

Station/Centre	Holdings	Major Crops
Delhi	38,708	Cereals, legumes, oilseeds, vegetables, forages, fruits
Akola	39,004	Chickpea, pigeon pea, sorghum, groundnut, small millets, soybean, safflower, sesame, lentil, amaranths, horse gram.
Amravati	5,800	Mung bean, rice bean, urid bean, sweet potato, chillies, onion, garlic, fruits (grapes, pomegranate, papaya).
Shimla	13,105	French bean, rice bean, soybean, lentil, Minor millets, pseudo-cereals, oilseeds, temperate fruits, ornamentals.
Jodhpur	12,076	Guar, moth bean, mung bean, sesame, cowpea, castor
Trichur	8,936	Paddy, horsegram, cowpea, finger millet, chillies, bittergourd, ginger, *Curcuma, Colocasia,* cassava, *Dioscorea.*
Bhowali	5,894	Wheat, maize, barley, lentil, beans, hill paddy, *Allium* spp.
Cuttack	1,943	Rices
Shillong	1,733	Hill rices, maize, rice bean, root crops, fruits.

10.6 SUMMARY

This Module provides comprehensive information about need of the conservation and also tries to explain why conservation of biodiversity is necessary. Explanatory notes on the various conservation methods like ex-situ and in-situ were also discussed in details along with the examples of the said methods (In-situ: National Parks, Wildlife Sanctuaries, Biosphere Reserves, Conservation Reserve and Community Reserves and Ex-situ: Seed

Banks, Cryobanks, Field repositories, Botanical Gardens, and Arboreta along with suitable definitions and list of all categories). It also helps to understand the concepts behind Protected Areas Network and its different categories. In this module attempt was also made to discuss history of Plant Genetic Resources and details in different Gene Banks and the responsibilities of the organizations involved in such types of work. Further, this module also discussed history; role and importance of National Bureau of Plant Genetic Resources (a nodal agency of conservation in India).

10.7 GLOSSARY

AVRDC= The World Vegetable Centre
CGIAR= Consultative Group for International Agricultural Research
CIMMYT= International Maize and Wheat Improvement Center
CIP= International Potato Center
CSIRO= The Commonwealth Scientific and Industrial Research Organization
DBT=Department of Biotechnology
DNA= Deoxyribonucleic Acid
FAO= Food and Agriculture Organization
IBPGR= International Board for Plant Genetic Resources
IBPGR=International Board for Plant Genetic Resources
ICAR=Indian Council of Agricultural Research
ICARDA= The International Center for Agriculture Research in the Dry Areas
ICRISAT= The International Crops Research Institute for the Semi-Arid Tropics
IRRI = International Rice Research Institute
NBPGR= National Bureau of Plant Genetic Resources
NDRI= National Dairy Research Institute
PGR= Plant Genetic Resources

10.8 SELF ASSESSMENT QUESTIONS

10.8.1 Objective Type Questions:

1- …… is most common example of the In-situ conservation.
(i) National Park (ii) Gene Bank
(iii) Botanical Garden (iv) Seed Banks

2- Sunderban is situated in ……
(i) Uttarakhand (ii) Eastern Ghats
(iii) Delta of Ganges and Brahamaputra (iv) Sikkim

3- Dibur-Saikhova is the ……. Biosphere Reserve.
(i) Smallest (ii) Largest
(iii) Both i & ii. (iv) None of the above

4- Head office of the NBPGR is located at ……
(i) New Delhi (ii) Mumbai
(iii) Kolkatta (iv) Dehra Dun

5- Core and Buffer zones are important constituents of …….
(i) Biosphere Reserve (ii) Wild Life Sanctuary
(iii) Community Reserve (iv) Arboreta

6- …….. will be the best conservation approach.
(i) In-situ followed by ex-situ (ii) Ex-situ followed by In-situ
(iii) Both (iv) None of the above

7- Nanda Devi Biosphere Reserve is located in……. state.
(i) Himachal Pradesh (ii) Jammu and Kashmir
(iii) Uttarakhand (iv) Sikkim

10.8.1 Answers Key:

1-(i); 2-(iii); 3-(i); 4-(i); 5-(i); 6-(ii); 7- (iii)

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10.10 SUGGESTED READINGS

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10.11 TERMINAL QUESTIONS

1. "Bio-diversity is the fundamental to the existence of life on the earth" Justify the statement by giving any two reasons.
2. State different objectives for establishment of Protected Areas Network in India.
3. Discuss the role of NBPGR in conserving the germplasm.
4. Discuss in brief various methods involved in the conservation of biodiversity with suitable examples.
5. What are the two biodiversity conservation measures? Explain.
6. How can you contribute to the conservation of green wealth of your locality? Make a list of actions to be taken by you.
7. In what ways in-situ conservation differs from ex-situ conservation. Justify your answer with quoting some suitable examples.

UNIT-11 BIODIVERSITY- HOTSPOTS AND MEGA BIODIVERSITY COUNTRIES

11.1- Objectives
11.2-Introduction
11.3-Global biodiversity hotspots
11.4-Megabiodiversity countries
11.5-India as mega-biodiversity country
11.6-Summary
11.7-Glossary
11.8-Self Assessment Questions
11.9-References
11.10-Suggested Readings
11.11-Terminal Questions

11.1 OBJECTIVES

After reading this unit students will be able-

- To provide an overview of Hotspots and concept behind the creation of Hot spots
- To provide the comprehensive information about the Global biodiversity hotspots and Mega-biodiversity countries
- To provide information regarding India as mega-biodiversity country

11.2 INTRODUCTION

As demonstrated by several researches, maintaining biodiversity is essential to the supply of ecosystem services and not less important to support their health and resilience (Pereira et al., 2013). However, despite there being an international interest to sustain and protect biodiversity, its loss does not seem to slow down (Butchart et al., 2010). Although there has been an extension of protected areas (Pimm et al., 2014), these provide a still low species coverage (Venter et al., 2014) and do not appear to optimally protect biodiversity (Pimm et al., 2014). For instance, a recent analysis (Selig et al., 2014) for conservation priorities in marine environments by combining spatial distribution data for nearly 12,500 species with human impacts information, identified new areas of high conservation value that are located in Arctic and Antarctic Oceans and beyond national jurisdictions. Overall, habitat change and their over-exploitation, pollution, invasive species and in particular climate change are the major causes for biodiversity loss. The combined effect of these anthropogenic pressures may have already started a critical transition toward a tipping point (Barnosky et al., 2012). In particular, climate is modifying rapidly forcing biodiversity to adapt either through the change of habitat and life cycles or the development of new physical traits (Berteaux et al., 2010). For instance, rising temperatures can lead to potential biodiversity increases in northern regions (i.e. northern biodiversity paradox) where low temperatures usually are a limiting factor for the establishment of many species (Berteaux et al., 2010). Given the importance that biodiversity plays, the understanding of the main threats to biodiversity is today than ever before a central objective in conservation biology. Nowadays there is serious concern about the effectiveness of existing strategies for biodiversity protection. A central issue in conservation is to identify biodiversity-rich areas to which conservation resources should be directed. Based on the observation that some parts of the world have far more species than others, the area-based approaches are widely advocated for species conservation planning. Areas with high concentrations of endemic species (species that are found nowhere else on Earth) and with high habitat loss are often referred to as ‘‘hotspots’’ (Myers, 1988). The hotspot approach can be applied at any geographical scale and both in terrestrial and marine environments. However, hotspots represent conservation priorities in terrestrial ecosystems but remain largely unexplored in marine habitats (Worm et al., 2003) where the amount of data is still poor (Mittermeier et al., 2011). Despite this lack of homogeneity in data between terrestrial and aquatic ecosystems, the recent concerns over loss of biodiversity

have led to calls for the preservation of hotspots as a priority. Edward O. Wilson, one of the leading authorities on conservation, described the hotspot approach as 'the most important contribution to conservation biology of the last century. Closely linked to the concept of biodiversity, the hotspot concept is used with increasing frequency in biology and conservation literature and often with different meanings. While in a strict sense, the meaning is based on an estimate of endemic species and habitat loss, in a broad sense it refers to any area or region with exceptionally high biodiversity at the ecosystem, species and genetic levels.

Biodiversity hotspots concept

The British ecologist Norman Myers first published the biodiversity hotspot thesis in 1988. Myers, although without quantitative criteria but relying solely on the high levels of habitat loss and the presence of an extraordinary number of plant endemism, identified ten tropical forest as ''hotspots'' (Mittermeier et al., 2011). A subsequent analysis (Myers, 1990) added a further eight hotspots, including four in Mediterranean region. Conservation International (CI—http://www.conservation.org) adopted Myers' hotspots as its institutional blueprint in 1989, and afterwards worked with him in a first systematic update of the global hotspots. Myers, Conservation International, and collaborators later revised estimates of remaining primary habitat and defined the hotspots formally as biogeographic regions with >1500 endemic vascular plant species and ≤30% of original primary habitat (Myers et al., 2000). This collaboration, which led to an extensive global review (Mittermeier et al., 1999) and a scientific publication (Myers et al., 2000) saw the hotspots expand in area as well as in number, on the basis of both the better-defined criteria and new data. A second major revision and update in 2004 (Mittermeier et al., 2004) did not change the criteria but by redefining several hotspots boundaries, and by adding new ones that were suspected hotspots for which sufficient data either did not exist or were not easily accessible, brought the total to 34 biodiversity hotspots (Mittermeier et al., 2011). Recently, a 35th hotspot was added (Williams et al., 2011), the Forests of East Australia.

Hotspots identification

Biodiversity hotspots are particular areas where extraordinary concentrations of biodiversity exist. Although hotspots have also been identified through different ways (Hoekstra et al., 2005), these areas are usually defined by one or more species-based metrics (number of species – species richness; number of species restricted to a particular area – endemic species richness; and number of rare or threatened species) or focusing on phylogenetic and functional diversity in order to protect species that support unique and irreplaceable roles within the ecosystem.

11.3 GLOBAL BIODIVERSITY HOTSPOTS

Globally, at as present the 35 biodiversity hotspots (Table 1) that cover only 17.3% of the Earth's land surface are characterized by both exceptional biodiversity and considerable habitat loss (Myers et al., 2000). More precisely, hotspots maintain 77% of all endemic plant species, 43% of vertebrates (including 60% of threatened mammals and birds), and 80% of all threatened amphibians (Mittermeier et al., 2011; Williams et al., 2011).

Table-1 Biodiversity hotspots from 1988 to present

Source: Modified from: Mittermeier et al. (2011).

Myers (1988) Revision	Myers (1990)	Myers et al. (2000)	Mittermeier et al. (2004)	2011
Uplands of Western Amazonia Andes	Uplands of Western Amazonia	Tropical Andes[a]	Tropical Andes	Tropical
Western Ecuador	Western Ecuador			
Colombian Choco Choco-	Colombian Choco	Choco/Darien/western Ecuador[b]	Tumbes-Choco-Magdalena	Tumbes- Magdal ena
Atlantic Coast Brazil Forest	Atlantic Coast Brazil	Atlantic Coast Brazil	Atlantic Forest	Atlantic
		Brazilian Cerrado	Cerrado	Cerrado
Rainfall	Central Chile	Central Chile[a]	Chilean Winter Rainfall and Valdivian Forest	Chilean Winter and Valdivian
		Forest		
		Mesoamerica	Mesoamerica	
			Mesoamerica	
			Madrean Pine-Oak Woodlands	Madrean Pine-Oak Woodla nds
		Caribbean	Caribbean Islands	Caribbean
	Islands			
Floristic	California Floristic Province	California Floristic Province	California Floristic Province	California Provi nce
West	Ivory Coast	Guinean Forest of West Africa[a]	Guinean Forest of West Africa	Guinean Forest of
			Africa	
Region	Cape Floristic Region	Cape Floristic Province	Cape Floristic Region	Cape Floristic
Karoo		Succulent Karoo	Succulent Karoo	Succulent
			Maputaland-Pondoland-Albany	Maputaland-Pondoland-Alb any
Afromontane Forest of	Tanzania	Eastern Arc and Coastal Tanzania/	Eastern Afromontane[d]	Eastern

		Kenya		
			Coastal Forests of Eastern Africa[d]	Coastal Forests of Eastern Af rica
			Horn of Africa	Horn of Africa
Eastern Madagascar Indian	Eastern Madagascar	Madagascar and Indian Ocean Islands	Madagascar and Indian Ocean Islands	Madagascar and Ocean Islands
		Mediterranean Basin	Mediterranean Basin	Mediterranean Basin
		Caucasus	Caucasus	Caucasus
			Irano-Anatolian	Irano-Anatolian
			Mountains of Central Asia	Mountains of Central Asia
	Western Ghats in India Southwestern Sri Lanka and Sri	Western Ghats and Sri Lanka[b]	Western Ghats and Sri Lanka	Western Ghats Lanka
		Mountains of South-Central China	Mountains of China	Mountains of South-Central China
			Indo-Burma	Indo-Burma
Eastern Himalayas	Eastern Himalayas Himalaya	Indo-Burma[e]	Himalaya[f]	
Peninsular Malaysia	Peninsular Malaysia			
Northern Borneo	Northern Borneo Sundaland	Sundaland[b]	Sundaland	
		Wallacea	Wallacea	Wallacea
Philippines	Philippines	Philippines	Philippines	Philippines
			Japan	Jap an
Australia	Southwest Australia	Southwest Australia[a]	Southwest Australia	Southwest Australia
				Forests of East Australia[g]
		Islands	East Melanesian Islands	East Melanesian Islands
		New Zeeland	New Zeeland	New Zeeland
New Caledonia	New Caledonia	New Caledonia	New Caledonia	New Caledonia
		Polynesia-Micronesia	Polynesia-Micronesia	Polynesia-Micronesia

a. Expanded.

b.Merged and/or expanded.

c. Expanded to include Coastal Forests of Tanzania and parts of Kenya.

d The Eastern Arc and Coastal Forests of Tanzania/Kenya hotspots was split into the Eastern Afromontane hotspot (the Eastern Arc Mountains and Southern Rift, the Albertine Rift, and the Ethiopian Highlands) and Coastal Forests of Eastern Africa (southern Somalia south through Kenya, Tanzania and Mozambique).

e Eastern Himalayas was divided into Mountains of South-Central China and Indo-Burma, the latter of which was expanded.

f .The Indo-Burma hotspot was redefined and the Himalayan chain was separated as a new Himalayan hotspot, which was expanded. g The Forests of Eastern Australia the 35th biodiversity hotspot.

11.4 MEGABIODIVERSITY COUNTRIES

As we have already discussed with you that as at present we have only 35 mega biodiversity hotspots in the world. For details please refer table 1 of this Unit.

11.5 INDIA AS MEGA-BIODIVERSITY COUNTRY

India is exceptionally rich in biodiversity and is one of the twelve mega diversity centres of the world. With 10 biogeographic zones and 25 biotic provinces, all major ecosystems are represented. India is a land mass of nearly 33 lakh sq km with a coastline of 7,616 km and 14 different types of climatic forests and the total forest coverage in India is about 6,50,000 sq km. The diverse physical features and climatic situations have formed ecological diverse habitats like forests, grasslands, wetlands, coastal and marine ecosystems and desert ecosystems, which harbor and sustain immense biodiversity. Biogeographically, India is situated at the tri-junction of three realms - Afro-tropical, Indo-Malayan and Paleo-Arctic realms, and therefore, has characteristic elements from each of them. This assemblage of three distinct realms makes the country rich and unique in biological diversity.

India is the home land of 13,000 species of flowering plants, 20,000 species of fungi, 50,000 species of insects, 65,000 species of fauna including 2000 species of birds, 350 mammals and 420 of reptiles. It covers nearly 7% of world's flora and 6.5% of world's fauna of which 33 % flora and 62% fauna are endemic. India has over 30 National parks that constitute about 1% of the landmass and 441 sanctuaries that constitute 3.5% of the area. India is a home of over 35,000 tigers and the umbrella of project tiger 23 specially demarcated project tiger reserves covering 33,000 sq.km representing different climatic forests are spread across the country. The country is also one of the 12 primary centres of origin of cultivated plants and domesticated animals. It is considered to be the homeland of 167 important plant species of cereals, millets, fruits, condiments, vegetables, pulses, fibre crops and oilseeds, and 114 breeds of domesticated animals.

India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats from tropical rainforests to alpine vegetation and from temperate forests to coastal wetlands. **India figured with two hotspots** - the Western Ghats and the Eastern Himalayas -

in an identification of 18 biodiversity hotspots carried out in the eighties. Recently, Norman Myers and a team of scientists have brought out an **updated list of 25 hotspots**. In the revised classification, the 2 hotspots that extend into India are The Western Ghats/Sri Lanka and the Indo-Burma region (covering the Eastern Himalayas); and they are included amongst the top eight most important hotspots. In addition**, India has 26 recognised endemic centres** that are home to nearly a third of all the flowering plants identified and described to date.

Of the estimated 5–50 million species of the world's biota, only 1.7 million have been described to date, and the distribution is highly uneven. About seven per cent of the world's total land area is home to half of the world's species, with the tropics alone accounting for 5 million. India contributes significantly to this latitudinal biodiversity trend. With a mere 2.4% of the world's area, India accounts for 7.31% of the global faunal total with a faunal species count of 89,451 species. Some salient features of India's biodiversity have been mentioned below.

1. India has two major realms called the Palaearctic and the Indo-Malayan, and three biomass, namely the tropical humid forests, the tropical dry/deciduous forests, and the warm desert/semi-deserts.
2. India has ten biogeographic regions including the Trans-Himalayan, the Himalayan, the Indian desert, the semi-arid zone(s), the Western Ghats, the Deccan Peninsula, the Gangetic Plain, North-East India, and the islands and coasts.
3. As of date, there are 911 properties under the World Heritage List, which cover 711 cultural sites, 180 natural sites and 27 mixed properties encompassing 152 countries, including India. India is one of the 12 centres of origin of cultivated plants.
4. India's first two sites inscribed on the list at the Seventh Session of the World Heritage held in 1983 were the Agra Fort and the Ajanta Caves. Over the years, 27 more sites have been inscribed, the latest site inscribed in 2012 being the Western Ghats. Of these 29 sites, 23 are cultural sites and the other six are natural sites. A tentative list of further sites/properties submitted by India for recognition includes 33 sites.
5. India has 17 biosphere reserves, and 19 Ramsar wetlands. Amongst the protected areas, India has 102 national parks and 490 sanctuaries covering an area of 1.53 lakh sq km.
6. The wildlife sanctuaries in India are home to around two thousand different species of birds, 3500 species of mammals, nearly 30000 different kinds of insects and more than 15000 varieties of plants.

The endemism of Indian biodiversity is high. About 33% of the country's recorded flora are endemic to the country and are concentrated mainly in the North-East, Western Ghats, North-West Himalaya and the Andaman and Nicobar islands. Of the 49,219 plant species, 5150 are endemic and distributed into 141 genera under 47 families corresponding to about 30% of the world's recorded flora, which means 30% of the world's recorded flora are endemic to India. Of these endemic species, 3,500 are found in the Himalayas and adjoining regions and 1600 in the Western Ghats alone. About 62% of the known amphibian species are endemic with the majority occurring in the Western Ghats. Nearly 50% of the lizards of India are endemic

with a high degree of endemicity in the Western Ghats. India is a centre of crop diversity - the homeland of 167 cultivated species and 320 wild relatives of crop plants.

Corals reefs in Indian waters surround the Andaman and Nicobar Islands, the Lakshadweep Islands, and the Gulf areas of Gujarat and Tamil Nadu. They are nearly as rich in species as tropical evergreen forests.

India's record in agro-biodiversity is equally impressive. There are 167 crop species and wild relatives. India is considered to be the centre of origin of 30,000-50,000 varieties of rice, pigeon-pea, mango, turmeric, ginger, sugarcane, gooseberries etc and ranks seventh in terms of contribution to world agriculture.

Conservation and sustainable use of biological resources based on local knowledge systems and practices is ingrained in Indian ethos. The country has a number of alternative medicines, like *Ayurveda, Unani, Siddha* and Homeopathic systems which are predominantly based on plant based raw materials in most of their preparations and formulations. Herbal preparations for various purposes including pharmaceutical and cosmetic purposes form part of the traditional biodiversity uses in India.

Role of Government agencies for conserving the mega biodiversity of the country

About 4,900 species of flowering plants are endemic to the country. These are distributed among 141 genera belonging to 47 families. These are concentrated in the floristically rich areas of North-East India, the Western Ghats, North-West Himalayas and the Andaman and Nicobar Islands. These areas constitute two of the 18 hot spots identified in the world. It is estimated that 62 percent of the known amphibian species are endemic to India of which a majority is found in Western Ghats. Approximately 65 percent of the total geographical area has been surveyed so far. Based on this, over 46,000 species of plants and 81,000 species of animals have been described by the Botanical Survey of India (BSI) established in 1890 and Zoological Survey of India (ZSI) established in 1916, respectively. This list is being constantly upgraded, especially in lower plants and invertebrate animals. The Forest Survey of India established in 1981 assesses the forest cover with a view to develop an accurate database for planning and monitoring purposes.

The strategies for conservation and sustainable utilization of biodiversity have comprised providing special status and protection to biodiversity - rich areas by declaring them as National Parks, Wildlife Sanctuaries, Biosphere Reserves, Ecologically Fragile and Sensitive Areas. Other strategies include offloading pressure from Reserve Forests by alternative measures of fuel wood and fodder need satisfaction by afforestation of degraded areas and wastelands and creation of *ex-situ* conservation facilities such as Gene Banks. For example,

the Tura Range in Garo Hills of Meghalaya is a gene sanctuary for preserving the rich native diversity of wild *Citrus* and *Musa* species.

Approximately, 4.2 percent of the total geographical area of the country has been earmarked for extensive *in-situ* conservation of habitats and ecosystems. A protected area network of 85 National Parks and 448 Wildlife Sanctuaries has been created. The results of this network have been significant in restoring viable population of large mammals such as tiger, lion, rhinoceros, crocodiles and elephants. The Indian Council of Forestry Research and Education (ICFRE) have identified 309 forest preservation plots of representative forest types for conservation of viable and representative areas of biodiversity. Out of these plots, 187 are in natural forests and 112 are in plantations, covering a total area of 8,500 hectares.

Recently a programme "Eco-development" for *in-situ* conservation of biological diversity involving local communities has also been initiated. The concept of eco-development integrates the ecological and economic parameters for sustained conservation of ecosystems by involving the local communities with the maintenance of earmarked regions surrounding protected areas. The economic needs of the local communities are taken care under this programme through provision of alternative sources of income and a steady availability of forest and related produce.

Further, several programmes have also been launched for scientific management and sustainable use of Wetlands, Mangroves and Coral reef ecosystems. Twenty one Wetlands, and Mangrove areas and 4 Coral reef areas have been identified for intensive conservation and management purposes. Six significant wetlands of India have been declared as "Ramsar Sites" under the Ramsar Convention. Under the World Heritage Convention, five natural sites have been declared as "WHS " such as NDBR in Uttarakhand.

To conserve the representative ecosystems, a Biosphere Reserve Programme is being implemented. Eighteen biodiversity rich areas of the country have been designated as Biosphere Reserves applying the UNESCO/MAB criteria. These reserves aim at conserving the biological diversity and genetic integrity of plants, animals and microorganisms in their totality as part of the natural ecosystems, so as to ensure that self-perpetuation and unhindered evolution of the living resources.

Government of India under the umbrella of Ministry of Environment and Forests constituted the National Afforestation and Eco-development Board (NAEB) in 1992 for promoting afforestation and management strategies which help the states in developing specific afforestation and management strategies and eco-development packages for augmenting biomass production through a participatory planning process of joint forest management and micro planning.

India is also a party to the Convention on Biological Diversity (CBD). The main objectives of this convention are; conservation of biological diversity, sustainable use of the components of

biodiversity and fair and equitable sharing of benefits arising out of the utilization of genetic resources.

11.6 SUMMARY

Module started with the basic concepts of the hotspots and mega biodiversity countries. This also includes the need of the declaration regarding the designation/Identification of Hotspots. This also discussed Biodiversity Hotspot concept followed by Hotspots identification and Global Biodiversity Hotspots criteria. A comprehensive table consisting list of Biodiversity Hotspots from 1988 to present was also given to update the students. In the later section of module a case was presented to highlight India as a mega biodiversity country with all the facts and figures along with the role of Government agencies for conservation of the mega biodiversity of the country like Botanical Survey of India and Zoological Survey of India, Man and Biosphere Programme etc.

11.7 GLOSSARY

BSI = Botanical Survey of India
ZSI = Zoological Survey of India
ICFRE = Indian Council of Forestry Research and Education
UNESCO = The United Nations Educational, Scientific and Cultural Organization
MAB = Man and Biosphere Program
NAEB = National Afforestration and Eco-development Board
CBD = Convention on Biological Diversity
WHS=World Heritage Site
NDBR=Nanda Devi Biosphere Reserve

11.8 SELF ASSESSMENT QUESTIONS

11.8.1 Objective Type Questions:

1. From the point of view of natural vegetation and wildlife, India belongs to which of the following categories?
(i) One of the twelve mega biodiversity countries of the world
(ii) The richest wildlife zone in the world
(iii) The country with the greatest forest cover
(iv) A country lacking in biodiversity cover

2. Who published the Biodiversity Hotspots Concept?
(i) Myers (ii) E.O. Wilson
(iii) E.P. Odum (iv)S.K.Jain

3. As at present how many Global Biodiversity Hotspots we have?
(i) 35 (ii) 40
(iii) 33 (iv) 34

4. India is one of the …… mega diversity countries.
(i) 15 (ii) 12
(iii) 11 (iv) 10

5. India is the home land of ……flowering plants.
(i) 13,000 (ii) 15,000
(iii) 70000 (iv) 5000

11.8.1 Answer Key:

1.(i); 2. (i); 3. (i); 4. (ii); 5. (i)

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11.11 TERMINAL QUESTIONS

1. India is a mega biodiversity country. Discuss with suitable examples.
2. Explain as to how protection of biodiversity hot spots alone can reduced upto 30 % for the current rate of species Extinction.
3. Discuss the role of Government agencies for conserving the mega biodiversity of the country.
4. What are the various concepts for Hotspot identification? Discuss.
5. Your friend comments that hotspots are not that important because hotspots only focus on plants, not animals, and it's most important to save the animals. Explain in a few sentences why you agree or disagree with your friend's statement.
6. How many Hotspots we have globally or nationall

UNIT-12 FLORISTIC DIVERSITY OF INDIA AND ENDEMISM

12.1- Objectives
12.2-Introduction
12.3- Floristic Regions of India
12.4- Flora and vegetation
12.5-Endemism
12.6-Summary
12.7-Glossary
12.8-Self Assessment Questions
12.9-References
12.10-Suggested Readings
12.11-Terminal Questions

12.1 OBJECTIVES

After reading this unit students will be able-

- to know about the different floristic regions of the India
- acquaint with the floral profile of the different floristic regions
- acquaint with the concept of the Endemism

12.2 INTRODUCTION

India, with 2.4% of the world's area, has over 8% of the world's total biodiversity, making it one of the 12 megadiversity 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. This diversity can be attributed to the vast variety of landforms and climates, resulting in 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. Being a predominantly agricultural country, India also has a mix of wild and cultivated habitats, giving rise to very specialized biodiversity, which is specific to the confluence of two or more habitats.

12.3 FLORISTIC REGIONS OF INDIA

The tendency to classify ecological regions, and plant and animal groupings, according to their geographical distribution and their essential similarities and differences, is not new. Traditional human communities did this on the basis of their own understanding, though their knowledge was necessarily somewhat restricted in its geographical spread (Banwari 1992; Gurukkal 1989). Unfortunately, this aspect of traditional community knowledge is not well appreciated or studied. In modern times, biogeographical classification started in the latter half of the 19th century, with Elwes (1873) using the distribution of animals to classify bioregions, and Clarke (1898) followed by Hooker (1907), using plant distribution to the same end. What distinguished most of these early attempts and indeed all except some recent efforts was that they were either phytogeographic, i.e., based solely on plant distribution, or zoogeographic, i.e., based only on animal distribution. An attempt to synthesise the two approaches, or come up with a fresh classification based on the combination of plant and animal distribution, is very recent, and has been prompted by the need to use such zonation in fixing conservation priorities. These three kinds of approaches have been used or analysed by several authors recently, including Mani (1974), Puri *et al.*, (1983), Meher-Homji and Mishra (1973), and Rodgers and Panwar (1988).

Rodgers *et al*., (2002) recognizes ten biogeographic zones divided into twenty-six biotic provinces in India. Biogeographic zones of India and their spatial extent is presented in Table 1.

Table 1. Biogeographic zones of India and their spatial extent

S.No.	Zone	Biotic Province	Area	% of India's land area
1	Trans-Himalaya		174225	
		Ladakh	98618	3.3
		Tibetan Plateau	75607	2.3
2	Himalaya		210385	
		North-Western	69033	2.1
		Western	52596	1.6
		Central	6575	0.2
		Eastern	82182	2.5
3	Desert		213672	
		Kachchh	36160	1.1
		Thar	177512	5.4
4	Semi-Arid		545686	
		Central India	121629	3.7
		Gujarat-Rajputana	424057	12.9
5	Western Ghats		131491	
		Malabar Coast	65745	2
		Western Ghat Mountains	65745	2
6	Deccan Peninsula		1377363	
		Deccan South Plateau	341875	10.4
		Deccan Central Plateau	410908	12.5
		Eastern Plateau	207098	6.3
		Chhota Nagpur	177512	5.4
		Central Highlands	239970	7.3
7	Gangetic Plain		355024	
		Upper	207098	6.3

		Gangetic		
		Lower Gangetic	147927	4.5
8	Coasts		82182	
		East Coast	62458	1.9
		West Coast	19724	0.6
9	North East		170938	
		Brahmaputra Valley	65745	2
		North-Eastern Hills	105192	3.2
10	Islands		12971	
		Andaman Islands	6575	0.2
		Nicobar Islands	3287	0.1
		Lakshadweep Island	3110	0.1
	Marine Influenced Area		10440	0.3
	Grand Total		3287263	

(Source: Wildlife Institute of India (Rodgers et al., 2002)/Zoological Survey of India)

Trans-Himalaya

The Trans-Himalaya zone covers mainly the districts of Ladakh and Kargil in Jammu and Kashmir, and the Spiti valley, Lingti plains (Lahaul valley), and Pooh tehsil (district Kinnaur) in Himachal Pradesh. Small areas in the rain shadows of Nanda Devi range (Uttaranchal) and Kangchendzonga range (Sikkim) are also part of this zone (Mehta and Julka 2002). The area is a distinct biogeographic unit with harsh climatic conditions and is usually referred to as cold desert (Rodgers and Panwar 1998). The region is the most elevated zone on the earth and varies from 2800 m in the Indus to over 7000 m in the Himalayan and Karakoram ranges (Mehta and Julka 2001). The vegetation is primarily of dry alpine scrub formation, chiefly of *Juniperus* spp. The other genera that contribute to the sparse vegetation are *Saxifrga*, *Draba*, *Ephedra*, and *Carex.*

Himalaya

The Himalaya zone consists of an area of 210385 sq km, approximately 6.4% of the country's total land surface. It includes northwest Himalaya (Kashmir to the Sutlej river in Himachal Pradesh), west Himalaya (Sutlej river to the Gandak river in Nepal), central Himalaya

(Gandak river in Nepal through West Bengal and Sikkim to central Bhutan) and east Himalaya (central Bhutan and Arunachal Pradesh). Himalaya supports a remarkable assemblage of vegetational formation. Broadly subtropical, temperate, subalpine, and alpine forest types are met with in this region. Chir-pine, tall conifers, Oaks are common in the West Himalaya and show a distinct altitudinal distribution while the slopes of East Himalaya are occupied by colorful *Rhododendrons*, bamboos, primulas and orchids.

Desert

The Indian desert is the northwestern boundary of India and covers mainly the western and northwestern regions of Rajasthan and part of Kachchh region of Gujarat in the southwest. It has an elevation of about 350-450 m above sea level at the Aravalli range in the east, about 100 m in the south and west and about 20 m in the Rann of Kachchh (Baqri and Kankane 2001). Indian dessert is characterized by *Leptadenia*, *Crotalaria*, *Citrulus* species. Tree species are sparce and mainly represented by *Acacia*, *Tecomella* and some multipurpose tree species like *Prosopis*. Bushes of *Ziziphus* and *Capparis* species.

Semi-Arid

This region is a zone of transition between the true desert in the west to the extensive communities of the Deccan Peninsular India, to the south and east. This zone includes the Punjab plains, Delhi, Haryana, fringes of Jammu and Kashmir, Himachal Pradesh, western edges of Uttar Pradesh, eastern Rajasthan, eastern Gujarat and northwest Madhya Pradesh. The Semi-arid zone represents a characteristic savannah woodland and dry deciduous and tropical thorn forest zone in Western India. The Aravalli System constitutes the heart of this zone, which primarily supports two types of vegetation: Tropical Dry Deciduous Forest and Tropical Thorn Forest. The semi-arid vegetation chiefly constists of thorn-scrub forests of *Ailanthus excelsa*, *Capparis decidua*, *Prosopis cineraria*, *Acacia* sp. and *Boswellia serrata*.

Western Ghats

The Western Ghats stretch from the Tapti river in the north to Kanyakumari in the south, along the west coast of peninsular India through the states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala (Lakshminarayana *et. al.*, 2001).The Western Ghats zone is one of the 25 biodiversity 'hotspots' in the world (Myers *et. al.*, 2000) and is one of the major tropical evergreen forested regions in India, exhibiting enormous plant diversity. About 4000 species of flowering plants occur in the region, which harbours nearly 27% of the total flora in India (Nayar 1996). Among these, 1500 species are endemic (Mackinnon and Mackinnon (1986). The Western Ghats region is a major genetic estate with a rich biodiversity of ancient lineage. Western Ghats comes next to Himalayan zone in terms of floristic richness and diversity. More than 4000 species of flowering plants are expected here, out of which 1500 species are endemic. Diversity of forest types constitute this zone. The moist deciduous forests contain highly valued timber species such as *Dalgergia latifolia*, *Terminalia crenulata*, *Pterocarpus marsupium* and *Tectona grandis*. The wet evergreen forests include species of *Mesua*, *Calophyllum*, *Hopea* and *Dipterocarpus*. At higher level

montane flora generally known as Shola formation is common. Species of *Syzygium, Machilus, Elaeocarpus, Wendlandia* are common.

Deccan Peninsula

The Deccan Peninsula biogeographic zone includes a major portion of the states of Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and Bihar. The zone is relatively homogenous and ranges from semi-arid to moist deciduous/ semi-evergreen type of climate. The central highlands comprise the Vindhya and Satpura hill ranges, Chhota Nagpur Plateau, Eastern Ghats, Tamil Nadu Plains and Karnataka Plateau (Cherian 2001). The Vindhya and Satpura hill ranges are known for a rich diversity of flora. A major portion of the Deccan Peninsula is covered by Tropical thorn forests and Tropical dry and moist deciduous forests. *Tectona grandis*, *Anogeissus latifolia, Boswellia serrata, Butea monosperma* and several other thorny species of semi-arid zone are common here. *Hardwickia binata*, an endemic Caesalpiniaceae tree species occurs scattered in patches on the drier parts of the Peninsula. The tropical moist deciduous forest chiefly includes *Adina cordifolia*, *Chloroxylon swietenia*, *Diospyros exsulpta* and in some parts of southeastern Madhya Pradesh *Shorea robusta* occurs.

Gangetic Plains

This zone includes the Gangetic divide, the Upper Gangetic plain, the Middle Gangetic plain and the Lower Gangetic plain (Hooker 1907). This zone is mostly under agriculture and supports dense human population stretching from eastern Rajasthan through Uttar Pradesh to Bihar and West Bengal. The Gangetic plain includes the area adjacent to Terai-Bhabar tracts in Uttar Pradesh, Bihar and West Bengal. In this particular zone natural vegetation has been replaced by cultivated plants. In the Terai areas (foothills) the natural stands of tall grasses of *Themeda*, *Saccharum* and *Phargmites* admist which a few scattered trees exists.

Coasts

The coastline of India stretches from Gujarat to Cape Comorin (Kanyakumari) in the west, and onwards from Cape Comorin to the Sundarbans in the east. The long stretch of coastline in the mainland has a very diverse set of biotic communities. This zone includes two major vegetation types mangrove forests and beach forests. The most characteristic tree species of beach forest are *Casuarina equisetifolia, Anacardium occidentale* (planted), *Manilkara* species, *Calophyllum inophyllum* and *Hernandia peltata*.

North-East Region

The north-east Indian biogeographic zone is most significant as it represents the transition zone between the Indian, Indo-Malay and Indo-Chinese biogeographic regions, as well as a meeting-place of Himalayan mountains with those of Peninsular India. It comprises eight states i.e., Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region acts as a biogeographic gateway for plant migration. In India, apart from the Western Ghats. Northeast India is one of the 25 biodiversity 'hotspots' in the world

(Myers *et. al.*, 2000). About 50% of the total number of species of India occur in this zone which also includes a portion of Arunchal Pradesh. The presence of a large number of primitive flowering plants (Table 2) has prompted Takhtajan (1969) to call it the "Cradle of Flowering Plants". Many primitive angiosperms occur in the humid tropics of northeast India and east Himalaya. The vegetation of northeast India is rich and diverse and is broadly classified into tropical, subtropical, temperate types. *Shorea assamica*, *Diplterocarpus macrocarpa* are the important tree species of the tropical zone. *Pinus kesiya* is the principal conifer in the subtropical zone. Species of *Quercus*, *Castanopsis*, *Rosa*, *Photinia*, *Prunus* and *Sorbus* are conspicuous in the temperate vegetation.

Table 2. Primitive Angiosperm genera in India

Families	**Genera**
Magnoliaceae	*Magnolia, Manglictia, Michelia, Pachylarnax, Paramichelia, Talauma*
Tetracentraceae	*Tetracentron* (*T. sinense* var. *himlaayana*)
Illiciaceae	*Illicium*
Eupteliaceae	*Euptelea*
Annonaceae	*Alphonsca*, *Annona*, *Artabortys*, *Cyathocalyx*, *Desmos*, *Fissitigma*, *Melodorum*, *Goniothalamus*, *Melodorum*, *Miliusa*, *Mitrephora*, *Orophea*, *Polyalthia*, *Trivalvaria*, *Unona*, *Uvaria*
Myristicaceae	*Horsfieldia*, *Kuema*, *Myristica*
Schisandraceae	*Kadsura* (*K. heteroclite*)
Lauraceae	*Actinodaphne*, *Alseodaphne*, *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Dehaasia*, *Endiandra*, *Lindera*, *Litsea*, *Machilus*, *Neociannamomum*, *Presea*, *Phoebe*
Chloranthaceae	*Chloranthus* (*C. elatior*)

Islands

Islands are essentially in two major groups the Lakshadweep islands and the Andaman group of islands. The Lakshadweep Islands are an archipelago of 27 small islands stretching from 8° to 12° N latitude and 71° to 74° E longitude in the Arabian Sea. They are 320 kms away from the Kerala coast. The Andaman and Nicobar Islands are an elongated north-south oriented group of 348 islands in the Bay of Bengal stretching for 590 km from 6° to 13° N latitude and 92° to 93° E longitude. The Andaman Islands are about 190 km from Cape Negrais in Burma, the nearest point on the mainland. Five islands close together constitute the Great Andaman (300 km long), and the Little Andaman lies to the south. The Nicobar groups of Islands are separated from the Andamans as well as internally from each other by 800 m deep channels. The vegetation of the island can be broadly classified as littoral and inland types. The littoral forests are composed of trees like *Manilkara littoralis*, *Calophyllum inophyllum*, *Terminalia catappa*, *Barringtonia asiastica* and mangroves like *Rhizophora mucronata*, *R. apiculata*, *Avicennia marina*, *Lumnitzera littorea*, *Nypa fruticans* and few others. The inland vegetation includes the evergreen and deciduous forests with a number of

economically important timber species such as *Dipterocarpus grandis*, *Pterocarpus dalbergioides*, *Terminalia bialata*, *Albizia lebbeck*, *Ailanthus kurzii*.

12.4 FLORA AND VEGETATION

As indicated above, the different parts of the country are covered by the distinct vegetational types. The richness and diversity of flora of India can be appreciated by the fact that as many as 10 biogeographic regions representing three basic biomes and two natural realms as identified by Udvardy (1975) are recognized within the territory of the Indian Republic. These are Himalayan highlands, Thar dessert, Malabar rain forest, Indo-Ganges monsoon forest, Deccan thorn forest, Coromandel, Mahanadian, Bengalian rain forest, Laccadive islands, Andaman and Nicobar islands.

It is estimated that over 45,000 species of plants are accounted for India which represent 11% of the known species of the World. These are distributed in the following groups: Angiosperms: 15000 species; Gymnosperms: 64 species; Pteridophytes: 1022 species; Bryophytes: 2584 species; Lichens: 1600 species; Fungi: 23000 species; Algae: 2500 species and Bacteria: 850 species.

The flowering plants of India comprise about 15000 species and represent 6 % of the World's known flowering plants (Nayar, 1977). About 315 families and 2250 genera of flowering plants are known to occur in India in different ecosystems. The ten largest families in terms of numbers of species are listed in table 3. On the other end of the spectrum there are several monotypic families. Over 60 families are reported to be presented by only one species in India like Coriariaceae, Turneraceae, Illiciaceae, Ruppiaceae etc.

Table 3. Ten large families of flowering plants in Indian Flora

S.No.	Name of the family	No. of genera (approximate)	No. of species (approximate)
1	Poaceae	255	1225
2	Fabaceae	179	1152
3	Orchidaceae	145	990
4	Asteraceae	161	1000
5	Rubiaceae	90	495
6	Cyperaceae	24	449
7	Euphorbiaceae	74	419
8	Lamiaceae	68	393
9	Acanthaceae	84	379
10	Scrophulariaceae	66	356

Nearly 17 % of the species of Indian flora are tree species and they predominantly occur in Euphorbiaceae, Lauraceae, Annonaceae, Rubiaceae, Moraceae, Fabaceae, Rutaceae, Arecaceae, Meliaceae, Mimosaceae and Caesalpiniaceae.

The Indian Sub-continent has approximately half of world's aquatic flowering plants (Lavania *et al*., 1990). The aquatic families in the Indian flora are Alsimataceae, Aponogetonaceae, Azollaceae, Barclayaceae, Butomaceae, Cabombaceae, Hydrocharitaceae, Lemnaceae, Isoetaceae, Nymphaeaceae, Podostemaceae, Pontederiaceae, Potamogetonaceae, Ruppiaceae, Salviniaceae, Trapaceae, Typhaceae etc.

The families having characterisitc insectivorous plants are Droseraceae (3 species), Nepenthaceae (01 species) and Lentibulariaceae (36 species). The parasitic families are represented by Loranthaceae (46 species), Santalaceae (10 species), Balanophoraceae (06 species) and Cuscutaceae (12 species). There are several unique root parasites in the country. *Sapria himalayana* of the family Rafflesiaceae is a recently discovered large root parasite of great botanical interest.

The size, shape, biology and economic aspects of different taxa again provide a highly varied spectrum. Several reputed medicinal plants constitute the natural component of Indian flora. These are *Dioscorea deltoidea*, *Atropa acuminata*, *Aconitum heterophyllum*, *A. ferox*, *Ephedra gerardiana*, *Nardostachys grandiflora*, *Rauvolfia serpentiana*, *Sassurea lappa*, *Coptis teeta*, *Gentiana kurroo*, *Mesua ferrea*, *Swertia chirayita*, *Podophyllum hexandrum*, *Artemesia* species, *Phyllanthus emblica*, *Withania somnifera*, *Andrographis paniculata*, *Berberis* species, *Mentha* species etc.

Certain groups like orchids, rhododendrons, bamboos, legumes, balsams and primulas exhibit a remarkable diversity in the Indian region. The diversity in a few important groups is discussed below:

Diversity in Orchids

The orchids which are well-known for their showy and long-lasting flowers are represented by diverse epiphytic and terrestrial forms. There are about 163 terrestrial genera and 1100 species, of which about 780 species occur in northeast India and Eastern Himalaya. Some of the large genera having maximum diversity are *Habenaria* (95 species), *Dendrobium* (75 species), *Bulbophyllum* (50 species), *Liparis* (46 species) and *Coelogyne* (35 species).

Diversity in Bamboos

Bamboos play an important role in the economy of the country and are associated with the human kind since ancient times. Tropical Asia including the India is the main centre of bamboo diversity. Bamboo forests come up in both tropical and temperate regions. Approximately 13% of the total forest area in India is covered by Bamboos. Out of 18 genera and 130 species so far known in India, 15 genera and 63 species are represented in northeastern India, which is also considered as the centre of genetic diversity for the species of *Bambusa*, *Dendrocalamus*, *Arundinaria* and a few others. Some of the dominant genera area *Arundinaria* (10 species), Bambusa (22 species) and *Dendrocalamus* (15 species).

Diversity in the Genus *Rhododendron*

The genus *Rohdodendron* of the family Ericaceae is another remarkable group bearing showy flowers, which have maximum diversity in the Himalaya. Out of the total 90 species in India nearly 80 species are confined to east Himalaya whereas only one species *Rhododendron arboreum* extends its distribution to Nilgiris in south India. *R. nivale* is the smallest Rhododendron in India. In Sikkim, we have the *Rhododendron* sanctuary only for the conservation of *Rhododendron* genus.

Diversity in Legumes

The economic importance of legumes is too well recognized. Leguminosae is the second largest family in the Indian region. Out of 179 genera and 1152 species in India (Sanjappa, 1991), 236 taxa (23%) are endemic. Approximately 56 % of the total Leguminosae of India is represented in the Himalayan region (Rao and Husain, 1993). Some of the dominant genera of legumes are *Crotalaria* (96 species), *Astragalus* (72 species), *Acacia* (70 species), *Indigofera* (60 species), and *Dalbergia* (35 species).

12.5 ENDEMISM

The idea of endemism dates back to more than 200 years, and has been employed, as it is actually understood, by de Candolle. Since then, the concepts of endemicity and areas of endemism have been widely discussed. Some problems around these concepts emerge from the diverse uses and interpretations given to them in literature (Harold and Moii). Although differences between diverse uses as regards connotations could seem minor, the lack of precision in the definition of these concepts hinders an unambiguous interpretation and causes confusion. Additionally, numerous expressions, such as “generalized track”, “track”, “biotic element”, “centers of endemicity”, “units of co-ocurrence”, among others, are commonly used as synonyms of area of endemism. Although basically related with the term “areas of endemism”, these concepts refer to different patterns of distribution and are defined on different theoretical grounds.

Brief Review of ideas on Endemism

Naturalists and Botanists have recognized the existence of rare or endemic plants for centuries. Cain (1944) ascribes the origin of the world endemic as it is applied to the distribution of organism to A. De Candolle (1855) the great voyages of discovery from the seventeen through nineteenth centuries brought to light countless rare and endemic taxa. Linnaeus’s *Species Plantarum* of 1753 lists no rarities from different areas but only recorded some local endemic species, some of them are still rare and some are extinct. Adolph Engler (1882) appears to be the originator of the dichotomy of old Vs new endemics, which has been extensively by other plant geographers ever since Stebbins (1942) and Stabbins and Major (1965). Willis (1922) quantified the idea of the youthful endemic with his J-shaped or hollow curves; they became the backbone of his controversial and largely discredited theory of age and area. Stebbins (1942) provided a genetical explanation for the epibiotic or relictual

endemic. Stebbins and Major (1965) recast Cain's two categories as paleoendemism and neoendemism. These authors point to persistent defects in the new vs old endemic dichotomy. Stabbins and Major based their classification upon the way in which narrow endemics have achieved their restricted distribution, since this varies among species; this system was also proposed by Favarger and Contandriopouplos (1961). Stebbins and Major's system incorporates the age of endemic, its systematic position, and cytological data. In groups of related species, diploids are older than derivative low polyploids, while both high polyploids and diploids are paleoendemics. Endemics with more than one disjunct population are most likely (paleoendemics), while endemics confined to a single population can be either paleoendemics or neoendemics. Stebbins and Major use the ploidal level and its modes of origin both to categories endemics and to explain their origin. Paleoendemics are ancient vestiges of taxa that were once more widespread. Their present relictual status is preseumably the result of the increasing constriction of their specialized habitats over time. The neoendemics, on the other hand, are recent in origin, have just split off from a parental entity, and may be poised for a further expansion of their ranges and gene pools. *Plantago cordata* (Meagher et al., 1978) and *Stephanomeria malheurensis* (Gottlieb, 1979) demonstrate that both paleoendemics and neoendemics indeed occur, but we currently have no way to evaluate their relative proportion in floras. Between the two extremes in age of endemics, there are, of course, endemics of intermediate age; they remain narrow endemics, confined to a restricted, local habitat. Recent reviews agree that there are multiple causes of rarity and endemism. Neither genetics, ecology, nor history alone will suffice to explain the origin of endemic taxa. Moreover, the interplay among various casual factors will vary in intensity, depending on the particular taxon under scrutiny. Stebbins (1942) proposes the gene pool/niche interaction theory to explain origin or rarity and endemism. His notion is grounded on the assumption of multiple causation:

"According to this theory, the primary cause of localized of endemic distribution patterns is adaptation to a combination of ecological factors that are themselves localized. Factors of soil texture or chemical composition are the most common but by no means the only ones…… Next to climate and edaphic factors, those inherent in the gene pool of the population are of critical importance. They include the total amount of variability, the amount of variability that can be released at any one time, and the amount of variation that can be generated with respect to those particular characteristics that affect most strongly the establishment of new populations (Stebbins, 1980).

The Geography of Endemism

The narrow or local endemic is the one that best fits the colloquial notion of rarity. However, the term endemism, in its classical biogeographic usage, does not necessarily imply rarity or even small range. Thus, continental or regional endemics need not be, and in fat seldom are, rare. For example *Quercus chrysolepis* and *Pinus sylvestris* are endemic to their respective continents or extensive regions, but they are hardly rare. Good (1974) states that endemism, in the sense of restriction to a floristic province, accounts for more than 90% of the worlds plant species. Further, endemism manifests itself at various taxonomic levels from variety to

higher category. Many of the smaller angiosperm families are endemic (Good 1974) and are found in the tropics and Australasia.

Three primary factors –geographic are, ecological breadth and isolation. Carlquist (1974) describe the distribution of endemics. Endemism is found on all land massess of the world, both continent and islands and in all major biomes. More curious is the well-known fact, first identified by Charles Darwin that the quantity and quality of endemism differ among the major geographic, topographic and vegetation types. For examples, while species number is smaller for island than for areas of comparable size on continents, the islands have higher proportions of endemics. Most oceainc islands are far richer in endemics than isalnd, their endemics would perforce to be narrowly distributed i.e., true rarities.

Endemic plants also are distributed unevenly across the land areas of the world. Some places, like mountains and islands, are rich in endemics, while boreal and arctic regions are relatively poor in them. Many parts of the world are well-known centres of endemics: California, The European Alps, The Mediterrnean region, Alpine regions of Central Africa, New Caledonia, Hawaii, the Cape region of South Africa, and the Sino-Himalayan region. Nonetheless, examples of narrow endemics abound in nearly all floras.

Generally Endemism is a unique phenomenon in the geographical distribution of species. Endemic species are restricted to extremely small ranges, even a single rock out crop. The environmental factors and topography play an important role in speciation. Especially in the Himalayan context, high mountain peaks and deep river valley, together with the environmental factors, play important role in the range restriction/speciation.

12.6 SUMMARY

Module provides the basic information regarding floristic region of the India, Biogeographic zones of India and their extent. Each category wise clarifications and parts covered in each category was also discussed and also highlighted the important vegetations in each category. In this module an attempt was also made to highlight the primitive angiosperm genera of the India. Further diversity of various important groups like legumes, bamboos, orchids, and Important Himalayan genus *Rhododendron* was also discussed in details to let the students know that how much diversity exists in nature. Further attempt was also made highlight the concept of endemism right from the A. De Candolle, to present scenario and also review of concept of Endemism and the geography of endemism.

12.7 GLOSSARY

Angiosperm = Angiosperms are seed-bearing vascular plants. Their reproductive structures are flowers in which the ovules are enclosed in an ovary.

Geography = Geography is a field of science devoted to the study of the lands, the features, the inhabitants, and the phenomena of Earth.

Endemism: a species which is only found in a given region or location and nowhere else in the world.

Alpine Species: Plants grows at higher altitude where generally no tree species are available.
Evergreen: An evergreen is a plant that has leaves throughout the year, always green.
Deciduous: Shedding or losing foliage at the end of the growing season:
Biodiversity: generally refers to the variety and variability of life on Earth.

12.8 SELF ASSESSMENT QUESTIONS

12.8.1 Objective Type Questions:

1-Which of the following terms is used for virgin vegetation which is purely Indian in origin?
(i) Endangered species (ii) Endemic species
(iii) Exotic species (iv) Normal species

2- Which of the following types of natural vegetation have originally come to India from abroad?
(i) Rare species (ii) Endemic Species
(iii) Endangered species (iv) Exotic Species

3- How many Biogeographic regions are present in India
(i) 12 (ii) 10
(iii) 15 (iv) 16

4- Ladakh is mainly located in ……..zone
(i) Island (ii) Gangetic Plain
(iii) Trans Himalaya (iv) Coasts

5- Himalayan Rhododendron belongs to the family……
(i) Ericaceae (ii) Bamboo
(iii) Orchids (iv) Legumes

12.8.1 Answer Keys:

1-(ii); 2-(iv); 3-(ii); 4-(iii); 5-(i)

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12.11 TERMINAL QUESTIONS

1. Define various biogeographic regions along with floral diversity.
2. In what way degree of endemism helps in classifying various biogeographic regions? Support your answer with suitable examples.
3. Discuss the role of Endemism in Indian floristic diversity.
4. Discuss the various biogeographic regions of the India.
5. In your own words, define what the term "endemic" means, in a few sentences. Give one example of an endemic species.
6. Define Endemism. Discuss its importance in context to the taxonomy.