Summary

Flowering plants consist of two major organ systems: Underground root system and aerial root system. Roots perform the functions of anchoring and absorbing nutrients from the soil. However some roots perform additional functions for which they undergo various modifications in shape, form and structure. Tap root continue the growth from the radical which further branches into secondary roots. Adventitious roots arise from different parts of the plant other than radical. Stem helps to display the leaves to get maximum sunlight and positioning flowers and fruits to attract pollination and dispersal agents. Apart from the normal functions the stems are modified to perform various functions such as food storage, perennation and protection. Leaves are exogenous in origin and function as food synthesizing and gaseous exchange sites. Some leaves also perform additional functions for which they are modified in their morphology. Leaves possess vascular tissues in the form of veins which render support to the lamina and help in transport of water, nutrients and food in and out of leaves. Phyllotaxy is the arrangement or distribution of leaves on the stem or its branches in such a way that they receive maximum sunlight to perform photosynthesis.

Activity

1. Collection of medicines prepared from root, stem, leaf of organic plants.
2. Prepare a report of traditional medicines.
3. Classroom level exhibition on Siddha and Ayurvedic medicine prepared from root, leaf, stem.
4. Growing micro greens in class room – project work. (Green seed sprouts)

Evaluation

5FYT1X

1. Roots are
   a. Descending, negatively geotropic, positively phototropic
   b. Descending, positively geotropic, negatively phototropic
   c. Ascending, positively geotropic, negatively phototropic
   d. Ascending, negatively geotropic, positively phototropic
2. When the root is thick and fleshy, but does not take a definite shape, it said to be
   a. Nodulose root
   b. Tubercular root
   c. Moniliform root
   d. Fasciculated root
3. Example for negatively geotropic roots
   a. *Ipomoea, Dahlia*
   b. *Asparagus, Ruellia*
   c. *Vitis, Portulaca*
   d. *Avicennia, Rhizophora*
4. *Curcuma amada, Curcuma domestica, Asparagus, Maranta* are example of
   a. Tuberous root
   b. Beaded root
   c. Moniliform root
   d. Nodulose root
5. *Bryophyllum* and *Dioscorea* are example for
   a. Foliar bud, apical bud
   b. Foliar bud, cauline bud
   c. Cauline bud, apical bud
   d. Cauline bud, foliar bud
6. Why lateral roots are endogenous?

7. Write the similarities and differences between
   1. *Avicennia* and *Trapa*
   2. Banyan and silk cotton
   3. Fusiform and Napiform root
8. How root climbers differ from stem climbers?
9. Compare sympodial branching with monopodial branching.
10. Compare pinnate unicostate and palmate multicostate venation?

ICT Corner

Monocot and Dicot plants

Is plants differ **morphologically**?

→

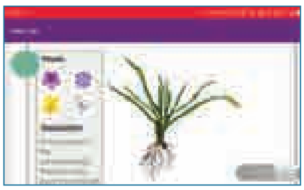
Steps

- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Characteristics of plants
- Click theory to know the basic about Characteristics of plants
- Register yourself with mail-id and create password to access online lab simulations

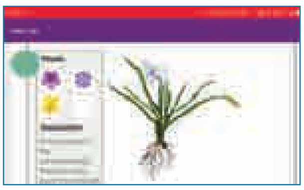
Activity

- Select video and record your observations of different forms of plant group.

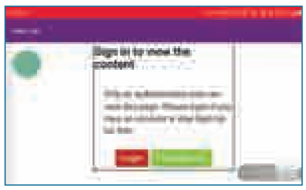
Step 1



Step 2



Step 3



Step 4

URL:

https://play.google.com/store/apps/details?id=in.edu.olabs.olabs&hl=en

B181_11_BOT

* Pictures are indicative only

Chapter 4

Reproductive Morphology

Learning Objectives

The learner will be able to,

- *List the types of inflorescence.*
- *Distinguish racemose and cymose inflorescence*
- *Dissect a flower and explore the parts of a flower.*
- *Compare various types of aestivation.*
- *Explore various types of placentation.*
- *Understands the types of fruits and seeds*

Chapter Outline

4.1. Inflorescence

4.2. Flower

4.3. Accessory parts

4.4. Androecium

4.5. Gynoecium

4.6. Construction of floral diagram and floral formula

4.7. Fruits

4.8. Seed

5G8P3K

Flowers of five types of land in tamil literature.

(a) (b) (c) (d) (e)

a. Kurinji (*Strobilanthus kunthianus*),
b. Mullai (*Jasminum auriculatum*),
c. Marutham (*Lagerstroemia speciosa*),
d. Neithal (*Nymphaea pubescens*),
e. Palai (*Wrightia tinctoria*)

Flowers have been a universal cultural object for millennia. They are an important aesthetic element in everyday life, and have played a highly symbolic role in our culture throughout the ages. Exchange of flowers marks respect, affection, happiness, and love. However, the biological purpose of the flower is very different from the way we use and perceive. Flower helps a plant to reproduce its own kind. This chapter discusses flowers, their arrangement, fruits and seeds which are the reproductive units of a plant.

Floriculture

Floriculture is a branch of Horticulture. It deals with the cultivation of flowers and ornamental crops. The Government of India has identified floriculture as a sunrise industry and accorded the status of 100% export oriented. Agriculture and Processed food product Export Development Authority (APEDA) is responsible for export promotion of agricultural and horticultural products from India.

4.1 Inflorescence

Have you seen a bouquet being used during functions? Group of flowers arranged together on our preference is a bouquet. But an inflorescence is a group of flowers arising from a branched or unbranched axis with a definite pattern. Function of inflorescence is to display the flowers for effective pollination and facilitate seed dispersal. The grouping of flowers in one place gives a better attraction to the visiting pollinators and maximize the energy of the plant.

4.1.1 Types of Inflorescence

Based On Position

Have you ever noticed the inflorescence arising from different positions? Where is the inflorescence present in a plant? Apex or axil?

Based on position of inflorescences, it may be classified into three major types. They are,

Terminal: Inflorescence grows as a part of the terminal shoot. Example: Raceme of *Nerium oleander*

Axillary: Inflorescence present in the axile of the nearest vegetative leaf. Example: *Hibiscus rosa-sinensis*

Cauliflorous: Inflorescence developed directly from a woody trunk. Example: *Theobroma cocoa, Couroupita guianensis*

Observe the inflorescence of Jackfruit and Canon ball tree. Where does it arise?

Figure 4.1: Cauliflorous inflorescence

4.1.2 Based on branching pattern and other characters

Inflorescences may also have classified based on branching, number and arrangement of flowers, and some specialized structures.

I. **Indeterminate (racemose)**
II. **Determinate (cymose)**
III. **Mixed inflorescence**: Inflorescence of some plants show a combination of indeterminate and determinate pattern
IV. **Special inflorescence**: Inflorescence which do not confined to these patterns

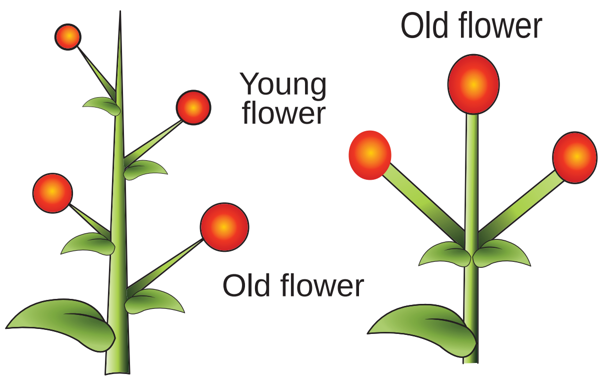


Figure 4.2: (a) Racemose   **Figure 4.2: (b)** Cymose inflorescence

Racemose	Cymose
Main axis of unlimited growth	Main axis of limited growth.
Flowers arranged in an acropetal succession	Flowers arranged in a basipetal succession
Opening of flowers is centripetal	Opening of flowers is centrifugal
Usually the oldest flower at the base of the inflorescence axis.	Usually the oldest flower at the top of the inflorescence axis.

I. Racemose

The central axis of the inflorescence (peduncle) possesses terminal bud which is capable of growing continuously and produce lateral flowers is called **racemose inflorescence**. Old flowers are at the base and younger flowers and buds are towards the apex. It is further divided into 3 types based on growth pattern of main axis.

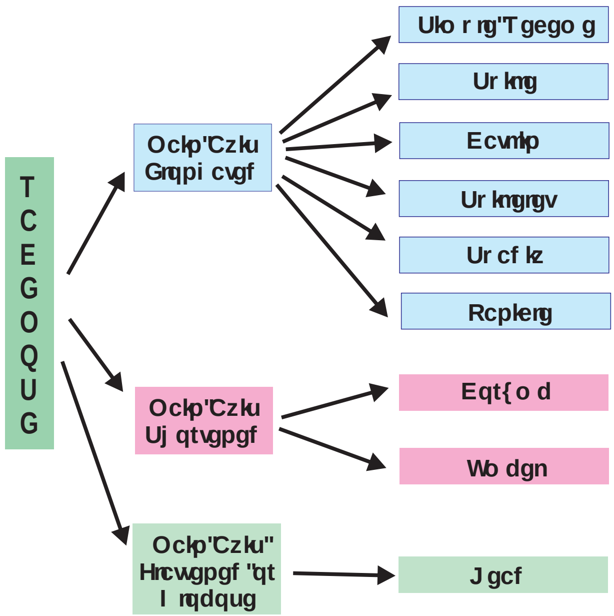


Figure 4.3: Racemose

1. Main axis elongated

The axis of inflorescence is elongated and contains pedicellate or sessile flowers on it. The following types are discussed under main axis elongated type.

a. Simple raceme: The inflorescence with an unbranched main axis bears **pedicellate flowers** in acropetal succession. Example: *Crotalaria retusa*, mustard and radish.

b. Spike: Spike is an unbranched indeterminate inflorescence with **sessile flowers**. Example: *Achyranthes*, *Stachytarpheta*.

c. Spikelet: Literally it is a small spike. The Inflorescence is with

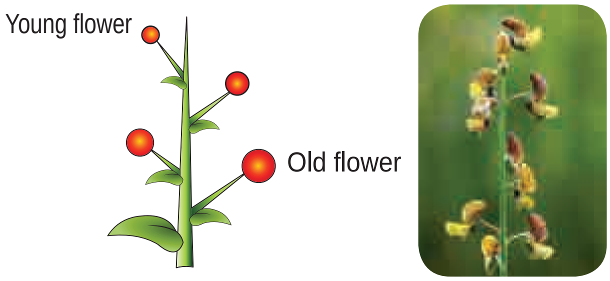


Figure 4.4: (a) diagrammatic, **(b)** Simple raceme

Figure 4.4: (c) diagrammatic, **(d)** Spike

branched central axis. Each branch is a **spikelet**. Sessile flowers are formed in acropetal succession on the axis. A pair of inflorescence bracts called **glumes** is present at the base. Each sessile flower has a **lemma** (bract) and a **palea** (bracteole). Tepals reduced to colourless scaly leaves (lodicule). Each flower has stamen and pistil only. Example: Paddy, Wheat, Barley, *Sorghum*.

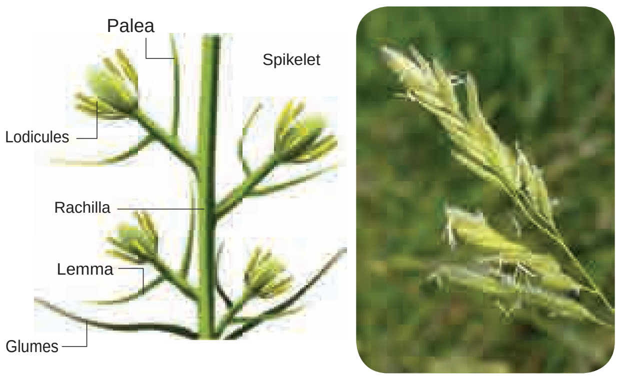


Figure 4.4: (e) diagrammatic, **(f)** Spikelet

d. Catkin: **Pendulous spikes** with a long and drooping axis bearing small unisexual or bisexual flowers. It is also

Figure 4.4: (g) diagrammatic, **(h)** Catkin

called **ament**. Example: *Acalypha hispida*, *Prosopis juliflora*, *Piper nigrum*.

e. Spadix: An inflorescence with a fleshy or thickened central axis that possesses many unisexual sessile flowers in acropetal succession. Usually female flowers are found towards the base and male flowers are found at the apex. Entire

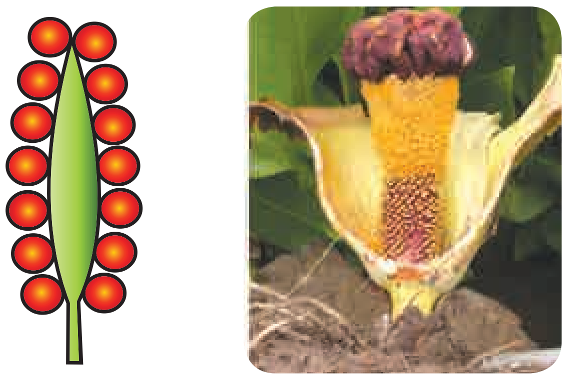


Figure 4.4: (i) diagrammatic, **(j)** Spadix

inflorescence is covered by a brightly coloured or hard bract called a **spathe**. Example: *Amorphophallus*, *Colocasia*, *Phoenix*, *Cocos*.

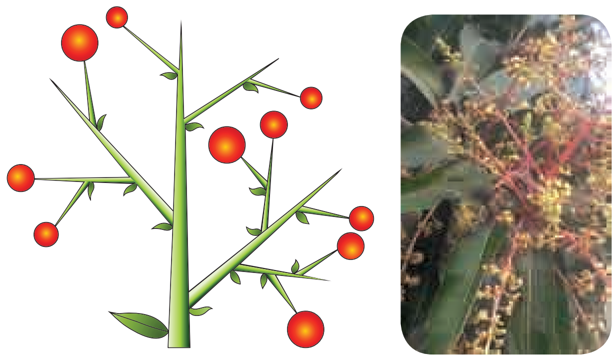


Figure 4.4: (k) diagrammatic, **(l)** Panicle

f. Panicle: A branched raceme is called **panicle**. Example: *Mangifera*, neem, *Delonix regia*. It is also called **Compound raceme** or **raceme of racemes**.

2. Main axis shortened:

Inflorescence with reduced growth of central axis. There are two types namely corymb and umbel.

a. Corymb: An inflorescence with shorter pedicellate flowers at the top and longer pedicellate flowers at the bottom. All flowers appear at the same level to form convex or flat topped racemose inflorescence. Example: *Caesalpinia*. **Compound corymb:** A branched corymb is called **compound corymb**. Example: Cauliflower.

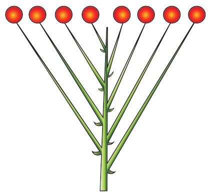


Figure 4.4: (m) Corymb diagrammatic

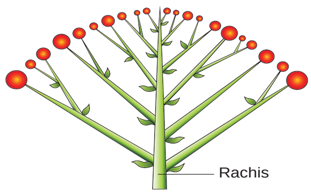


Figure 4.4: (n) Compound corymb diagrammatic

Figure 4.4: (o) Corymb

Figure 4.4: (p) Compound corymb

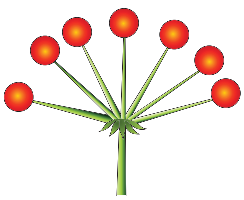


Figure 4.4: (q) Umbel diagrammatic

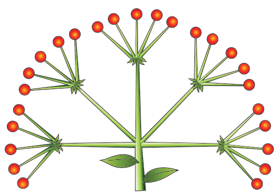


Figure 4.4: (r) Compound umbel diagrammatic

b. Umbel: An inflorescence with indeterminate central axis and pedicellate flowers arise from a common point of peduncle at the apex. Example: *Allium cepa*, *Centella asiatica*, *Memecylon umbellatum*. **Compound umbel**: It is a branched umbel. Each smaller unit is called **umbellule**. Example: *Daucas carota*, *Coriandrum sativum, Memecylon edule*.

Figure 4.4: (s) Umbel

Figure 4.4: (t) Compound umbel

3. Main axis flattened:

The main axis of inflorescence is mostly flattened (convex or concave) or globose. A **head** or **capitulum** is a determinate or indeterminate, group of sessile or sub sessile flowers arising on a receptacle, often subtended by an involucre.

a. Head: A head is a characteristic inflorescence of Asteraceae and is also found in some members of Rubiaceae.

Figure 4.4: (u) *Neolamarkia cadamba* head

Example: *Neolamarkia cadamba*, *Mitragyna parvifolia* and in some members of Fabaceae-Mimosoideae. Example:

Acacia nilotica, *Albizia lebbeck*, *Mimosa pudica* (sensitive plant).

Torus contains two types of florets: 1. Disc floret or tubular floret. 2. Ray floret or ligulate floret.

The flower and inflorescence are subtended by a lateral appendage called bract. In sunflower, you may notice that the whorl of bracts forms a cup like structure beneath mimicking the calyx. Such whorl of bracts is called involucre. A group of bracts present beneath the sub unit of inflorescence is known as Involucel.

Heads are classified into two types.

i. Homogamous head: This type of inflorescence exhibits single kind of florets. Inflorescence has disc florets alone. Example: *Vernonia, Ageratum* or Ray florets alone. Example: *Launaea, Sonchus*.

Figure 4.4: Homogamous head (v) disc floret, (w) ray floret

ii. Heterogamous head: The inflorescence possesses both types of florets. Example: *Helianthus, Tridax*.

Disc florets at the centre of the head are tubular and bisexual whereas the **ray florets** found at the margin of the head which are ligulate pistilate (unisexual).

II. Cymose inflorescence.

Central axis stops growing and ends in a flower, further growth is by means of axillary buds. Old flowers present at apex and young flowers at base

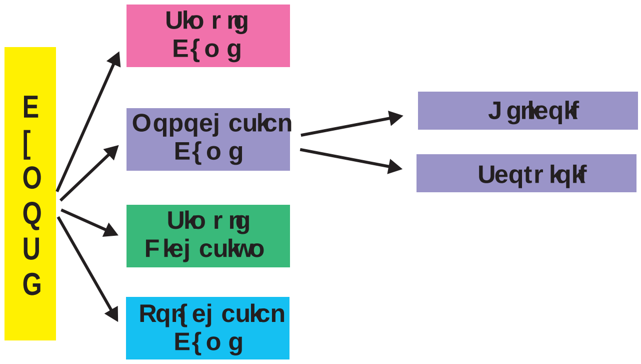


Figure 4.5: Cyme

1. Simple cyme (solitary): Determinate inflorescence consists of a single flower. It may be terminal or axillary. Example: terminal in *Trillium grandiflorum* and axillary in *Hibiscus*.

Figure 4.6: (a) Simple cyme

2. Monochasial Cyme (uniparous): The main axis ends with a flower. From two lateral bracts, only one branch grows further. It may be **helicoid (bostryx)** or **Scorpioid (cincinnus).**

a. Helicoid: Axis develops on only one side and forms a coil structure atleast at the earlier development stage. Example: *Hamelia*, potato.

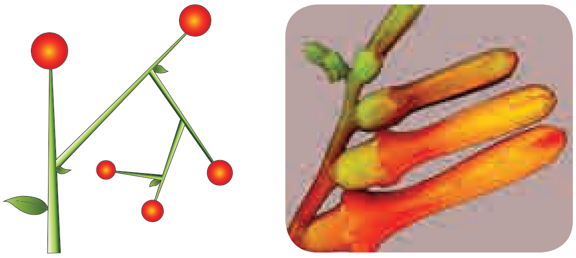


Figure 4.6: (b) diagrammatic,
(c) Monochasial Helicoid

b. Scorpioid: Axis develops on alternate sides and often becomes a coil structure. Example: *Heliotropium*.

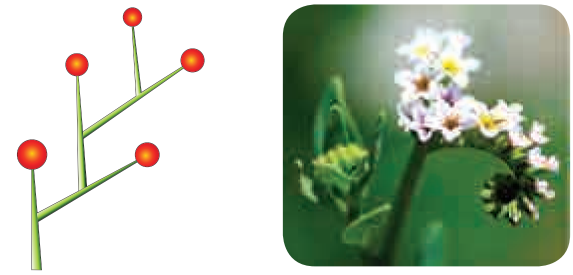


Figure 4.6: (d) diagrammatic,
(e) Monochasial Scorpioid

3. Simple dichasium (Biparous): A central axis ends in a terminal flower; further growth is produced by two lateral buds. Each cymose unit consists of three flowers of which central one is old one. This is **true cyme**. Example: *Jasminum*.

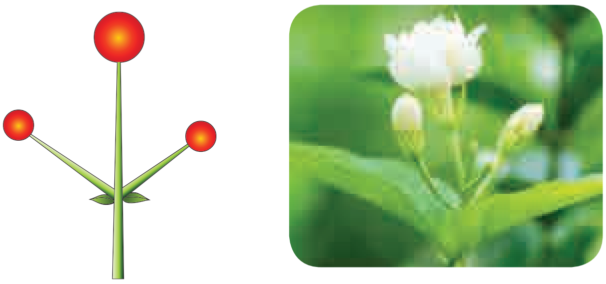


Figure 4.6: (f) diagrammatic,
(g) Simple dichasium

4. **Compound dichasium:** It has many flowers. A terminal old flower develops lateral simple dichasial cymes on both sides. Each compound dichasium consists of seven flowers. Example: *Clerodendron*.

A small,simple dichasium is called **cymule**

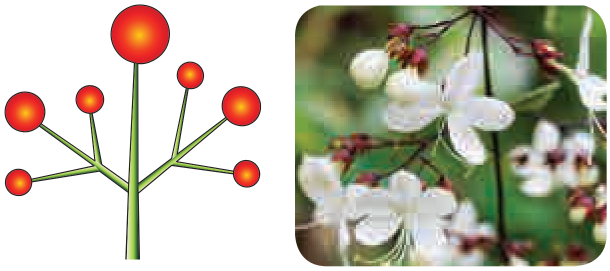


Figure 4.6: (h) diagrammatic,
(i) Compound dichasium

5. Polychasial Cyme (multiparous): The central axis ends with a flower. The lateral axes branches repeatedly. Example: *Nerium*

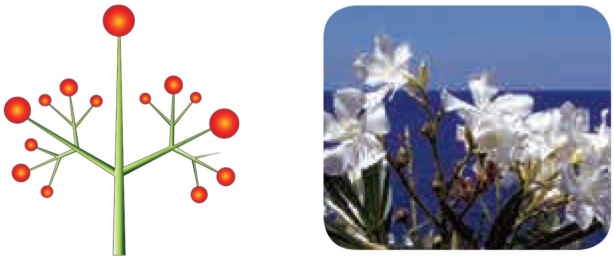
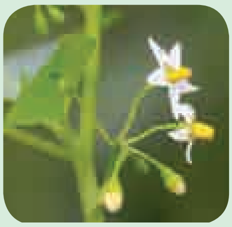


Figure 4.6: (j) diagrammatic,
(k) Polychasial cyme



Sympodial Cyme: In monochasial cyme, successive axes at first develop in a zigzag manner and later it develops into a straight pseudo axis. Example: *Solanum americanum*.

III. Mixed Inflorescence

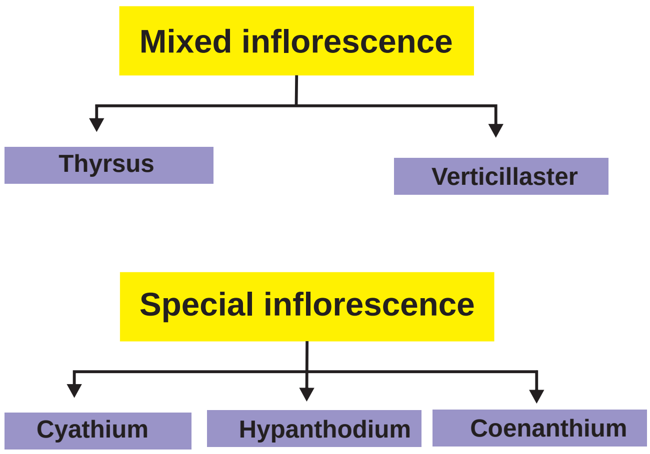


Figure 4.7: Mixed and special inflorescence

Inflorescences in which both racemose and cymose patterns of development occur in a mixed manner. It is of the following two types.

1. Thyrsus: It is a '**Raceme of cymes**'. Indefinite central axis bears lateral pedicellate cymes, (simple or compound dichasia). Example: *Ocimum*, *Anisomeles*.

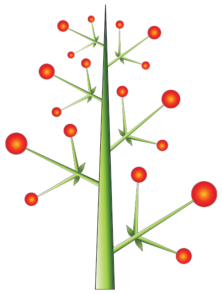


Figure 4.8: (a) diagrammatic, **(b)** Thyrsus

2. Verticil or Verticillaster: Main axis bears two opposite lateral sessile cymes at the axil of the node,each of it produces monochasial scorpioid lateral branches so that flowers are crowded around the node. Example: *Leonotis, Leucas*.

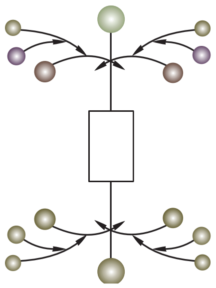


Figure 4.8: (c) diagrammatic, **(d)** Verticillaster

IV. Special Inflorescence

The inflorescences do not show any of the development pattern types are classified under special type of inflorescence.

1. Cyathium: Cyathium inflorescence consists of small unisexual flowers enclosed by a common involucre which mimics a single flower. Male flowers are organised in a scorpioid manner. Female flower is solitary and centrally located on a long pedicel. Male flower is represented only by stamens and female flower is represented only by pistil. Cyathium may be actinomorphic (Example: *Euphorbia*) or zygomorphic (Example: *Pedilanthus*.). Nectar is present in involucre.

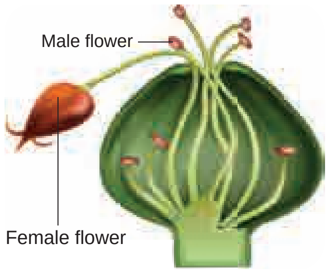


Figure 4.9: (a) diagrammatic, **(b)** Cyathium

2. Hypanthodium: Receptacle is a hollow, globose structure consisting unisexual flowers present on the inner wall of the receptacle. Receptacle is closed except a small opening called **ostiole** which is covered by a series of bracts. Male flowers are present nearer to the ostiole, female and neutral flowers are found in a mixed manner from middle below. Example: *Ficus sp*. (Banyan and Pipal).

3. Coenanthium: Circular disc like fleshy open receptacle that bears pistillate flowers at the center and staminate flowers at the periphery. Example: *Dorstenia*

Figure 4.9: (c) Hypanthodium

Figure 4.9: (d) Coenanthium

4.2 Flower

In a plant, which part would you like the most? Of course, it is a flower, because of its colour and fragrance. The flower is a significant diagnostic feature of angiosperms. It is a modified condensed reproductive shoot. The growth of the flower shoot is determinate.

4.2.1 Whorls of flower

There are two whorls, accessory and essential. Accessory whorl consists of calyx and corolla and essential whorl comprises of androecium and gynoecium.

Flower is said to be **Complete** when it contains all four whorls. An **Incomplete** flower is devoid of one or more whorls.

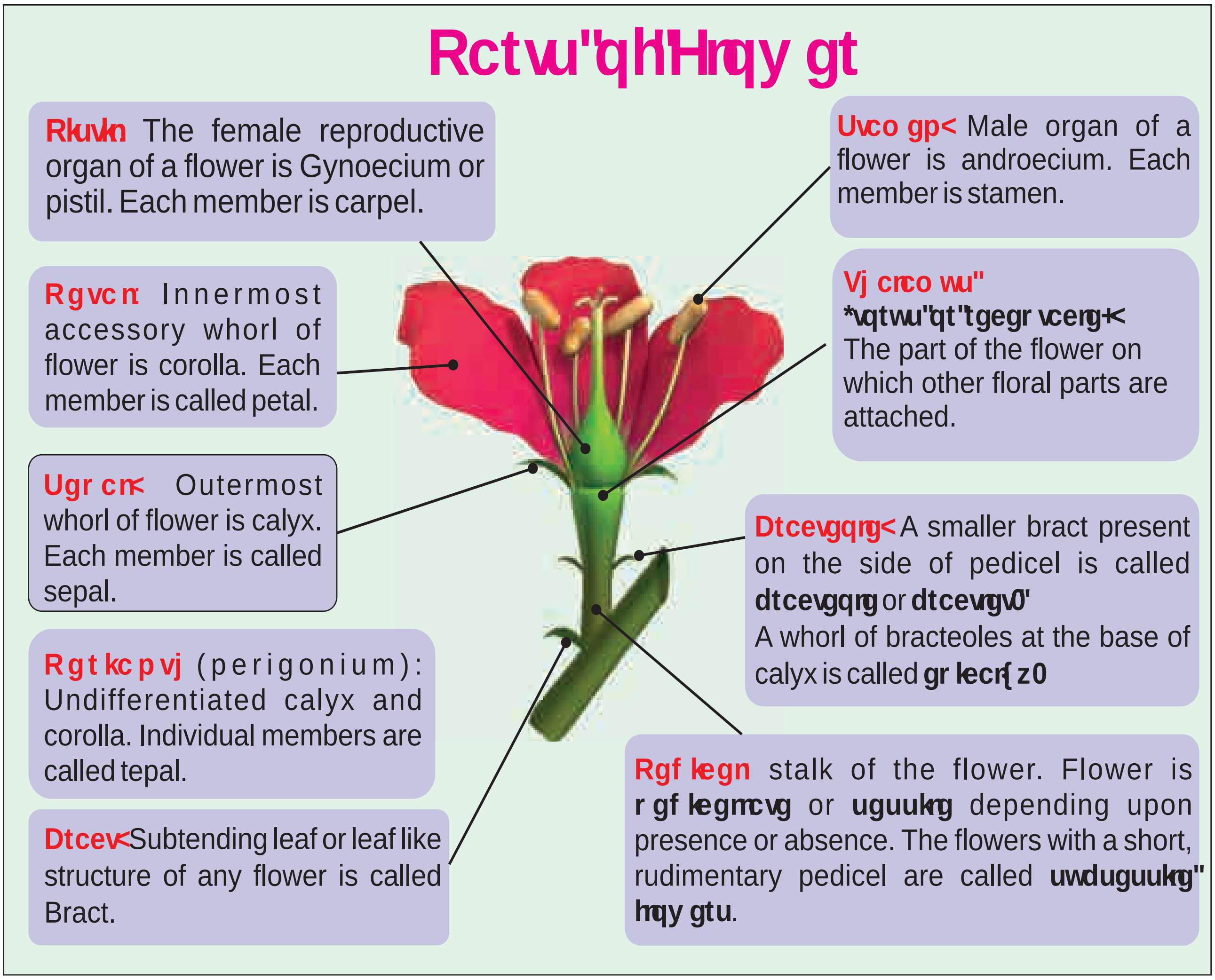


Figure 4.10: Parts of flower

4.2.2 Flower sex

Flower sex refers to the presence or absence of androecium and gynoecium within a flower.

1. Perfect or bisexual(monoclinous): When a flower contains both androecium and gynoecium is called **perfect flower**.

2. Imperfect or unisexual (diclinous): When the flower contains only one of the essential whorls is called **Imperfect flower**. It is of two types:

i) **Staminate flowers**: Flowers only with androecium alone are called **staminate flowers**.

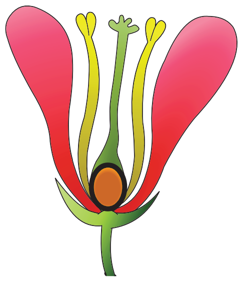


Figure 4.11: (a)
Bisexual flower

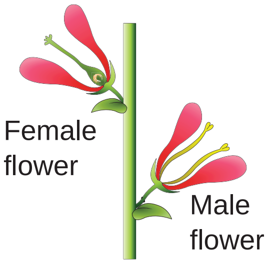


Figure 4.12: (a)
Monoecious

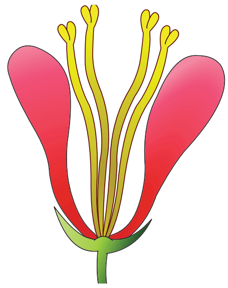


Figure 4.11: (b)
Male flower

Figure 4.12: (b)
Dioecious

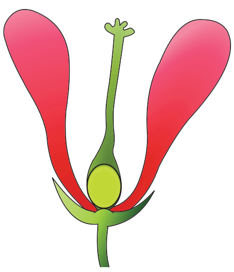


Figure 4.11: (c)
Female flower

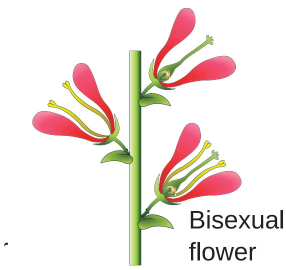


Figure 4.12: (c)
Polygamous

ii) Pistillate flowers: Flowers with only gynoecium are called **pistillate flowers**.

4.2.3 Plant sex

Plant sex refers to the presence and distribution of flowers with different sexes in an individual plant.

1. **Hermaphroditic**: All the flowers of the plant are bisexual.

2. **Monoecious** (*mono*-**one;** *oikos*-**house**): Both male and female flowers are present in the same plant Example: Coconut.

3. **Dioecious** (*di*-**two:** *oikos*-**house**): Male and Female flowers are present on separate plants. Example: Papaya, Palmyra.

Types of Polygamous:

Andromonoecious: A plant with both male flowers and bisexual flowers.

Gynomonoecious: A plant with both pistillate and bisexual flowers.

Polygamomonoecious: A plant with pistillate, staminate and bisexual flowers. It is also called trimonoecious.

Androdioecious: A plant with staminate flowers on one individual and bisexual flower on other individual

Gynodioecious: A plant with pistillate flowers on one individual and bisexual flowers on other individual.

Polygamodioecious: A plant with staminate flowers and bisexual in one individual and pistillate flowers and bisexual flowers in other individual.

Trioecious: A plant with staminate,pistillate and bisexual flowers on different individuals

4. **Polygamous**: The condition in which bisexual and unisexual (staminate/pistillate) flowers occur in a same plant is called **polygamous**. It is of several types. See box. Example: Musa, *Mangifera*.

4.2.4 Flower symmetry

What is the radius of a circle? Cut a paper into round shape, fold it so as to get two equal halves. In how many planes will you get equal halves? In how many planes you can divide a cucumber in two equal halves? A flower is symmetrical when it is divided into equal halves in any plane running through the center. Flower symmetry

Figure 4.13: (a) Actinomorphic

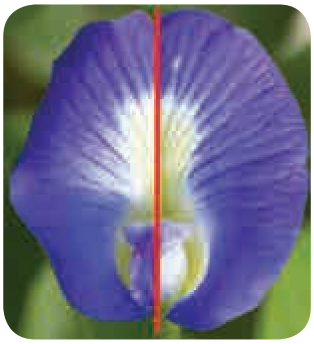


Figure 4.13: (b) Zygomorphic

Figure 4.13: (c) Asymmetric

is an important structural adaptation related to pollination systems.

1. **Actinomorphic (or) radial or polysymmetric**: The flower shows two mirror images when cut in any plane or radius through the centre.Normally there are more than two planes of symmetry. Example: *Hibiscus, Datura*, water lily.

2. Zygomorphic (bilateral symmetry) or monosymmetric: The flower can be divided into equal halves in only one plane. Zygomorphic flower can efficiently transfer pollen grains to visiting pollinators. Example: *Pisum*, Bean, Cassia, Gulmohar, *Salvia, Ocimum*.

3. Asymmetric (amorphic): Flower lacks any plane of symmetry and cannot be divided into equal halves in any plane. Parts of such flowers are twisted. Example: *Canna indica*.

4.3 Accessory organs

4.3.1 Arrangement of whorls

The position of perianth (sepals, petals, tepals) parts relative to one another is called **perianth arrangement**.

1. **Cyclic or whorled:** All the floral parts are arranged in definite whorls. Example: *Brassica*, *Solanum*.

2. **Acyclic or spiral:** The floral parts are arranged in spirals on the elongated fleshy torus. Example: *Magnolia*.

3. **Spirocyclic or hemicyclic**: Some parts are in whorls and others parts are in spirals. Example: *Nymphaea, Annona, Polyalthia*

4.3.2 Cycly

It explains the number of whorls of floral parts. Perianth cycly is the number of whorls of perianth (sepals, petals) parts.

Figure 4.14: (a) Cyclic

Figure 4.14: (b) Acyclic

Figure 4.14: (c) Spirocyclic

1. Uniseriate: It is a single whorl of accessory(non-essential) floral part. It is less common.Example: *Sterculia.*

2. Biseriate (dicyclic): It is with two whorls of accessory floral parts. (outer=lower,inner=upper)It is the most common type of perianth cycly. Example: *Hibiscus.*

3. Multiseriate: (**triseriate,tetraseriate**) More than two whorls of non–essential floral parts.Example: *Chrysanthemum.*

4. Dichlamydeous: A flower is composed of distinct outer calyx and inner corolla.

5. Homochlamydeous: Perianth is undifferentiated into calyx and corolla and composed of similar parts called **tepals**. Most monocots have a homochlamydeous perianth.

6. Achlamydeous: Perianth is absent altogether.Flowers without petals are called **apetalous** and flowers without sepals are called **asepalous.**

Figure 4.15: (a)
Uniseriate

Figure 4.15: (b)
Biseriate

Figure 4.15: (c)
Multiseriate

Figure 4.16: (a)
Dichlamydeous

Figure 4.16: (b)
Homochlamydeous

4.3.3 Merosity

Number of floral parts per whorl is called **merosity**. Perianth merosity is the number of perianth parts per whorl.

1. Isomerous: Presence of same number of perianth parts in different whorls of a flower. (five sepals, five petals). Example: *Hibiscus*.

2. Anisomerous: Each whorl of flower contains different number of members. Example: *Annona*.

3. Bimerous: Floral parts in two or multiples of two. Example: *Ixora*

4. Trimerous: Floral parts in three or multiples of three. Example: *Allium*, Monocots.

5. Tetramerous: Floral parts in four or multiples of four. Example: *Brassica juncea.*

6. Pentamerous: Floral parts in five or multiples of five. Example: *Hibiscus*, Dicots.

4.3.4 Calyx

Calyx protects the flower in bud stage. Outermost whorl of flower is calyx. Unit of calyx is sepal. Normally green in colour.

Figure 4.17: (a)
Trimerous

Figure 4.17: (b)
Tetramerous

Figure 4.17: (c)
Pentamerous

1. Fusion: a. **Aposepalous** (polysepalous or chorisepalous): The flower with distinct sepals. Example: *Brassica, Annona.*

Figure 4.18 (a): Aposepalous

b. Synsepalous: The flower with united or fused sepals. Example: *Hibiscus, Brugmansia.*

Figure 4.18: (b) Synsepalous

2. Duration of floral parts:

What is the green part of brinjal fruit? Have you seen similar to this in any other fruits?

a. Caducous or fugacious calyx: Calyx that withers or falls during the early development stage of flower. Example: *Papaver*.

Figure 4.19: (a)
Caducous bud with sepal

Figure 4.19: (b)
Caducous flower without sepal

b. Deciduous: Calyx that falls after the opening of flower (anthesis) Example: *Nelumbo*.

Figure 4.19: (c) Deciduous

c. Persistant: Calyx that persists and continues to be along with the fruit and forms a cup at the base of the fruit. Example: Brinjal.

d. Accrescent: Calyx that is persistent, grows along with the fruit and encloses the fruit either completely or partially. Example: *Physalis*, Palmyra.

Figure 4.19: (d)
Persistant calyx

Figure 4.19: (e)
Accrescent

3. Shapes of calyx

Have you noticed the shoe flower's calyx? It is bell shaped called **Campanulate**. The fruiting calyx is urn shaped in *Withania* and it is called **urceolate**. In *Datura* calyx is tube like and it is known as **tubular**. Two lipped calyx is present *in Ocimum*. Sometimes calyx is coloured and called **petaloid.** Example: *Saraca*, *Sterculia*. Calyx is distinctly leafy,large and often yellow or orange coloured sometimes white as in *Mussaenda*. It is modified into hair like structure or scaly called **pappus** as in *Tridax* of Compositae.

Figure 4.20: (c)
Mussaenda

Figure 4.20: (a)
Companulate

Figure 4.20: (b)
Pappus

What is the use of pappus ?

4.3.5 Corolla

Corolla is the most attractive part in majority of the flowers and is usually brightly coloured. Corolla helps to display the flower and attracts the pollinators.

1. Fusion:

a. **Apopetalous (polypetalous, choripetalous)**: Petals are distinct. Example: *Hibiscus*.

b. **Sympetalous (gamopetalous)**: Petals are fused. Example: *Datura*.

2. Shapes of corolla

I. Apopetalous Actinomorphic

1. Cruciform: Four petals arranged in the form of a cross. Example: *Brassica*, mustard, radish, cauliflower.

2. Caryophyllaceous: Five petals with long claws with limb at right angles to the claw. Example: Caryophyllaceae. *Dianthus*.

3. Rosaceous: Five to many sessile or minutely clawed petals with radiating limbs. Example: Rose, Tea.

Figure 4.21: (a)
Cruciform

Figure 4.21: (b)
Caryophyllaceous

II. Apopetalous Zygomorphic

1. Papilionaceous:

Made up of five distinct petals organized in a butterfly shape. Corolla has three types of petals. One usually large posterior petal called **vexillum**(standard)two lateral petals-wings **(alae**) and two anterior sympetalous petals called **carina**. Example: *Clitoria ternatea*, Pea, Bean.

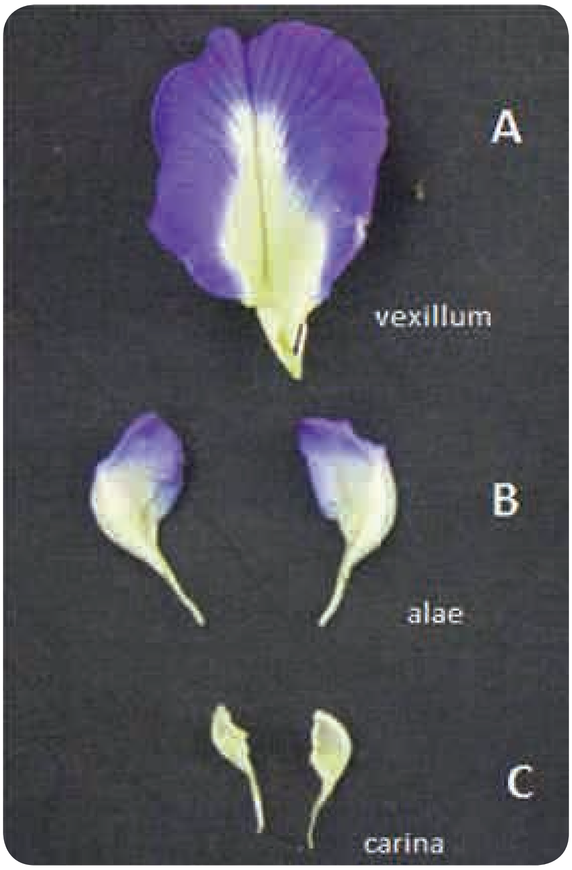


Figure 4.21: (c) Papilionaceous

Figure 4.21: (d) Campanulate

Figure 4.21: (e) Infundibuliform

Figure 4.21: (f) Rotate

Figure 4.21: (g) Salvershaped

Apopetalous		Sympetalous	
Actinomorphic	Zygomorphic	Actinomorphic	Zygomorphic

III. Sympetalous Actinomorphic

1. Tubular:

Petals united to form a narrow tubular structure with very short limbs. Example: Disc floret of sunflower.

2. Campanulate:

Petals fused to form a bell-shaped corolla. Example: *Physalis*,*Cucurbita maxima*, *Campanula*.

3. Infundibuliform:

Petals fused to form funnel-shaped corolla. Tube gradually widens into limbs. Example: *Datura*, *Ipomoea*.

4. Rotate:

Petals fused to form a wheel shaped corolla with very short tube and a spreading circular limb. Example: brinjal, *Evolvulus*

5. Salver shaped or **Hypocrateriform**;

Petals fused to form a long narrow tube with spreading limbs. Example: *Catharanthus*, *Ixora*, *Tabernaemontana*

6. Urceolate:

Petals fused to form urn-shaped or pot-shaped corolla.Example: *Bryophyllum calycinum*, *Diospyros*.

Figure 4.21: (h) Urceolate

IV. Sympetalous Zygomorphic

1. Bilabiate:

Corolla with two lips. Example: *Ocimum,Leucas,Adhatoda*.

Tubular corolla with a single strap-shaped limb. Example: Ray floret of *Helianthus*

2. Personate:

Corolla made up of two lips with the upper arched and the lower protruding into the corolla throat. Example: *Antirrhinum,Linaria*.

3. Ligulate:

Tubular corolla with a single strap-shaped limb. Example: Ray floret of *Helianthus*.

Figure 4.21: (i) Bilabiate

Figure 4.21: (j) Personate

4.3.6 Perianth

Can you recall the term homochlamydeous? undifferentiated calyx and corolla in a flower is called **perianth**. Each member is called **tepal**. If the tepals are distinct they are called **Apotepalous** (Polyphyllous). Example: *Allium sativum*. Fused tepals are called **Syntepalous**. (Gamophyllous). Example: *Allium cepa*.

C0'Xcnxcvg<'Margins of sepals or petals do not overlap but just touch each other.
Example: Calyx in members of Malvaceae, *Calotropis, Annona.*

B. **Vy kuvgf " qt" eqpxqnwvg" qt" eqpvqtvgf <**
One margin of each petal or sepal overlapping on the other petal
Example:Petals of chinarose

Cguvkxcvkqp"
Arrangement of sepals and petals in the flower bud.

C. Imbricate: Sepals and petals irregularly overlap on each other; one member of the whorl is exterior, one interior and rest of the three having one margin exterior and the other interior.
Example: *Cassia*, *Delonix*
There are 3 types.
1.Ascendingly imbricate.
2.Quincuncial.
3.Vexillary.

D. Quincuncial: It is a type of imbricate aestivation in which two petals are external and two internal and one petal with one margin internal and the other margin external.
Example:Guava,calyx of *Ipomoea*, *Catharanthus*.

E. Vexillary: Large posterior petals both margins overlap lateral petals.
Lateral petals other margin overlaps anterior petals
Example: Pea,bean.

4.3.7 Aestivation: Arrangement of sepals and petals in the flower bud is said to be aestivation.

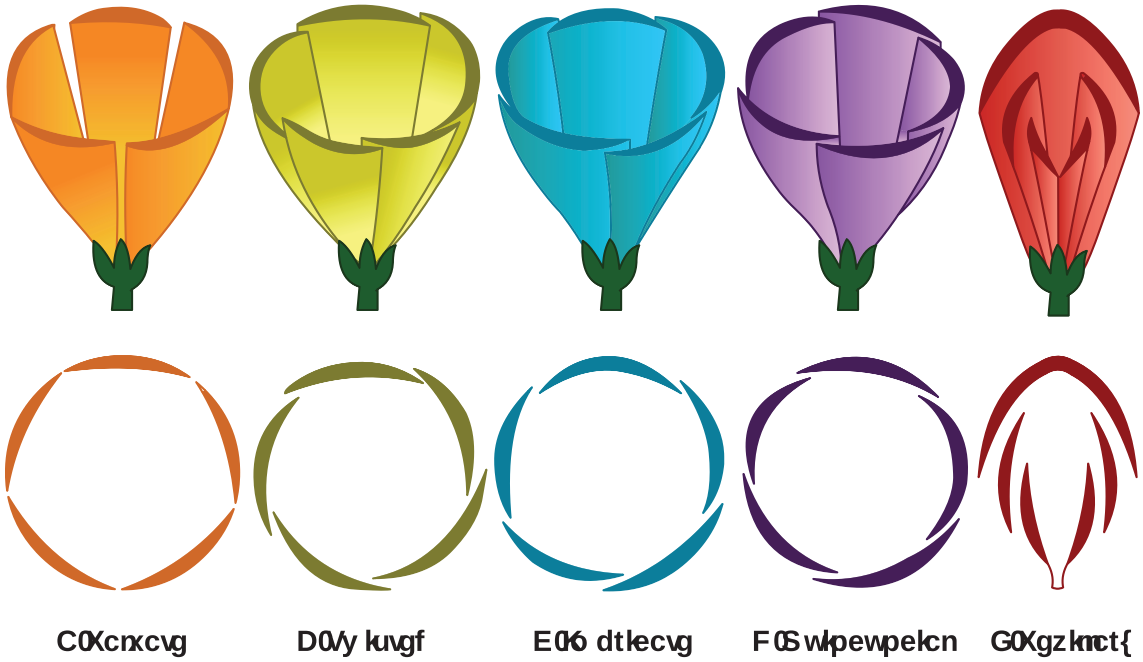


Figure 4.22: Aestivation

Lodicule: Reduced scale like perianth in the members of Poaceae is called lodicule.

Ikebana

A creative mind can earn more money in floral art industry. Ikebana is a Japanese form of floral art. Ikebana is all about flowers arranged in angles. Floral art is not just an arrangement of flowers, but it is also about coordinating colours and texture. Ikebana experts are needed for marriages, other functions and in star hotels.

Essential Parts of Flower

4.4 Androecium

Androecium: Third whorl of flower is the male reproductive part of the flower. It is composed of stamens(microsporophylls). Each Stamen consist of 3 parts,

a. Filament b. Anther c. Connective

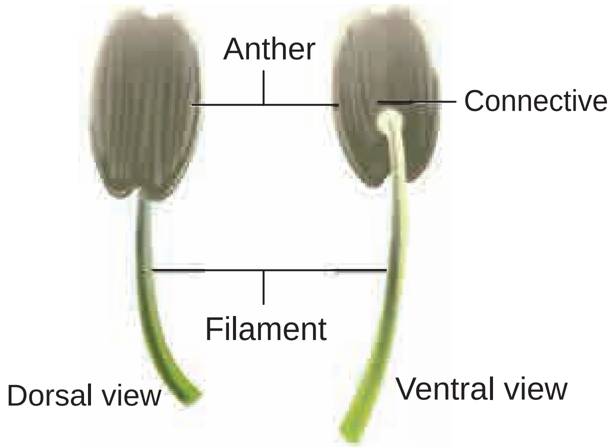


Figure 4.23: Stamen

Anther: Upper swollen part with microsporangia.

Filament: Stalk of stamen

Connective: Tissue connecting anther lobes with filament

Anther typically contains two compartments called **thecae** (singular theca). Each theca consists of two microsporangia. Two microsporangia fused to form a **locule.**

Sterile stamens are called **Staminodes**. Example: *Cassia*. **Distinct:** stamens which do not fuse to one another. **Free:** stamens which do not fuse with other parts of flower. **Apostemonous:** flowers with stamens that are free and distinct.

4.4.1 Fusion of stamens: Refers to the stamens fusing among themselves or with other parts of flower. Two types.

1. Connation and 2. Adnation

1. Connation: Refers to the fusion of stamens among themselves. It is of 3 types. **a.** Adelphy. **b.** Syngenecious. **c.** Synandrous.

a. Adelphy: Filaments connate into one or more bundles but anthers are free. It may be the following types.

1. Monadelphous: Filaments of stamens connate into a single bundle. Example: malvaceae (chinarose,cotton).

Figure 4.24: (a)
Monadelphous

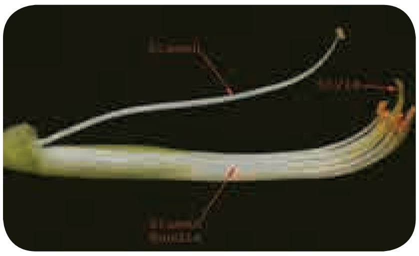


Figure 4.24: (b)
Diadelphous

Figure 4.24: (c)
Polyadelphous

2. Diadelphous: Filaments of stamens connate into two bundles. Example: Fabaceae, pea.

3. Polyadelphous: Filaments connate into many bundles. Example: *Citrus*, *Bombax*

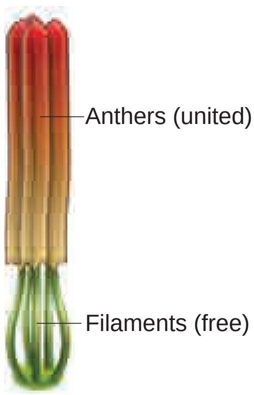


Figure 4.24: (d)
Syngenesious

Figure 4.24: (e)
Synandrous

b. Syngenesious: Anthers connate, filaments free. Example: Asteraceae.

c. Synandrous: Filaments and anthers are completely fused. Example: *Coccinea*.

2. Adnation: Refers to the fusion of stamens with other floral parts. **Epipetalous** (petalostemonous): Stamens are adnate to petals .Example: brinjal,*Datura*.

a. Episepalous: stamens are adnate to sepals. Example: *Grevillea* (Silver oak)

b. Epitepalous (epiphyllous): stamens are adnate to tepals. Example: *Asphodelus*, *Asparagus*.

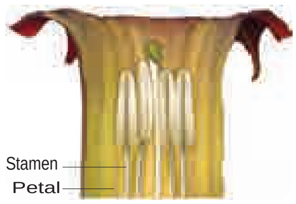


Figure 4.25: (a)
Epipetalous

c. Gynostegium:Connation product of stamens and stigma is called **gynostegium**. Example: *Calotropis* and Orchidaceae.

d. Pollinium: Pollen grains are fused together as a single mass

Figure 4.25: (b)
Gynostegium

Figure 4.25: (c)
Pollinium

4.4.2 Arrangement of stamens relate to length of stamens:

1. **Didynamous (di-two, dynamis-strength)**: Four stamens in which two with long filaments and two with short filaments. Example: Lamiaceae, *Ocimum*. If all four stamens are in two equal pairs then the condition is called **didynamous.**

Figure 4.26: (a)
Didynamous

2. **Tetradynamous(tetra-four)**: Six stamens of which four with long filaments and two with short filaments. Example: Brassicaceae, (*Brassica*).

3. **Heterostemonous**: stamens are of different lengths in the same flower. Example: *Cassia, Ipomoea.*

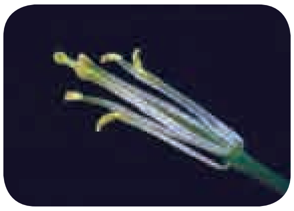


Figure 4.26: (b)
Tetradynamous

Figure 4.26: (c)
Heterostemonous

4.4.3 Stamen insertion

1.Inserted: Shorter than the corolla tube and included within. Example: *Datura*.

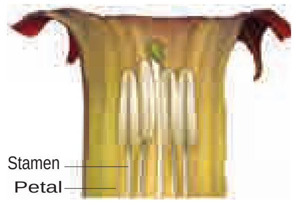


Figure 4.27: (a)
Inserted

Figure 4.27: (b)
Exserted

2.Exserted:Longer than the corolla tube and project out.Example: *Mimosa, Acacia arabica*

The number of whorls of stamens present in a flower is called **stamen** cycly. Two major types are 1.**uniseriate**,a single whorl of stamens and 2.**biseriate**,two whorls of stamens.

4.4.4 Anther types

1. **Monothecal**: One lobe with two microsporangia. They are kidney shaped in a cross section. Example: Malvaceae

Figure 4.28: (a)
Monothecal

Figure 4.28: (b)
Dithecal

Some other types: **a) Haplostemonous**: stamens are uniseriate and equal in number to the petals and opposite the sepals (antisepalous)

b) Obhaplostemonous: Stamens are uniseriate, number equal to petals and opposite the petals (antipetalous)

c) Diplostemonous: Stamens are biseriate, outer antisepalous, inner antipetalous. Example: *Murraya*.

d) Obdiplostemonous: Stamens are biseriate, outer antipetalous, inner antisepalous. Example: Caryophyllaceae.

e) Polystemonous: Numerous stamens are normally many more than the number of petals.

c d e

2. Dithecal: It is a typical type,having two lobes with four microsporangia.They are butterfly shaped in cross section. Example: solanaceae.

4.4.5 Anther attachment

1. Basifixed:(Innate) Base of anther is attached to the tip of filament. Example: *Brassica, Datura*.

2. Dorsifixed: Apex of filament is attached to the dorsal side of the anther. Example: *Citrus, Hibiscus*.

3. Versatile: Filament is attached to the anther at midpoint. Example: Grasses.

4. Adnate: Filament is continued from the base to the apex of anther. Example: *Verbena, Ranunculus, Nelumbo*

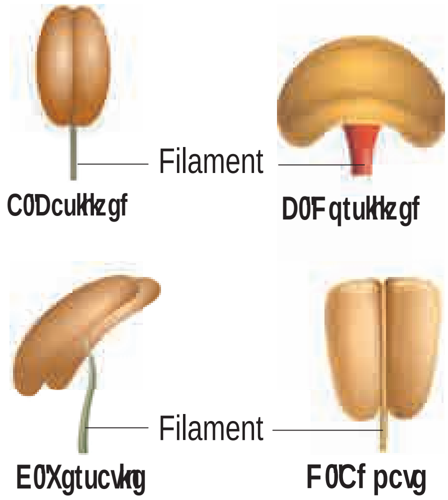


Figure 4.29: Anther attachment

4.4.6 Anther dehiscence

It refers to opening of anther to disperse pollen grains.

1. Longitudinal: Anther dehisces along a suture parallel to long axis of each anther lobe. Example: *Datura*, chinarose, cotton.

2. Transverse: Anther dehisces at right angles to the long axis of anther lobe. Example: Malvaceae.

3. Poricidal: Anther dehisces through pores at one end of the thecae. Example: Ericaceae, *Solanum*, potato, brinjal, *Cassia*.

4. Valvular: Anther dehisces through a pore covered by a flap of tissue. Example: Lauraceae, *Cinnamomum*.

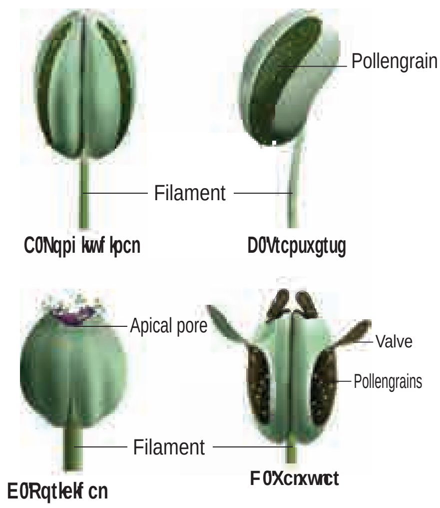


Figure 4.30: Anther dehiscence

4.4.7 Anther dehiscing direction

It shows the position of anther opening relative to the anther of the flower.

1.Introrse: Anther dehisces towards the center of the flower. Example: *Dianthus*.

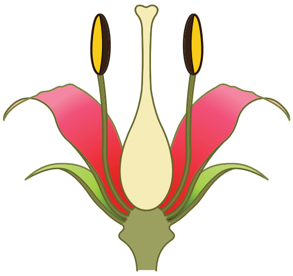


Figure 4.31: (a)
Introrse

Figure 4.31: (b)
Extrorse

2. Extrorse: Anther dehisces towards periphery of the flower. Example: *Argemone*.

4.5 Gynoecium

Gynoecium or pistil is the female reproductive part of the flower.

A pistil consists of an expanded basal portion called the ovary, an elongated section called a **style** and an apical structure that receives pollen called a **stigma**. Ovary with stipe is called **stipitate ovary.**

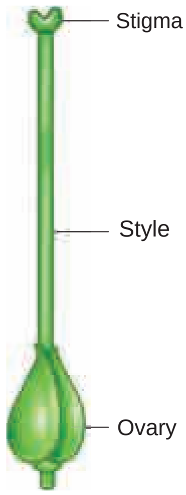


Figure 4.32:
Pistil

Carpel: They are components of a gynoecium. Gynoecium is made of one or more carpels. Carpels may be distinct or connate.

4.5.1 Number of carpel

Unicarpellary	Bicarpellary	Tricarpellary	Tetracarpellary	Multicarpellary
(monocarpellary) Single carpel Example: Fabaceae	Two carpels Example: Rubiaceae	Three carpels Example: Cucurbitaceae	Four carpels Example: Lamiaceae.	Many carpels Example: Nymphaeceae.

4.5.2 Fusion of carpels

It is an important systematic character. Apocarpous gynoecium is generally thought to be ancestral condition in Angiosperms.

Apocarpous	Syncarpous
A pistil contains two or more distinct carpels. Example: *Annona*.	A pistil contains two or more carpels which are connate. Example: Citrus, tomato.

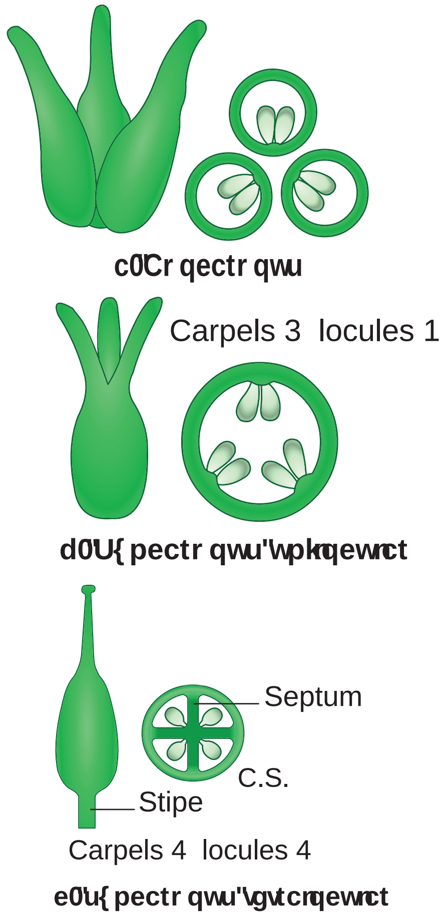


Figure 4.33: Fusion of carpels

4.5.3 Number of locules

Ovary bears ovules on a specialized tissue called **placenta**. A **septum** is a crosswall or partition of ovary. The walls of ovary and septa form a cavity called **locule**.

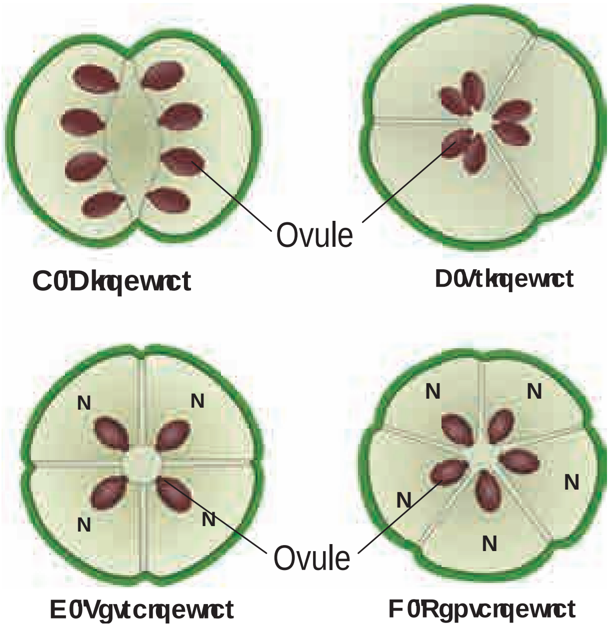


Figure 4.34: Locules

Number of locules

Unilocular	**Bilocular**	**Trilocular**
Ovary with one chamber Example: pea, groundnut.	Ovary with two chambers Example: mustard, *Crossandra*.	Ovary with three chambers Example: banana, *Euphorbia*.

Like that tetralocular and pentalocular ovaries are present according to the locule numbers four and five. More than one locule ovaries are called **plurilocular.**

4.5.4 Style and stigma

1. Style is a stalk like structure of a pistil connecting ovary and stigma.

a. Simple: Single unbranched style. Example: *Hibiscus*.

b. Bifid: A style branched into two. Example: Asteraceae

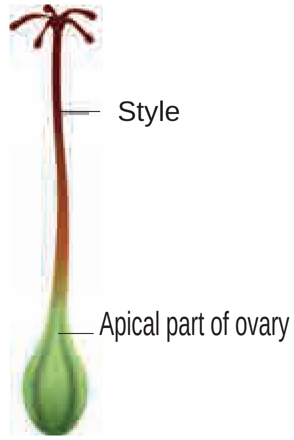


Figure 4.35: (a) Simple style

Figure 4.35: (b) Bifid style

c. Gynobasic style: arising from base of the ovary. Example: Lamiaceae (*Ocimum*), characteristic of Boraginaceae.

d. Lateral style: Style arises from the side of ovary. Example: *Mangifera*.

Figure 4.35: (c) Gynobasic style, **(d)** Lateral style

2. Stigma: A stigma is a structure present at the tip of a pistil which receives the pollen grains.

a. Discoid: A disk-shaped stigma is called **discoid**.

b. Capitate: Stigma appearing like a head. Example: *Alchemilla*

c. Globose: Stigma is spherical in shape is called **globose**.

d. Plumose stigma: Stigma feathery which is unbranched or branched as in Asteraceae, Poaceae.

3. Pistillode: A reduced sterile pistil. Example: ray floret of head infloresence in *Helianthus*.

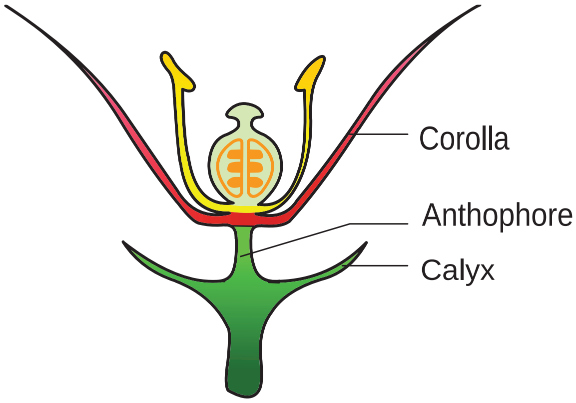


Figure 4.36: (a) Anthophore

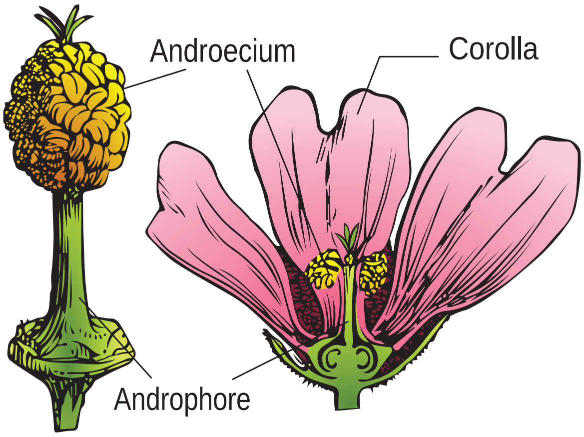


Figure 4.36: (b) Androphore

4.5.5 Extension of the condensed internode of the receptacle

1. Anthophore:The internodal elongation between calyx and corolla. Example: caryophyllaceae (*Silene conoidea*)

2. Androphore: The internodal elongation between the corolla and androecium. Example: *Grewia*.

3. Gynophore: The internodal elongation between androecium and gynoecium. Example: *Capparis*.

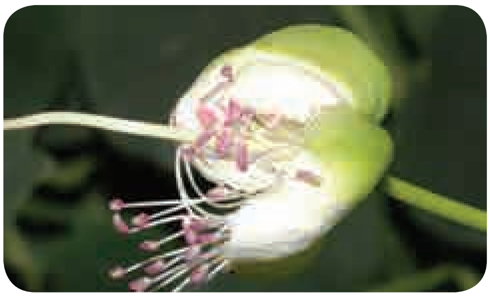


Figure 4.36: (c) Gynophore

Saffron flower stigma is costly. One gram of saffron is around Rs.300. In traditional texts ascribe a few medicinal properties to saffron stigma.It is also used as a flavoring substance.

4. Gynandrophore or **Androgynophore**: The unified internodal elongation between corolla and androecium and androecium and gynoecium. Example: *Gynandropsis*.

Figure 4.36: (d) Androgynophore

4.5.6 Ovary position

Hypanthium: (staminal disk); a fleshy, elevated often nectariferous cup like thalamus.

The position or attachment of ovary relative to the other floral parts. It may be classified into

1. **Superior ovary:** It is the ovary with the sepals, petals and stamens attached at the base of the ovary.

2. **Inferior ovary:** It is the ovary with the sepals, petals and stamens attached at the apex of the ovary.

3. **Half-inferior ovary:** It is the ovary with the sepals, petals and stamens or hypanthium attached near the middle of the ovary.

Hypogynous: The term is used for sepals, petals and stamens attached at the base of a superior ovary. Example: Malvaceae	**Epihypogynous:** The term is used for sepals, petals and stamens attached at the middle of the ovary (half-inferior). Example: Fabaceae, Rosaceae.	**Epigynous:** The term is used for sepals, petals and stamens attached at the tip of an inferior ovary. Example: cucumber, apple, Asteraceae.
5GRG6V	**Perigynous:** The term is used for a hypanthium attached at the base of a superior ovary.	**Epiperigynous:** The term is used for hypanthium attached at the apex of an inferior ovary.

4.5.7 Perianth / androecial position on thalamus:

It describes placement of the perianth and androecium relative to the ovary and to a hypanthium, if present.

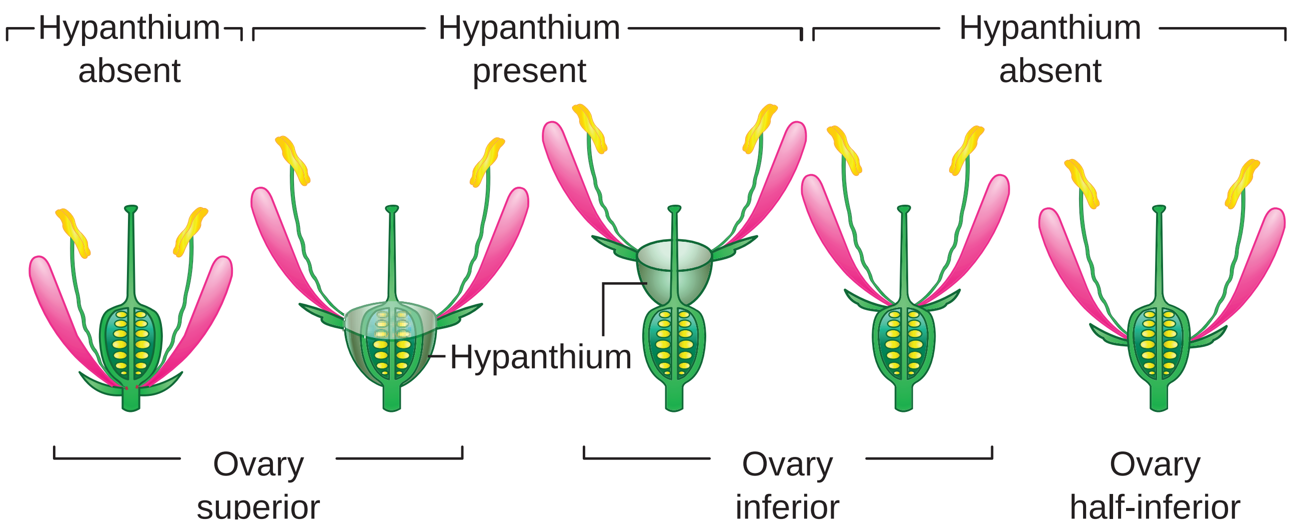


Figure 4.37: Perianth / androecial position on thalamus

Parietal axile: It is with the placentae at the junction of the septum and ovary wall of a two or more locular ovary. Example: Brassicaceae.	**Apical pendulous** It is with placenta at the top of ovary. Ovules hanging down.
Parietal septate: It is with placentae on the inner ovary walls but within septate locules as in Aizoaceae.	**Apical axile** It is with two or more placentae at the top of a septate ovary. Example: Apiaceae.

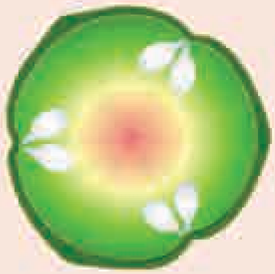
Placentation

The mode of distribution of placenta inside the ovary

Marginal
It is with the placentae along the margin of a unicarpellate ovary.
Example:Fabaceae.

Axile
The placentae arises from the column in a compound ovary with septa.
Example:
Hibiscus,tomato lemon

Superficial
Ovules arise from the surface of the septa.
Example:
Nymphaeaceae



Parietal
It is the placentae on the ovary walls or upon intruding partitions of a unilocular, compound Ovary.
Example:
Mustard, *Argemone*, cucumber.

Free-central
It is with the placentae along the column in a compound ovary without septa.
Example:
Caryophyllaceae, *Dianthus*, Primrose

Basal
It is the placenta at the base of the ovary.
Example: Sunflower (asteraceae) Marigold

4.6 Construction of floral diagram and floral formula

A floral formula is a simple way to explain the salient features of a flower. The floral diagram is a representation of the cross section of the flower. It represents floral whorls arranged as viewed from above. Floral diagram shows the number and arrangement of bract, bracteoles and floral parts, fusion, overlapping and placentation.

The branch that bears the flower is called **mother axis**.

The side of the flower facing the mother axis is called **posterior side**. The side facing the bract is the anterior side.

Floral formula and floral diagram of

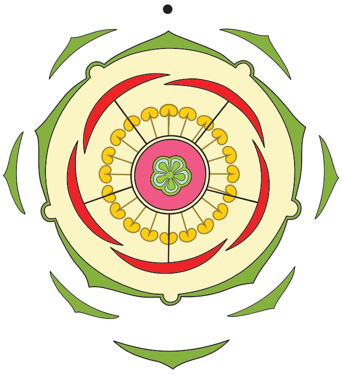


Figure 4.38: (a) *Hibiscus rosa-sinensis*

Br Brl $\oplus$ ⚥ $K_{(5)} \; \overset{\frown}{C_5 \; A_{(\infty)}} \; \underline{G}_{(5)}$

The members of different floral whorls are shown arranged in concentric rings.

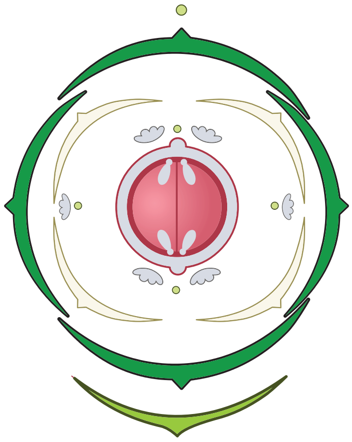


Figure 4.38: (b) *Brassica compestris*

Br Brl $\oplus$ ⚥ $K_{2+2} \; C_{2+2} \; A_{2+4} \; \underline{G}_{(2)}$

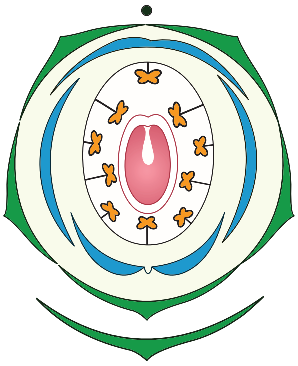


Figure 4.38: (c) *Crotalaria juncea*

Br Ebrl % ⚥ $K_{(5)} \; C_{1+2+(2)} \; A_{5+5} \; G^{-}_{(1)}$

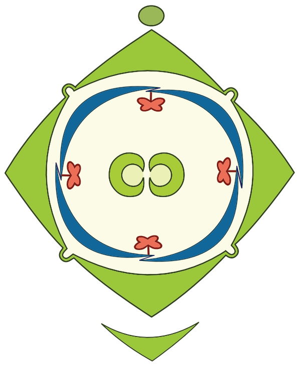


Figure 4.38: (d) *Ixora coccinea*

Br Brl $\oplus$ ⚥ $K_{(4)} \overset{\frown}{C_{(4)} \; A_4} \; \underline{G}_{(2)}$

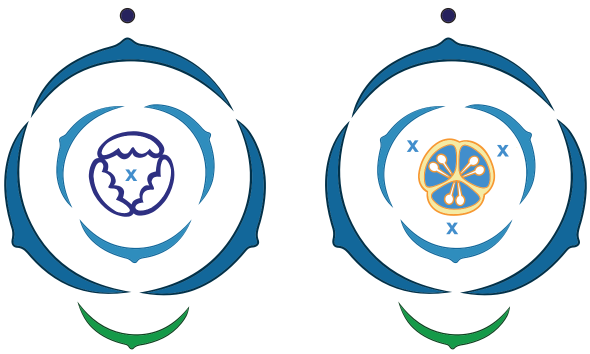


Figure 4.38: (e) *Phyllanthus amarus*

Br Ebrl $\oplus$ ♂ $P_{3+3} \; A_{(3)} \; G_0$

Br Ebrl $\oplus$ ♀ $P_{3+3} A_0 \; \underline{G}_{(3)}$

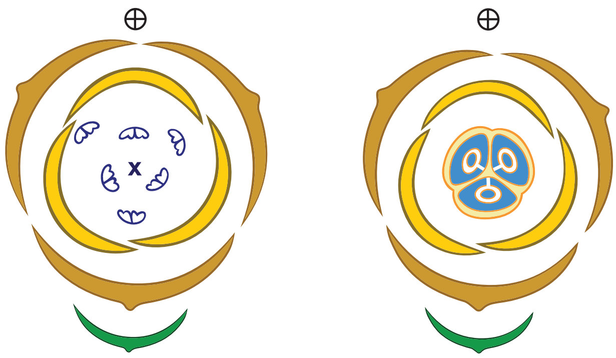


Figure 4.38: (f) *Cocos nucifera*

Br Brl $\oplus$ ♂ $P_{(3)+3} A_{3+3} \; G_0$

Br Brl $\oplus$ ♀ $P_{(3)+3} A_0 \underline{G}_{(3)}$

Br : Bracteate.

Ebr : Ebracteate

Brl : Bracteolate

Ebrl : Ebracteolate

⊕ : Actinomorphic flower or polysymmetric

% : Zygomorphic or monosymmetric

♂ : Staminate

♀ : Pistillate

⚥ : Bisexual flower

K : Calyx, **K_5** five sepals, **aposepalous**, **$K_{(5)}$** five sepals **synsepalous**.

C : Corolla, C_5 five petals ,**apopetalous**, $C_{(5)}$ five petals **sympetalous** **$C_{(2+3)}$** corolla bilabiate with upper lib two lobes.

A : Androecium A_3 three stamens free, A_2+_2, Stamens 4, two whorls (**didynamous**) each whorl two stamens (free)

$A_{(9)+1}$ – stamens ten, two bundles (**diadelphous**) 9 stamens unite to one bundle,1 another bundle.

$\overset{\frown}{C_5A_5}$—Epipetalous represents by an arc.

A^0 :**Staminode**(sterile stamen)

G. Gynoecium or pistil – **G_2** – Carpels two, free (**apocarpous**)

$G_{(3)}$ – Carpels three, united (**syncarpous**)

G_0 – pistillode (sterile carpel)

$\underline{G}$ – superior ovary, the line under G

$\overline{G}$ inferior ovary, the line above G

G– – semi-inferior ovary, the line before middle of G.

∞ – Indefinite number of units

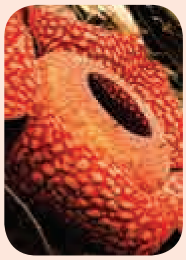
DO YOU KNOW?

Can you imagine a man sized inflorescence? The largest unbranched inflorescence is a spadix of titan arum(*Amorphophallus titanium*).It can grow upto 6 feet.Though the male and female flowers are very small,they combine to form a huge spadix surrounded by a huge modified leaf and appear like a single flower.The largest inflorescence of any flowering plant is *Corypha umbraculifera*.It grows upto 6 to 8 feet.

Do you accept a flower weigh as much as 11 kg.The largest single flower of giant refflesia(*Refflesia arnoldi*)grows up to 3 feet and weighs as much.

Titan arum

Corypha



Refflesia

4.7 Fruits

We know about several kinds of fruits, but by botanical study we will be surprised to know the types of fruits and how they are produced by plants. Fruits are the products of pollination and fertilization, usually containing seeds inside. In common person perpective a fruit may be defined as an edible product of the entire gynoecium and any floral part which is sweet, juicy or fleshy, coloured, aromatic and enclosing seeds. However the fruit is a fertilized and ripened ovary. The branch of horticulture that deals with the study of fruits and their cultivation is called **pomology**.

4.7.1 Structure of Fruit

Fruit has a fruit wall. It is otherwise called **pericarp**. It is differentiated into outer **epicarp**, middle **mesocarp** and inner **endocarp**. The inner part of the fruit is occupied by the seed.

4.7.2 Types of Fruit

Fruits are classified into various types:

Simple Fruits

The fruits are derived from a single ovary of a flower Example: Mango, Tomato. Simple fruits are classified based on the nature of pericarp as follows

A. Fleshy Fruit

The fruits are derived from single pistil where the pericarp is fleshy, succulent and differentiated into epicarp, mesocarp and endocarp. It is subdivided into the following.

a) Berry: Fruit develops from bicarpellary or multicarpellary, syncarpous ovary. Here the epicarp is thin, the mesocarp and endocarp remain undifferentiated. They form a pulp in which the seeds are embedded. Example: Tomato, Date Palm, Grapes, Brinjal.

b) Drupe: Fruit develops from monocarpellary, superior ovary. It is usually one seeded. Pericarp is differentiated into outer skinny epicarp, fleshy and pulpy mesocarp and hard and stony endocarp around the seed. Example: Mango, Coconut.

c) Pepo: Fruit develops from tricarpellary inferior ovary. Pericarp terns leathery or woody which encloses, fleshy mesocarp and smooth endocarp. Example: Cucumber, Watermelon, Bottle gourd, Pumpkin.

d) Hesperidium: Fruit develops from multicarpellary, multilocular, syncarpous,

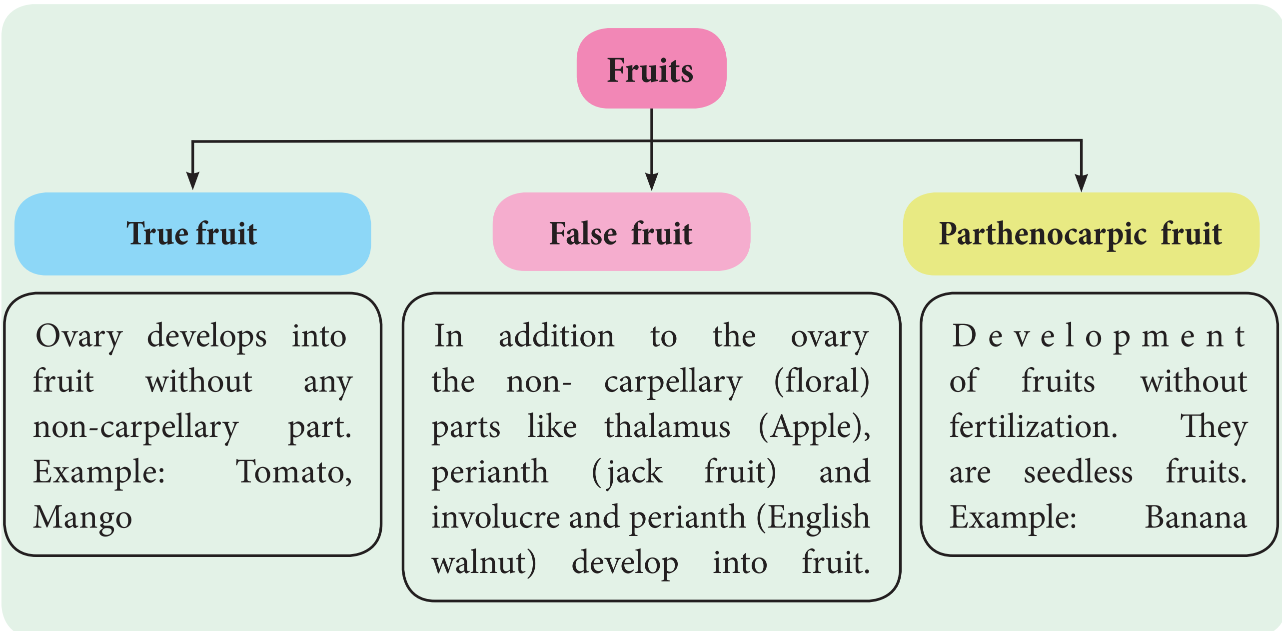
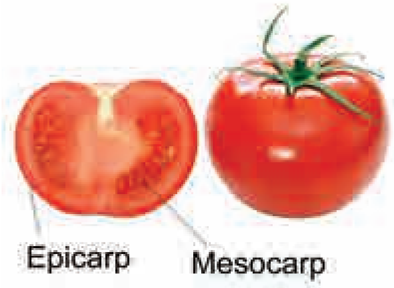
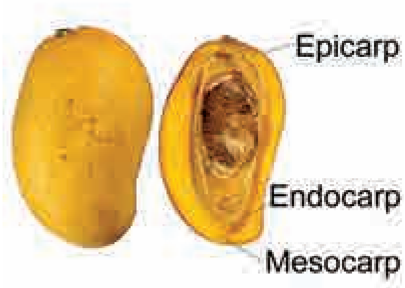


Figure 4.39: Classification of fruits based on formation

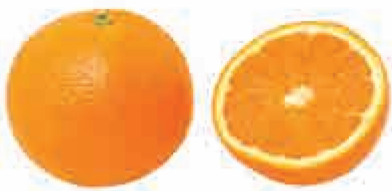


Berry (Tomato)

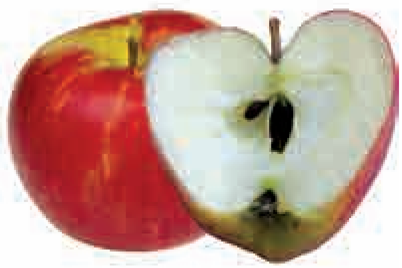


Drupe (Mango)

Pepo (Cucumber)



Hesperidium (Orange)



Pome (Apple)

Balausta (Pomegranate)

Figure 4.40: Simple fleshy fruits

superior ovary. The fruit wall is differentiated into leathery epicarp with oil glands, a middle fibrous mesocarp. The endocarp forms distinct chambers, containing juicy hairs. Example: Orange, Lemon.

e) Pome: It develops from multicarpellary, syncarpous, inferior ovary. The receptacle also develops along with the ovary and becomes fleshy, enclosing the true fruit. In pome the epicarp is thin skin like and endocarp is cartilagenous. Example: Apple, Pear.

f) Balausta: A fleshy indehiscent fruit developing from multicarpellary, multilocular inferior ovary whose pericarp is tough and leathery. Seeds are attached irregularly with testa being the edible portion. Example: Pomegranate.

B. Dry Fruit

They develops from single ovary where the pericarp is dry and not differentiated into epicarp, mesocarp and endocarp. It is further subdivided into three types.

1) Dry dehiscent fruit

Pericarp is dry and splits open along the sutures to liberate seeds. They can be classified into following types.

a) Follicle: Fruit develops from monocarpellary, superior ovary and dehisces along one suture. Example: *Calotropis*.

b) Legume or pod: Fruit develops from monocarpellary, superior ovary and dehisces through both dorsal and ventral sutures. Example: *Pisum*.

c) Siliqua: Fruit develops from bicarpellary, syncarpous, superior ovary initially one chambered but subsequently becomes two chambered due to the formation of false septum (**replum**). The fruit dehisces along two suture. Example: *Brassica*.

Follicle (*Calotropis*)

Legume (*Pisum*)

Siliqua (*Brassica*)

Silicula (*Capsella*)

Loculicidal (Lady's finger)

Septifragal (*Datura*)

Figure 4.41: Dry dehiscent fruit

d) Silicula: Fruit similar to siliqua but shorter and broader. Example: *Capsella, Lepidium, Alyssum.*

e) Capsule: Fruit develops from multicarpellary, syncarpous, superior ovary. Based on the dehiscence pattern they are sub divided into.

i) Septicidal: Capsule splitting along septa and valves remaining attached to septa. Example: *Linum, Aristolochia.*

ii) Loculicidal: Capsule splitting along locules and values remaining attached to septa. Example: Lady's finger.

iii) Septifragal: Capsule splitting so that valves fall off leaving seeds attached to the central axis. Example: *Datura.*

iv) Poricidal: Dehiscence through terminal pores. Example: *Papaver.*

v) Denticidal: Capsule opening at top exposing a number of teeth. Example: *Primula, Cerastium.*

vi) Circumscissile: (pyxidium) Dehisces transversely so that top comes off as a lid or operculum. Example: *Anagallis arvensis, Portulaca, Operculina.*

2) Dry indehiscent fruit

Dry fruit which does not split open at maturity. It is subdivided into.

a) Achene: Single seeded dry fruit developing from single carpel with superior ovary. Achenes commonly develop from apocarpous pistil, Fruit wall

Achene (*Clematis*)

Cypsela (*Tridax*)

Caryopsis (*Oryza*)

Nut (*Anacardium*)

Samara (*Acer*)

Utricle (*Chenopodium*)

Figure 4.42: Dry indehiscent fruit

is free from seed coat. Example: *Clematis, Delphinium,* Strawberry.

b) Cypsela: Single seeded dry fruit, develops from bicarpellary, syncarpous, inferior ovary with reduced scales, hairy or feathery calyx lobes. Example: *Tridax, Helianthus.*

c) Caryopsis: It is a one seeded fruit which develops from a monocarpellary, superior ovary. Pericarp is inseparably fused with seed. Example: *Oryza, Triticum.*

d) Nut: They develop from mulicarpellary, syncarpous, superior ovary with hard, woody or bony pericap. It is a one seeded fruit. Example: *Quercus, Anacardium.*

e) Samara: A dry indehiscent, one seeded fruit in which the pericarp devlops into thin winged structure around the fruit. Example: *Acer, Pterocarpus.*

f) Utricle: They develop from bicarpellary, unilocular, syncarpus, superior ovary with pericarp loosely enclosing the seeds. Example: *Chenopodium.*

3) Schizocarpic Fruit

This fruit type is intermediate between dehiscent and indehiscent fruit. The fruit instead of dehiscing rather splits into number of segments, each containing one or more seeds. They are of following types.

a) Cremocarp: Fruit develops from bicarpellary, syncarpous, inferior ovary and splitting into two one seeded segments known as **mericarps**. Example: Coriander, Carrot.

b) Carcerulus: Fruit develops from bicarpellary, syncarpous, superior ovary and splitting into four one seeded segments known as **nutlets**. Example: *Leucas, Ocimum, Abutilon*

Cremocarp (Coriander)

Carcerulus (*Abutilon*)

Lomentum (Mimosa)

Regma (Castor)

Figure 4.43: Schizocarpic Fruit

c) Lomentum: The fruit is derived from monocarpellary, unilocular ovary. A leguminous fruit, constricted between the seeds to form a number of one seeded compartments that separate at maturity. Example: *Desmodium, Mimosa*

d) Regma: They develop from tricarpellary, syncarpous, superior, trilocular ovary and splits into one-seeded cocci which remain attached to carpophore. Example: *Ricinus, Geranium*

Aggregate Fruits

Aggregate fruits develop from a single flower having an apocarpous pistil. each of the free carpel is develops into a simple fruitlet. A collection of simple fruitlets makes an **aggregate fruit**. An individual ovary develops into a drupe, achene, follicle or berry. An aggregate of these fruits borne by a single flower is known as an **etaerio**. Example: *Magnolia*, Raspberry, *Annona, Polyalthia*

Annona *Polyalthia*

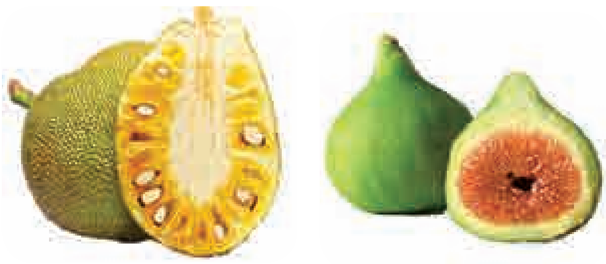
Figure 4.44: Aggregate Fruits

Multiple or Composite Fruit

A Multiple or composite fruit develops from the whole inflorescence along with its peduncle on which they are borne.

a) Sorosis: A fleshy multiple fruit which develops from a spike or spadix. The flowers fused together by their succulent perianth and at the same time the axis bearing them become fleshy or juicy and the whole inflorescence forms a compact mass. Example: Pineapple, Jack fruit, Mulberry

b) Syconus: A multiple fruit which develops from hypanthodium inflorescence. The receptacle develops further and converts into fleshy fruit which encloses a number of true fruit or achenes which develops from female flower of hypanthodium inflorescence. Example: *Ficus*



Sorosis (Jack fruit) **Syconus** (*Ficus*)

Figure 4.45: Multiple or composite fruit

DO YOU KNOW?

- *Lodoicea maldivica* is the world's largest fruit. The size of mature fruit is 40–50 cm in diameter and weights 15–30 kg.
- Progesterone which supports pregnancy is obtained naturally from a fruit of *Balanites aegyptiaca* and *Trigonella foenum - graecum*.

4.7.3 Functions of Fruit

1. Edible part of the fruit is a source of food, energy for animals.
2. They are source of many chemicals like sugar, pectin, organic acids, vitamins and minerals.
3. The fruit protects the seeds from unfavourable climatic conditions and animals.
4. Both fleshy and dry fruits help in the dispersal of seeds to distant places.
5. In certain cases, fruit may provide nutrition to the developing seedling.
6. Fruits provide source of medicine to humans.

DO YOU KNOW?

- *Lupinus arcticus* (legume family) of Artic Tundra is the oldest viable seed remained dormant for 10,000 years.
- *Pheonix dactylifera* (date palm) of king Herod's palace near dead sea has viable seed for 20,000 years.
- Powdered seeds of *Moringa oleifera* is used to purify water.

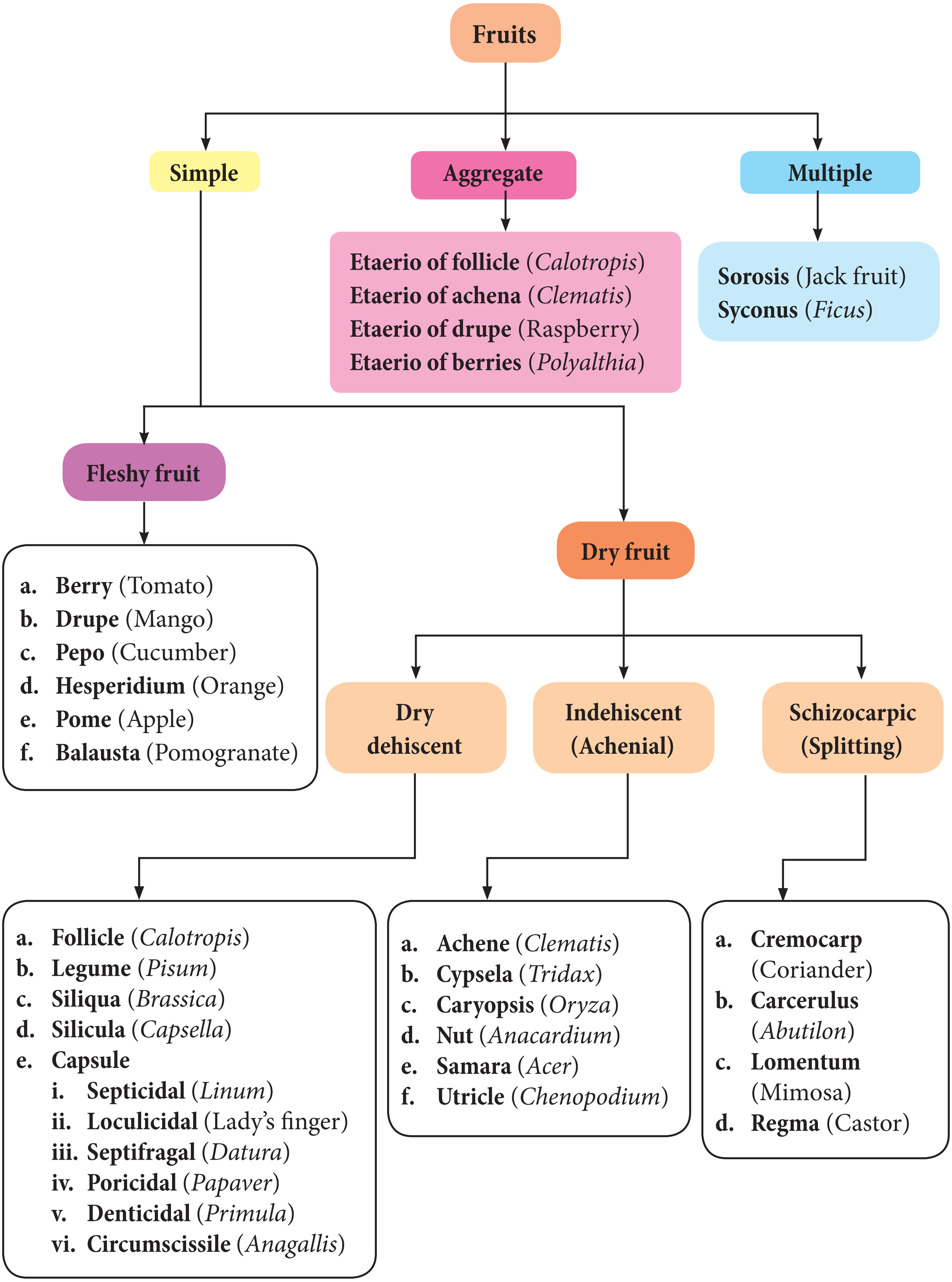


Figure 4.46: Types of fruits

Edible Parts of Fruit			
Type of Fruit	**Common Name**	**Botanical Name**	**Edible Part**
Berry	Tomato	*Lycopersicon esculentum*	Whole fruit
	Brinjal	*Solanum melongena*	Tender fruit
	Guava	*Psidium guajava*	Whole fruit
	Date	*Phoenix dactylifera*	Pericarp
Drupe	Mango	*Mangifera indica*	Mesocarp
	Coconut	*Cocos nucifera*	Endosperm (both cellular and liquid)
Pepo	Cucumber	*Cucumis sativus*	Whole fruit
Hesperidium	Citrus (Orange, Lemon)	*Citrus sinensis*	Juicy hairs on the endocarp
Pome	Apple	*Pyrus malus*	Thalamus (false fruit) and a part of pericarp
Balausta	Pomegranate	*Punica granatum*	Succulent testa of the seeds
Legume	Pea	*Pisum sativum*	Seed
Siliqua	Mustard	*Brassica campestris var.*	Seed
Poricidal capsule	Poppy	*Papaver somniferum*	Seeds
Loculicidal capsule	Lady's finger	*Abelmoschus esculentus*	Tender fruit
Cypsela	Sunflower	*Helianthus annuus*	Seed (for oil)
Caryopsis	Maize	*Zea maize*	Seed
	Paddy	*Oryza sativa*	Seed
Nut	Cashew nut	*Anacardium occidentale*	Pedicel (false fruit) and cotyledons (true fruit)
Cremocarp	Coriander	*Coriandrum sativum*	Mericarps
Lomentum	Touch-me-not	*Mimosa pudica*	Seed
Aggregate fruit	Custard apple	*Annona squamosa*	Pericarps
Composite fruits			
Sorosis	Jack fruit	*Artocarpus heterophyllus*	Perianth, seeds
	Pine apple	*Ananas comosus*	Perianth, rachis
	Mulberry	*Morus alba*	Whole fruit
Syconus	Fig	*Ficus carica*	Whole inflorescence

4.8 Seed

Do all fruits contain seeds? No, triploid fruits do not. The seed is a fertilized mature ovule which possess an embryonic plant, usually stores food material and has a protective coat. After fertilization, changes occur in various parts of the ovule and transforms into a seed.

4.8.1 Types of Seed

Do seeds germinate as soon as they are dispersed

I. Based on the number of cotyledons present two types of seeds are recognized.

i. Dicotyledonous seed: Seed with two cotyledons.

ii. Monocotyledonous seed: Seed with one cotyledon.

II. Based on the presence or absence of the endosperm the seed is of two types.

i. Albuminous or Endospermous seed: The cotyledons are thin, membranous and mature seeds have endosperm persistent and nourishes the seedling during its early development. Example: Castor, sunflower, maize.

ii. Ex-albuminous or non-endospermous seed: Food is utilized by the developing embryo and so the mature seeds are without endosperm. In such seeds, colyledons store food and become thick and fleshy. Example: Pea, Groundnut.

4.8.2 Significance of Seeds:

- The seed encloses and protects the embryo for next generation.
- It contains food for the development of embryo.
- It is a means for the dispersal of new individuals of the species.
- A seed is a means for perpetuation of the species. It may lie dormant during unfavorable conditions but germinates on getting suitable conditions.
- Seeds of various plants are used as food, both for animals and men.
- They are the basis of agriculture.
- Seeds are the products of sexual reproduction so they provide genetic variations and recombination in a plant.

Activity

Prepare a diet chart to provide balanced diet to an adolescent (a school going child) which includes food items (fruits, vegetable and seeds) which are non - expensive and are commonly available.

Summary

Inflorescence is a group of flowers present on a common stalk. Inflorescence may be classified into 3 types based on position. Inflorescence classified into racemose, cymose, mixed and special type based on the flower arrangement and branching of axis. Flower is a modified shoot and meant for sexual reproduction. Flower has various parts to enhance reproduction. Flower can be explained by its sex, symmetry and arrangement of whorls, merosity. Calyx is outermost whorl of flower and many types. Corolla is second whorl of flower and used for pollination. Corolla may be united or free and has various forms in different flowers. Aestivation is arrangement of sepals, petals in bud condition and is of many types. Androecium is the male part of flower and made up of stamens. Stamens contain filament,anther and connective.

Gynoecium is female part of flower. Ovary, style and stigma are parts of pistil. According to number of carpels it is divided into monocarpellary, bicarpellary etc. It may be apocarpous or syncarpous. Locule number may be one to many. The ovary is superior or inferior or semi inferior. Mode of distribution of placenta inside the ovary is placentation. Construction of floral diagram and floral formula for given flower with some examples.

Fruits are the products of pollination and fertilization. Fruit developed from single ovary of flower is called **simple fruit**. Simple fruits are two types based on the fruit wall as simple fleshy and simple dry. An intermediate between dehiscent and indehiscent fruit is called schizocarpic fruit. The simple fruits could be fleshy or dry which could again be dehiscent or indehiscent. Fruits that are developed from multicarpellary, apocarpus pistil is called aggregate. Multiple or composite fruit develops from the flowers of the complete inflorescence. Seed is a ripened ovule which contains the embryo or the miniature of plant body. Seeds with one cotyledon are monocotyledonous and with two cotyledons are dicotyledonous.

Evalution

5H1C8I

1. Vexillary aestivation is characteristic of the family
   a. Fabaceae
   b. Asteraceae
   c. Solanaceae d. Brassicaceae
2. Gynoecium with united carples is termed as
   a. Apocarpous b. Multicarpellary
   c. Syncarpous d. None of the above
3. Aggregate fruit develops from
   a. Multicarpellary, apocarpous ovary
   b. Multicarpellary, syncarpous ovary
   c. Multicarpellary ovary
   d. Whole inflorescence
4. In an inflorescence where flowers are borne laterally in an acropetal succession the position of the youngest floral bud shall be
   a. Proximal b. Distal
   c. Intercalary d. Anywhere
5. A true fruit is the one where
   a. Only ovary of the flower develops into fruit
   b. Ovary and calyx of the flower develops into fruit
   c. Overy, calyx and thalamus of the flower develops into fruit
   d. All floral whorls of the flower develops into fruit
6. Find out the floral formula for a bisexual flower with bract, regular, pentamerous, distinct calyx and corolla, superior ovary without bracteole.
7. Give the technical terms for the following: -
   a. A sterile stamen
   b. Stamens are united in one bunch
   c. Stamens are attached to the petals
8. Explain the different types of placentation with example.
9. Differenciate between aggregate fruit with multiple fruit.
10. Explain the different types of fleshy fruit with suitable example.

ICT Corner

Floral diagram and floral formula

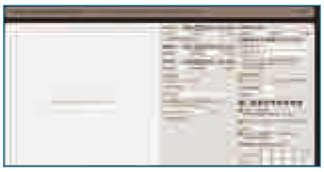
Let’s draw **floral formula**.

Steps

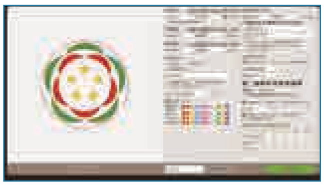
- Scan the QR code
- Enter sepal, petal, androecium & Gynoecium
- Select enable colour
- Select shape of sepal & petal, fused (if so)
- Enter carpel number & position submit the from
- Click formula to generate floral formula

Activity

- Make floral diagram and formula of various flower by changing numbers and positions of floral parts.
- You can edit the floral diagram using **Inkscape**, which is denoted in help tap.



Step 1



Step 2

Step 3

URL:

http://kvetnidiagram.8u.cz/index_en.php

B181_11_BOT

* Pictures are indicative only

Chapter 5

Taxonomy and Systematic Botany

5HA8A6

Learning Objectives

The learner will be able to,

- *Differentiate systematic botany from taxonomy.*
- *Explain the ICN principles and to discuss the codes of nomenclature.*
- *Compare the national and international herbaria.*
- *Appreciate the role of morphology, anatomy, cytology, DNA sequencing in relation to Taxonomy,*
- *Describe diagnostic features of families Fabaceae, Solanaceae, and Liliaceae.*

Chapter Outline

Plants are the prime companions of human beings in this universe. Plants are the source of food, energy, shelter, clothing, drugs, beverages, oxygen and the aesthetic environment. Taxonomic activity of human is not restricted to living organisms alone. Human beings learn to identify, describe, name and classify food, clothes, books, games, vehicles and other objects that they come across in their life. Every human being thus is a taxonomist from the cradle to the grave.

Taxonomy has witnessed various phases in its early history to the present day modernization. The need for knowledge on plants had been realized since human existence, a man started utilizing plants for food, shelter and as curative agent for ailments.

Theophrastus (372 – 287 BC), the Greek Philosopher known as "**Father of Botany**". He named and described some 500 plants in his "*De Historia Plantarum*". Later Dioscorides (62 – 127 AD), Greek physician, described and illustrated in his famous **"Materia medica"** and described about 600 medicinal plants. From 16th century onwards Europe has witnessed a major developments in the field of Taxonomy. Some of the key contributors include Andrea Caesalpino, John Ray, Tournefort, Jean Bauhin and Gaspard Bauhin. Linnaeus ***'Species Plantarum'*** (1753) laid strong foundation for the binomial nomenclature.

Taxonomy is no more classical morphology based discipline but become a dynamic and transdisciplinary subject, making use of many branches of botany such as Cell Biology, Physiology, Biochemistry, Ecology, Pharmacology and also Modern Biotechnology, Molecular Biology and Bioinformatics. It helps to understand Biodiversity, Wildlife, Forest Management of natural resources for sustainable use of plants and eco restoration.

5.1 Taxonomy and Systematics

The word taxonomy is derived from Greek words ***"taxis"*** (arrangement) and ***"nomos"*** (rules or laws). **Davis** and **Heywood** (1963) defined taxonomy as "the science dealing with the study of classification including the bases, principles, rules and procedures".

Though there were earlier usages of the term 'systematics', only during the latter half of 20th century 'Systematics' was recognized as a formal field of study. **Simpson** (1961) defined systematics as "Scientific study of the kinds and diversity of organisms and all relationships among them". Though there are two terms are used in an interchangeable way, they differ from each other.

Differences between Taxonomy and Systematics

Taxonomy	Systematics
• Discipline of classifying organisms into taxa. • Governs the practices of naming, describing, identifying and specimen preservation. • Classification + Nomenclature = Taxonomy	• Broad field of biology that studies the diversification of species. • Governs the evolutionary history and phylogenetic relationship in addition to taxonomy. • Taxonomy + Phylogeny = Systematics

5.2 Taxonomic Hierarchy

Taxonomic hierarchy was introduced by Carolus Linnaeus. It is the arrangement of various taxonomic levels in descending order starting from kingdom up to species.

Species is the lowest of classification and shows the high level of similarities among the organisms. For example, *Helianthus annuus* and Helianthus *tuberosus*. These two species differ in their morphology. Both of them are herbs but *Helianthus tuberosus* is a perennial herb.

Genus consist of multiple species which have similar characters but differ from the species of another genus. Example: *Helianthus*, *Tridax*.

Family comprises a number of genera which share some similarities among them. Example: Asteraceae.

Order includes group of families which show less similarities among them.

Class consists of group of orders which share few similarities.

Division is the next level of classification that consists of number of classes.

Example: Magnoliophyta.

Kingdom is the highest level or rank of the classification. Example: Plantae

Rank	Ending	Example
Kingdom	-	Plantae
Phylum = Division	-phyta	Magnoliophyta
Subphylum = Sub division	-phytina	Magnoliophytina
Class	-opsida	Asteropsida
Sub class	-idea	Asteridea
Order	-ales	Asterales
Suborder	-ineae	Asterineae
Family	-aceae	Asteraceae
Sub family	-oideae	Asteroideae
Tribe	-eae	Heliantheae
Genus	-	Helianthus
Sub genus	-	*Helianthus* subg. *Helianthus*
Series	-	*Helianthus* ser. *Helianthus*
Species	-	*Helianthus annuus*

5.3 Concept of species-Morphological, Biological and Phylogenetic

Species is the fundamental unit of taxonomic classification. Greek philosopher **Plato** proposed concept of *"eidos"* or species and believed that all objects are shadows of the *"eidos"*. According to **Stebbins** (1977) species is the basic unit of evolutionary process. Species is a group of individual organisms which have the following characters.

1. A population of organisms which closely resemble each other more than the other population.
2. They descend from a common ancestor.
3. In sexually reproducing organisms, they interbreed freely in nature, producing fertile offspring.
4. In asexually reproducing organisms, they are identified by their morphological resemblance.
5. In case of fossil organisms, they are identified by the morphological and anatomical resemblance.

Species concepts can be classified into two general groups. Concept emphasizing process of evolution that maintains the species as a unit and that can result in evolutionary divergence and speciation.

Another concept emphasises the product of evolution in defining a species.

Types of Species

There are different types of species and they are as follows:

1. Process of evolution - Biological Species
2. Product of evolution - Morphological Species and Phylogenetic Species

Morphological Species (Taxonomic species)

When the individuals are similar to one another in one or more features and different from other such groups, they are called **morphological species.** These species are defined and categorized with no knowledge of phylogenetic history, gene flow or detailed reproductive mechanisms.

Biological Species (Isolation Species)

According to **Ernest Mayr** 1963,“ these are groups of populations that interbreed and are reproductively isolated from other such groups in nature”.

Phylogenetic Species

This concept was developed by Meglitsch (1954), **Simpson** (1961) and **Wiley** (1978). Wiley defined phylogenetic species as “an evolutionary species is a single lineage of ancestor descendent populations which maintains its identity from other such lineages which has its own evolutionary tendencies and historical fate”.

5.4 International Code of Botanical Nomenclature

Assigning name for a plant is known as **Nomenclature.** This is based on the rules and recommendations of the International Code of Botanical Nomenclature. ICBN deals with the names of existing (living) and extinct (fossil) organisms. The elementary rule of naming of plants was first proposed by **Linnaeus** in 1737 and 1751 in his *Philosophia Botanica*. In 1813 a detailed set of rules regarding plant nomenclature was given by **A.P.de Candolle** in his famous work “*Theorie elementaire de la botanique*”. Then the present ICBN was evolved by following the same rules of **Linnaeus, A.P. de Candolle** and his son **Alphonse de Candolle.**

ICBN due to specific reasons and in order to separate plant kingdom from other organisms, is redesignated as ICN. The International Botanical Congress held in Melbourne in July 2011 brought this change. The ICN stands for International Code of Nomenclature for Algae, Fungi and Plants.

ICN Principles

International Code of Nomenclature is based on the following six principles.

1. Botanical nomenclature is independent of zoological and bacteriological nomenclature.
2. Application of names of taxonomic group is determined by means of nomenclatural types.
3. Nomenclature of a taxonomic group is based on priority of publication.
4. Each taxonomic group with a particular circumscription, position and rank can bear only one correct name, the earliest that is in accordance with the rules except in specified cases.

5. Scientific names of taxonomic groups are treated as Latin regardless of their derivation.
6. The rules of nomenclature are retroactive unless expressly limited.

Codes of Nomenclature

ICN has formulated a set of rules and recommendations dealing with the botanical name of plants. International Botanical Congress is held at different places every six years. Proposals for nomenclatural changes and changes in rules are discussed and implemented. Changes are published in their website.

18th International Botanical Congress held in 2011at Melbourne, Australia made the following major changes.

1. The code now permits electronic publication of names of new taxa.
2. Latin diagnosis or description is not mandatory and permits the use of English or Latin for the publication of a new name (Art-39).
3. "One fungus, one name" and "one fossil one name" are important changes, the concept of anamorph and telomorph (for fungi) and morphotaxa (for fossils) have been eliminated. (Previously, sexual and asexual stages of the fungus/fossils were provided with different names).

Anamorph – Asexual reproductive stage of fungus.

Telomorph – Sexual reproductive stage of fungus.

4. As an experiment with "registration of names" new fungal descriptions require the use of an identifier from a "recognized repository". There are two recognized repositories **Index fungorum** and **Myco Bank**.

19th International Botanical Congress was held in Shenzhen in China in 2017. Changes accepted by International Botanical Congress are yet to be published.

Vernacular names (Common names)

Vernacular names are known as **common names.** They are very often descriptive and poetic references to plants. Common name refer to more than one plant or many plants may have same common name. These names are regional or local and are not universal. Example: *Albizia amara* . L belongs to *Mimosaceae* is called as *Usilai* in South Tamilnadu and *Thurinji* in North Tamilnadu.

Activity

Write common name and scientific name of 10 different plants around your home.

Scientific Names / Botanical Names

Each and every taxon as per the ICN (species, genus, family etc) can have only one correct scientific name. Scientific name of a species is always a binomial. These names are universally applied. Example: *Oryza sativa L.*is the scientific name of paddy.

Polynomial

Polynomial is a descriptive phrase of a plant. Example: *Ranunculus calycibus retroflexis pedunculis falcatis caule* *erecto folius compositis.* It means butter cup with reflexed sepals, curved flower stalks, erect stem and compound leaves. Polynomial system did not hold good as it was cumbersome to remember and use. Polynomial system of naming a plant is replaced by a binomial system by Linnaeus.

Binomial

Binomial nomenclature was first introduced by **Gaspard Bauhin** and it was implemented by **Carolus Linnaeus**. Scientific name of a species consists of two words and according to binomial nomenclature, the first one is called **genus name** and second one is **specific epithet.** Example: *Mangifera indica*. *Mangifera* is a genus name and *indica* is specific epithet. This system is in vogue even now.

Author citation

This refers to valid name of the taxa accompanied by the author's name who published the name validly. Example: *Solanum nigrum* L. There are two types of author citation.

Single author: When a single author proposed a valid name, the name of the author alone is accompanied by his abbreviated name. Example: *Pithecellobium cinereum* Benth.

Multiple authors: When two or more authors are associated with a valid publication of name, their names should be noted with the help of Latin word *et* or &.

Example: *Delphinium viscosum* Hook. f. *et* Thomson.

Standard form of author's abbreviations has to be followed.

Author	Standard form of Abbreviation
Linnaeus	L.
G.Bentham	Benth.
William Hooker	Hook.
Robert Brown	R.Br.
J.P.Lamarck	Lamk.
A.P.de Candolle	DC.
Wallich	Wall.
Alphonse de Candolle	A. DC.

5.5 Type concept

ICN's second principle states that a specimen must be associated with the scientific name known as **nomenclatural type.** A nomenclatural type is either a specimen or may be an illustration. Example: Herbarium sheet for vascular plants.

There are different nomenclatural types.

Holotype: A specimen or illustration originally cited by the author in protologue. It is a definitive reference source for identity. Citation of holotype and submission of it is one of the criteria for valid publication of a botanical name.

Isotype: Duplicate specimen of the holotype collected from same population by same person on same date with same field number. They are the reliable duplicates of holotype and may be distributed to various herbaria of various regions.

Lectotype: Specimen selected from original material serves as a type, when no holotype was designated at the time of publications or if holotype is missing or destroyed.

Syntype: When more than one specimen cited by the author in the protologue without designating holotype.

Neotype: Specimen derived from non-original collection selected as the type, when original specimen is missing or destroyed.

Paratype: Specimen cited in the protologue is other than holotype, isotype or syntype.

Epitype: Specimen or illustration serves as an interpretive type, when holotype, neotype or lectotype is ambiguous.

5.6 Taxonomic Aids

Taxonomic aids are the tools for the taxonomic study. Some techniques, procedures and stored information that are useful in identification and classification of organisms are called **taxonomical aids.** They are required in almost all branches of biological studies for their proper identification and for finding their relationship with others. Some of the taxonomical aids are keys, flora, revisions, monograph, catalogues, herbarium, botanical gardens etc.

1. Keys

Taxonomic keys are the tools for the identification of unfamiliar plants. These keys are based on characters which are stable and reliable. The most common type of key is a dichotomous key. It consists of a sequence of two contrasting statements. A pair of contrasting statements is known as **couplet.** Each statement is known as **lead.** The plant is correctly identified with keys by narrowing down the characters found in plant.

Example:

1. a) Flowers cream-coloured; fruiting calyx enclosing the berry ......*Physalis*
b) Flowers white or violet; fruiting calyx not enclosing the berry 2
2. a) Corolla rotate; fruit a berry .....*Solanum*
b) Corolla funnel-form or salver-form; fruit a capsule: 3
3. a) Radical leaves present; flowers in racemes; fruits without prickles ...*Nicotiana*
b) Radical leaves absent; flowers solitary; fruits with prickles .....*Datura*

Another type of key for identification is the **Polyclave** or **Multi-entry key**. It consists of a list of numerous character states. The user selects all states that match the specimen. Polyclave keys are implemented by a computer algorithm.

2. Flora

Flora is the document of all plant species in a given geographic area. Flora consists of total number of plant species in an area and gives information about flowering season, fruiting season and distribution for the given geographic area. It also provides details on rare and endemic species of that area. Example: 'Flora of Tamil Nadu' Carnatic by K.M.Matthew. Floras are categorized based on the scope and area covered.

Local Flora

It covers the limited areas, usually state, country, city or mountain range. Example: 'Flora of Thiruvannamalai District' by R. Vijaysankar, K. Ravikumar and P. Ravichandran.

Regional Flora

It includes large geographical area or a botanical region. Example: 'Flora of Tamil Nadu Carnatic' by **K.M.Matthew** (1983), 'Flora of Madras Presidency' by **J.S. Gamble** and **Fischer**.

Continental Flora

This flora covers the entire continent. Example: 'Flora of Europaea' by D.A.Web.

Electronic Floras (e - floras)

It is nothing but the digitized form of a flora published online. Example: 'e – Flora China'. This provides the information and also functions as an identification tool.

3. Monograph

A Monograph is a complete global account of a taxon of any rank – family, genus or species at a given time. This includes the existing taxonomic knowledge and all relevant information about the group concerned such as Anatomy, Biochemistry, Palynology, chromosome number and phylogeny. It also includes extensive literature review, all nomenclatural information, identification key to all taxa, citation of specimens examined and distribution map.

Example: The Family *Lentibulariaceae* by Peter Tylor.

Revisions

Taxonomic revision is carried out for a family or genus. Usually taxonomic revision is less comprehensive than a monograph for a given geographical area. Revisions normally incorporate keys to identify the taxa, short descriptions, often confined to diagnostic characters, distribution maps and a classification. Illustrations mostly in the form of line drawings are included both in monographs and revisions. There are difficulties in identifying various members within a taxon. If there is inconsistency of the characters within the taxon's geographic range then a revision is needed. Taxonomic revisions are primarily based on original research work. Example: Malvaceae of India by T.K.Paul, Venu. P. 2006 Strobilanthes (Acanthaceae) in Peninsular India.

Catalogues

Catalogues are the books of libraries rich in botanical titles. They have special value in taxonomic studies. To refer a catalogue, one should know full name of the author, exact title of the book, exact date of publication the particulars of edition.

Example: Catalogue of the Library of British Museum (of Natural History) Catalogue of the Library of the Massachusetts Horticultural Society.

5.7 Botanical Gardens

In true sense all gardens are not botanical gardens. Botanical gardens are centres for collection of plants in their various stages of living. Gardens existed for growing ornamental plants for aesthetic value, religious and status reasons. The famous "hanging gardens" of Babylon in Mesopotamia is an example. For the purpose of science and education the first garden was maintained by **Theophrastus** in his public lecture hall at Athens.

First modern botanical garden was established by **Luca Ghini** (1490-1556) a professor of Botany at Pisa, Italy in 1544.

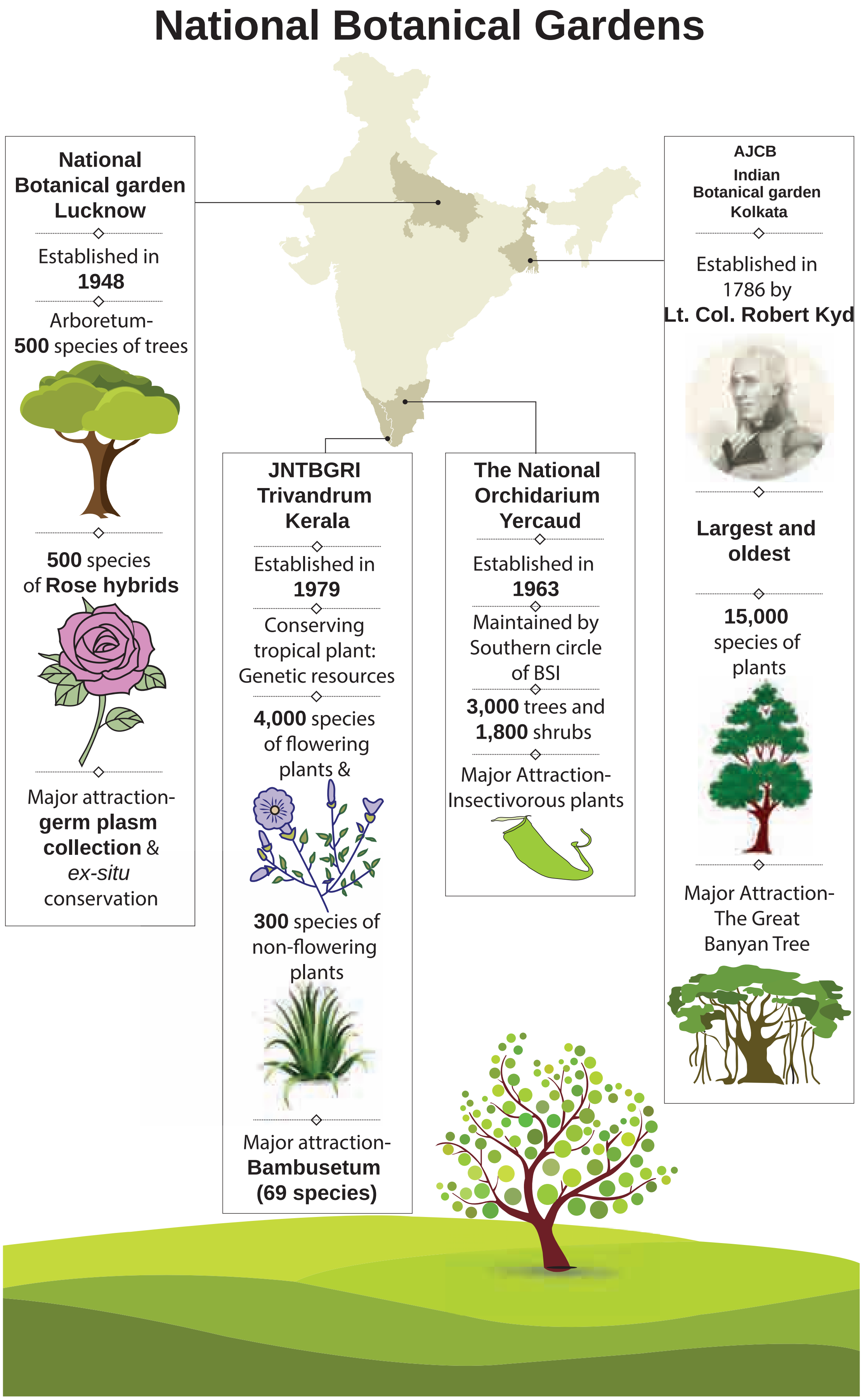


Figure 5.1: National Botanical Garden

Botanical garden contains special plant collections such as cacti, succulent, green house, shade house, tropical, alpine and exotic plants. Worldwide there are about 1800 botanical gardens and arboreta.

Role of Botanical Garden: Botanical Gardens play the following important roles.

1. Gardens with aesthetic value which attract a large number of visitors. For example, the Great Banyan Tree *(Ficus benghalensis)* in the Indian Botanical Garden at Kolkata.
2. Gardens have a wide range of species and supply taxonomic material for botanical research.
3. Garden is used for self-instruction or demonstration purposes.
4. It can integrate information of diverse fields like Anatomy, Embryology, Phytochemistry, Cytology, Physiology and Ecology.
5. Act as a conservation centre for diversity, rare and endangered species.
6. It offers annual list of available species and a free exchange of seeds.
7. Botanical garden gives information about method of propagation, sale of plant material to the general public.

Royal Botanic garden, Kew- England

Royal Botanic garden Kew- England is a non- departmental public body in the United Kingdom. It is the largest botanical garden in the world, established in 1760, but officially opened in the year 1841.

Figure 5.2: Royal Botanic garden, Kew - England

Plant collections include Aquatic garden, Arboretum with 14,000 trees, Bonsai collection, Cacti collection, Carnivorous plant collection.

5.8 Herbarium – Preparation and uses

Herbaria are store houses of preserved plant collections. Plants are preserved in the form of pressed and dried specimens mounted on a sheet of paper. Herbaria act as a centre for research and function as sources of material for systematic work.

Preparation of herbarium Specimen

Herbarium Specimen is defined as a pressed and dried plant sample that is permanently glued or strapped to a sheet of paper along with a documentation label.

Preparation of herbarium specimen includes the following steps.

1. **Plant collection:** Field collection, Liquid preserved collection, Living collection, Collection for molecular studies.
2. **Documentation of field site data**
3. **Preparation of plant specimen**
4. **Mounting herbarium specimen**
5. **Herbarium labels.**
6. **Protection of herbarium sheets against mold and insects**

Preparation of herbarium Specimen

Plant Collection
Plant specimen with flower or fruit is collected

↓

Documentation of field site data
Certain data are to be recorded at the time of plant collection. It includes date, time, country, state, city, specific locality information, latitude, longitude, elevation and land mark information. These data will be typed onto a herbarium label.

↓

Preparation of plant specimen
Plant specimen collected from the field is pressed immediately with the help of portable field plant press. plant specimen is transferred to a standard plant press (12” x 18”) which between two outer 12” x 18” frames and secured by two straps.

↓

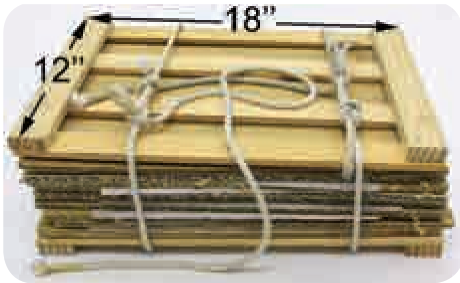
Mounting herbarium specimen
The standard size of herbarium sheet is used for mounting the specimen (29cm x 41cm). specimens are affixed to herbarium sheet with standard white glue or solution of Methyl cellulose.

↓

Herbarium label
Herbarium label size is generally 4-5” wide and 2-3”tall. A typical label contains all information like habit, habitat, vegetation type, land mark information, latitude, longitude, image document, collection number, date of collection and name of the collector.

↓

Protection of herbarium sheets against mold and insects
Applycation of 2% Mercuric chloride, Naphthalene, DDT, carbon disulphide. Fumigation using formaldehyde. Presently deep freezing(**-20°C**) method is followed throughout the world.



DO YOU KNOW?

World’s smallest water – lily *Nymphaea thermarum* was saved from extinction when it was grown from seed at Kew in 2009.

International Herbarium

S.No	Herbarium	Year Established	Acronym	Number of specimens
1.	*Museum National d'Histoire Naturelle*, Paris, France	1635	P ,PC	10,000,000
2.	New York Botanical Garden, Bronx, New York, U.S.A	1891	NY	72,00,000
3.	Komarov Botanical Institute, St.Petersburg (Leningrad), Russia	1823	LE	71,60,000
4.	Royal Botanic Gardens, Kew, England, U.K	1841	K	70,00,000

National Herbarium

S.No	Herbarium	Year Established	Acronym	Number of specimens
1.	Madras Herbarium BSI campus, Coimbatore	1955	MH	4,08,776
2.	Central National Herbarium West Bengal	1795	CAL	2,00,000
3.	Jawaharlal Nehru Tropical Botanical Garden and Research Institute Thiruvananthapuram, Kerala	1979	TBGT	30,500
4.	Presidency College Herbarium, Chennai.	1844	PCM	15,000

Uses of Herbarium

1. Herbarium provides resource material for systematic research and studies.
2. It is a place for orderly arrangement of voucher specimens.
3. Voucher specimen serves as a reference for comparing doubtful newly collected fresh specimens.
4. Voucher specimens play a role in studies like floristic diversity, environmental assessment, ecological mechanisms and survey of unexplored areas.
5. Herbarium provides opportunity for documenting biodiversity and studies related to the field of ecology and conservation biology.

Kew Herbarium

Kew Garden is situated in South West London that houses the "largest and most diverse botanical and mycological collections in the world" founded in the year 1840. Living collection includes more than 30,000 different kinds of plants. While herbarium which is one of the largest in the world has over seven million preserved plant specimens. The library contains more than 7,50,000 volumes and the illustrations and also a collection of more than 1,75,000 prints, books, photographs, letters, manuscripts, periodicals, maps and botanical illustrations.

International Botanic Garden

New York Botanic garden, USA.

Royal Botanic Garden, Kew - England.

Botanical Gardens of the New South Wales, Sydney.

Rio- de jenerio Botanic Garden, Brazil.

Botanical Survey of India

On 13 February 1890, a survey was formally constituted and designated as the Botanical Survey of India. After independence, the need was felt for a more comprehensive documentation of the country's plant resources to boost the economy. Padmashree **Dr.E.K.Janaki Ammal** was appointed as officer on special Duty on 14th Oct 1952. Then reorganization plan was finally approved by the Govt. of India on 29 March 1954, with Calcutta as the headquarters of BSI. Jammu Tavi Botanical Garden has been named after Dr. E. K. Janaki Ammal.

Figure 5.3: Dr. E.K. Janaki Ammal

Activity

Prepare herbarium of 5 common weed plants found inside your school campus /nearby garden /waste land.

5.9 Classification of Plants

Imagine walking into a library and looking for a Harry Potter story book. As you walk into the library you notice that it is under renovation and all the books are scattered. Will it not be hard to find the exact book you are looking for? It might take hours. So you decide to come the next day when all the books are arranged according to the genres. One rack for adventure, another for Detective, Fantasy, Horror, Encyclopaedia and so on. You automatically know Harry Potter is in the fantasy section and it takes less than ten minutes for you to find it. That is because the books have been classified and arranged according to a system.

Similarly there is a vast assemblage of group of plants in the world. Is it possible to study and understand all of these? No. Since it is difficult to study all these plants together, it is necessary to device some means to make this possible.

Classification is essential to biology because there is a vast diversity of organisms to sort out and compare. Unless they are organized into manageable categories it will be difficult for identification. Biological classifications are the inventions of biologists based upon the best evidence available. The scientific basis for cataloguing and retrieving information about the tremendous diversity of flora is known as **classification**.

Classification paves way for the arrangement of organisms into groups on the basis of their similarities, dissimilarities and relationships. The purpose of classification is to provide a systematic arrangement expressing the relationship between the organisms.

Taxonomists have assigned a method of classifying organisms which are called **ranks.** These taxonomical ranks are hierarchical. The scheme of classification has to be flexible, allowing newly discovered living organisms to be added where they fit best.

5.9.1 Need for Classification

- Understanding the classification of organisms can gives an insight in to other fields and has significant practical value.
- Classification helps us to know about different taxa, their phylogenetic relationship and exact position.
- It helps to train the students of plant sciences with regard to the diversity of organisms and their relationship with other biological branches.

5.10 Types of classification

Taxonomic entities are classified in three ways. They are artificial classification, natural classification and phylogenetic classification.

5.10.1 Artificial system of classification

Carolus Linnaeus (1707 -1778) was a great Swedish Botanist and said to be the "**Father of Taxonomy**." He outlined an artificial system of classification in "***Species Plantarum***" in 1753, wherein he listed and described 7,300 species and arranged in 24 classes mostly on the basis of number, union (adhesion and cohesion), length, and distribution of stamens. The classes were further subdivided on the basis of carpel characteristics into orders. Hence the system of classification is also known as **sexual system of classification**.

Figure 5.4: Carolus Linnaeus

24 classes recognized by Linnaeus in his *Species Plantarum* (1753) on the basis of stamens.

No	Classes	Characters
1	Monandria	stamen one
2	Diandria	stamens two
3	Triandria	stamens three
4	Tetrandria	stamens four
5	Pentandria	stamens five
	up to 24^{th} class Cryptogamia	flowerless plants

This system of classification though artificial, was continued for more than 100 years after the death of Linnaeus, due to its simplicity and easy way of identification of plants.

However the system could not hold good due to the following reasons.

1. Totally unrelated plants were kept in a single group, whereas closely related plants were placed in widely separated groups. Example:
   a. Zingiberaceae of monocotyledons and Anacardiaceae of dicotyledonous were placed under the class **Monandria** since these possess single stamens.
   b. *Prunus* was classified along with *Cactus* because of the same number of stamens.

No attempts were made to classify plants based on either natural or phylogenetic relationships which exist among plant groups.

5.10.2 Natural system

Botanists who came after Linnaeus realised that no single character is more important than the other characters. Accordingly an approach to a natural system of classification sprouted in France. The first scheme of classification based on overall similarities was presented by **Antoine Laurent de Jessieu** in 1789.

Bentham and Hooker system of classification

Figure 5.5: George Bentham and J.D. Hooker.

A widely followed natural system of classification considered the best was proposed by two English botanist **George Bentham** (1800 - 1884) and **Joseph Dalton Hooker** (1817–1911). The classification was published in a three volume work as "*Genera Plantarum*" (1862–1883) describing 202 families and 7569 genera and 97, 205 species. In this system the seeded plants were classified into 3 major classes such as Dicotyledonae, Gymnospermae and Monocotyledonae.

Class I Dicotyledonae: Plants contain two cotyledons in their seed, leaves with reticulate venation, tap root system and tetramerous or pentamerous flowers come under this class. It includes three sub-classes – **Polypetalae, Gamopetalae** and **Monochlamydeae**.

Sub-class 1. Polypetalae: Plants with free petals and dichlamydeous flowers come under polypetalae. It is further divided into three series – **Thalamiflorae, Disciflorae** and **Calyciflorae**.

Series (i) Thalamiflorae: Plants having flowers with dome or conical shaped thalamus and superior ovary are included in this series. It includes 6 orders and 34 families.

Series (ii) Disciflorae: Flowers having prominent disc shaped thalamus with superior ovary come under this series. It includes 4 orders and 23 families.

Series (iii) Calyciflorae: It includes plants having flowers with cup shaped thalamus and with inferior or sometimes with half inferior ovary. Calyciflorae includes 5 orders and 27 families.

Sub-class 2. Gamopetalae: Plants with united petals, which are either partially or completely fused to one another and dichlamydeous are placed under Gamopetalae. It is further divided into three series – Inferae, Heteromerae and Bicarpellatae.

Series (i) Inferae: The flowers are epigynous and with inferior ovary. Inferae includes 3 orders and 9 families.

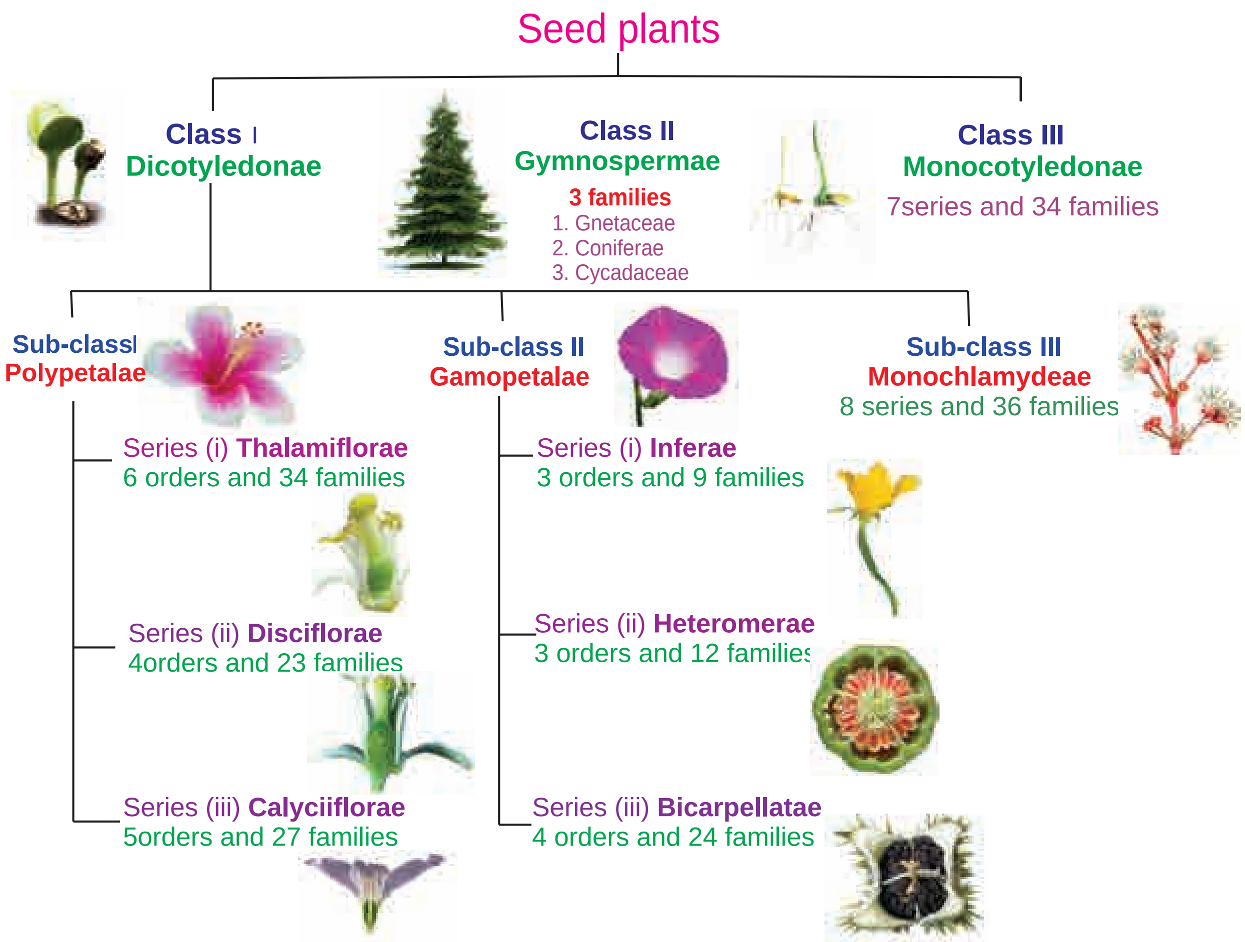


Figure 5.6: Bentham and Hooker system of classification

Series (ii) Heteromerae: The flowers are hypogynous, superior ovary and with more than two carpels. Heteromerae includes 3 orders and 12 families.

Series (iii) Bicarpellatae: The flowers are hypogynous, superior ovary and with two carpels.Bicarpellatae includes 4 orders and 24 families.

Sub-class 3. Monochlamydeae: Plants with incomplete flowers either apetalous or with undifferenciated calyx and corolla are placed under Monochlamydeae. The sepals and petals are not distinguished and they are called **perianth.** Sometimes both the whorls are absent. Monochlamydeae includes 8 series and 36 families.

Class II Gymnospermae: Plants that contain naked seeds come under this class. Gymnospermae includes three families – Gnetaceae, Coniferae and Cycadaceae.

Class III Monocotyledonae: Plants contain only one cotyledon in their seed, leaves with parallel venation, fibrous root system and trimerous flowers come under this class. The Monocotyledonae has 7 series and 34 families.

The Bentham and Hooker system of classification is still supposed to be the best system of classification. It has been widely practiced in colonial countries and herbaria of those countries were organised based on this system and is still used as a key for the identification of plants in some herbaria of the world due to the following reasons:

- Description of plants is quite accurate and reliable, because it is mainly based on personal studies from actual specimens and not mere comparisons of known **facts.**

- As it is easy to follow, it is used as a key for the identification of plants in several herbaria of the world.

Though it is a natural system, this system was not intended to be phylogenetic.

Figure 5.7: Adolph Engler and Karl A Prantl

5.10.3 Phylogenetic system of classification

The publication of the ***Origin of Species*** (1859) by **Charles Darwin** has given stimulus for the emergence of phylogenetic system of classification.

I Adolph Engler and Karl A Prantl system of classification

One of the earliest phylogenetic system of classification of the entire plant Kingdom was jointly proposed by two German botanists **Adolph Engler** (1844 -1930) and **Karl A Prantl** (1849 - 1893). They published their classification in a monumental work "***Die Naturelichen Pflanzen Familien***" in 23 volumes (1887- 1915)

In this system of classification the plant kingdom was divided into 13 divisions. The first 11 divisions are Thallophytes, twelfth division is **Embryophyta Asiphonogama** (plants with embryos but no pollen tubes; Bryophytes and Pteridophytes) and the thirteenth division is **Embryophyta Siphonogama** (plants with embryos and pollen tubes) which includes seed plants.

II Arthur Cronquist system of classification

Arthur Cronquist (1919 - 1992) an eminent American taxonomist proposed phylogenetic classification of flowering plants based on a wide range of taxonomic characters including anatomical and phytochemical characters of phylogenetic importance. He has presented his

Division: Embryophyta (Siphonogama)

- Sub-division: Gymnospermae
- Sub-division: Angiospermae
  - Class: Monocotyledonae (includes 11 orders 45 families)
  - Class: Dicotyledonae (includes 44 orders)
    - Archichlamydeae (Apetalae)
      (i) Corolla polypetalous
      (ii) Perianth single or double
      (iii) Includes 33 orders 201 families
    - Metachlamydeae (Sympetalae)
      (i) Corolla Gamopetalous
      (ii) Perianth in two whorls
      (iii) Includes 11 orders 57 families

Figure 5.8: Outline of Engler and Prantl classification

classification in 1968 in his book titled "**The evolution and classification of flowering plants.**" His classification is broadly based on the Principles of phylogeny that finds acceptance with major contemporary authors.

Figure 5.9: Arthur Cronquist

Cronquist classified the angiosperms into two main classes **Magnoliopsida** (=dicotyledons) and **Liliopsida** (= monocotyledons). There are 6 subclasses, 64 orders, 320 families and about 165,000 species in Magnoliopsida, whereas in Liliopsida there are 5 sub classes, 19 orders, 66 families and about 50,000 species.

Cronquist system of classification also could not persist for a long time because, the system is not very useful for identification and cannot be adopted in herbaria due to its high phylogenetic nature.

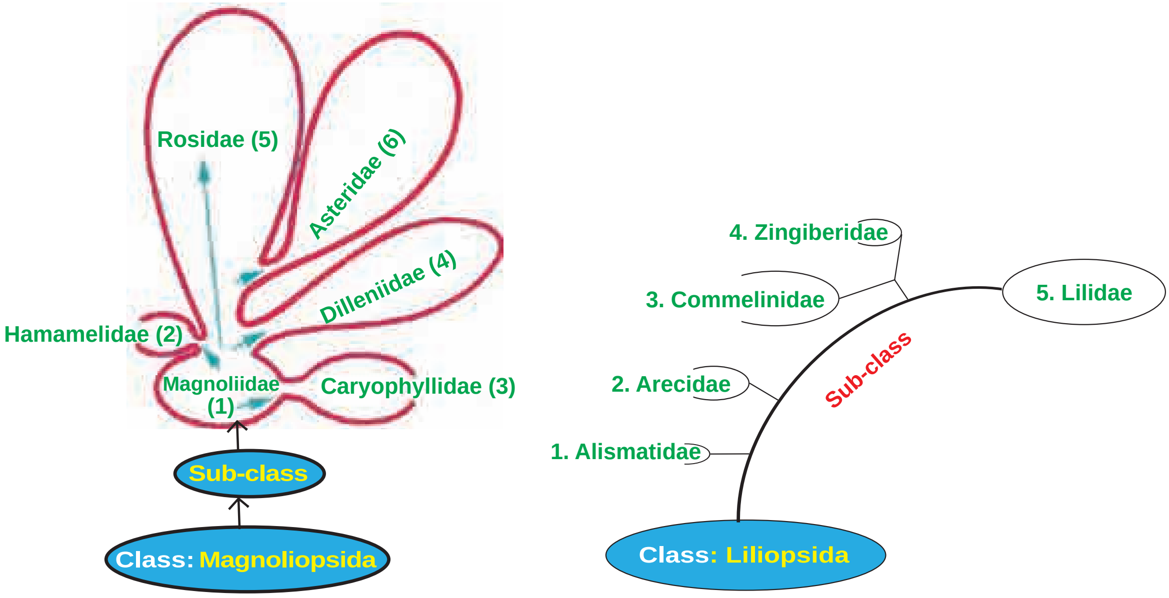


Figure 5.10: Diagramatic representation of the relationship between class Magnoliopsida and Liliopsida.

5.10.4 Angiosperm phylogeny group (APG) classification

The most recent classification of flowering plants based on **phylogenetic data** was set in the last decade of twentieth century. Four versions of Angiosperm Phylogenetic group classification (APG I, APG II, APG III & APG IV) have been published in 1998, 2003, 2009 and 2016 respectively. Each version supplants the previous version. Recognition of **monophyletic** group based on the information received from various disciplines such as gross

Morphology, Anatomy, Embryology, Palynology, Karyology, Phytochemistry and more strongly on molecular data with respect to DNA sequences of two chloroplast genes (*atp*B and *rbc*L) and one nuclear gene (nuclear ribosomal 18s DNA).

The most recent updated version, APG IV (2016) recognised 64 orders and 416families. Of these, 416 families 259 are represented in India.

The outline of APG IV classification is given below.

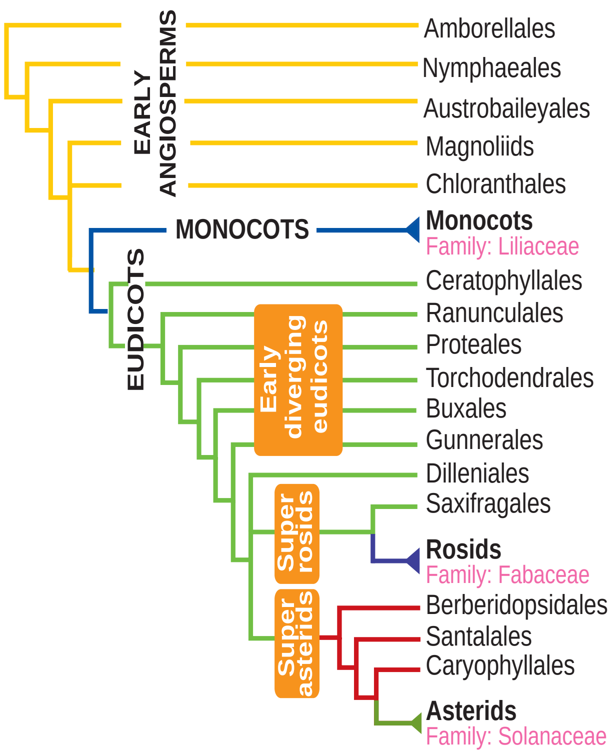


Figure 5.11: Simplified version of APG IV
(Source: Plant Gateway's The Global Flora, Vol. I January 2018)

Angiosperms are classified into three clades early angiosperms, monocots and eudicots. Early angiosperms are classified into **8 orders** and **26 families** (ANA-grade + magnoliids + Chloranthales)

Amborellales
Nymphaeales
Austrobaileyales

- Seeds always with two cotyledons.
- Presence of ethereal oils.
- Leaves are always simple net-veined.
- Each floral whorls with many parts.
- Perianth usually spirally arranged or parts in threes.
- Stamens with broad filaments.
- Anthers tetrasporangiate.
- Pollen monosulcate.
- Nectaries are rare.
- Carpels usually free and.
- Embryo very small.

Monocots are classified into 11 orders and 77 families (basal monocots + lilioids + commelinids)

- Seeds with single cotyledon.
- Primary root short-lived.
- Single adaxial prophyll.
- Ethereal oils rarely present.
- Mostly herbaceous, absence of vascular cambium.
- Vascular bundles are scattered in the stem.
- Leaf simple with parallel-veined.
- Floral parts usually in threes.
- Perianth often composed of tepals.
- Pollen monosulcate.
- Styles normally hollow and.
- Successive microsporogenesis.

Eudicots are divided into 45 orders and 313 families (early diverging eudicots + super rosids + super asterids).

- Seeds with always two cotyledons.
- Nodes trilacunar with three leaf traces.
- Stomata anomocytic.
- Ethereal oils rarely present.
- Woody or herbaceous plants.
- Leaves simple or compound, usually net-veined.
- Flower parts mostly in twos, fours or fives.
- Microsporogenesis simultaneous.
- Style solid and .
- Pollen tricolpate.

APG system is an evolving system that might undergo change periodically based on the new sets of data from various disciplines of Botany. It is the currently accepted system across the world and followed by all the leading taxonomic institutions and practising taxonomists. However, it is yet to percolate into the Indian botanical curriculum.

Classification reflects the state of our knowledge at a given point of time. It will continue to change as we acquire new information.

DO YOU KNOW?

A significant number of major herbaria, including Kew are changing the order of their collections in accordance with APG.

The influential world checklist of selected plant families (also from kew) is being updated to the APG III system.

A recent photographic survey of the plants of USA and Canada is organized according to the APG III system.

In UK, the latest edition of the standard flora of the British Isles written by Stace is based on the APG III system.

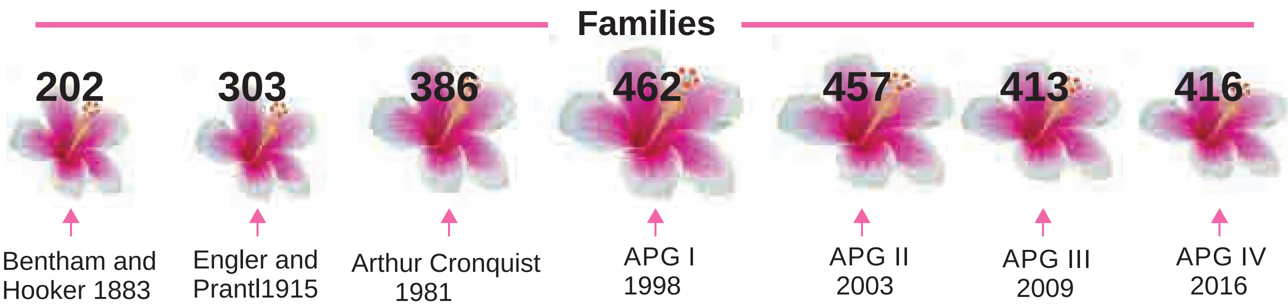


Figure 5.12: A timeline showing the history of classifying flowering plants into families. (Source: Royal Botanic Gardens Kew State of World's Plant 2017)

5.11 Modern trends in taxonomy

Taxonomists now accept that, the morphological characters alone should not be considered in systematic classification of plants. The complete knowledge of taxonomy is possible with the principles of various disciplines like Cytology, Genetics, Anatomy, Physiology, Geographical distribution, Embryology, Ecology, Palynology, Phenology, Bio-chemistry, Numerical taxonomy and transplant experiments. These have been found to be useful in solving some of the taxonomical problems by providing additional characters. It has changed the face of classification from **alpha** (classical) to **omega** (modern kind). Thus the new systematic has evolved into a better taxonomy.

5.11.1 Chemotaxonomy

Various medicines, spices and preservatives obtained from plant have drawn the attention of Taxonomists. Study of various chemicals available in plants help to solve certain taxonomical problems. Chemotaxonomy is the scientific approach of classification of plants on the basis of their biochemical constituents. As proteins are more closely controlled by genes and less subjected to natural selection, it has been used at all hierarchical levels of classification starting from the rank of 'variety' up to the rank of division in plants. Proteins, amino acids, nucleic acids, peptides etc. are the most studied chemicals in chemotaxonomy.

The chemical characters can be divided into three main categories.

1. Easily visible characters like starch grains, silica etc.
2. Characters detected by chemical tests like phenolics, oil, fats, waxes etc.
3. Proteins

Aims of chemotaxonomy

1. To develop taxonomic characters which may improve existing system of plant classification.
2. To improve present day knowledge of phylogeny of plants.

5.11.2 Biosystematics

Biosystematics is an "Experimental, ecological and cytotaxonomy" through which life forms are studied and their relationships are defined. The term biosystematics was introduced by **Camp** and **Gilly** in 1943. Many authors feel Biosystematics is closer to Cytogenetics and Ecology and much importance given not to classification but to evolution.

Aims of biosystematics

The aims of biosystematics are as follows:

1. To delimit the naturally occurring biotic community of plant species.
2. To establish the evolution of a group of taxa by understanding the evolutionary and phylogenetic trends.
3. To involve any type of data gathering based on modern concepts and not only on morphology and anatomy.
4. To recognize the various groups as separate biosystematic categories such as ecotypes, ecospecies, cenospecies and comparium.

5.11.3 Karyotaxonomy

Chromosomes are the carriers of genetic information. Increased knowledge about the chromosomes have been used for extensive biosystematic studies and resolving many taxonomic problems. Utilization of the characters and phenomena of cytology for the explanation of taxonomic problem is known as **cytotaxonomy** or **karyotaxonomy**. The characters of chromosome such as number, size, morphology and behaviour during meiosis have proved to be of taxonomic value.

5.11.4 Serotaxonomy (immunotaxonomy)

Systematic serology or serotaxonomy had its origin towards the end of twentieth century with the discovery of serological reactions and development of the discipline of immunology. The classification of very similar plants by means of differences in the proteins they contain, to solve taxonomic problems is called **serotaxonomy**.

Smith (1976) defined it as "**the study of the origins and properties of antisera**."

Importance of serotaxonomy

It determines the degree of similarity between species, genera, families etc. by comparing the reactions of antigens from various plant taxa with antibodies raised against the antigen of a given taxon.

Example: 1. The assignment of *Phaseolus aureus* and *P. mungo* to the genus *Vigna* is strongly supported by serological evidence by **Chrispeels** and **Gartner**.

5.11.5 Molecular taxonomy (molecular systematics / molecular phylogenetics)

Molecular Taxonomy is the branch of phylogeny that analyses hereditary molecular differences, mainly in DNA sequences, to gain information and to establish genetic relationship between the members of different taxonomic categories. The advent of DNA cloning and sequencing methods have contributed immensely to the development of molecular taxonomy and population genetics over the years. These modern methods have revolutionised the field of molecular taxonomy and population genetics with improved analytical power and precision.

The results of a molecular phylogenetic analysis are expressed in the form of a tree called **phylogenetic tree.** Different molecular markers like allozymes, mitochondrial DNA, micro satellites, RFLP (Restriction Fragment Length Polymorphism), RAPD (Random amplified polymorphic DNA), AFLPs (Amplified Fragment Length Polymorphism), single nucleotide polymorphism- SNP, microchips or arrays are used in analysis.

Uses of molecular taxonomy

1. Molecular taxonomy helps in establishing the relationship of different plant groups at DNA level.
2. It unlocks the treasure chest of information on evolutionary history of organisms.

RFLP (Restriction Fragment Length Polymorphism)

RFLPs is a molecular method of genetic analysis that allows identification of taxa based on unique patterns of restriction sites in specific regions of DNA. It refers to differences between taxa in restriction sites and therefore the lengths of fragments of DNA following cleavage with restriction enzymes.

Amplified Fragment Length Polymorphism (AFLP)

This method is similar to that of identifying RFLPs in that a restriction enzyme is used to cut DNA into numerous smaller pieces, each of which terminates in a characteristic nucleotide sequence due to the action of restriction enzymes.

AFLP is largely used for population genetics studies, but has been used in studies of closely related species and even in some cases, for higher level cladistic analysis.

Random Amplified Polymorphic DNA (RAPD)

It is a method to identify genetic markers using a randomly synthesized primer that will anneal (recombine (DNA) in the double stranded form) to complementary regions located in various locations of isolated DNA. If another complementary site is present on the opposing DNA strand at a distance that is not too great (within the limits of PCR) then the reaction will amplify this region of DNA.

RAPDs like microsatellites may often be used for genetic studies within species but may also be successfully employed in phylogenetic studies to address relationships within a species or between closely related species. However RAPD analysis has the major disadvantage that results are difficult to replicate and in that the homology of similar bands in different taxa may be nuclear.

Significance of Molecular Taxonomy

1. It helps to identify a very large number of species of plants and animals by the use of conserved molecular sequences.
2. Using DNA data evolutionary patterns of biodiversity are now investigated.
3. DNA taxonomy plays a vital role in phytogeography, which ultimately helps in genome mapping and biodiversity conservation.
4. DNA- based molecular markers used for designing DNA based molecular probes, have also been developed under the branch of molecular systematics.

5.11.6 DNA Barcoding

Have you seen how scanners are used in supermarkets to distinguish the **Universal Product Code** (UPC)? In the same way we can also distinguish one species from another. DNA barcoding is a taxonomic method that uses a very short genetic sequence from a standard part of a genome. The genetic sequence used to identify a plant is known as "**DNA tags**" or "**DNA barcodes**". **Paul Hebert** in 2003 proposed '**DNA barcoding**' and he is considered as 'Father of barcoding'.

The gene region that is being used as an effective barcode in plants is present in two genes of the chloroplast, matK and rbcL, and have been approved as the barcode regions for plants.

Sequence of unknown species can be matched from submitted sequence in GenBank using Blast (web-programme for searching the closely related sequence).

Significance of DNA barcoding

1. DNA barcoding greatly helps in identification and classification of organism.
2. It aids in mapping the extent of biodiversity.

DNA barcoding techniques require a large database of sequences for comparison and prior knowledge of the barcoding region.

However, DNA barcoding is a helpful tool to determine the authenticity of botanical material in whole, cut or powdered form.

5.11.7 Differences between classical and modern taxonomy

Classical Taxonomy	Modern Taxonomy
It is called old systematics or Alpha (ἀ) taxonomy or Taxonomy	It is called Neosystematics or Biosystematics or Omega (Ω) taxonomy
It is pre Darwinean	It is post Darwinean
Species is considered as basic unit and is static	species is considered as dynamic entity and ever changing
Classification is mainly based on morphological characters	Classification is based on morpho-logical, reproduc-tive characters and phylogenetic (evolu-tionary) relationship of the organism
This system is based on the observation of a few samples/ individuals	This system is based on the observation of large number of sam-ples/individuals

5.12 Cladistics

5HJ4BT

Analysis of the taxonomic data, and the types of characters that are used in classification have changed from time to time. Plants have been classified based on the morphology before the advancement of microscopes, which help in the inclusions of **sub microscopic** and **microscopic** features. A closer study is necessary while classifying closely related plants. Discovery of new finer molecular analytical techniques coupled with advanced software and computers has ushered in a new era of modern or phylogenetic classification.

The method of classifying organisms into monophyletic group of a common ancestor based on shared apomorphic characters is called **cladistics** (from Greek, *klados*-branch).

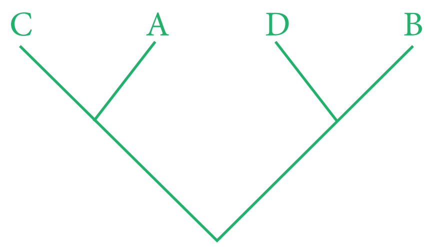
The outcome of a cladistic analysis is a **cladogram**, a tree-shaped diagram that represent the best hypothesis of phylogenetic relationships. Earlier generated cladograms were largely on the basis of morphological characters, but now genetic sequencing data and computational softwares are commonly used in phylogenetic analysis.

Cladistic analysis

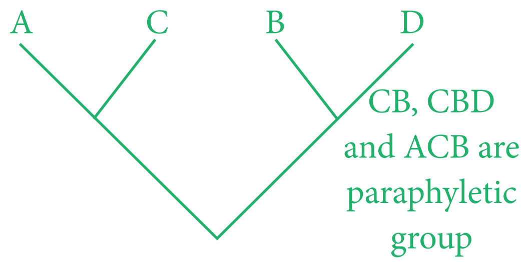
Cladistics is one of the primary methods of constructing phylogenies, or evolutionary histories. Cladistics uses shared, derived characters to group organisms into clades. These clades have atleast one shared, derived character found in their most recent common ancestor that is not found in other groups hence they are considered more closely related to each other. These shared characters can be morphological such as, leaf, flower, fruit, seed and so on; behavioural, like opening of flowers nocturnal/diurnal; molecular like, DNA or protein sequence and more.

Cladistics accept only **monophyletic groups**. **Paraphyletic** and **polyphyletic** taxa are occasionally considered when such taxa conveniently treated as one group for practical purposes. Example: dicots, sterculiaceae. Polyphyletic groups are rejected by cladistics.

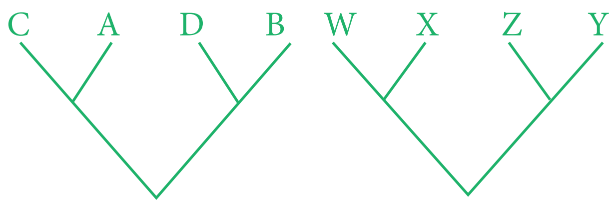
i. **Monophyletic group;** Taxa comprising all the descendants of a common ancestor.



ii. **Paraphyletic group;** Taxon that includes an ancestor but not all of the descendants of that ancestor.



iii. **Polyphyletic group;** Taxa that includes members from two different lineages.



Need for cladistics

1. Cladistics is now the most commonly used and accepted method for creating phylogenetic system of classifications.

2. Cladistics produces a hypothesis about the relationship of organisms to predict the morphological characteristics of organism.
3. Cladistics helps to elucidate mechanism of evolution.

5.13 Selected Families of Angiosperms

Dicot Families

Plant kingdom is so vast and varied. For the purpose of study, they have been classified into Artificial, Natural, Phylogenetic and APG system in course of time. Bentham and Hooker system of classification is followed in India till recently. Great variation occurs not only in different families, but also varies in genera and species which are included within the family. Variation occurs in number, arrangement, adhesion and cohesion of the floral parts. We study a few families for understanding the process and purpose of classification.

5.13.1 Family: Fabaceae (Pea family)

Systematic position

APG classification		**Bentham and Hooker classification**	
Kingdom:	**Plantae**	**Kingdom:**	**Plantae**
Clade	Angiosperms	Class:	Dicotyledonae
Clade	Eudicots	Sub-class:	Polypetalae
Clade	Rosids	Series:	Calyciflorae
Order:	Fabales	Order:	Rosales
Family:	Fabaceae	Family:	Fabaceae

Diagnostic features

- Leaves simple or imparipinnately compound or palmate, leaf base pulvinate, leaflets stipellate.
- Flowers Zygomorphic
- Corolla: Papilionaceous, descendingly imbricate aestivation, posterior petal outermost,
- Petals clawed.
- Stamens : Monadelphous, diadelphous
- Ovary stipitate (a short stalk as the base), monocarpellary, unilocular with marginal placentation.
- Fruit a legume or lomentum.

General characters

Distribution: Fabaceae includes about 741 genera and more than 20,200 species. The members are cosmopolitan in distribution but abundant in tropical and subtropical regions.

Habit: All types of habits are represented in this family. Mostly herbs (*Indigofera, Crotalaria*), prostrate (*Indigofera enneaphylla)* erect (*Crotalaria verrucosa*), shrubs (*Cajanus cajan*), small trees (*Sesbania*), climbers (*Clitoria*), large tree (*Pongamia, Dalbergia, Erythrina, Butea*), woody climber (*Mucuna*), hydrophyte (*Aeschynomene aspera*) commonly called **pith plant.**


Root nodule

Root: Tap root system, roots are nodulated, have tubercles containing nitrogen – fixing bacteria (*Rhizobium leguminosarum)*

Stem: Aerial, herbaceous, woody (*Dalbergia*) twining or climbing *Clitoria*.

Leaf: Leaf simple or unifoliate (*Desmodium gangeticum*) bifoliate (*Zornia diphylla,*), Trifoliate (*Lablab purpureus)*, unipinnate or simple pinnate (*Clitoria*), alternate, stipulate, leaf base, **pulvinate**, stipulus 2, free. Leaves showing reticulate venation terminal leaflet modifies into a **tendril** in *Pisum sativum.*

Inflorescence: Raceme (*Crotalaria verrucosa*), panicle (*Dalbergia latifolia*) axillary solitary (*Clitoria ternatea*)

Flowers: Bracteate, bracteolate (*Sesbania*), pedicellate, complete, bisexual, pentamerous, heterochlamydeous, zygomorphic hypogynous or sometimes perigynous.

Calyx: Sepals 5, green, synsepalous, more or less united in a tube and persistant, valvate or imbricate, odd sepal is anterior in position.

Corolla: Petals 5, apopetalous, unequal and **papilionaceous**, **vexillary** or **descendingly imbricate** aestivation all petals have claw at the base. The outer most petal is large called **standard petal** or **vexillum**, Lateral 2 petals are lanceolate and curved. They are called **wing petals** or **alae**. Anterior two petals are partly fused and are called **keel petals** or **carina** which encloses the stamens and pistil.

Androecium: Stamens 10, diadelphous, usually 9+1 (*Clitoria ternatea*). The odd stamen is posterior in position. In *Aeschynomene aspera*, the stamens are fused to form two bundles each containing five stamens (5)+5. Stamens are **monadelphous** and **dimorphic** ie. 5 stamens have longer filaments and other 5 stamens have shorter filaments thus the stamens are found at two levels and the shape of anthers also varies in (*Crotalaria verrucosa)*. (5 anthers are long and lanceolate, and the other 5 anthers are short and blunt). Anthers are dithecous, basifixed and dehiscing longitudinally.

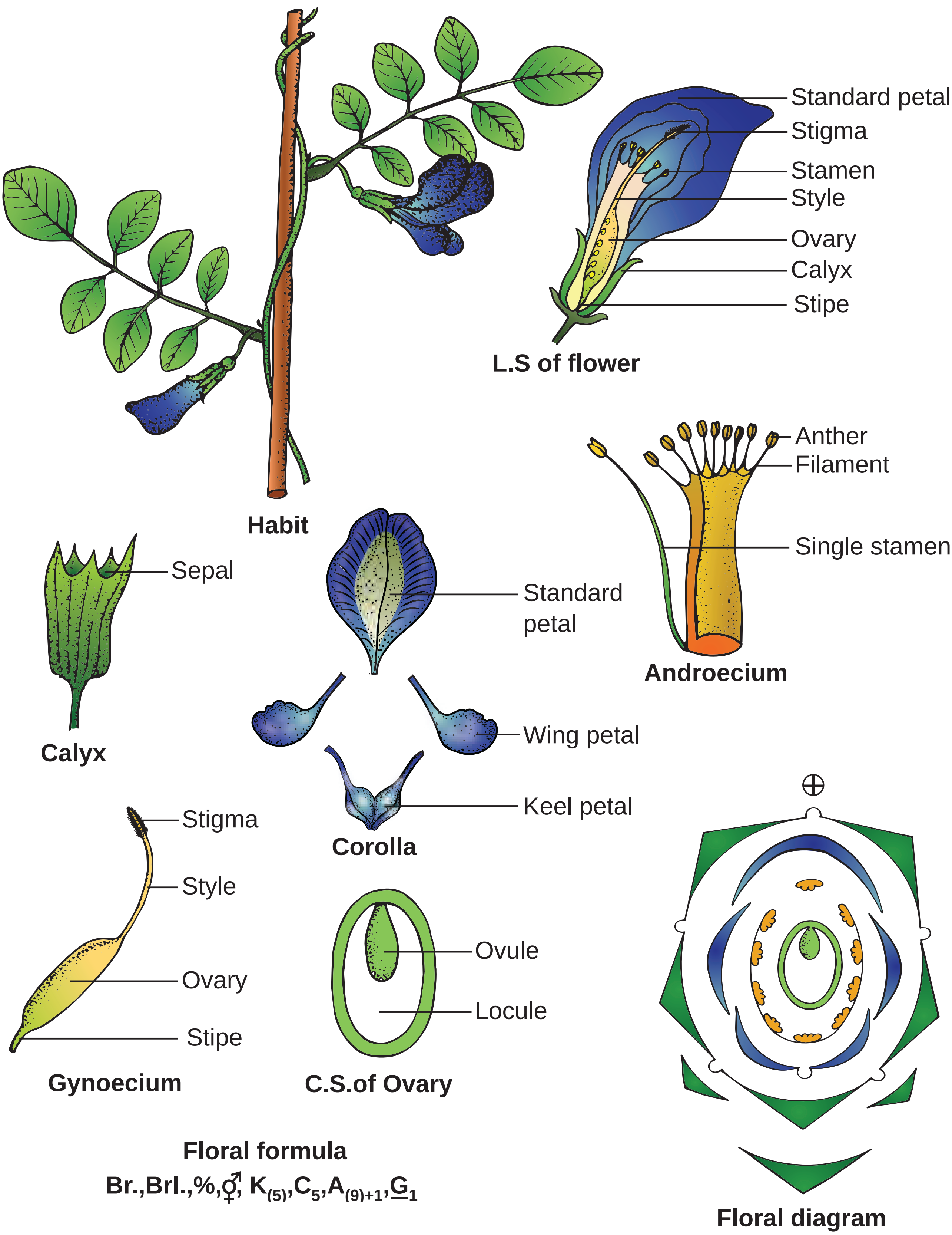
Gynoecium: Monocarpellary, unilocular, ovary superior, with two alternating rows of ovules on marginal placentation. Style simple and bent, stigma flattened or feathery.

Fruit: The characteristic fruit of Fabaceae is a legume (*Pisum sativum)*, sometimes indehiscent and rarely a lomentum (*Desmodium)*.

In *Arachis hypogea* the fruit is ***geocarpic*** (fruits develops and matures from underground). After fertilization the stipe of the ovary becomes meristematic and grows down into the soil. This ovary gets buried into the soil and develops into fruit.

Seed: Endospermic or non-endospermic (*Pisum sativum*), mostly **reniformed**.

Botanical description of *Clitoria ternatea* (Sangu pushpam)



Floral formula

Br., Brl., %, ⚥, $K_{(5)}, C_5, A_{(9)+1}, \underline{G}_1$

Figure 5.13: *Clitoria ternatea*

Habit: Twining climber

Root: Branched tap root system having nodules.

Stem: Aerial, weak stem and a twiner

Leaf: Imparipinnately compound, alternate, stipulate showing reticulate venation. Leaflets are stipellate. Petiolate and stipels are pulvinated.

Inflorescence: Solitary and axillary

Flower: Bracteate, bracteolate, bracteoles usually large, pedicellate, heterochlamydeous, complete, bisexual, pentamerous, zygomorphic and hypogynous.

Calyx: Sepals 5, synsepalous, green showing valvate aestivation. Odd sepal is anterior in position.

Corolla: Petals 5, white or blue apopetalous, irregular papilionaceous corolla showing, descendingly imbricate aestivation.

Androecium: Stamens 10, diadelphous (9)+1 nine stamens fused to form a bundle and the tenth stamen is free. Anthers are dithecous, basifixed, introse and dechiscing by longitudinal slits.

Gynoecium: Monocarpellary, unilocular, with many ovules on mariginal placentation, ovary superior, style simple and incurved with feathery stigma.

Fruit: Legume

Seed: Non-endospermous, reniform.

Floral Formula: Dt0Dtn0' .⚥'M$_{7+}$E$_{7}$.C$_{*;+3}$'I$_{3}$

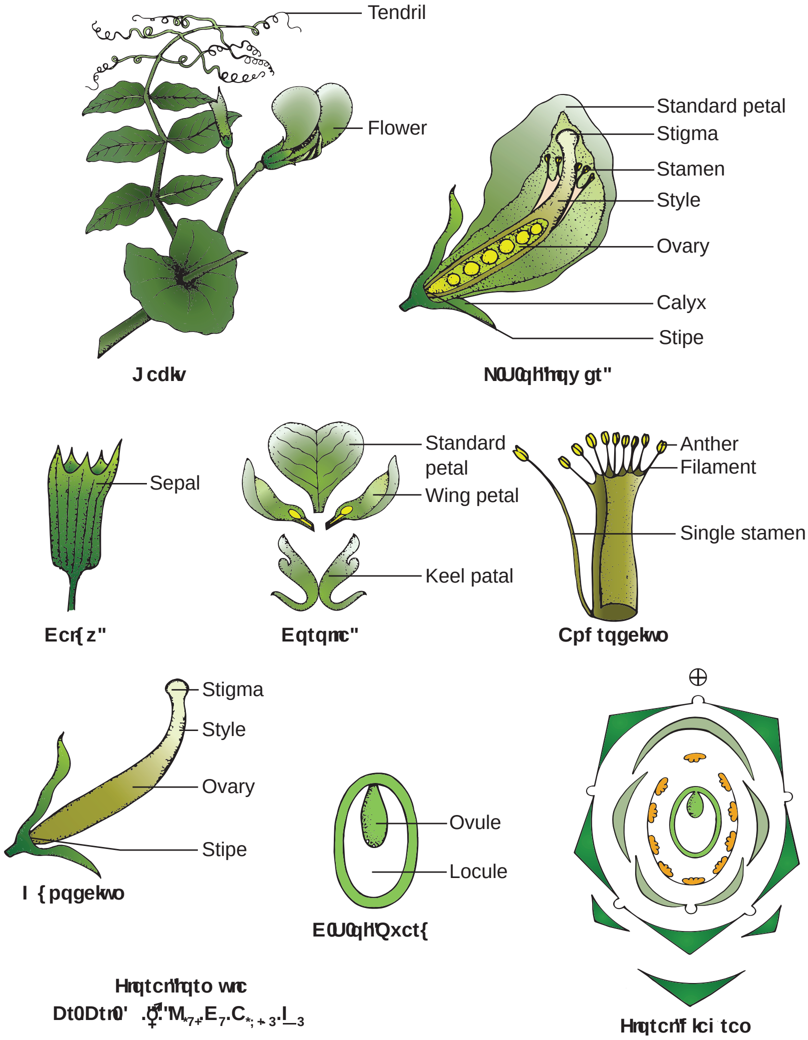


Figure 5.14: *Pisum sativum*

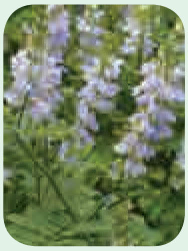
Economic Importance of the family Fabaceae

Economic importance	Binomial	Useful part	Uses
Pulses	*Cajanus cajan* (Pigeon Pea) *Phaseolus vulgaris* (French bean) *Cicer arietinum* (Chick pea / Channa / கொண்டைக்கடலை) *Vigna mungo* (black gram / உளுந்து) *Vigna radiata* (green gram / பாசிப்பயறு) *Vigna unguiculata* (cow pea / தட்டைப்பயறு) *Glycine max* (soya bean) *Macrotyloma uniflorum* (Horse gram / கொள்ளு)	Seeds	Sources of protein and starch of our food.
Food plants	*Lablab purpureus* (field bean) *Sesbania grandiflora* (agathi, vegetable humming bird) *Cyamopsis tetragonoloba* (cluster bean)	Tender fruits Leaves Tender fruits	Vegetable Greens Vegetable
Oil Plants	*Arachis hypogea* (Ground nut) *Pongamia pinnata* (Pungam)	Seeds Seeds	Oil extracted from the seeds is edible and used for cooking. Pongam oil has medicinal value and is used in the preparation of soap.
Timber Plants	*Dalbergia latifolia* (rose wood) *Pterocarpus santalinus* (red sandalwood) *P.dalbergioides* (Padauk) *P.marsupium* (வேங்கை)	Timber	Timber is used for making furniture, cabinet articles and as building materials.
Medicinal Plants	*Crotalaria albida* *Psoralea corylifolia* (கார்போக அரிசி) *Glycirrhiza glabra* (Licorice root / அதிமதுரம்) *Mucuna pruriens* (பூனைக்காலி)	Roots Seeds Roots Seeds	Used as purgative used in leprosy and leucoderma Immuno modulater Neurological remedy
Fibre Plants	*Crotalaria juncea* (sunhemp / சணப்பை) *Sesbania* sesban *(aegyptiaca)*	Stem fibres (Bast)	Used for making ropes.

Continued

Economic importance	Binomial	Useful part	Uses
Pith Plant	*Aeschynomene aspera*	Stem pith	Used for packing, handicraft and fishing floats
Dye Plants	*Indigofera tinctoria* (Avuri) *Clitoria ternatea* *Butea monosperma*	Leaves Flowers and seeds Flowers	Indigo dye obtained from leaves is used to colour printing and in paints. Blue dye is obtained Natural dye
Green Manuring	*Indigofera tinctoria* *Tephrosea purpurea* *Gliricidia sepium*	Entire plant	Used as green manure because of the presence of nitrogen fixing bacteria in the lateral roots.
Ornamental Plants	*Butea frondosa* (Flame of the forest), *Clitoria ternatea*, *Lathyrus odoratus* (Sweet pea) and *Lupinus hirsutus* (Lupin)	Entire plant	Grown as ornamental plants.

Diabetes Remedy



The aerial parts of *Galega officinalis* (Fabaceae) contains Metformin (dimethyl biguanide). It is now reputed to be the most widely prescribed agent in the treatment of diabetes all over the world.

The seeds of *Abrus precatorius* are used in necklaces and rosaries, but are extremely poisonous and can be fatal if ingested.

The attractive seeds of *Adenanthera pavonina* (Family: Caesalpineacece) have been used as units of weight for the measures of gold throughout India.

The Food and Agriculture Organization (FAO) of the United Nations has been nominated to declare 2016 as the year for pulses, to make people more aware of the nutritional value of pulses,


Arachis hypogea


Crotalaria verrucosa


Indigofera tinctoria


Aeschynomene aspera

Figure 5.15: Selected plants belongs to the Family Fabaceae

5.13.2 Family: Solanaceae (Potato Family / Night shade family)

Systematic Position

APG system of classification		Bentham and Hooker system of classification	
Kingdom:	**Plantae**	**Kingdom:**	**Plantae**
Clade :	Angiosperms	Class:	Dicotyledonae
Clade:	Eudicot	Subclass:	Gamopetalae
Clade:	Asterids	Series:	Bicarpellatae
Clade:	Solanales	Order:	Polemoniales
Family:	Solanaceae	Family:	Solanaceae

Diagnostic Features

- Leaves alternate, exstipulate
- Flowers actinomorphic, pentamerous
- Calyx often persistence / accrescent
- Stamens 5, epipetalous, poricidal in dehiscence
- Carpels 2, ovary superior, 2 chambered, obliquely placed, falsely four chambered placenta swollen, ovule numerous.
- Fruits berry or capsule, vascular bundles with both outer and inner phloem (Bicollateral vascular bundle)

General Characters

Distribution:

Family Solanaceae includes about 88 genera and about 2650 species, of these *Solanum* is the largest genus of the family with about 1500 species. Plants are worldwide in distribution but more abundant in South America.

Habit: Mostly annual herbs, shrubs, small trees (*Solanum violaceum*) lianas with prickles (*Solanum trilobatum*) many with stellate trichomes; rarely vines (*Lycium sinensis*)

Root: Branched tap root system.

Stem: Herbaceous or woody; erect or twining, or creeping; sometimes modified into tubers (*Solanum tuberosum*) often with **bicollateral** vascular bundles.

Leaves: Alternate, simple, rarely pinnately compound(*Solanum tuberosum* and (*Lycopersicon esculentum*) exstipulate, opposite or sub-opposite in upper part, unicostate reticulate venation.

Inflorescence: Generally axillary or terminal cymose (*Solanum*) or solitary flowers (*Datura stramonium*). Extra axillary scorpiod cyme called **rhiphidium** (*Solanum nigrum*) solitary and axillary (*Datura* and *Nicotiana*) umbellate cyme (*Withania somnifera*).

Flowers: Bracteate (*Petunia*), or ebracteate (*Withania*) pedicellate, bisexual, heterochlamydeous, actinomorphic or weakly zygomorphic due to oblique position of ovary pentamerous, hypogynous.

Calyx: Sepals 5, rarely 4 or 6, Synsepalous, valvale peristaent, often accrescent (enlarging to envelop the fruit) occasionally enclosing the fruit (*Physalis, Withania*)

Corolla: Petals 5, sympetalous, rotate, tubular (*Solanum*) or bell- shaped (*Atropa*) or infundibuliform (*Petunia*) usually alternate with sepals; rarely bilipped and zygomorphic (*Schizanthus*) usually valvate, sometimes convolute (*Datura*).

Androecium: Stamens 5, epipetalous, filaments usually unequal in length, stamens only 2 in *Schizanthus,* 4 and didynamous in (*Salpiglossis*) Anthers dithecous, dehisce longitudinally or poricidal.

Gynoecium: Bicarpellary, syncarpous obliquely placed, ovary superior, bilocular but looks tetralocular due to the formation of false septa, numerous ovules in each locule on axile placentation.

Fruit: A capsule or berry. In *Lycopersicon esculentum, Capsicum*, the fruit is a berry and in species of *Datura* and *Petunia*, the fruit is a capsule.

Seed: Endospermous.

Botanical description of *Datura metel*

Habit: Large, erect and stout herb.

Root: Branched tap root system.

Stem: Stem is hollow, green and herbaceous with strong odour.

Leaf: Simple, alternate, petiolate, entire or deeply lobed, glabrous exstipulate showing unicostate reticulate venation.

Inflorescence: Solitary and axillary cyme.

Flower: Flowers are large, greenish white, bracteate, ebracteolate, pedicellate, complete, heterochlamydeous, pentamerous, regular, actinomorphic, bisexual and hypogynous.

Calyx: Sepals 5, green synsepalous showing valvate aestivation. Calyx is mostly persistant, odd sepal is posterior in position.

Corolla: petals 5, greenish white, sympetalous, plicate (folded like a fan) showing twisted aestivation, funnel shaped with wide mouth and 10 lobed.

Androecium: Stamens 5, free from one another, epipetalous, alternipetalous and are inserted in the middle of the corolla tube. Anthers are basifixed, dithecous, with long filament, introse and longitudinally dehiscent.

Gynoecium: Ovary bicarpellary, syncarpous superior. Basically biloculear but tetralocular due to the formation of false septum. Carpels are obliquely placed and ovules on swollen axile placentation. Style simple long and filiform, stigma two lobed.

Fruit: Spinescent capsule opening by four apical valves with persistent calyx.

Seed: Endospermous.

Floral Formula: Dt0Gdtn0$\oplus$.⚥.$M_{*7+}.\overset{\frown}{E_{*7+}.C_{7}}.\underline{I}_{*4+}$

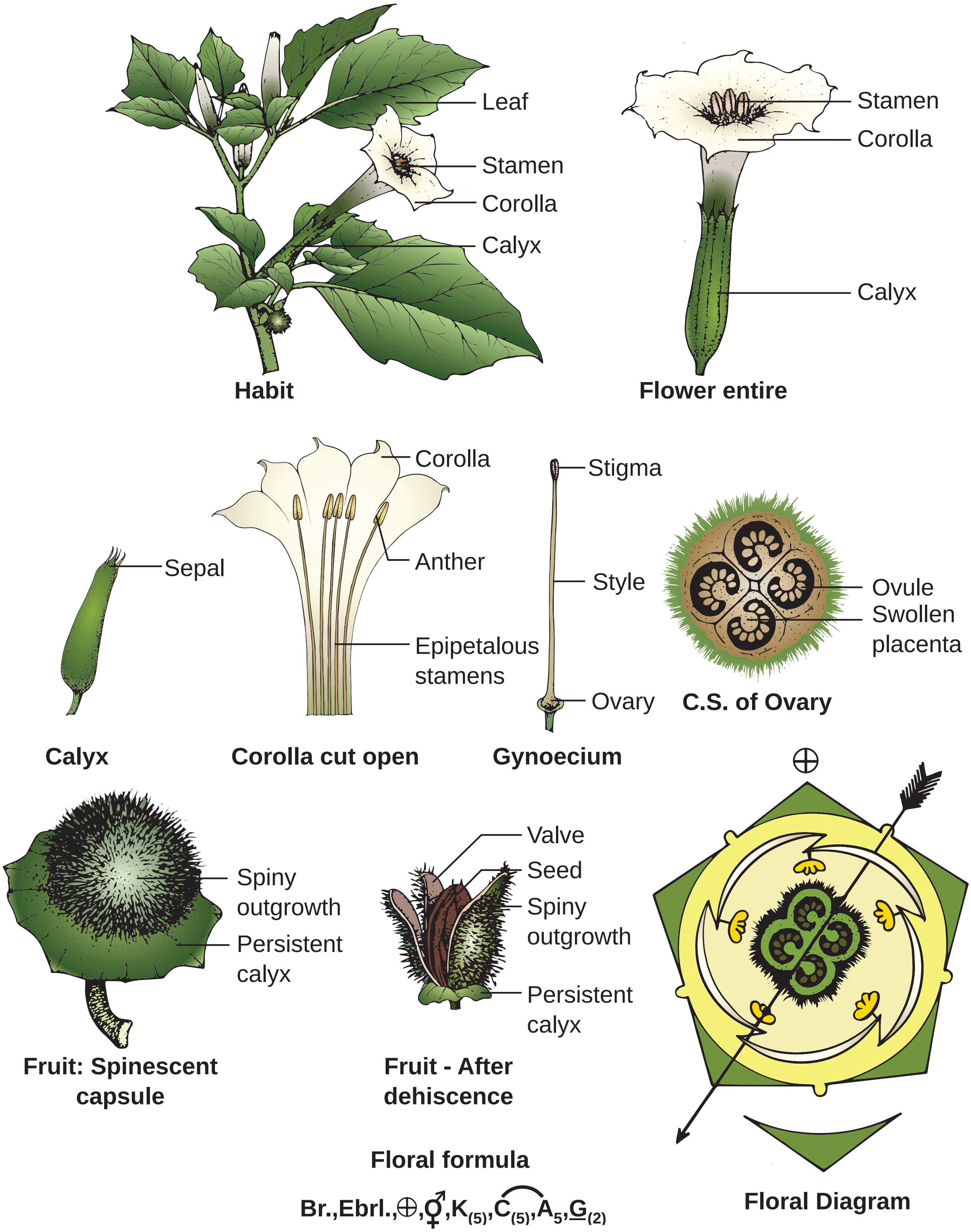


Figure 5.16: *Datura metel*

Economic importance

Economic importance of the family solanaceae				
S.No	**Economic importance**	**Binomial**	**Useful part**	**Uses**
1.	Food plant	*Solanum tuberosum* (potato)	Underground stem tubers	Used as vegetables and also used for the production of starch.
		Lycopersicon esculentum (tomato)	Ripened fruits	Used as delicious vegetable and eaten raw.
		Solanum melongena (brinjal)	Tender fruits	Cooked and eaten as vegetable.
		Capsicum annuum (bell peppers & chilli papers) *C. frutescens* (மிளகாய்)	Fruits	Used as vegetables and powdered chilli is the dried pulverized fruit which is used as spice to add pungency or piquancy and flavour to dishes .
		Physalis peruviana (cape gooseberry / சொடக்கு தக்காளி)	Fruit	Used as delicious fruit.
2.	Medicinal plant	*Atropa belladonna* (deadly nightshade)	Roots	A powerful alkaloid 'atropine' obtained from root is used in belladona plasters, tinctures etc. for relieving pain and also for dialating pupils of eyes for eye –testing.
		Datura stramonium (ஊமத்தை)	Leaves and roots	Stramonium drug obtained from the leaves and roots of this is used to treat asthma and whooping cough.
		Solanum trilobatum (தூதுவளை)	Leaves, flowers and berries	Used to treat cough.
		Withania somnifera (Ashwagandha / அமுக்காரா)	Roots	Used in curing cough and rheumatism.

Continued

Economic importance of the family solanaceae				
S.No	**Economic importance**	**Binomial**	**Useful part**	**Uses**
3.	Tobacco	*Nicotiana tabaccum* (tobacco / புகையிலை)	Leaves are dried and made into tobacco.	Used in cigarette, beedi, hukkah, pipes as well as for chewing and snuffing, alkaloids like nicotine, nornicotine and anabasin are present in tobacco.
4.	Ornamental plants	*Cestrum diurnum* (Day Jasmine) *Cestrum nocturnum* (Night Jasmine) *Nicotiana alata* *Petunia hybrida*, *Schizanthus pinnatus* *Brugmansia* species (Angel trumpet)	Plant	Grown in garden as ornamental plants for their aesthetic nature. Do tomatoes come from a tree?  *Solanum betaceum* (Tree tomato)

Solanum trilobatum

Atropa belladonna

Withania somnifera

Schizanthus pinnatus

Figure 5.17: Selected plants belongs to the Family Solanace

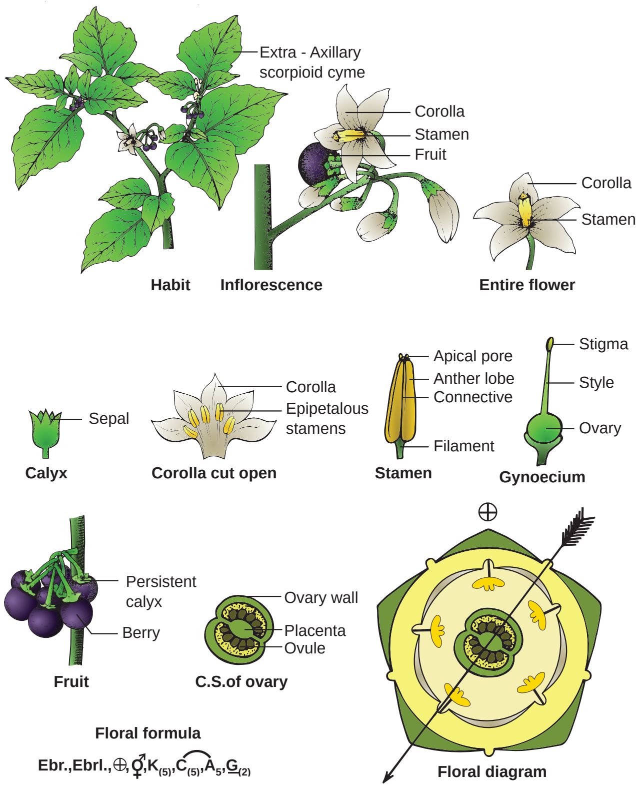


Figure 5.18: *Solanum americanum*

5.13.3 Monocot Family

Family: Liliaceae (Lily Family)

Systematic position

APG Classification		**Bentham and Hooker Classification**	
Kingdom:	**Plantae**	**Kingdom:**	**Plantae**
Clade:	Angiosperms	Class:	Monocotyledons
Clade:	Monocots	Series:	Coronarieae
Order:	Liliales	Order:	Liliales
Family:	Liliaceae	Family:	Liliaceae

Diagnostic Features

- Perennial herbs often with bulbous stem / rhizomes
- Radical leaves
- Perianth showy
- Stamens six
- Ovary superior

Note: Liliaceae of Bentham and Hooker included *Allium, Gloriosa, Smilax, Asparagus, Scilla, Aloe, Dracaena* etc. Now under APG, it includes only ***Lilium*** and ***Tulipa***. All others are placed under different families.

General Characters

Distribution: Liliaceae are fairly large family comprising about 15 genera and 550 species. Members of this family are widely distributed over most part of the world.

Habit: Mostly perennial herbs persisting by means of a sympodial rhizome (*Polygonatum*), by a bulb (*Lilium*) corm (*Colchicum*), shrubby or tree like (*Yucca* and *Dracaena*). Woody climbers, climbing with the help of stipular tendrils in *Smilax*. Trees in *Xanthorrhoea*, succulents in *Aloe*.

Root: Adventitious and fibrous, and typically contractile.

Stem: Stems usually bulbous, rhizomatous in some, aerial, erect (*Dracaena*) or climbing (*Smilax*) in *Ruscus* the ultimate branches are modified into phylloclades, In *Asparagus* stem is modified into cladodes and the leaves are reduced to scales.

Leaf: Leaves are radical (*Lilium*) or **cauline** (*Dracaena*), usually alternate, opposite (*Gloriosa*), sometimes fleshy and hollow, reduced to scales (*Ruscus* and *Asparagus*). The venation is parallel but in species of *Smilax* it is reticulate. Leaves are usually exstipulate, but in *Smilax*, two tendrils arise from the base of the leaf, which are considered modified stipules.

Inflorescence: Flowers are usually borne in simple or branched racemes (*Asphodelus*) spikes in *Aloe*, huge terminal panicle in *Yucca*, solitary and axillary in *Gloriosa*, solitary and terminal in *Tulipa*.

Flowers: Flowers are often showy, pedicellate, bracteate, usually ebracteolate except *Dianella* and *Lilium*, bisexual, actinomorphic, trimerous, hypogynous, rarely unisexual (*Smilax*) and are dioecious, rarely tetramerous (*Maianthemum*), slightly zygomorphic (*Lilium*) and hypogynous.

Perianth: Tepals 6 biseriate arranged in two whorls of 3 each, apotepalous or rarely syntepalous as in *Aloe.* Usually petaloid or sometimes sepaloid, odd tepal of the outer whorl is anterior in position, valvate or imbricate, tepals more than six in *Paris quadrifolia*.

Androecium: Stamens 6, arranged in 2 whorls of 3 each: rarely stamens are 3 (*Ruscus*),4 in *Maianthemum*, or up to 12, apostamenous, opposite to the tepals, sometimes epitepalous; filaments distinct or connate, anthers dithecous, basifixed or versatile, extrose, or intrese, dehiscing usually by vertical slit and sometimes by terminal pores; rarely **synstamenous** (*Ruscus*).

Gynoecium: Tricarpallary, syncarpous, the odd carpel usually anterior, ovary superior, trilocular, with 2 rows of numerous ovules on axile placextation; rarely unilocular with parietal placentation, style usually one; stigmas 1 or 3; rarely the ovary is inferior (*Haemodorum*), nectar – secreting **septal glands** are present in the ovary.

Fruit: Fruit usually a septicidal or loculicidal capsule or a berry as in *Asparagus* & *Smilax*.

Activity

Can you identify this?

a. Name the family
b. Write the binomial
c. List the economic uses

Botanical description of *Allium cepa*

(In APG classification, *Allium cepa* is placed under the family Amaryllidaceae)

Habit: Perennial herb with bulb.

Root: Fibrous adventitious root system

Stem: Underground bulb

Leaf: a cluster of radical leaves emerges from the underground bulb, cylindrical and fleshy having sheathy leaf bases with parallel venation.

Inflorescence: Scapigerous i.e. the inflorescence axis (peduncle) arising from the ground bearing a cluster of flowers at its apex. Pedicels are of equal length, arising from the apex of the peduncle which brings all flowers at the same level.

Flower: Small, white, bracteate, ebrcteolate, pedicellate, complete, trimerous, actinomorphic and hypogynous. Flowers are protandrous.

Perianth: Tepals 6, white,arranged in two whorls of three each, syntepalous showing valvate aestivation.

Androecium: Stamens 6, arranged in two whorls of three each, epitepalous, apostamenous /free and opposite to tepals. Anthers dithecous, basifixed, introse, and dehiscing longitudinally.

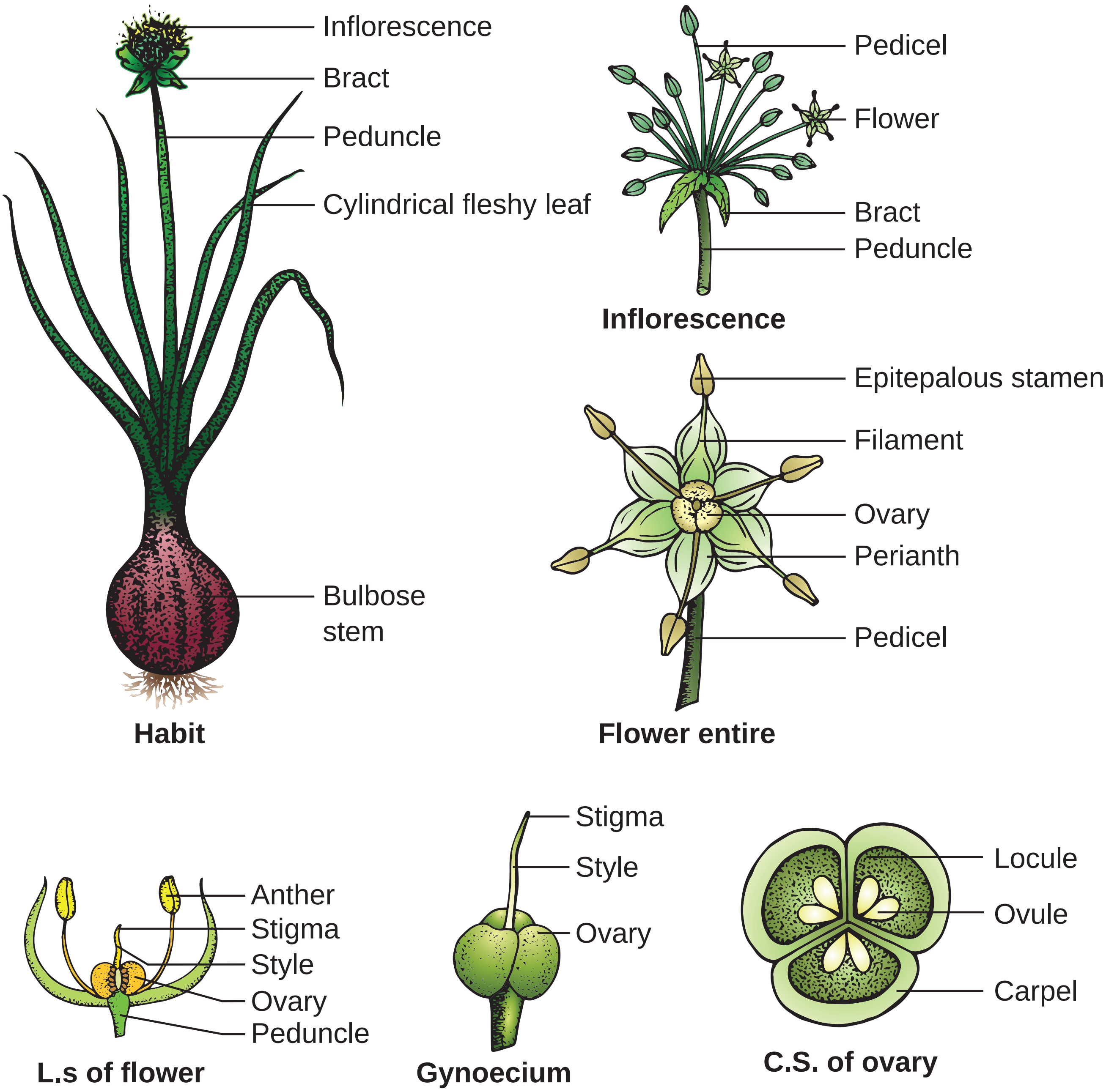
Gynoecium: Tricarpellary and syncarpous. Ovary superior, trilocular with two ovules in each locule on axile placentation. Style simple, slender with simple stigma.

Fruit: A loculicidal capsule.

Seed: Endospermous

Floral Formula:

$$Br., Ebrl., \oplus, ⚥, \overset{\frown}{P_{(3+3)} + A_{3+3}}, \underline{G}_{(3)}$$



Floral formula

Br.,Ebrl.,⊕,⚥,$\widehat{P_{(3+3)}+A_{3+3}}$,$\underline{G}_{(3)}$

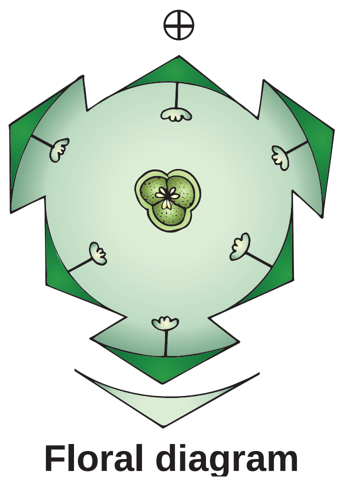


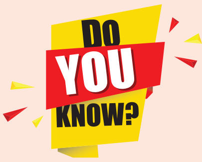
Figure 5.19: *Allium cepa*

Economic Importance of the family liliaceae

S.No.	Economic importance	Binomial	Useful part	Uses
1.	Food plant	*Allium cepa*	Bulbs	Used as vegetable, stimulative, diuretic, expectorant with bactericidal properties.
		Allium sativum	Bulbs	Used as condiment and also good for heart.
		Asparagus officinalis	Fleshy shoots	Used as vegetables.
		A. racemosus	Tuberous roots	Used as vegetables.
2.	Medicinal plant	*Aloe barbadense*	Leaves	Leaves are the source of resinous drug, used as a purgative.
		Aloe vera	Leaves	Gelatinous glycoside called aloin from succulent leaves are used in soothing lotions, piles and inflammations, hemorrhoidal salves and shampoos.
		Asparagus racemosus	Roots	Medicinal oil is prepared from the root is used for nervous and rheumatic complaints and also in skin diseases.
		Colchichum luteum	Roots	Used in the treatment of gout and rheumatism.
		Gloriosa superba	Tubers	Tubers helpful in promoting labour pains in women.
		Scilla hyacinthiana	Bulbs	Used as heart stimulant.
		Smilax glabra and *S.ovalifolia*	Roots	Used in the treatment of venereal diseases.
3.	Fibre yielding plant	*Phormium tenax*	Fibre	Used for cordage, fishing net, mattings, twines
4.	Raticides Insecticides	*Urginea indica* *Veratrum album*	Bulbs Bulbs	Used for killing rats Used as insecticide.

Continued

S.No.	Economic importance	Binomial	Useful part	Uses
5.	Polyploidy	*Colchicum luteum* is	Corm	Colchicine (alkaloid) used to induce polyploidy.
6.	Ornamental plants	*Agapanthus africanus* (African Lilly) *Hemerocallis fulva* (Orange Day Lilly) *Gloriosa superba* (Malabar glory lilly) *Lilium candidum* *Lilium giganteum* *Ruscus aculeatus* (Butchers Broom) *Tulipa suaveolens* *Yucca alcifolia* and *Y.gloriosa*	Plant	Some of the well known garden ornamentals.



In *Yucca* the cross-pollination carried out by special moth, *Pronuba yuccasella*. Fully opened flowers emit perfumes and are visited by the female moth, especially during nights. This moth collects a lot of pollen grains from one flower and visits another flower. Life history of this moth is intimately associated with the pollination mechanism in *Yucca*.

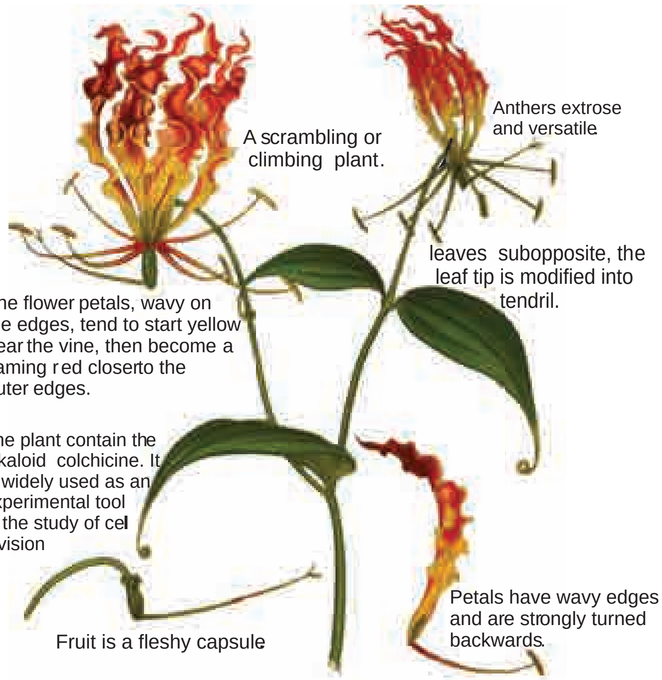
Lilium nilgiriensis

Smilax

Tulipa

Ruscus

State Flower of Tamil Nadu
Gloriosa superba



The name of *Gloriosa superba* is composed of two greek words *Gloriosa* means full of glory, *superba* means superb. This plant was placed earlier in Liliaceae.

Summary

Taxonomy deals with the identification, naming and classification of plants. But systematics deals with evolutionary relationship between the organisms in addition to taxonomy. Taxonomic hierarchy was introduced by Carolus Linnaeus. It includes ranks. Species is the fundamental unit of taxonomic classification. Species concept can be classified into two groups based on the process of evolution and product of evolution. There are three types of species, morphological, biological and phylogenetic species. Type concept emphasizes that a specimen must be associated with the scientific name which is known as nomenclatural type. There are different types and they are holotype, isotype, lectotype etc. Taxonomic aids are the tools for the taxonomic study such as keys, flora, revisions, catalogues, botanical gardens and herbaria. Botanical gardens serve different purposes. They have aesthetic value, offers scope for botanical research, conservation of rare species and propagation of many species. Botanical survey of India explores and documents biodiversity all over India. It has 11 regional centres in India. Herbarium preparation includes plant collection, documentation of field data, preparation of plant specimens and mounting and labeling. There are several national and international herbaria. National herbaria include MH, PCM, CAL etc. Kew herbarium is the world's largest one.

Classification is the basis for cataloguing and retrieving information about the tremendous diversity of flora. It helps us to know about different varieties, their phylogenetic relationship and exact position. Some important systems of classification are fall in to three types; artificial, natural and phylogenetic. Carolus Linnaeus outlined an artificial system of classification in "*Species Plantarum*" in 1753. The first scheme of classification based on overall similarities

was presented by Antoine Laurent De Jessieu in 1789. A widely followed natural system of classification was proposed by George Bentham (1800 - 1884) and Joseph Dalton Hooker. This system was not intended to be phylogenetic. One of the earliest phylogenetic systems of classification was jointly proposed by Adolf Engler and Karl A Prantl in a monumental work "***Die Naturelichen Pflanzen Familien***". Arthur Cronquist proposed phylogenetic classification of flowering plants based on a wide range of taxonomic characters including anatomical and phytochemical of phylogenetic importance in his book titled "The evolution and classification of flowering plants." Angiosperm phylogeny group (APG) classification is the most recent classification of flowering plants based on phylogenetic data. APG system is an evolving and currently accepted system across the world and followed by all the leading taxonomic institutions and practising taxonomists.

Cladistics is the methodology, used to classify organisms into monophyletic groups, consisting of all the descents of the common ancestors. The outcome of a cladistic analysis is a cladogram and is construed to represent the best hypothesis of phylogenetic relationships. Chemotaxonomy is the scientific approach of classification of plants on the basis of their biochemical constituents in them. Utilization of the characters of chromosome for the taxonomic inference is known as karyotaxonomy. The application of serology in solving taxonomic problems is called serotaxonomy. Molecular Taxonomy is the branch of phylogeny that analyses hereditary molecular differences, mainly in DNA nuclear and chloroplast sequences, to gain information and to establish genetic relationship between the members of different taxonomic categories. Different molecular markers like allozymes, mitochondrial DNA, microsatellites, RAPDs, AFLPs, single nucleotide polymorphism-SNP, microchips or arrays are used in analysis. Molecular Taxonomy unlocks the treasure chest of information on evolutionary history of organisms. It plays a vital role in phytogeography, which ultimately helps in genome mapping and biodiversity conservation. DNA barcoding is a taxonomic method that uses a very short genetic sequence from a standard part of a genome. It helps in identification of organisms.

Evaluation

1. Specimen derived from non-original collection serves as the nomenclatural type, when original specimen is missing. It is known as
   a. Holotype b. Neotype
   c. Isotype d. Paratype

5QIV5Y

2. Phylogenetic classification is the most favoured classification because it reflects
   a. Comparative Anatomy
   b. Number of flowers produced
   c. Comparative cytology
   d. Evolutionary relationships
3. The taxonomy which involves the similarities and dissimilarities among the immune system of different taxa is termed as
   a. Chemotaxonomy
   b. Molecular systematics
   c. Serotaxonomy
   d. Numerical taxonomy
4. Which of the following is a flowering plant with nodules containing filamentous nitrogen fixing micro - organisms?
   a. *Crotalaria juncea*
   b. *Cycas revoluta*
   c. *Cicer arietinum*
   d. *Casuarina equisetifolia*

5. Flowers are zygomorphic in
   a. *Ceropegia* b. *Thevetia*
   c. *Datura* d. *Solanum*
6. What is the role of national gardens in conserving biodiversity – discuss
7. Where will you place the plants which contain two cotyledons with cup shaped thalamus?
8. How does molecular markers work to unlock the evolutionary history of organisms?
9. Give the floral characters of *Clitoria ternatea.*
10. How will you distinguish Solanaceae members from Liliaceae members?

ICT Corner

Character of flower

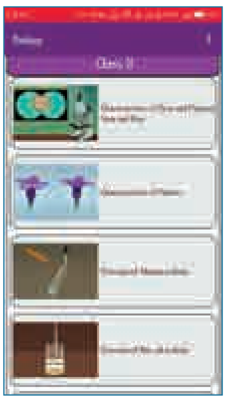
Look inside the **Flower.** →

Steps

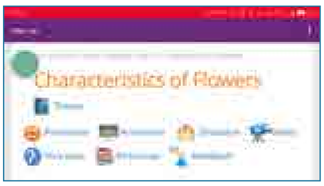
- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Character of flower
- Click theory to know the basic about Character of flower
- Register yourself with mail-id and create password to access online lab simulations

Activity

- Select simulation and dissect the different flowers
- Record your observations

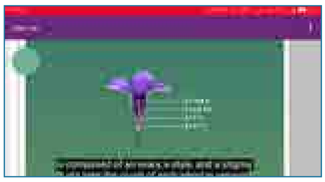


Step 1



Step 2

Step 3



Step 4

URL:

https://play.google.com/store/apps/details?id=in.edu.olabs.olabs&hl=en

B181_11_BOT

* Pictures are indicative only

Unit III: Cell biology and Biomolecules

Chapter 6

Cell: The Unit of Life

Learning Objectives

The learner will be able to,

- *Describe the cell and contributions of early scientist towards its discovery*
- *Appreciate the use of light and electron microscopes for better understanding of the cell*
- *Understand the ideas of cell theory and the different concepts associated with it*
- *Distinguish the significant characters of various groups of life forms*
- *Recognize the basic structure of cell and differentiate the cells of animals, plants, bacteria and viruses*
- *Explain the structure and functions of cell organelles including nucleus*
- *Recognize the structure of chromosome and its types*
- *Describe the flagellar structure, types and movements*
- *Get acquainted with the cytological techniques*

Chapter Outline

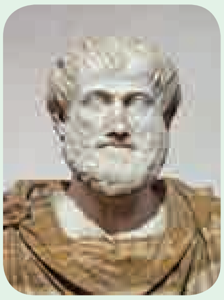
5QSR7L

The word '*cell*' comes from the Latin word '*Celle*" which means 'a small compartment'. The word cell was first used by Robert Hooke (1662) therefore the term '*cell*' is as old as 300 years.

6.1. Discovery

Aristotle (384-322BC), was the one who first recognised that animals and plants consists of organised structural units but unable to explain what it was. In 1660's **Robert Hooke** observed something which looks like 'honeycomb with a great little boxes' which was later called as '**cell**' from the cork tissue in 1665. He compiled his work as **Micrographia**. Later, **Antonie von Leeuwenhoek** observed unicellular particles which he named as '***animacules***'. **Robert Brown** (1831-39) described the spherical body in the plant

Scientist



Aristotle (384–322BC)

Robert Hooke (1635–1703)

Antonie von Leeuwenhoek (1632–1723)

Schleiden (1804–1881) & Schwann (1810–1882)

Rudolf Virchow (1821–1902)

Figure 6.1

cells as nucleus. **H. J. Dutrochet** (1824), a French scientist, was the first to give idea on cell theory. Later, **Matthias Schleiden** (German Botanist) and **Theodor Schwann** (German Zoologist) (1833) outlined the basic features of the cell theory. **Rudolf Virchow** (1858) explained the cell theory by adding a feature stating that all living cells arise from pre-existing living cells by 'cell division'.

6.2. Microscopy

Microscope is an inevitable instrument in studying the cell and subcellular structures. It offers scope in studying

Resolution: The term resolving power or resolution refers to the ability of the lenses to show the details of object lying between two points. It is the finest detail available from an object. It can be calculated using the following formula

$$\text{Resolution} = \frac{0.61\lambda}{NA}$$

Where, λ= wavelength of the light and NA is the numerical aperture.

Numerical Aperture: It is an important optical constant associated with the optical lens denoting the ability to resolve. Higher the NA value greater will be the resolving power of the microscope.

Magnification: The optical increase in the size of an image is called magnification. It is calculated by the following formula

$$\text{Magnification} = \frac{\text{size of image seen with the microscope}}{\text{size of the image seen with normal eye}}$$

microscopic organisms therefore it is named as microscope (mikros – small; skipein – to see) in Greek terminology. Compound microscope was invented by **Z. Jansen**.

Microscope works on the lens system which basically relies on properties of light and lens such as reflection, magnification and numerical aperture. The common light microscope which has many lenses are called as **compound microscope**. The microscope transmits visible light from sources to eye or camera through sample, where interaction takes place.

6.2.1 Bright field Microscope

Bright field microscope is routinely used microscope in studying various aspects of cells. It allows light to pass directly through specimen and shows a well distinguished image from different portions of the specimen depending upon the contrast from absorption of visible light. The contrast can be increased by staining the specimen with reagent that reacts with cells and tissue components of the object.

The light rays are focused by condenser on to the specimen on a microslide placed upon the adjustable platform called as **stage**. The light comes from the Compact Flourescent Lamp (CFL) or Light Emitting Diode (LED) light system. Then it passes through two lens systems namely objective lens (closer to the object) and the eye piece (closer to eye). There are four objective lenses (5X, 10X, 45X and 100X) which can be rotated and fixed at certain point to get required magnification. It works on the principle of numerical aperture value and its own resolving power.

The first magnification of the microscope is done by the objective lens which is called **primary magnification** and it is real, inverted image. The second magnification of the microscope is obtained through eye piece lens called as **secondary magnification** and it is virtual and inverted image (Figure 6.2 a, b and c).

6.2.2 Dark Field Microscope

The dark field microscope was discovered by **Z. Sigmondy** (1905). Here the field will be dark but object will be glistening so the appearance will be bright. A special effect in an ordinary microscope is brought about by means of a special component called '**Patch Stop Carrier**'. It is fixed in metal ring of the condenser component. Patch stop is a small glass device which has a dark patch at centre of the disc leaving a small area along the margin through which the light passes. The light passing through the margin will travel oblique like a hollow cone and strikes the object in the periphery, therefore the specimen appears glistening in a dark background. (Figure 6.2 d and e).

6.2.3 Phase contrast microscope

This was invented by **Zernike** (1935). It is a modification of light microscope with all its basic principle. The objects observed by increasing the contrast by bringing about change in amplitude of the light waves. The contrast can be increased by introducing the '**Phase Plate**' in the condenser lens. Phase plate is a circular component with circular annular etching.

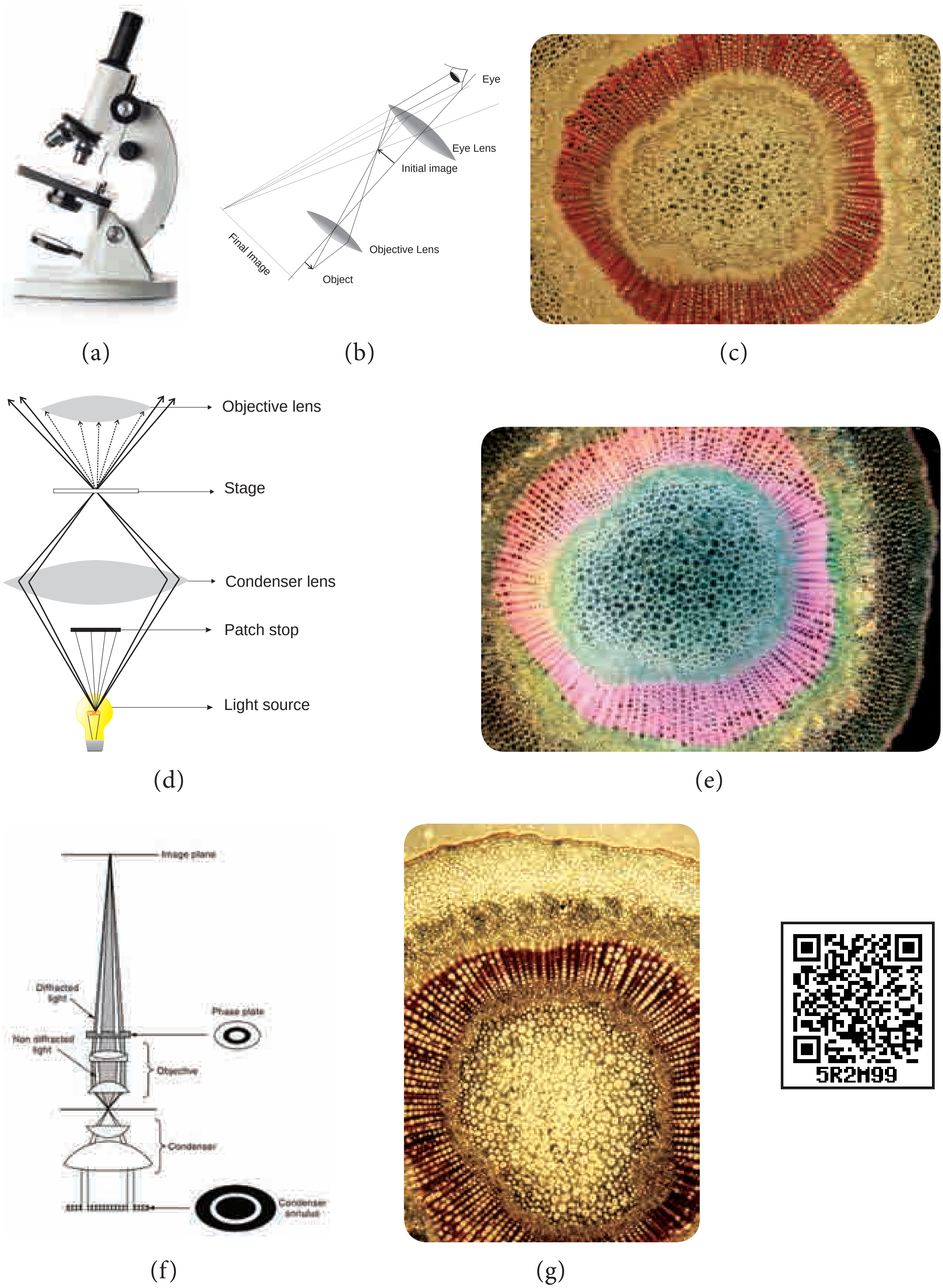


Figure 6.2: a. Light microscope; **b.** Ray diagram - light path; c. Image taken using light microscope; **d.** Light path in dark field; **e.** Image taken using dark field microscope; **f.** Light path in phase contrast microscope; **g.** Image taken using phase contrast microscope

DO YOU KNOW?

Microscopic measurements:

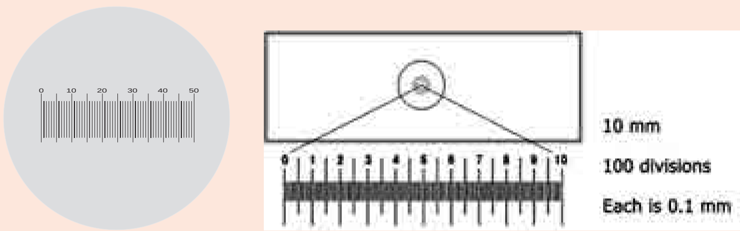
The microscope also has facility to measure microscopic objects through a technique called '**micrometry**'. There are two scales involved for measuring.

1. Ocular Micrometer
2. Stage Micrometer

Ocular Micrometer: It is fixed inside the eye piece lens. It is a thin transparent glass disc where there are lines divided into 100 equal units. The scale has no value.

Stage Micrometer: This is a slide with a line divided into 100 units. The line is about 1mm. The distance between two adjacent lines is 10 μm. The known value of the stage micrometer is transferred to the ocular micrometer, thereby the measurements can be made using ocular micrometer.

$$\text{The distance between two adjacent line of ocular meter} = \frac{\text{Number of stage divisions}}{\text{Number of ocular divisions}} \times 10$$



(a) (b)

Figure 6.3: a. Ocular micrometer; b. Stage micrometer

Light passes with different velocity after coming out of the thinnest and thickest areas of the phase plate thereby increasing the contrast of the specimen. A hollow cone of light passes through the condenser. Direct light pass through thin area of phase plate, whereas light passing from the specimen reaches thick area of phase plate. The light passing through thicker area travel at low speed, on the other hand the light passing through thin area reach fast therefore contrast is increased in the specimen. Phase contrast microscope is used to observe living cells, tissues and the cells cultured *invitro* during mitosis (Figure 6.2 f and g).

6.2.4 Electron Microscope

Electron Microscope was first introduced by **Ernest Ruska** (1931) and developed by **G Binning** and **H Roher** (1981). It is used to analyse the fine details of the cell and organelles called ultrastructure. It uses beam of accelerated electrons as source of illumination and therefore the resolving power is 1,00,000 times than that of light microscope.

The specimen to be viewed under electron microscope is dehydrated and impregnated with electron opaque chemicals like gold or palladium. This is essential for withstanding electrons and also for contrast of the image.

There are two kinds of electron microscopes namely

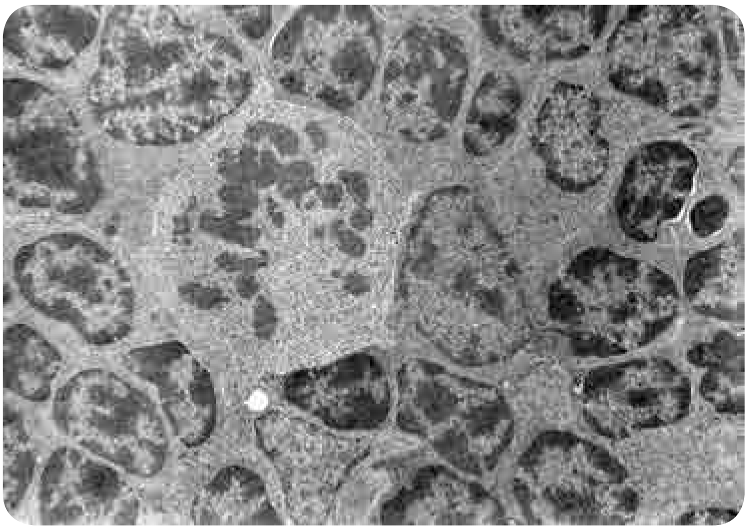
1. Transmission Electron Microscope (TEM)
2. Scanning Electron Microscope (SEM)

1. Transmission electron microscope:

This is the most commonly used electron microscope which provides two dimensional image. The components of the microscope are as follows:

a. Electron Generating System
b. Electron Condensor
c. Specimen Objective
d. Tube Lens
e. Projector

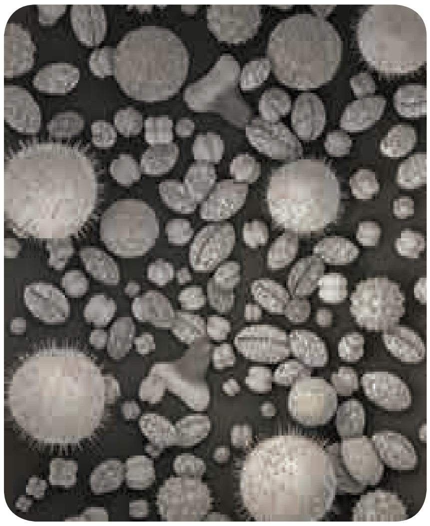
(a)



(b)

Figure 6.4: a. Transmission electron microscope; b. Image of TEM

(a)

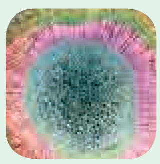
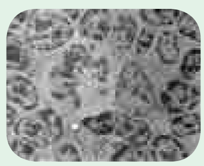
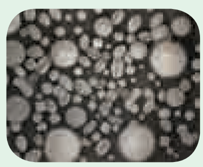


(b)

Figure 6.5: a. Scanning electron microscope; b. Image of SEM

A beam of electron passes through the specimen to form an image on fluorescent screen. The magnification is 1–3 lakhs times and resolving power is 2–10 Å. It is used for studying detailed structrue of viruses, mycoplasma, cellular organelles, etc (Figure 6.4 a and b).

Comparison of Microscopes

Features	Light Microscope	Dark Field Microscope	Phase Contrast Microscope	Transmission Electron Microscope	Scanning Electron Microscope
Source of illumination for Image Formation	Visible light	Visible light	Visible light	Electrons	Electrons
Types of cells visualized	Individual cells can be visualised, even living ones.	Individual cells can be visualised, even living ones.	Individual cells can be visualised, even living ones.	Thin sections of the specimen are obtained. The electron beam pass through the sections and form an image with high magnification and high resolution.	The specimen is coated with gold and the electrons are reflected back and give the details of surface topography of the specimen.
Image	2-D	2-D	2-D	2-D	3-D
Nature of Lenses	Glass lenses	Glass lenses	Glass lenses	One electrostatic lens with few electromagnetic lenses	One electrostatic lens with few electromagnetic lenses
Medium	Air/oil	Air/oil	Air/oil	Vacuum	Vacuum
Specimen mounting	Glass slides	Glass slides	Glass slides	Mounted on coated or uncoated copper grids	Mounted on aluminium stubs and are coated in gold
Focusing and Magnification Adjustments	Changing objectives	Changing objectives	Changing objectives	Electrical, using deflection coil	Electrical, using deflection coil
Means for obtaining specimen Contrast	Light diffraction	Through patch stop	Through phase plate	Electron scattering	Electron scattering
Microscope picture					

2. Scanning Electron Microscope:

This is used to obtain three dimensional image and has a lower resolving power than TEM. In this, electrons are focused by means of lenses into a very fine point. The interaction of electrons with the specimen results in the release of different forms of radiation (such as auger electrons, secondary electrons, back scattered electrons) from the surface of the specimen. These radiations are then captured by an appropriate detector, amplified and then imaged on fluorescent screen. The magnification is 2,00,000 times and resolution is 5–20 nm (Figure 6.5 a and b).

6.3. Cell Theory

In 1833, German botanist **Matthias Schleiden** and German zoologist **Theodor Schwann** proposed that all plants and animals are composed of cells and that cells were the basic building blocks of life.

These observations led to the formulation of modern cell theory.

- All organisms are made up of cells.
- New cells are formed by the division of pre-existing cells.
- Cells contains genetic material, which is passed on from from parents to daughter cells.
- All metabolic reactions take place inside the cells.

6.3.1 Exception to Cell Theory

Viruses are puzzle in biology. Viruses, viroids and prions are the exception to cell theory. They lack protoplasm, the essential part of the cell and exists as obligate parasites which are sub-cellular in nature.

6.3.2 Cell Doctrine (Cell Principle)

The features of cell doctrine are as follows:

- All organisms are made up of cells.
- New cells are produced from the pre-existing cells.
- Cell is a structural and functional unit of all living organisms.
- A cell contains hereditary information which is passed on from cell to cell during cell division.
- All the cells are basically the same in chemical composition and metabolic activities.
- The structure and function of cell is controlled by DNA.
- Sometimes the dead cells may remain functional as tracheids and vessels in plants and horny cells in animals.

6.3.3 Protoplasm Theory

Corti first observed protoplasm. **Felix Dujardin** (1835) observed a living juice in animal cell and called it "**Sarcode**". **Purkinje** (1839) coined the term protoplasm for sap inside a plant cell. **Hugo Van Mohl** (1846) indicated importance of protoplasm.

Max Schultze (1861) established similarity between Protoplasm and Sarcode and proposed a theory which later on called "**Protoplasm Theory**" by **O. Hertwig** (1892). **Huxley** (1868) proposed Protoplasm as a "**physical basis of life**".

Protoplasm as a Colloidal System

Protoplasm is a complex colloidal system which was suggested by **Fisher** in 1894 and **Hardy** in 1899. It is primarily made of water contents and various other solutes of biological importance such as glucose, fatty acids, amino acids, minerals, vitamins, hormones and enzymes.