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 organs
**4.4.** Androecium
**4.5.** Gynoecium
**4.6.** Construction of floral diagram and floral formula
**4.7.** Fruits
**4.8.** Seed

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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

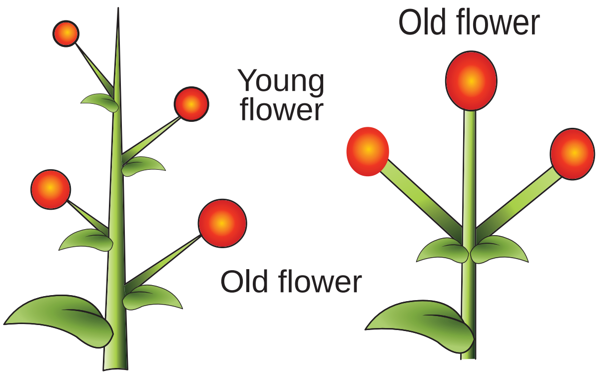



**Figure 4.2: (a)** Racemose     **Figure 4.2: (b)** Cymose inflorescence

| 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.

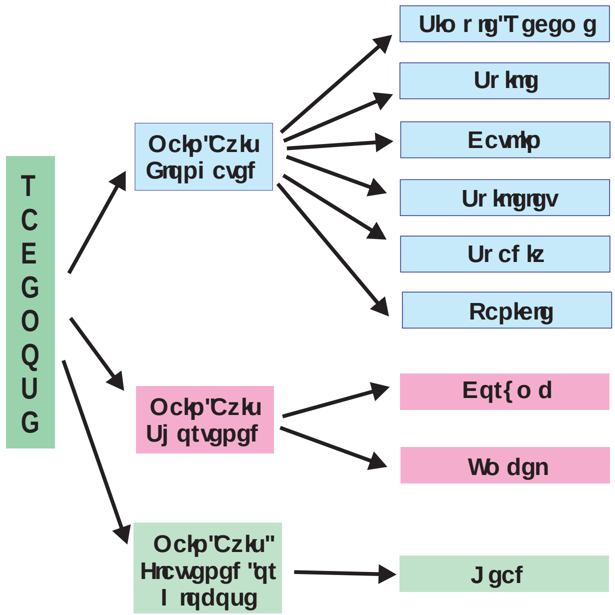


**Figure 4.3:** Racemose

**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

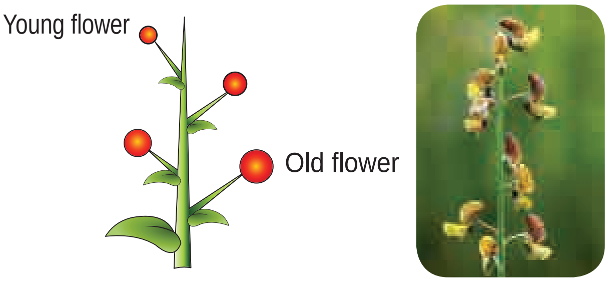



**Figure 4.4: (a)** diagrammatic, **(b)** Simple raceme


**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*.

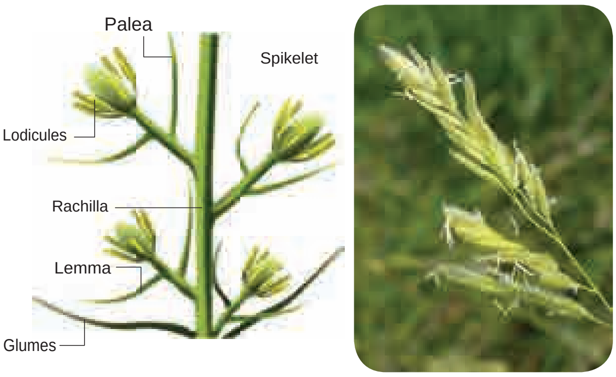



**Figure 4.4: (e)** diagrammatic, **(f)** Spikelet

**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

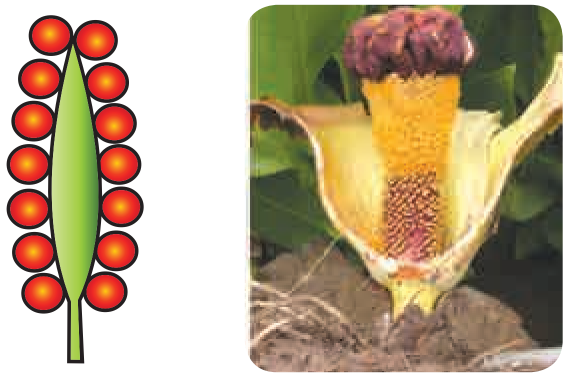


**Figure 4.4: (i)** diagrammatic, **(j)** Spadix

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

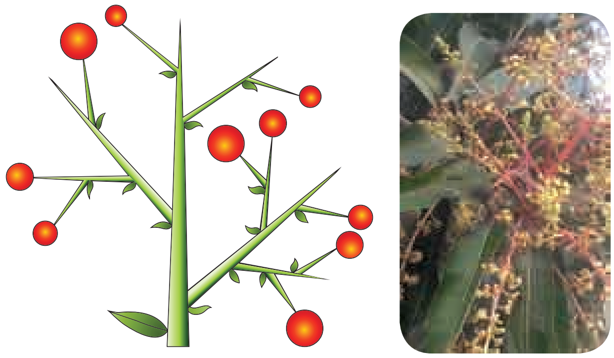


**Figure 4.4: (k)** diagrammatic, **(l)** Panicle

**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.

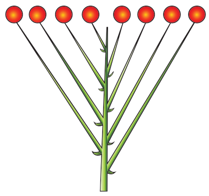


**Figure 4.4: (m)** Corymb diagrammatic

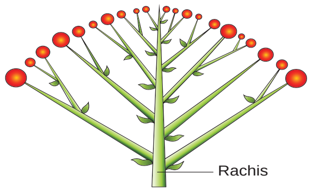



**Figure 4.4: (n)** Compound corymb diagrammatic

**Figure 4.4: (o)** Corymb

**Figure 4.4: (p)** Compound corymb

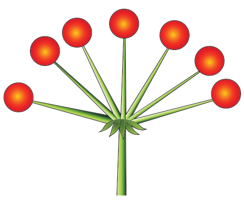


**Figure 4.4: (q)** Umbel diagrammatic

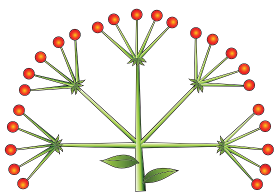


**Figure 4.4: (r)** Compound umbel diagrammatic

**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

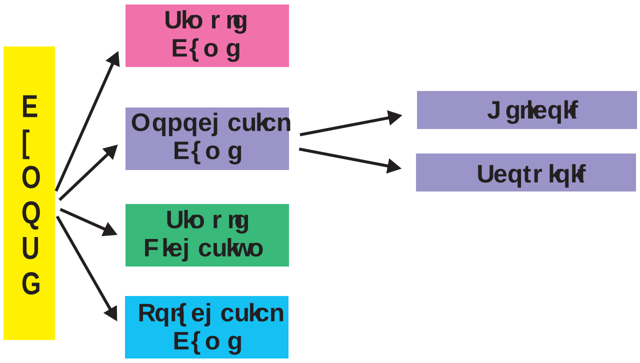


**Figure 4.5:** Cyme

**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.

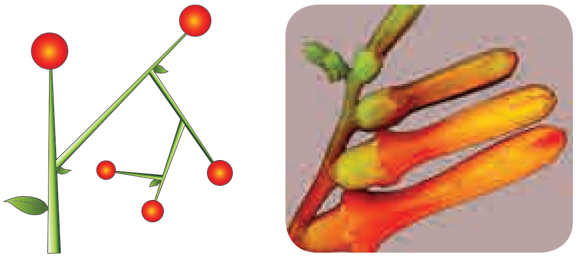


**Figure 4.6: (b)** diagrammatic, **(c)** Monochasial Helicoid

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

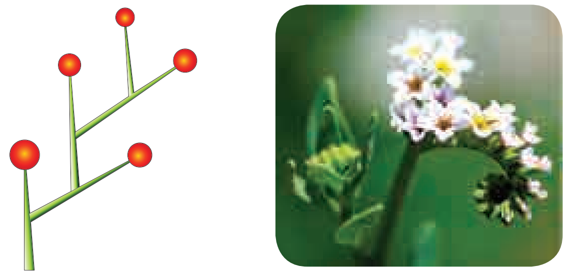


**Figure 4.6: (d)** diagrammatic, **(e)** Monochasial Scorpioid

**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*.

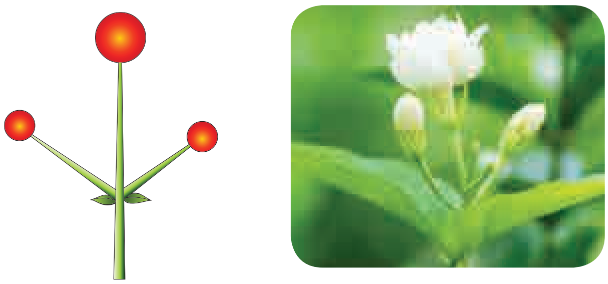


**Figure 4.6: (f)** diagrammatic, **(g)** Simple dichasium

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**

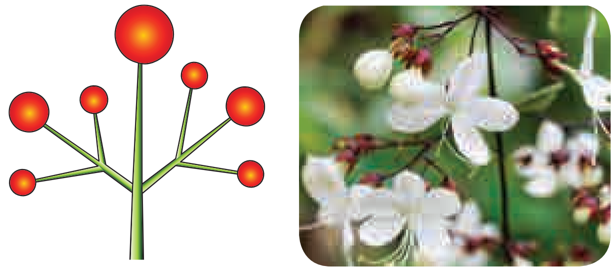


**Figure 4.6: (h)** diagrammatic, **(i)** Compound dichasium

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

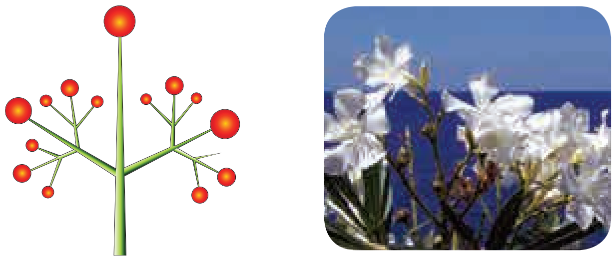
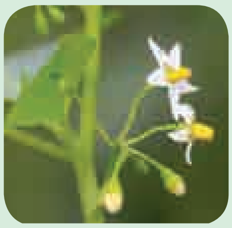


**Figure 4.6: ( j)** diagrammatic, **(k)** Polychasial cyme



**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

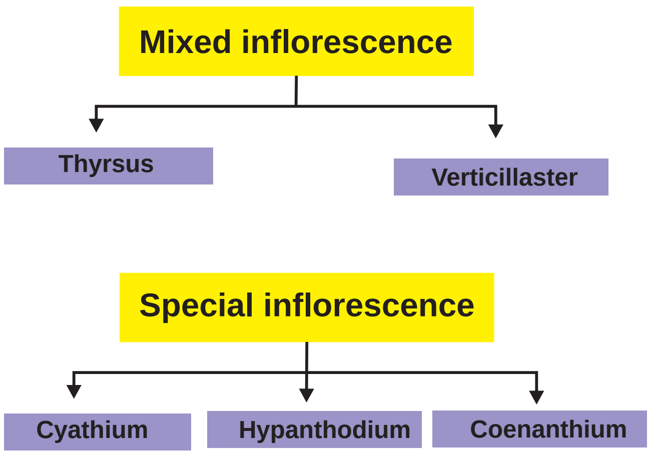



**Figure 4.7:** Mixed and special inflorescence

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*.

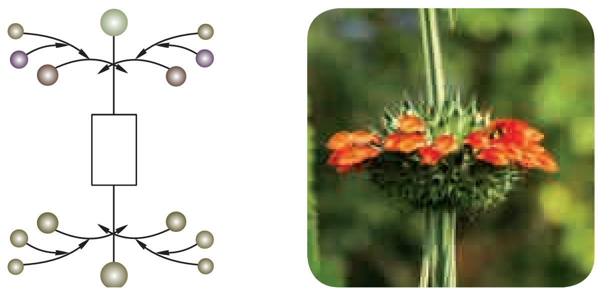


**Figure 4.8: (c)** diagrammatic, **(d)** Verticillaster

## 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.

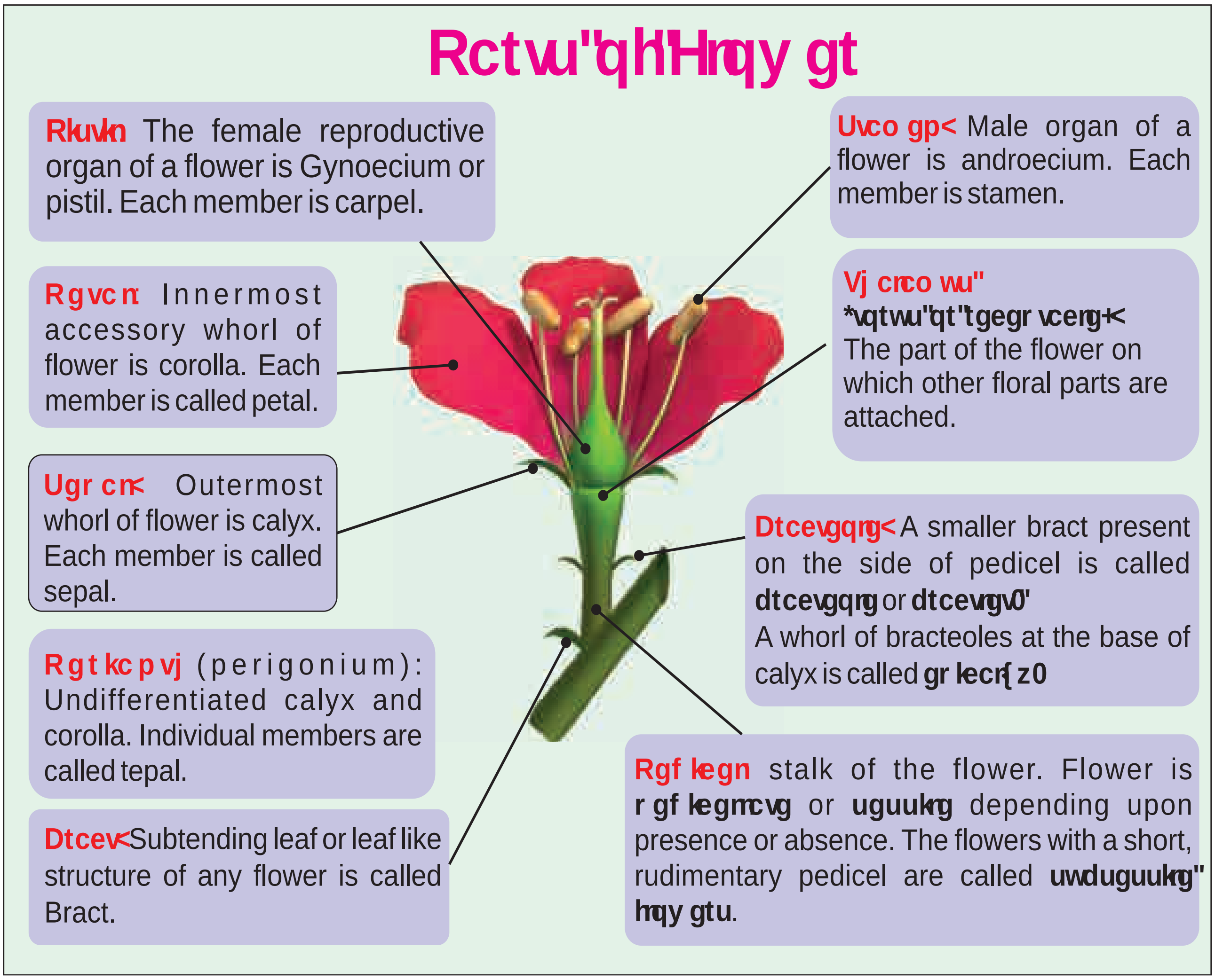



**Figure 4.10:** Parts of flower

### 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**.

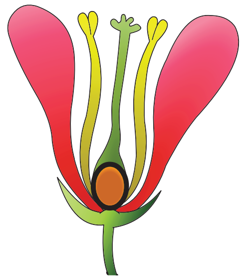


**Figure 4.11: (a)**
Bisexual flower

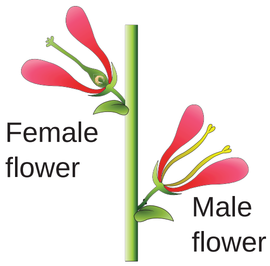



**Figure 4.12: (a)**
Monoecious

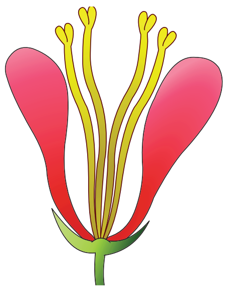


**Figure 4.11: (b)**
Male flower


**Figure 4.12: (b)**
Dioecious

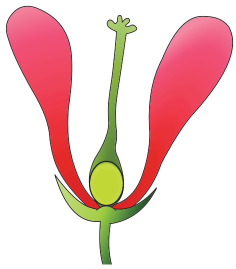


**Figure 4.11: (c)**
Female flower

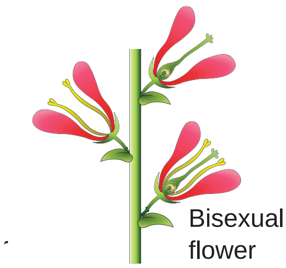



**Figure 4.12: (c)**
Polygamous

**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

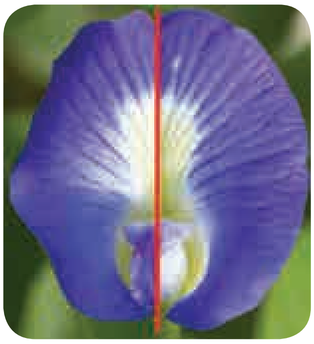


**Figure 4.13: (b)** Zygomorphic

**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 un-differentiated into calyx and corolla and com-posed 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.

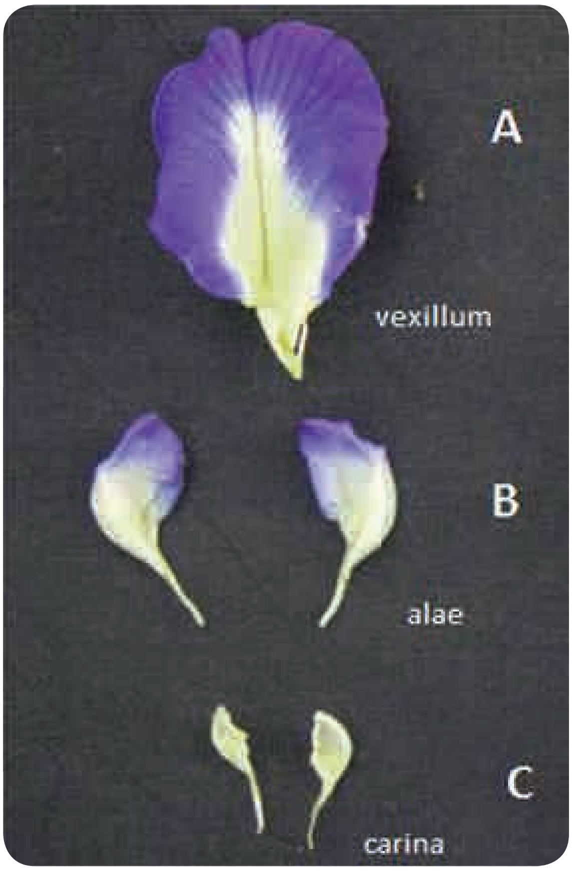



Figure 4.21: (c) Papilionaceous

**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*.

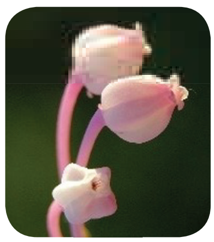


**Figure 4.21: (h)** Urceolate

### 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.

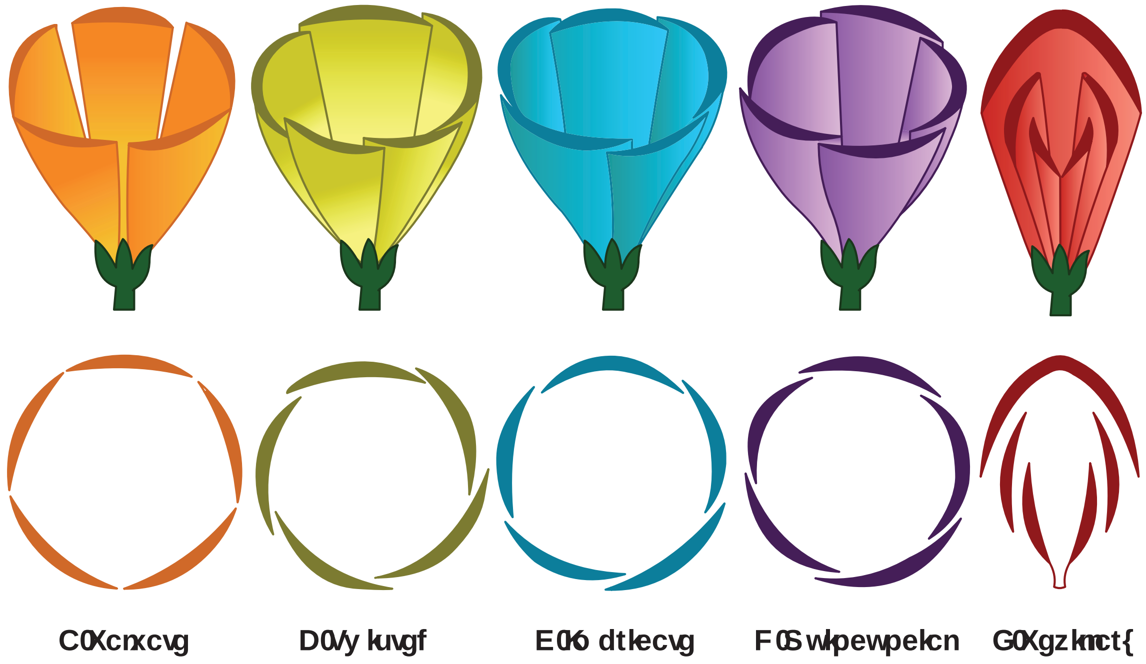


**Figure 4.22:** Aestivation

**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

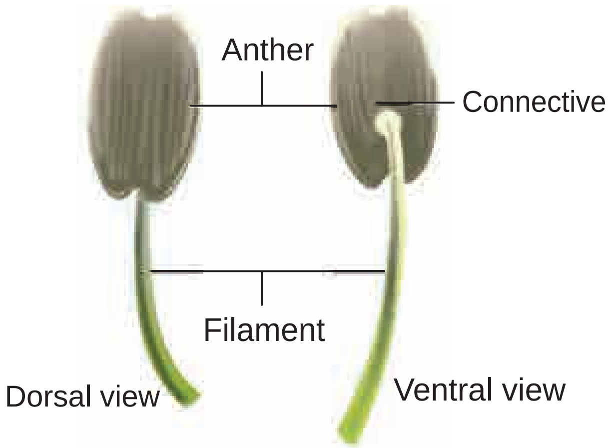



**Figure 4.23:** Stamen

**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

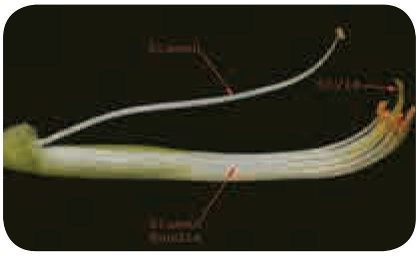


**Figure 4.24: (b)**
Diadelphous

**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*

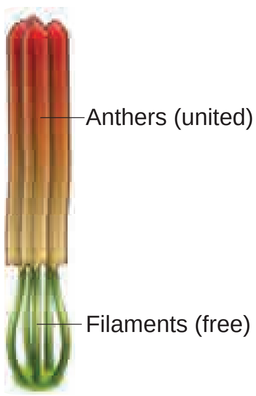



**Figure 4.24: (d)**
Syngenesious

**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*.

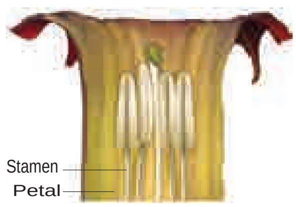



**Figure 4.25: (a)**
Epipetalous

**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*.

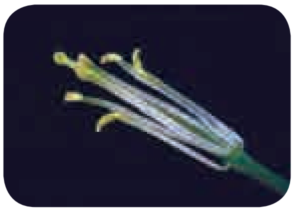


**Figure 4.26: (b)**
Tetradynamous

**Figure 4.26: (c)**
Heterostemonous

### 4.4.3 Stamen insertion

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

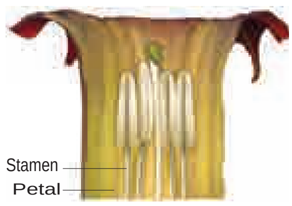



**Figure 4.27: (a)**
Inserted

**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.

ⓒ ⓓ ⓔ

**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*

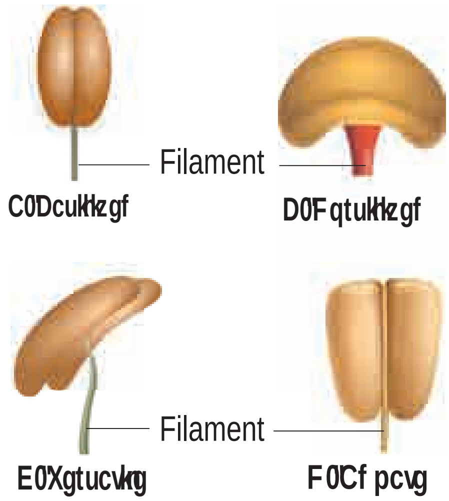



**Figure 4.29:** Anther attachment

### 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*.

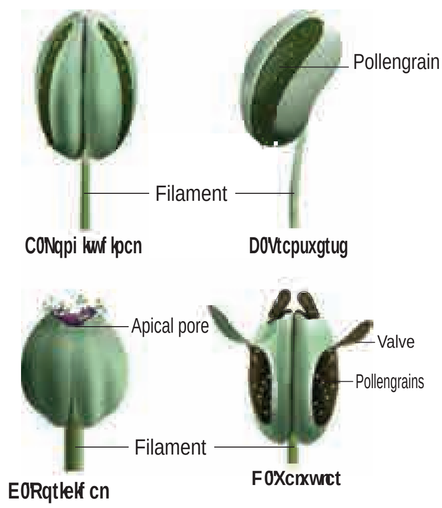



**Figure 4.30:** Anther dehiscence

### 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*.

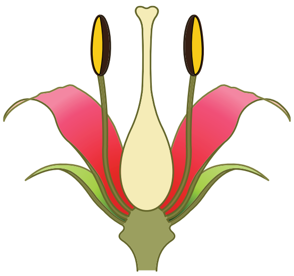


**Figure 4.31: (a)** Introrse

**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.**

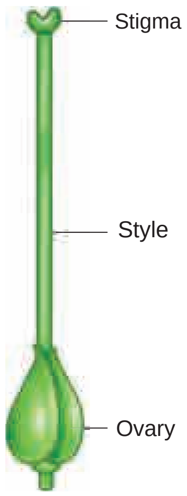



**Figure 4.32:** Pistil

**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. |

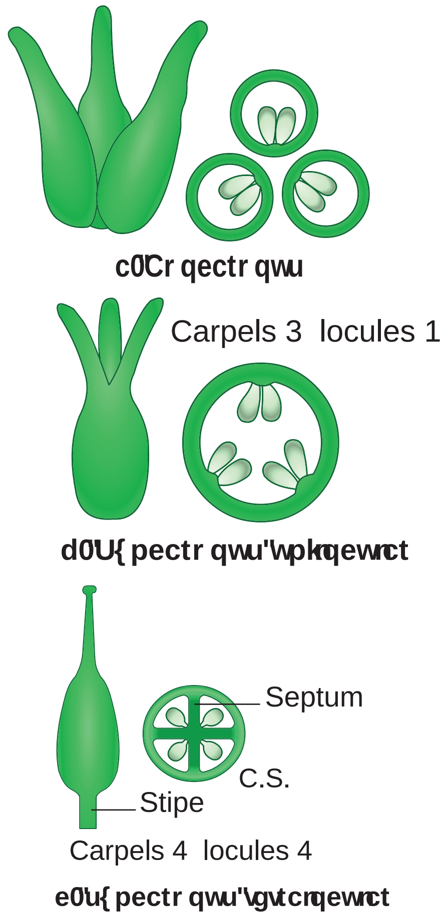



**Figure 4.33:** Fusion of carpels

### 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**.

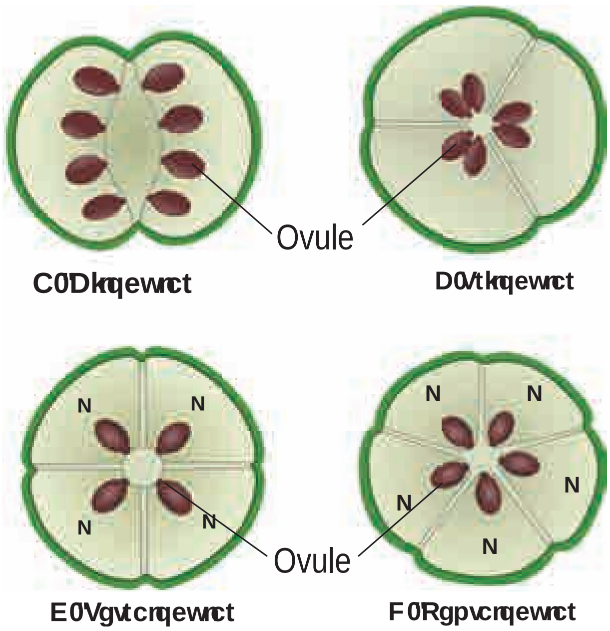



**Figure 4.34:** Locules

*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

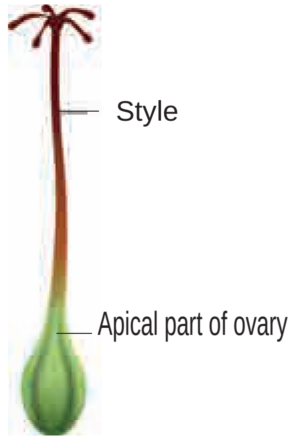



**Figure 4.35: (a)** Simple style

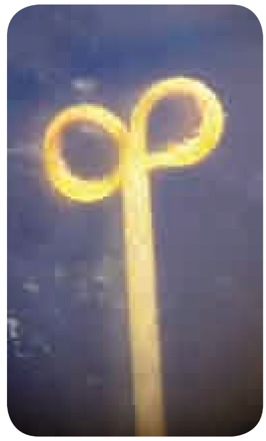


**Figure 4.35: (b)** Bifid style

**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*.

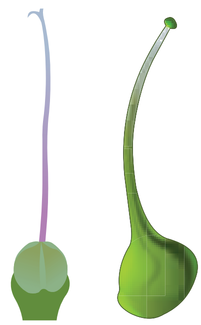


**Figure 4.35: (c)** Gynobasic style, **(d)** Lateral style

**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*.

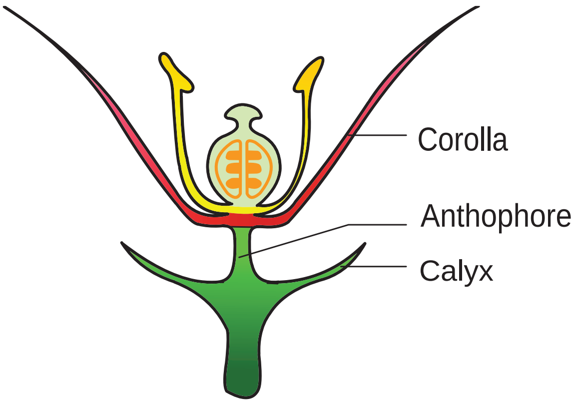



**Figure 4.36: (a)** Anthophore

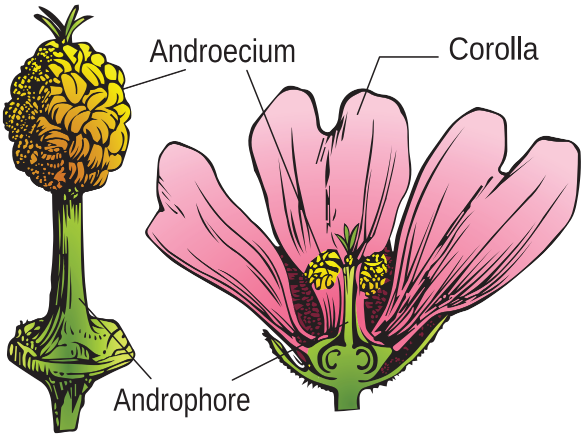



**Figure 4.36: (b)** Androphore

### 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*.

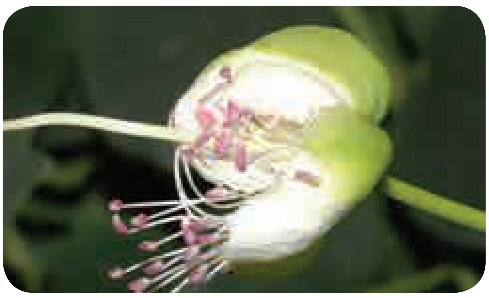


**Figure 4.36: (c)** Gynophore

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.

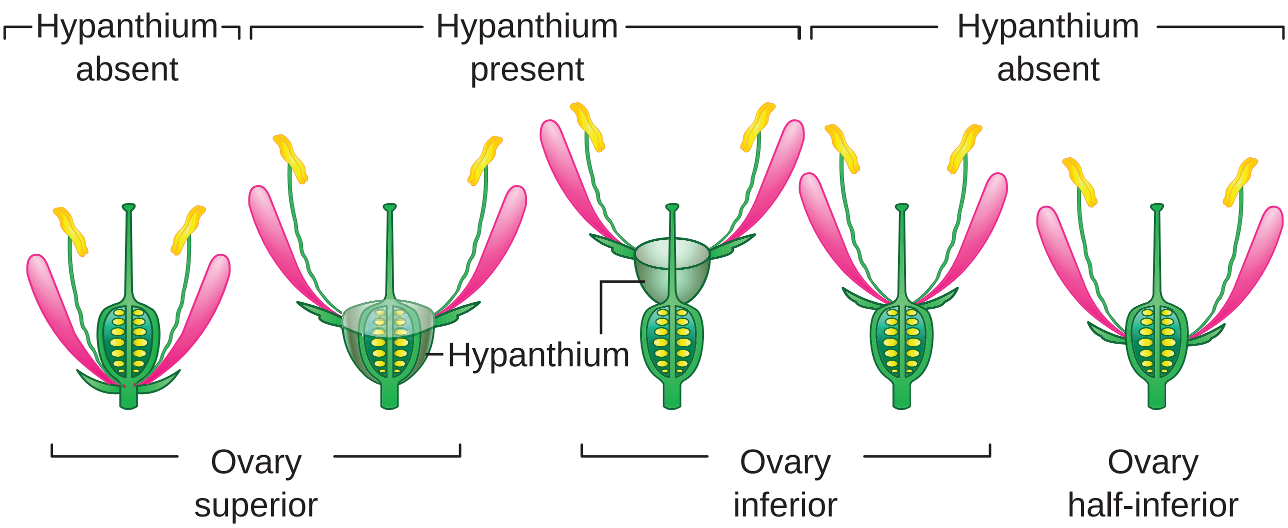



**Figure 4.37:** Perianth / androecial position on thalamus

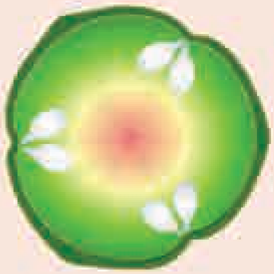
| | |
|---|---|
| **Parietal axile:** It is with the placentae at the junction of the septum and ovary wall of a two or more locular ovary. Example: Brassicaceae. | **Apical pendulous** It is with placenta at the top of ovary. Ovules hanging down. |
| **Parietal septate:** It is with placentae on the 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.

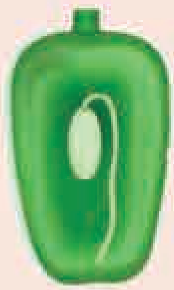
**Axile**
The placentae arises from the column in a compound ovary with septa.
Example:
Hibiscus,tomato
lemon

**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**

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

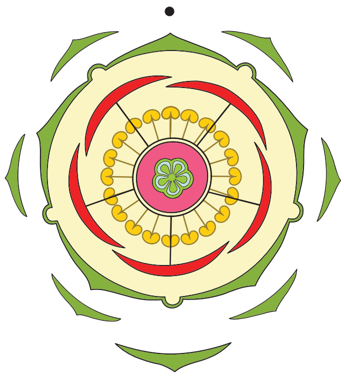


**Figure 4.38: (a)** *Hibiscus rosa-sinensis*

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

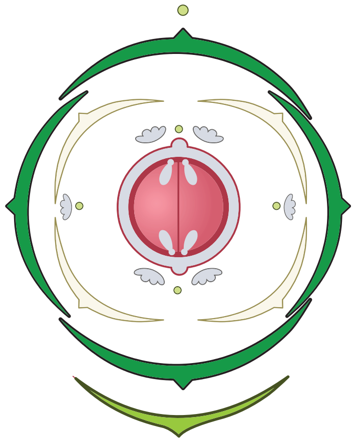


**Figure 4.38: (b)** *Brassica compestris*

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

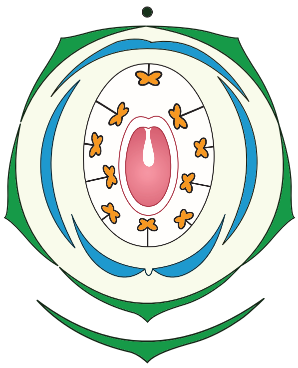


**Figure 4.38: (c)** *Crotalaria juncea*

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

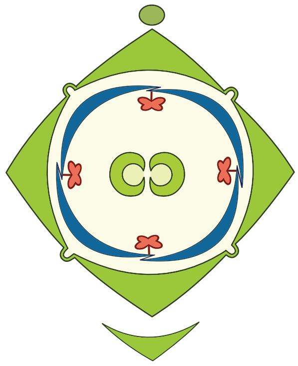
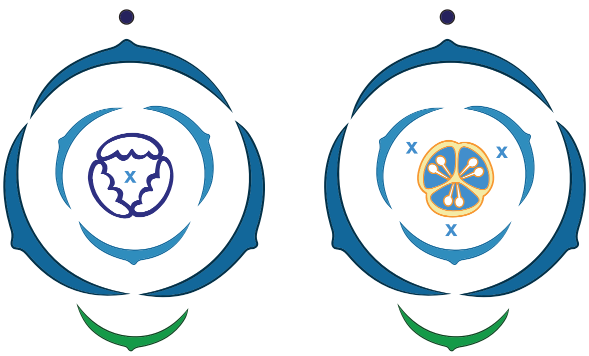


**Figure 4.38: (d)** *Ixora coccinea*

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



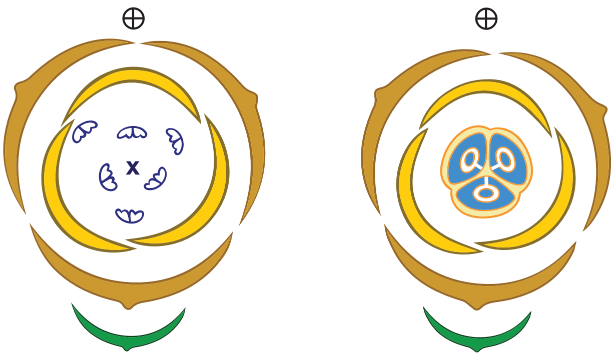
Ocrg'hmy gt

Hgo crg'hmy gt

**Figure 4.38: (e)** *Phyllanthus amarus*

Br Ebrl ⊕ ♂ $P_{3+3}\ A_{(3)}\ G_0$

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



Ocrg'Hmy gt

Hgo crg'Hmy gt

**Figure 4.38: (f)** *Cocos nucifera*

Br Brl ⊕ ♂ $P_{(3)+3}\ A_{3+3}\ G_0$

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

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.

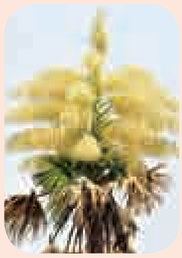
∞ – Indefinite number of units

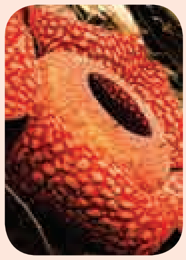
DO YOU KNOW?

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,

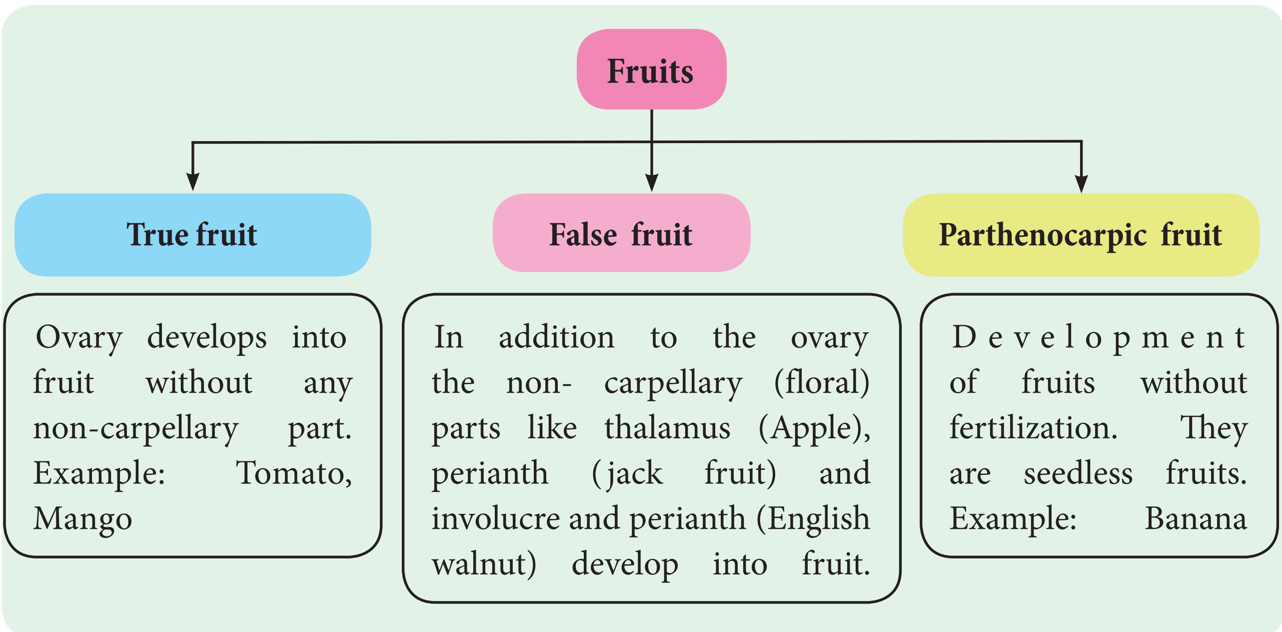
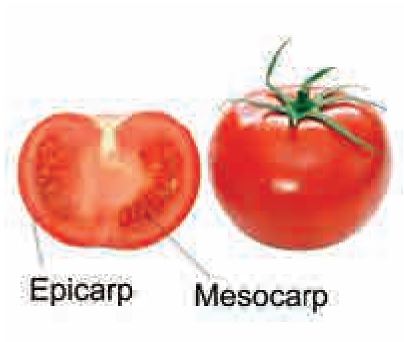
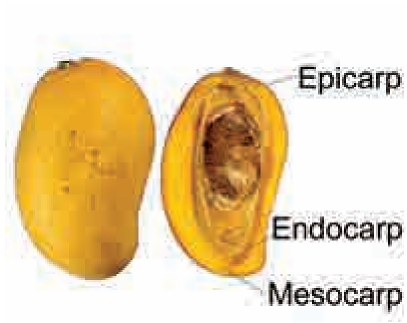



**Figure 4.39:** Classification of fruits based on formation

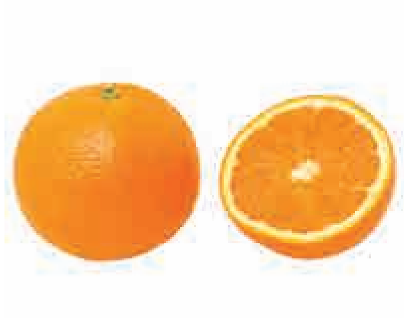



**Berry** (Tomato)




**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

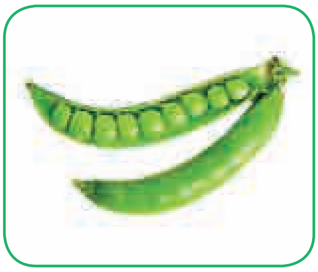
Pericarp is dry and splits open along the sutures to liberate seeds. They can be classified into following types.

**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 develops 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

**Cremocarp** (Coriander)

**Carcerulus** (*Abutilon*)

**Lomentum** (Mimosa)

**Regma** (Castor)

**Figure 4.43:** Schizocarpic Fruit

segments known as **nutlets**. Example: *Leucas, Ocimum, Abutilon*

**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.

- **Fruits**
  - **Simple**
    - **Fleshy fruit**
      - a. **Berry** (Tomato)
      - b. **Drupe** (Mango)
      - c. **Pepo** (Cucumber)
      - d. **Hesperidium** (Orange)
      - e. **Pome** (Apple)
      - f. **Balausta** (Pomogranate)
    - **Dry fruit**
      - **Dry dehiscent**
        - a. **Follicle** (*Calotropis*)
        - b. **Legume** (*Pisum*)
        - c. **Siliqua** (*Brassica*)
        - d. **Silicula** (*Capsella*)
        - e. **Capsule**
          - i. **Septicidal** (*Linum*)
          - ii. **Loculicidal** (Lady's finger)
          - iii. **Septifragal** (*Datura*)
          - iv. **Poricidal** (*Papaver*)
          - v. **Denticidal** (*Primula*)
          - vi. **Circumscissile** (*Anagallis*)
      - **Indehiscent (Achenial)**
        - a. **Achene** (*Clematis*)
        - b. **Cypsela** (*Tridax*)
        - c. **Caryopsis** (*Oryza*)
        - d. **Nut** (*Anacardium*)
        - e. **Samara** (*Acer*)
        - f. **Utricle** (*Chenopodium*)
      - **Schizocarpic (Splitting)**
        - a. **Cremocarp** (Coriander)
        - b. **Carcerulus** (*Abutilon*)
        - c. **Lomentum** (Mimosa)
        - d. **Regma** (Castor)
  - **Aggregate**
    - **Etaerio of follicle** (*Calotropis*)
    - **Etaerio of achena** (*Clematis*)
    - **Etaerio of drupe** (Raspberry)
    - **Etaerio of berries** (*Polyalthia*)
  - **Multiple**
    - **Sorosis** (Jack fruit)
    - **Syconus** (*Ficus*)

**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

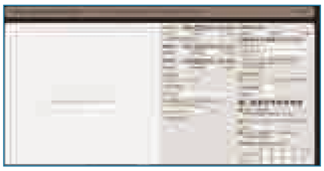
Let's generate
**Floral diagram and**
**Floral formula.**

### Steps

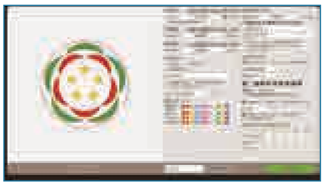
- Scan the QR code
- Enter sepal, petal, androecium & Gynoecium
- Select enable colour
- Select shape of sepal & petal, fused (if so)
- Enter carpel number & position submit the from
- Click formula to generate floral formula

### Activity

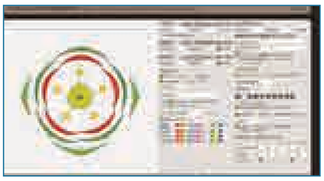
- Make floral diagram and formula of various flower by changing numbers and positions of floral parts.
- You can edit the floral diagram using **Inkscape**, which is denoted in help tap.



**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

## 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, Apocynaceae, Solanaceae, Euphorbiaceae, Musaceae and Liliaceae.*

## Chapter Outline



5HA8A6

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 16$^{th}$ 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 $20^{th}$ 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.<br>• Governs the practices of naming, describing, identifying and specimen preservation.<br>• Classification + Nomenclature = Taxonomy | • Broad field of biology that studies the diversification of species.<br>• Governs the evolutionary history and phylogenetic relationship in addition to taxonomy.<br>• 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.

# National Botanical Gardens

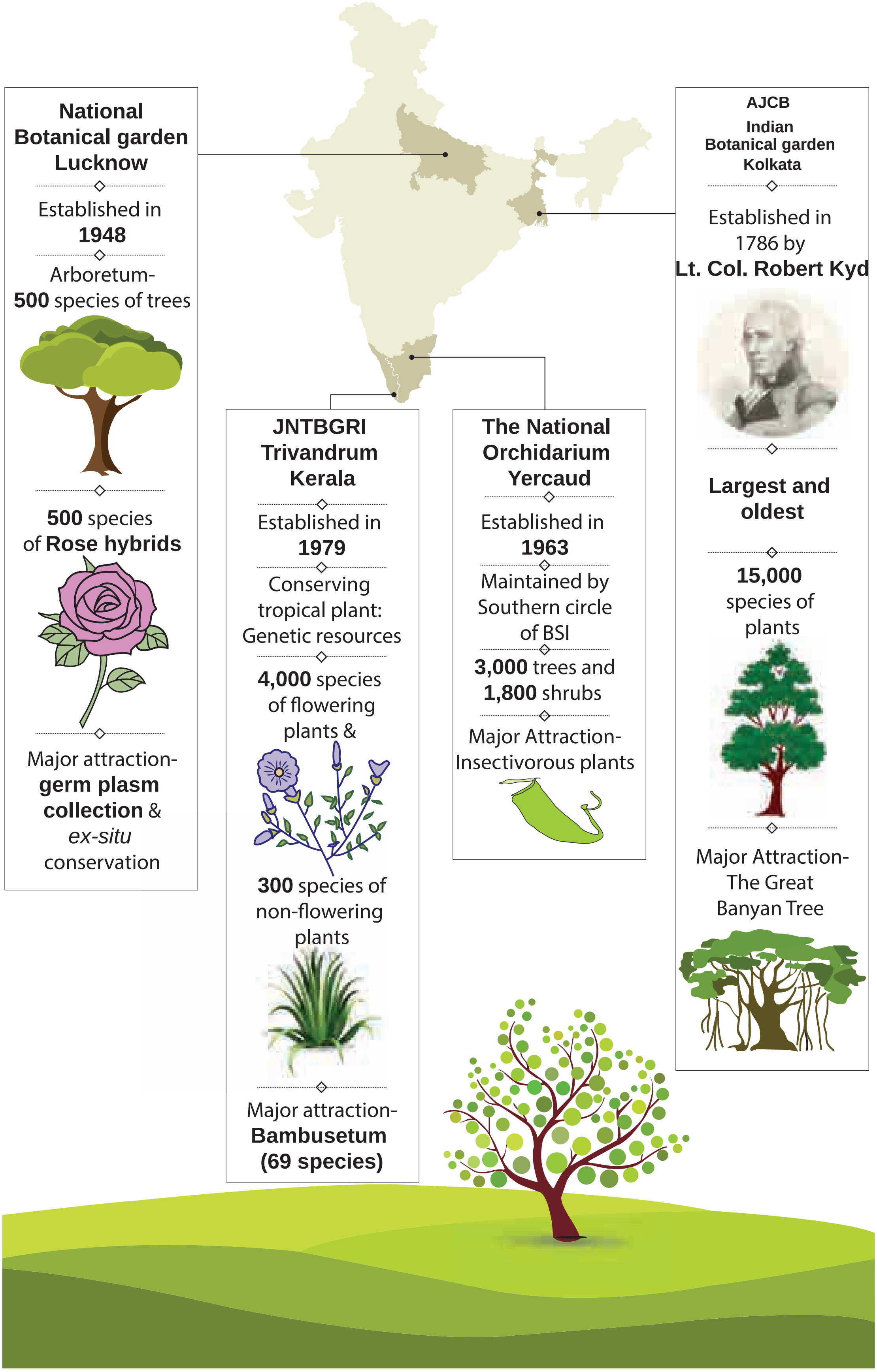



**Figure 5.1:** National Botanical Garden

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.

↓

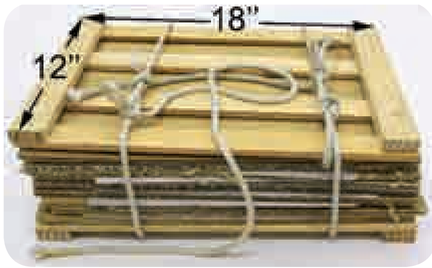
**Mounting herbarium specimen**
The standard size of herbarium sheet is used for mounting the specimen (29cm x 41cm). specimens are affixed to herbarium sheet with standard white glue or solution of Methyl cellulose.

↓

**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

**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 |
| 6 | Hexandria | stamens six |
| 7 | Heptandria | stamens seven |
| 8 | Octandria | stamens eight |
| 9 | Ennandria | stamens nine |
| 10 | Decandria | stamens ten |
| 11 | Dodecandria | stamens 11-19 |
| 12 | Icosandria | stamens 20 or more, on the calyx |
| 13 | Polyandria | stamens 20 or more, on the receptacle |
| 14 | Didynamia | stamens didynamous; 2 short, 2 long |
| 15 | Tetradynamia | stamens tetradyna-mous; 4 long, 2 short |
| 16 | Monadelphia | stamens monadelphous; united in 1 group |
| 17 | Diadelphia | stamens diadelphous; united in 2 groups |
| 18 | Polyadelphia | stamens polyadelphous; united in 3 or more groups |
| 19 | Syngenesia | stamens syngenesious; united by anthers only |
| 20 | Gynandria | stamens united with the gynoecium |
| 21 | Monoecia | plants monoecious |
| 22 | Dioecia | plants dioecious |
| 23 | Polygamia | plants polygamous |
| 24 | Cryptogamia | flowerless plants |

(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**.

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**.

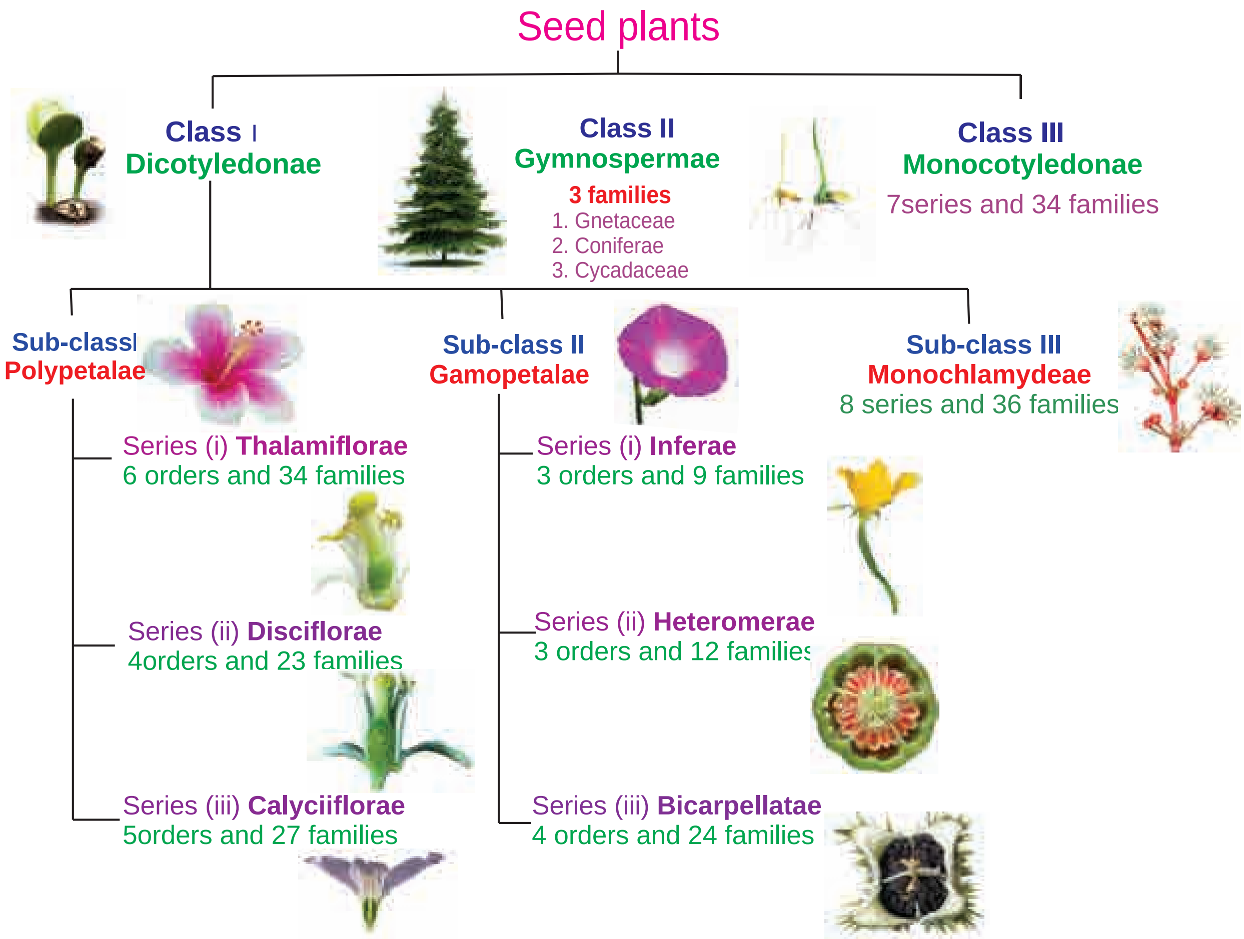



**Figure 5.6:** Bentham and Hooker system of classification

**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.

**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.

### 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

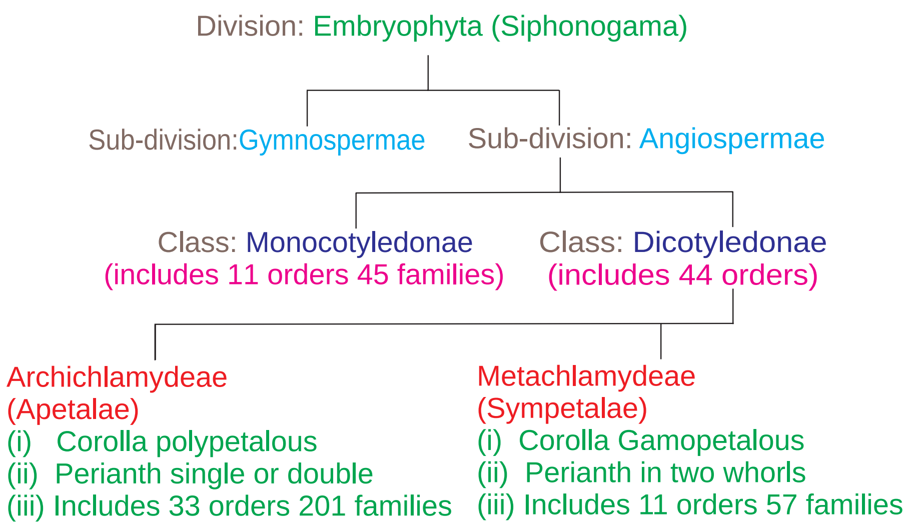



**Figure 5.7:** Outline of Engler and Prantl classification

**Figure 5.8:** Adolph Engler and Karl A Prantl

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 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**

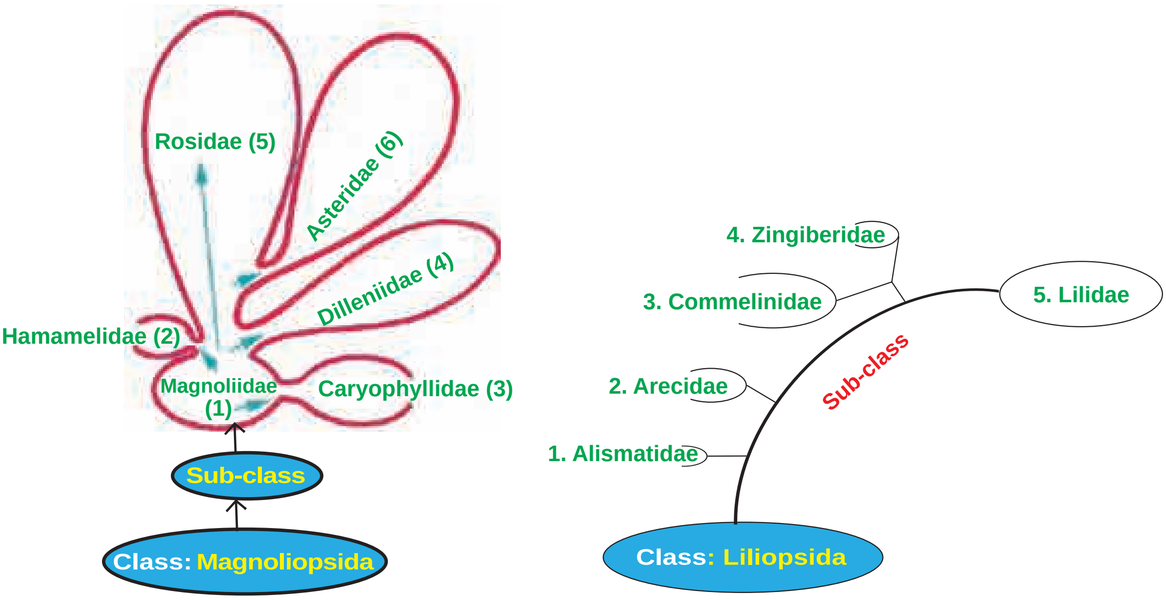



**Figure 5.10:** Diagramatic representation of the relationship between class Magnoliopsida and Liliopsida.

(= 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.

### 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.

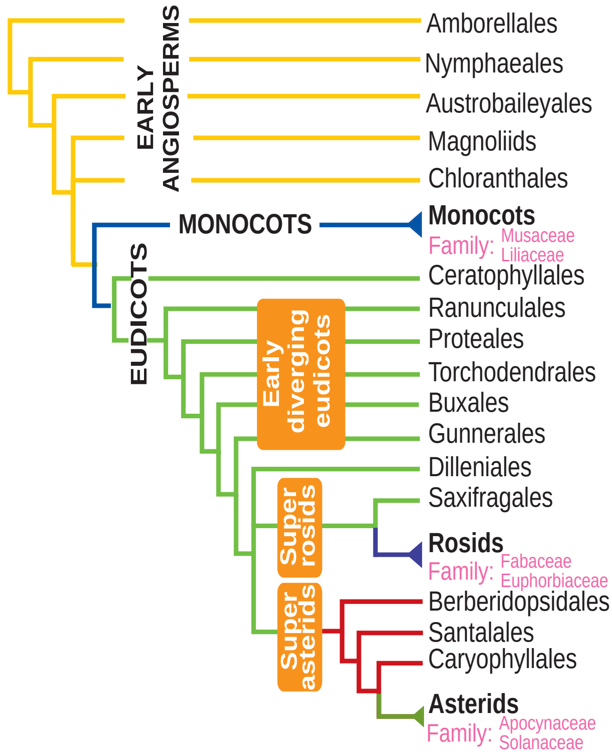



**Figure 5.11:** Simplified version of APG IV ( Source: Plant Gateway's The Global Flora, Vol. I January 2018 )

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)

**A**mborellales
**N**ymphaeales
**A**ustrobaileyales

- 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.

**Changes in earlier taxonomic understanding.**

The newly proposed APG classification system has brought many changes in our earlier understanding on the concept of primitive flowering plant families. Some of them are given below:

- The real Ranalean families, especially the arborescent ones are no more the primitive families. But as per APG classification system, Amborellaceae, Nymphaceae, Austrobaileyaceae, Magnoliaceae and Chloranthaceae form the early angiosperms.
- Monocots are recognised as a monophyletic group and hence terminology is retained.
- Dicots are polyphyletic group and as a result the use of the term dicotyledons as a group becomes outdated.
- Liliaceae (Sensu lato) is split into 14 families.
- Molluginaceae and Gisekiaceae are recognised separately from Aizoaceae.
- Euphorbiaceae (s.l.) is split in to Phyllanthaceae, Picrodendraceae and Putranjivaceae.
- Asclepiadaceae are merged with Apocynaceae (s.l.)
- Many genera that were conventionally treated under Verbenaceae such as *Clerodendron*, *Tectona* and *Vitex* are transferred to Lamiaceae based on the modified circumscription of these families.

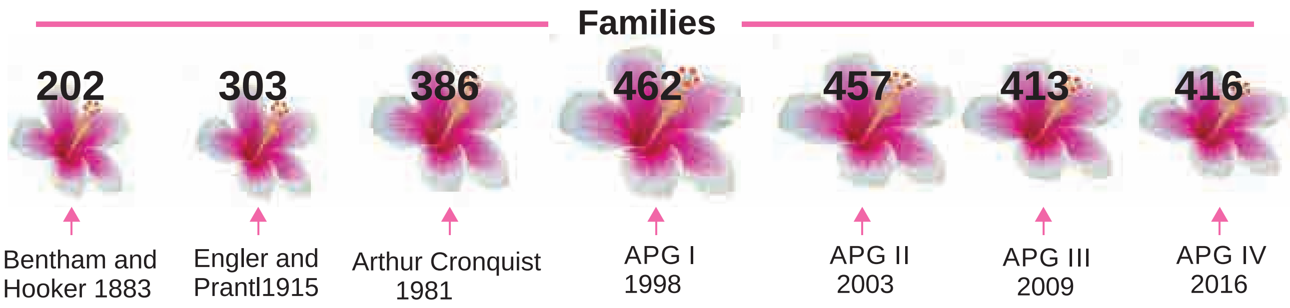



**Figure 5.12:** A timeline showing the history of classifying flowering plants into families. ( Source: Royal Botanic Gardens Kew State of World's Plant 2017 )

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.

## 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

### Molecular Markers

**Allozyme electrophoresis** is a method which can identify genetic variation at the level of enzymes that are directly encoded by DNA.

**Mitochondrial DNA markers** are non- nuclear DNA located within organelles in the cytoplasm called mitochondria. The entire genome undergoes transcription as one single unit. They are not subjected to recombination and thus they are homologous markers.

**Microsatellite** is a simple DNA sequence which is repeated several times across various points in the DNA of an organism. These (usually 2-5) repeats are highly variable and these loci can be used as markers. (Example: TGTGTG, in which two base pairs repeat, the region are termed **tandem repeat**.)

**Single nucleotide polymorphisms** arise due to single nucleotide substitutions (transitions/transversions) or single nucleotide insertions/deletions. SNPs are the most abundant polymorphisms in the genome (coding and non-coding) of any organism. These single nucleotide variants can be detected using PCR, microchip arrays or fluorescence technology.

**DNA microarray or DNA chip** consists of small glass microscope slides, silicon chip or nylon membranes with many immobilized DNA fragments arranged in a standard pattern. A DNA microarray can be utilized as a medium for matching a reporter probe of known sequence against the DNA isolated from the target sample which is of unknown origin. Species-specific DNA sequences could be incorporated to a DNA microarray and this could be used for identification purposes.

**Arbitrary markers** are sometimes used to target a segment of DNA of unknown function. The widely used methods of amplifying unknown regions are RAPD and AFLP DNA.

**Specific Nuclear DNA markers:** Variable Number of Tandem Repeat is a segment of DNA that is repeated tens or even hundreds to thousands of times in nuclear genome. They repeat in tandem; vary in number in different loci and differently in individuals. There are two main classes of repetitive and highly polymorphic DNA viz. **minisatellite** DNA referring to genetic loci with repeats of length 9-65 bp and microsatellite DNA with repeats of 2-8 bp (1-6) long. Microsatellites are much more numerous in the genome of vertebrates than minisatellites.

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)**

**RFLP**s 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.

List of conferences of International Barcode was held

| S.No. | Year | Place |
|---|---|---|
| 1. | 2005 | London, United Kingdom |
| 2. | 2007 | Taipei, Taiwan |
| 3. | 2009 | Mexico City, Mexico |
| 4. | 2011 | Adelaide, Australia |
| 5. | 2013 | Yunnan, China |
| 6. | 2015 | Guelph, Canada |
| 7. | 20-24 Nov' 2017 | Skukuza, South Africa |

### 5.11.7 Differences between classical and modern taxonomy

| Classical Taxonomy | Modern Taxonomy |
|---|---|
| It is called old systematics or Alpha (ά) 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

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.

5HJ4BT

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

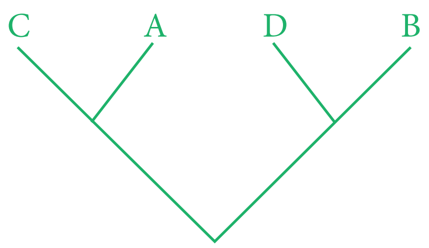
The outcome of a cladistic analysis is a **cladogram**, a tree-shaped diagram that represent the best hypothesis of phylogenetic relationships. Earlier generated cladograms were largely on the basis of morphological characters, but now genetic sequencing data and computational softwares are commonly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

### Cladistic analysis

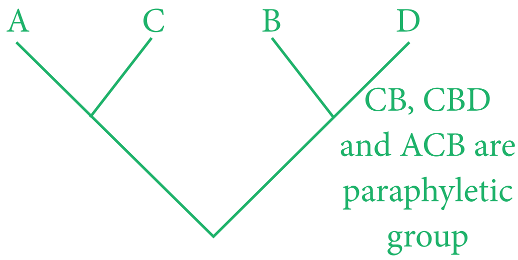
Cladistics is one of the primary methods of constructing phylogenies, or evolutionary histories. Cladistics uses shared, derived characters to group organisms into clades. These clades have atleast one shared, derived character found in their most recent common ancestor that is not found in other groups 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.

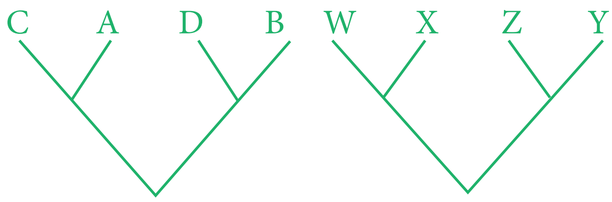
i. **Monophyletic group;** Taxa comprising all the descendants of a common ancestor.




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

Root nodule

**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*), pedicellete, 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)

**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.

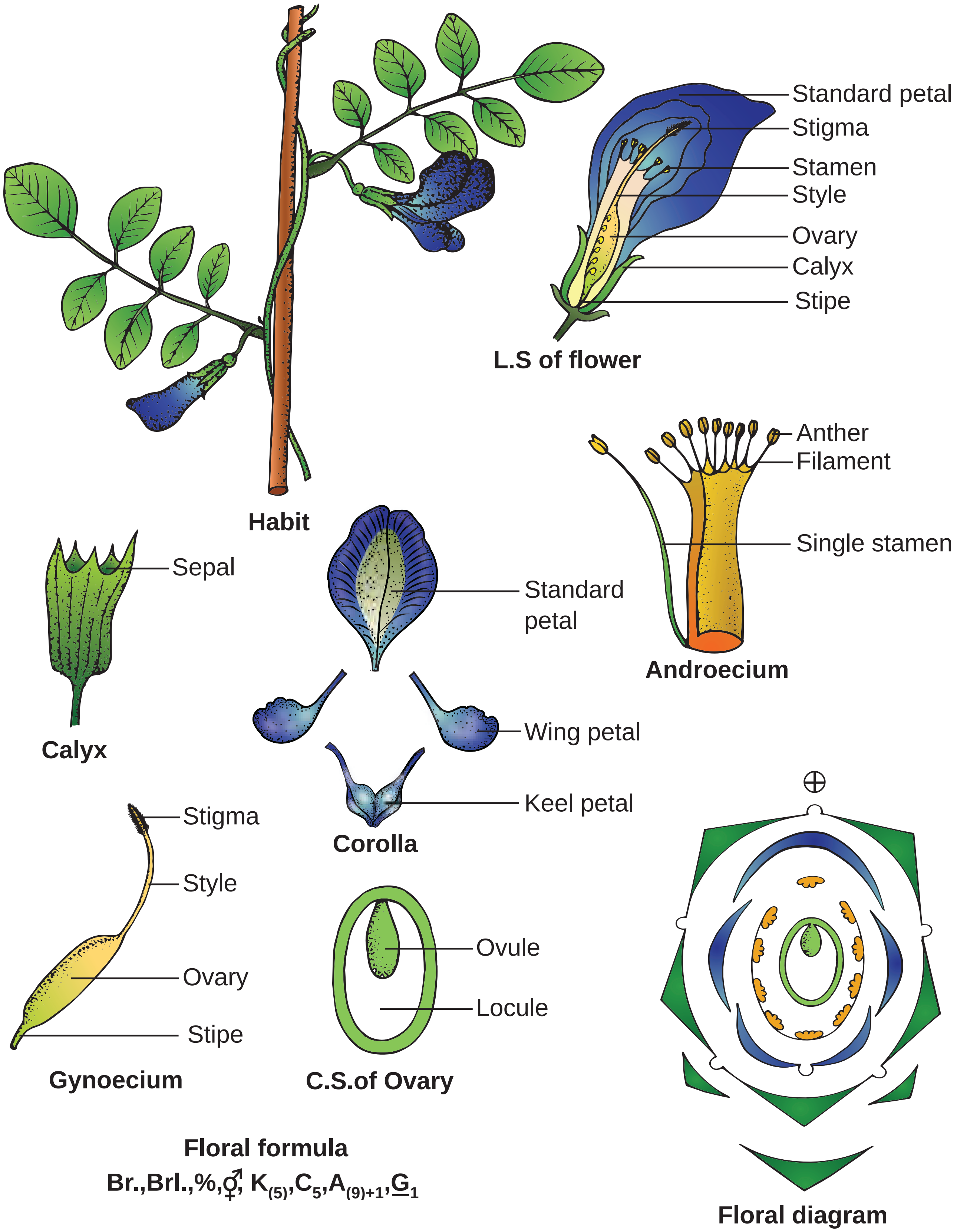
**Inflorescence:** Solitary and axillary

**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




**Floral formula**

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

**Figure 5.13:** *Clitoria ternatea*

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' .⚥'$M_{*7+}.E_{7}.C_{*;+3}.\underline{I}_{3}$

**Botanical description of *Pisum sativum* (Pea Plant)**

**Habit**: Cultivated herb, becoming shrubby.

**Root**: Branched tap root system, nodulated due to the presence of nitrogen fixing bacteria (*Rhizobium leguminosorum).*

**Stem**: Erect and climbing, one to three feet high, young stem densely pubescent, somewhat angular, herbaceous, green and branched.

**Leaves**: Alternate, petiolate, stipulate, stipules ¼ to ½ inch long attached near the base, compound (trifoliate), leaflets dark green, entire, acuminate, pubescent on both the sides, reticulate venation.

**Inflorescence**: Clustered axillary racemes.

**Flower**: Bracteate (small and deciduous), bracteolate (usually persistent), pedicellate, heterochlamydeous, complete, bisexual, pentamerous, zygomorphic and hypogynous.

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

**Corolla**: Petals 5, apopetalous, irregular papillionaceous, consisting of a posterior standard, two lateral wings, two anterior ones forming a keel which encloses stamen and pistil, vexillary / descendingly imbricate aestivation.

**Androecium:** Stamens 10, diadelphous (9)+1 nine stamens fused to form a bundle and the tenth one is posterior and free. Anthers dithecous, basifixed, introse and dehisce longitudinally.

**Gynoecium:** Monocarpellary, ovary superior, unilocular, with many ovules on marginal placentation, style simple and curved, stigma capitate.

**Fruit:** Legume

**Seed:** non-endospermous with thick cotyledons.

Floral Formula: Dt0Dtn0' .⚥'$M_{*7+}.E_{7}.C_{*;+3}.\underline{I}_{3}$

*Arachis hypogea*

*Crotalaria verrucosa*

*Indigofera tinctoria*

*Aeschynomene aspera*

**Figure 5.14:** Selected plants belongs to the Family Fabaceae

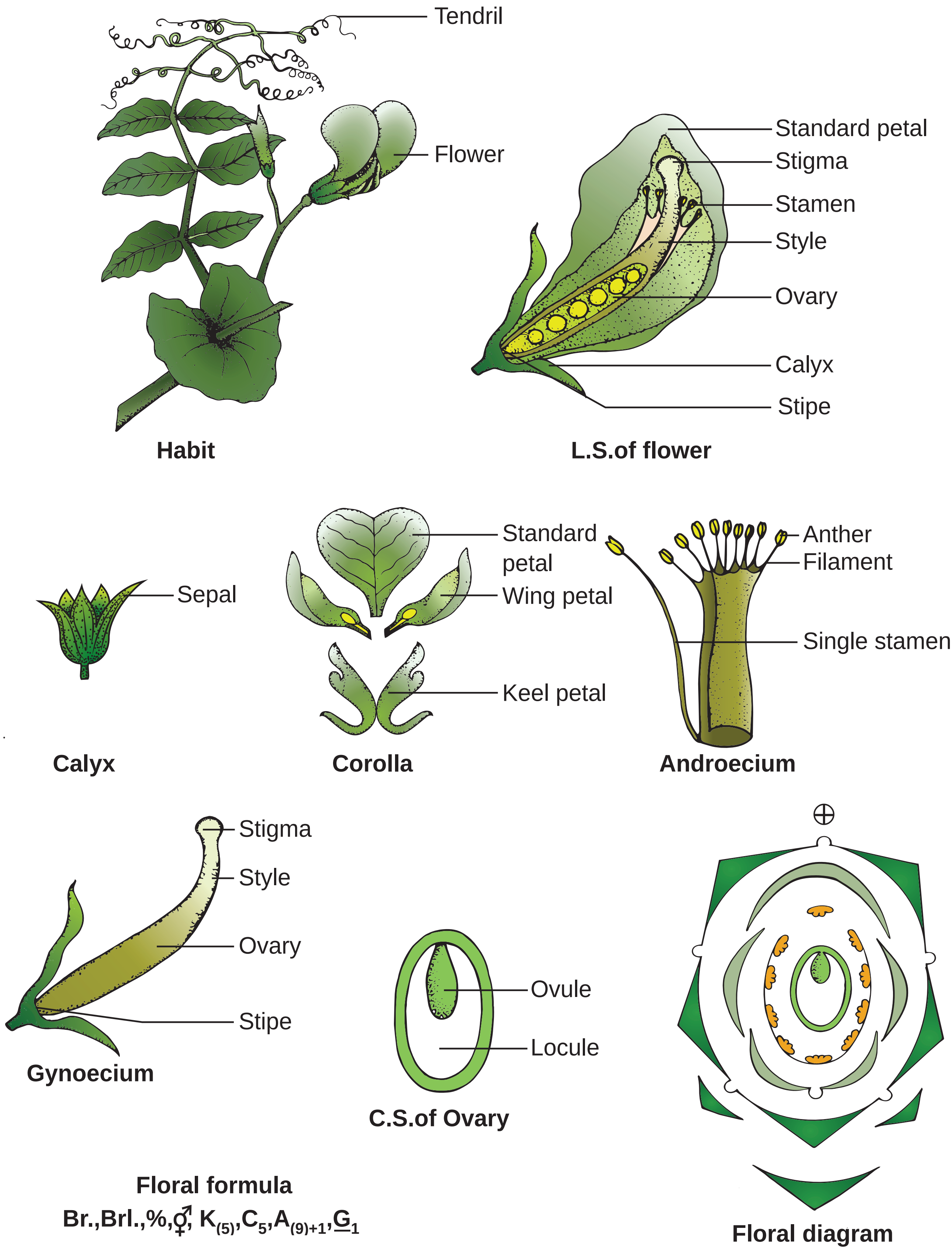



**Figure 5.15:** *Pisum sativum*

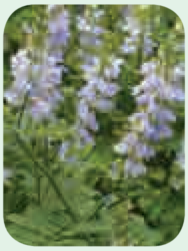
## Economic Importance

| Economic importance | Binomial | Useful part | Uses |
|---|---|---|---|
| Pulses | *Cajanus cajan* (Pigeon Pea)<br>*Phaseolus vulgaris* (French bean)<br>*Cicer arietinum* (Chick pea / Channa / கொண்டைக்கடலை)<br>*Vigna mungo* (black gram / உளுந்து)<br>*Vigna radiata* (green gram / பாசிப்பயறு)<br>*Vigna unguiculata* (cow pea / தட்டைப்பயறு)<br>*Glycine max* (soya bean)<br>*Macrotyloma uniflorum* (Horse gram / கொள்ளு) | Seeds | Sources of protein and starch of our food. |
| Food plants | *Lablab purpureus* (field bean)<br>*Sesbania grandiflora* (agathi, vegetable humming bird)<br>*Cyamopsis tetragonoloba* (cluster bean) | Tender fruits<br>Leaves<br>Tender fruits | Vegetable<br>Greens<br>Vegetable |
| Oil Plants | *Arachis hypogea* (Ground nut)<br>*Pongamia pinnata* (Pungam) | Seeds<br>Seeds | Oil extracted from the seeds is edible and used for cooking.<br>Pongam oil has medicinal value and is used in the preparation of soap. |
| Timber Plants | *Dalbergia latifolia* (rose wood)<br>*Pterocarpus santalinus* (red sandalwood)<br>*P.dalbergioides* (Padauk)<br>*P.marsupium* (வேங்கை) | Timber | Timber is used for making furniture, cabinet articles and as building materials. |
| Medicinal Plants | *Crotalaria albida*<br>*Psoralea corylifolia* (கார்போக அரிசி)<br>*Glycirrhiza glabra* (Licorice root / அதிமதுரம்)<br>*Mucuna pruriens* (பூனைக்காலி) | Roots<br>Seeds<br>Roots<br>Seeds | Used as purgative<br>Used in leprosy and leucoderma<br>Immuno modulater<br>Neurological remedy |
| Fibre Plants | *Crotalaria juncea* (sunhemp / சணப்பை)<br>*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)<br><br>*Clitoria ternatea*<br><br>*Butea monosperma* | Leaves<br><br>Flowers and seeds<br>Flowers | Indigo dye obtained from leaves is used to colour printing and in paints.<br><br>Blue dye is obtained<br><br>Natural dye |
| Green Manuring | *Indigofera tinctoria*<br>*Tephrosea purpurea*<br>*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),<br>*Clitoria ternatea,*<br>*Lathyrus odoratus* (Sweet pea) and<br>*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 attractive seeds of *Adenanthera pavonina* (Family: Caesalpiniaceae) have been used as units of weight for the measures of gold throughout India.

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

2016
INTERNATIONAL
YEAR OF PULSES

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.

### 5.13.2 Family: Apocynaceae (milk weed family) (including Asclepiadaceae)

**Systematic position**

| APG classification | | Bentham and Hooker classification | |
|---|---|---|---|
| Kingdom | Plantae | Kingdom | Plantae |
| Clade | Angiosperms | Class | Dicotyledonae |
| Clade | Eudicots | Sub-class | Gamopetalae |
| Clade | Asterides | Series | Bicarpellatae |
| Order | Gentianales | Order | Gentianales |
| Family | Apocynaceae | Family | Apocynaceae |

**Diagnostic features**

- Plants with milky sap.
- Leaves opposite or whorled, exstipulate.
- Flowers pentamerous.
- Stamens epipetalous, connate with corona.
- Fruit a follicle.
- Stigma is thick and massive often connate to stamen to form Gynostegium
- Seeds often with coma (hair).
- Presence of nectariferous disc.

**General Characters**

**Distribution:**

This family is represented by 345 genera, 4,675 species. Mostly tropical and subtropical whereas a few species found in temperate region.

**Habit:** Tree (*Alstonia*), shrub, (*Nerium*), herb (*Catharanthus*), woody twiner (*Allamanda*, Succulent, *Adenium* usually twining shrubs with milky sap in laticiferous vessels.

**Root:** Branched tap root system

**Stem:** The stems are succulent in some taxa (*Stapelia, caralluma*), usually erect, branched solid, glabrous, rarely tube like and thick.

**Leaves**: Simple, undivided, sometimes reduced, exstipulate, opposite decusate (*Calotropis*) or sometimes alternate (*Thevetia*) or in whorls of 3 (Nerium), entire, rarely stipulate (*Tabernaemontana*).

**Inflorescence**: A Panicle, dichasial cyme, often umbelliform in (Asclepiadoids) or raceme, or axillary cluster of two flowers each (*Catharanthus*).

**Flowers:** Bracteate, bracteolate, pedicellate, complete, bisexual, actinomorphic, zygomorphic in *Ceropegia* heterochlamydeous , pentamerous, hypogynous but rarely perigynous or epigynous (*Plumeria*)

*Ceropegia spp*

**Calyx:** Sepals 5, synsepalous (at least basally) sometimes aposepalous (*Catharanthus*) deeply lobed ; valvate or quincuncial (*Thevetia*), odd sepal posterior, glandular appendages (*Squamellae*) present on the adaxial side.

**Corolla:** Petals 5, sympetalous united into a tube, salver or funnel shaped; twisted or rarely valvate, often hairy within or contain some corona like out growths at the mouth of the corolla tube.

**Androecium:** Stamens 5 , alternipetalous, often epipetalous, apostemonous to monadelphous, In *Asclepiadoids* the stamens are connate to the styles to form a **gynostegium**, pollen grains of each theca of an anther are fused into a waxy mass called **pollinium**. The right pollinium of each anther attached to the left pollinium of the adjacent anther by a hair like translator, translator arms (**retinacula**) attached together with the gland like structure called **corpusculum**. Anthers are dithecous, basifixed, often sagitate, introse; dehisce longitudinally, anthers basally awned; sometimes bear hairy appendages over the lobes (*Nerium*).

**Gynoecium:** Bicarpellary, carpels apically united, superior, or rarely half inferior (*Plumeria*) 1 to 2 locule with 2 to many ovules in each locule on marginal placentation. Style one and simple, stigma is characteristically thickened, massive and bilobed. A nectariferous disc is often present around or at the base of the gynoecium, (*Thevetia, Catharanthus, Allamanda* and *Rauvolfia*).

**Fruit:** The fruit is variable and can be a berry (*Landolphia*), drupe (*Cerbera*) follicle (*Asclepias*), capsule (*Allamanda*).

**Seed:** Seeds are endospermous often with crown of hairs.

### Botanical description of *Catharanthus roseus*

**Habit:** Erect ever blooming ornamental plant with milky latex.

**Root:** Branched tap root system

**Stem:** Aerial, erect, cylindrical reddish green, glabrous and branched.

**Leaves:** Usually simple, opposite decussate, exstipulate, subsessile, or petiolate, elliptic – ovate, entire, mucronate, unicostate reticulate venation.

**Inflorescence:** cymose, axillary pairs.

**Flower:** Ebracteate, Ebracteolate, subsessile, complete, bisexual, heterochlamydeous, actinomorphic, hypogynous, pentamerous, rosy purple, white or pink.

**Calyx:** Sepals 5, slightly synsepalous, green showing valvate aestivation.

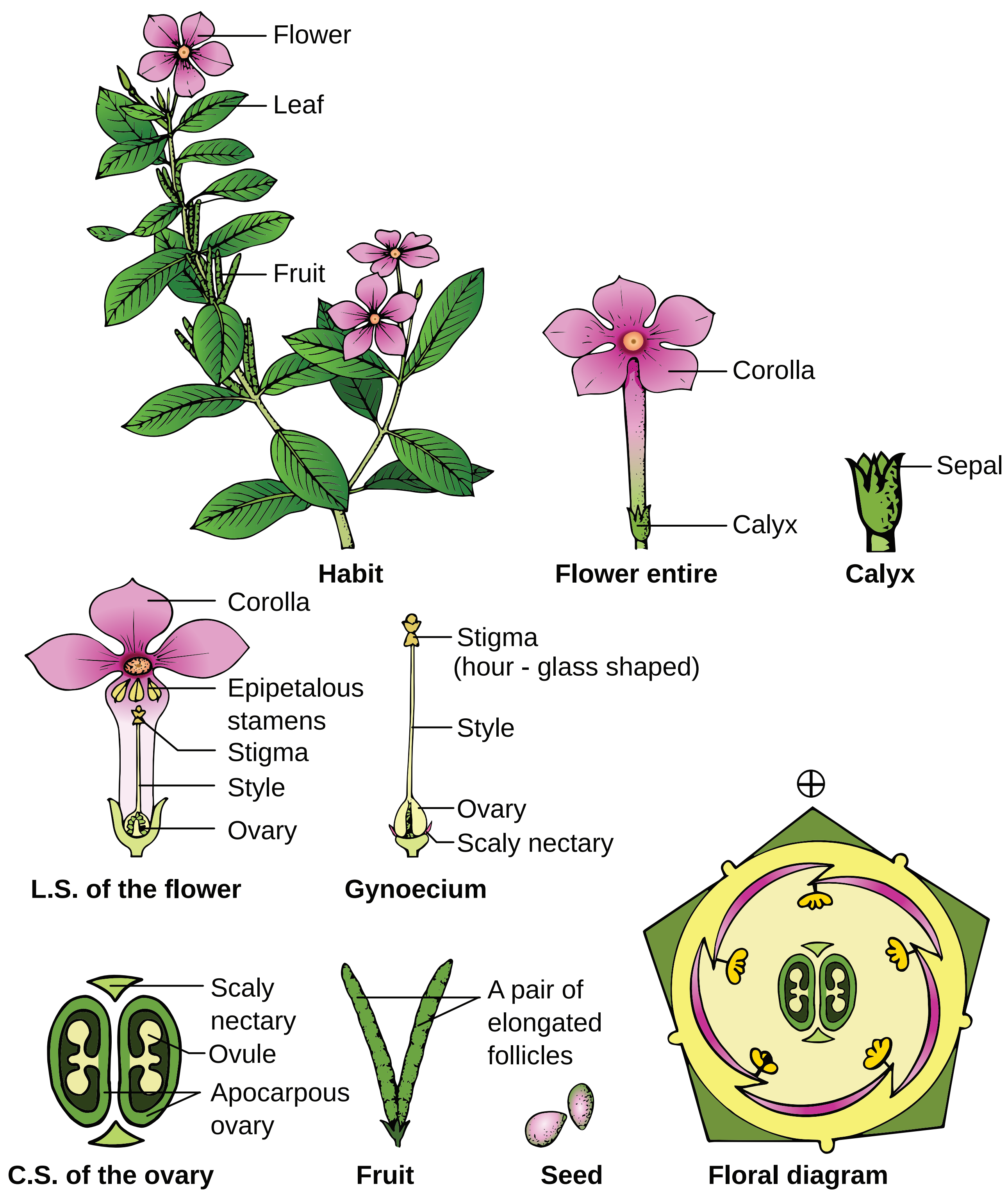
**Corolla:** Petals 5, sympetalous, throat of corolla tube hairy forming a corona, twisted (hypocrateriform).

**Androecium:** Stamens 5, apostemanous, epipetalous, inserted at the mouth of the corolla tube, filaments short, anthers sagittate, dithecous, dorsifixed, introse.

**Gynoecium:** Bicarpellary, apocarpous, ovaries superior, unilocular, ovules many, placentation marginal, style simple, stigma hour-glass shaped. Two scaly nectaries are present one on the anterior and another on the posterior side of the ovary.

**Fruit:** A pair of elongated follicles.

Floral Formula: $\mathrm{Ebr.,Ebrl.,}\oplus,⚥,K_{(5)},\overset{\frown}{C_{(5)},A_5},\underline{G}_{(2)}$




**Floral formula**

$$\text{Ebr., Ebrl.}, \oplus, ⚥, K_{(5)}, \overset{\frown}{C_{(5)}, A_5}, \underline{G}_2$$

**Figure 5.16:** *Catharanthus roseus*

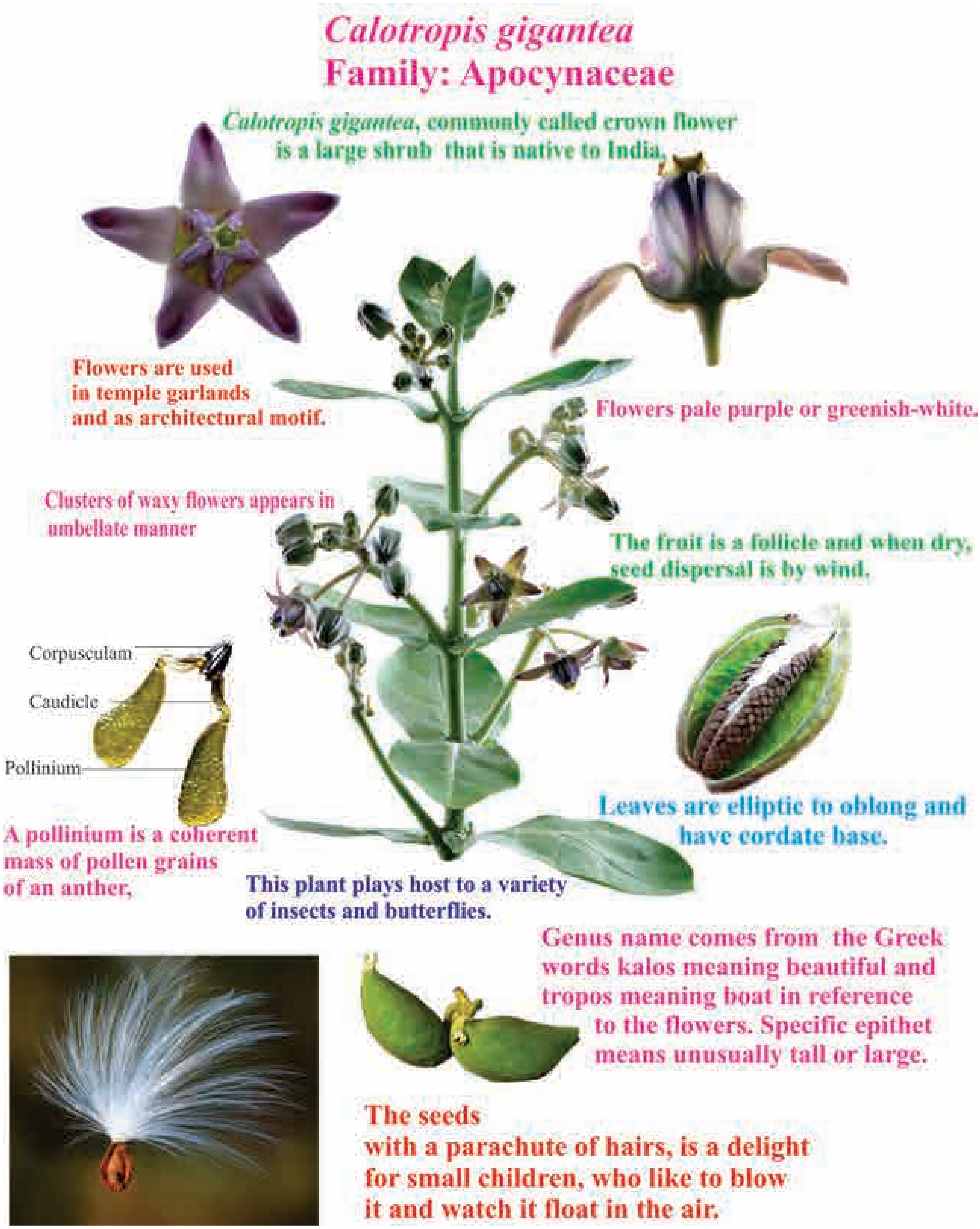



**Figure 5.17:** *Calotropis gigantea*

## Economic importance of the family Apocynaceae

| S.No | Economic importance | Binomial | Useful part | Uses |
|---|---|---|---|---|
| 1 | **Food plant** | *Carissa carandas* (பெரும்களா)<br>*Carissa spinarum* (சிறுகளா) | Fruits | Edible and used in pickles |
| 2 | **Medicinal plant** | *Rauvolfia serpentina* (Indian snake root / sarpagandha) | Shoot | To treat hypertension and mental disorders |
| | | | Dried roots | Alkaloid (reserpine) obtained from the dried roots, of the plant can lower the blood pressure and used as sedative for patients suffering from *Schizophrenia*. |
| | | *Thevetia peruviana* (lucky nut/ தங்கஅலரி) | Seeds | Used in rheumatism |
| | | *Vallaris solanacea* | Latex | Useful in toothache and to treat inflated gums. |
| | | *Cerbera odollam* | Latex | Used as an emetic and purgative. |
| | | *Alstonia scholaris* | Bark | Used in malaria and dysentery. |
| | | *Strophanthus hispidus* | Seeds | Yield the drug strophanthin |
| | | *Wrightia tomentosa* (பாலை) | Bark and Roots | Used as antidote to snakebite. |
| | | *Catharanthus roseus* | Aerial parts | Used to treat muscle pain, the alkaloids like vinblastine and vincris-tine are mainly used to treat various human cancers. |
| | | *Caralluma umbellate* (களிமுளியான்) | Succulent stem | Antiobesity |

| | | | | |
|---|---|---|---|---|
| 3. | **Dye yielding plant** | *Wrightia tinctoria* | Seeds | An indigo- like dye is obtained from the seeds. |
| 4. | ***Ornamental plants*** | *Allamanda nerifolia* (golden trumpet), *Alstonia scholaris*, *Beaumontia grandiflora*, *Catharanthus roseus*, *Nerium indicum* *Plumeria obtusa*, *Plumeria alba*, *Stapelia spp, Hoya, Asclepias*, and *Cryptostegia*. | plant | Grown as ornamentals plants. |

*Thevetia*

*Plumeria*

*Rauvolfia*

*Tabernaemontana*

**Figure 5.18:** *Selected plants belongs to the family Apocynaceae*

## 5.13.3 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*(others 3 are reduced to staminode), 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.

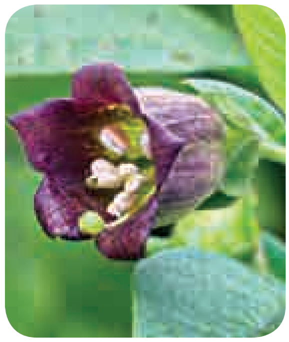
**Gynoecium:** Ovary bicarpellary, syncarpous superior ovary, basically biloculear but tetralocular due to the formation of false septum. Carpels are obliquely placed and ovules on swollen axile placentation. Style simple long and filiform, stigma two lobed.

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

**Seed:** Endospermous.

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

*Solanum trilobatum*

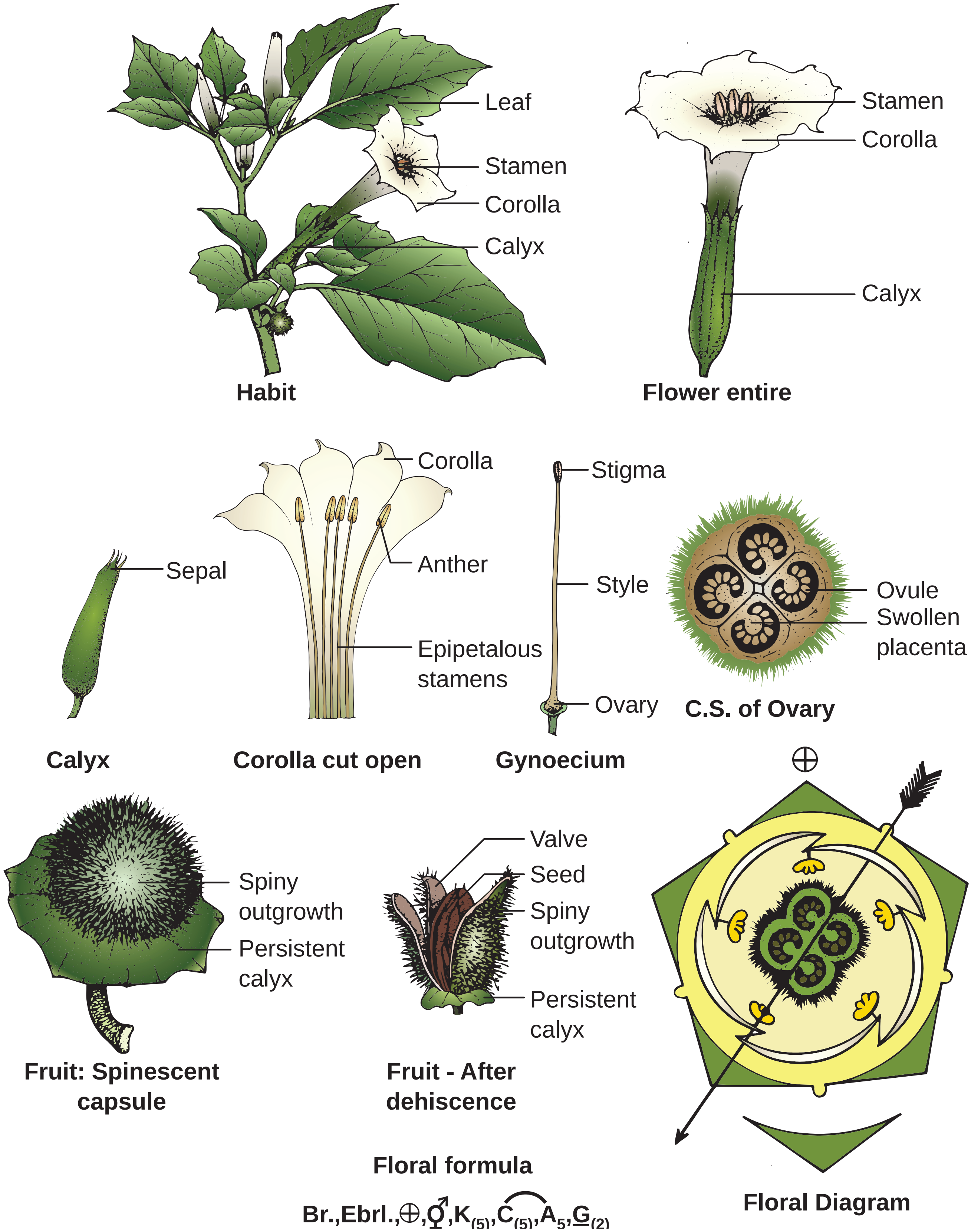


*Atropa belladonna*

*Withania somnifera*

*Schizanthus pinnatus*

**Figure 5.19:** Selected plants belongs to the Family Solanace




**Floral formula**

**Br.,Ebrl.,⊕,⚥,$K_{(5)}$,$\overset{\frown}{C_{(5)},A_5}$,$\underline{G}_{(2)}$**

**Figure 5.20:** *Datura metel*

## Botanical description of *Solanum americanum*

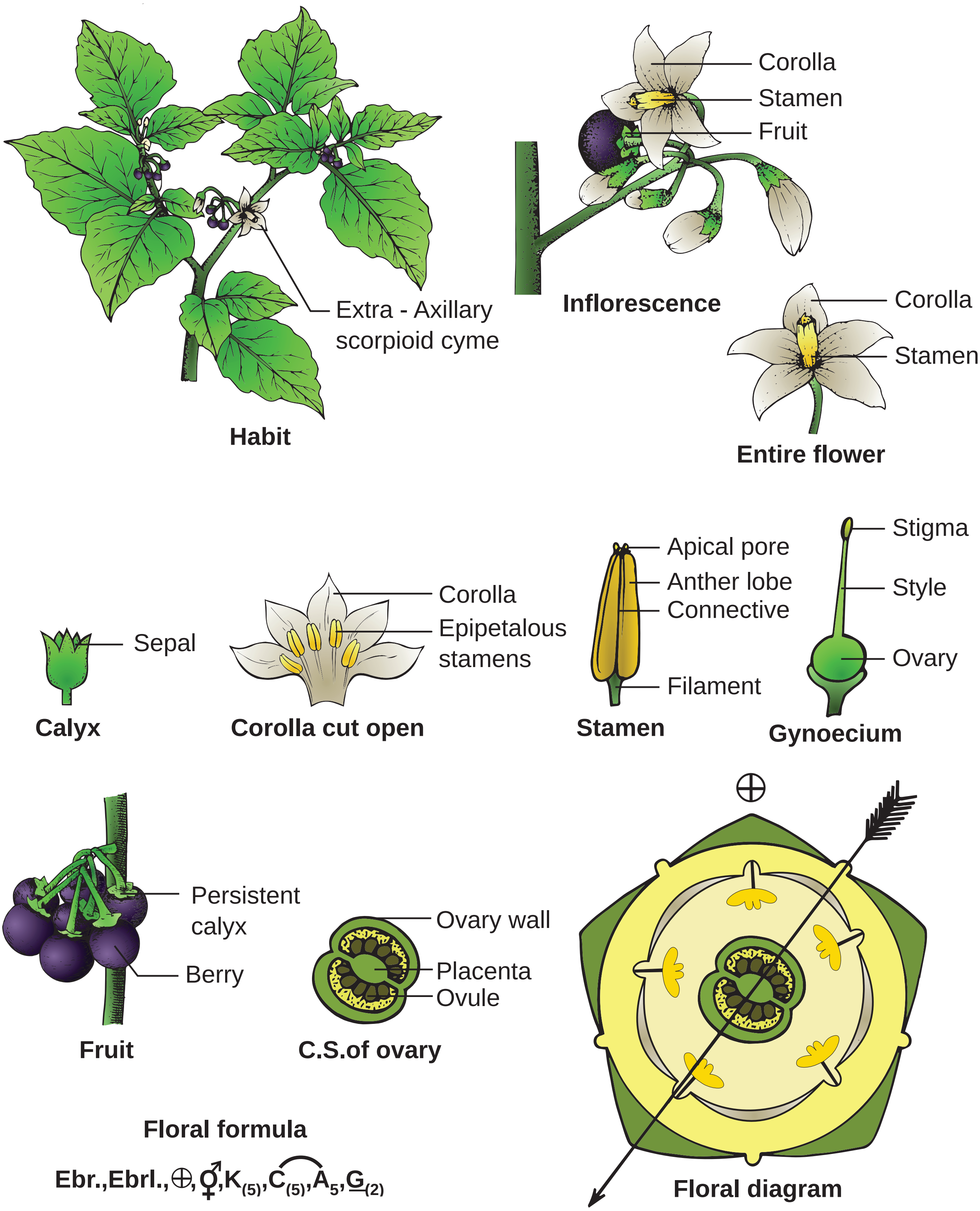



**Figure 5.21:** *Solanum americanum*

**Habit:** A small annual herb

**Root:** Branched tap root system.

**Stem:** Aerial, erect, green and herbaceous

**Leaf:** Simple, alternate but opposite in the floral region, petiolate, exstipulate ovate, entire or slightly lobed, acute unicostate reticulate venation.

**Inflorescence:** Extra-axillary (due to fusion of floral axis) scorpioid cyme called rhiphidium

**Flower:** Ebracteate, pedicellate, white, bisexual, actinomorphic, heterochlamydeous, pentamerous, hypogynous white.

**Calyx:** Sepals 5, synsepalous, green, persistent and showing valvate aestivation.

**Corolla:** petals 5, sympetalous, white, showing valvate aestivation.

**Androecium:** Stamens 5, apostamenous, epipetalous, filaments short, anthers conniving and forming an envelope around the style dithecous, basifixed with apical pores.

**Gynoecium:** Bicarpellary, syncarpous, superior, bilocular, many ovules in each locule on axile placentation, septum oblique, highly swollen placenta, style long and hairy at the base, stigma bifid.

**Fruit:** Berry

**Floral Formula:** Ebr.,Ebrl.,$\oplus$,⚥,$K_{(5)},\overset{\frown}{C_{(5)},A_5},\underline{G}_{(2)}$

## 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. |

| Economic importance of the family solanaceae | | | | |
|---|---|---|---|---|
| **S.No** | **Economic importance** | **Binomial** | **Useful part** | **Uses** |
| 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. |
| 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)

### 5.13.4 Family: Euphorbiaceae (Castor Family / Spurge Family )

**(In APG classification Peraceae, Phyllanthaceae and Picrodendraceae are excluded from the family Euphorbiaceae)**

**Systematic position**

| APG Classification | | Bentham and Hooker Classification | |
|---|---|---|---|
| Kingdom | Plantae | Kingdom | Plantae |
| *Clade*: | Angiosperms | Class: | Dicotyledonae |
| *Clade*: | Eudicots | Sub-class: | Monochlamydeae |
| *Clade*: | Rosids | Series: | Unisexuales |
| Order: | Malpighiales | Order: | Euphorbiales |
| Family: | Euphorbiaceae | Family: | Euphorbiaceae |

#### Diagnostic features

- Latex is present either milky or watery.
- Inflorescence generally cymose, catkin in *Acalypha*, cyathium in *Euphorbia* sp.
- Flowers apetalous, unisexual.
- Ovary tricarpellary, distinctly trilobed.
- Fruit capsule or regma.

#### General characters

**Distribution:** Euphorbiaceae includes 214 genera and about 5600 species. The plants of this family are found throughout the world. Well represented in Africa and South America.

**Habit:** Mostly shrubs (*Ricinus communics, Jatropha gossypifolia*) or tree *Emblica officinalis*, herbs (*Phyllanthus amarus*) , twiners (*Tragia involucrata*) some are xerophytic (*Euphorbia*) with cactus – like (phylloclades) plants usually contain milky or watery sap.

**Root**: Well branched tap root system.

**Stem**: Aerial, erect or prostrate (*E.prostrata*), herbaceous or woody. Stem becomes modified into flattened, leaf-like and becomes succulent in several species of *Euphorbia*. Such modified stem is called phylloclades. Cylindrical, branched, solid or hollow, usually contain latex either milky (*E.tirucalli*) or watery (*Jatropha curcas*).

**Leaf:** Stipulate or exstipulate. Mostly simple, alternate, often reduced or deciduous as in several species of *Euphorbia*, palmately lobed in *Ricinus* or deeply lobed in *Manihot*. The stiplues are modified into a pair of spines (*E.splendens*) or glandular hairs (*Jatropha curcas* ). The leaves around the cyathium inflorescence become beautifully coloured in *E.pulcherrima* (Paalperukki tree) with unicostate or multicostate reticulate venation.

**Inflorescence**: The inflorescence of Euphorbiaceae varies greatly, Terminal raceme – *Croton, Ricinus,*

Catkin – *Acalypha hispida* Cyme - *Jatropha*, solitary axillary – *Phyllanthus asperulatus*, cyathium – *Euphobia* species.

Cyathium is the an unique and special inflorescence of this family. Each cyathium contains centrally a single, naked terminal female flower, usually represented by a tricarpellary gynoecium. The female flower is surrounded by a cup-like involucre formed by 4 or 5 connate sepaloid bracts. In the axil of each bract develops a group of stamens in a scorpioid manner. Each stamen represents a naked male flower because it is a jointed structure, its upper portion is the filament bearing the anther and its lower portion represents the pedicel of the male flower bearing stamen. A nectar secreting gland is present on the rim of the involucre. Glands are oval or crescent shaped and often brightly coloured. Though cyathium appears like a single flower, it actually an inflorescence.

**Flowers:** Flowers are always unisexual, and are highly variable. Bracteate, ebracteolate, generally unisexual, homochlamydeous, rarely heterochlamydeous, monoecious (*Baliospermum*) or dioecious (*Bridelia*), actinomorphic, rarely zygomorphic, hypogynous, rearly perigynous (*Bridelia*).

**Perianth:** Tepals 0 to 5 **biseriate** (male flowers of *Croton bonplandianum*) uniseriate or aphyllous (*Euphorbia*), valvate or imbricate when present, apophyllous or synphyllous.

**Androecium:** The number of stamens vary from 1 to many. In *Euphorbia* a single stalked stamen represents a single male flower. In *Ricinus* usually 5 stamens are present, but each stamen is profusely branched. In *Jatropha* they are arranged in two whorls each of 5 stamens. The stamens are indefinite (*Crotons*), the filaments may be free or connate. The anthers are dithecous, dehisce either by apical or by transverse or longitudinal slits.

**Gynoecium:** Tricarpellary, rarely bicarpellary (*Bridelia, Mercurialis*), tetra or pentacarpellary

(*Wielandia*), syncarpous, ovary superior, rarely semi-inferior, ovules one or two in each locule on axile placentation, rarely locule splits into two forming six chambers (*Phyllanthus*). Styles 3, each split into two feathery stigma. Nectaries are usually present, gynoecium is present as a pistillode in staminate flowers.

**Fruit**: Fruits are capsule or schizocarp. It breaks violently and dehisce into three one seeded cocci called regma (*Ricinus* ), drupe in *Emblica officinalis* and berry or samara.

**Seed:** Seeds are endospermous. In *Ricinus* knob-like caruncle develops from the micorpyle, that absorbs and temporarily retains water enabling germination.

*Ricinus*

## Botanical Description Of *Ricinus communis* (Castor)

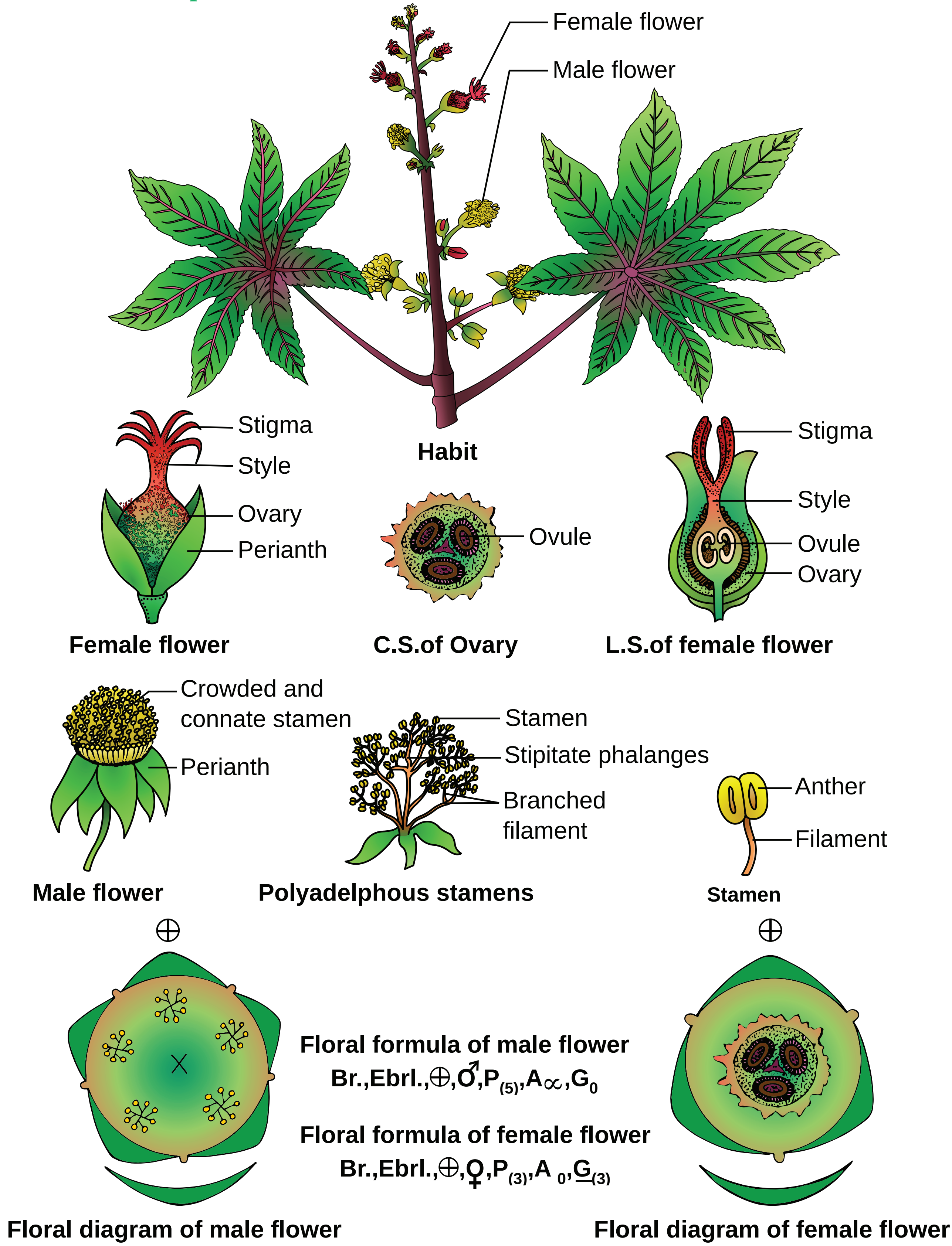



**Figure 5.22:** *Ricinus communis*

**Habit**: Tall perennial shrub

**Root:** Branched tap root system

**Stem:** Aerial, erect, cylindrical, branched and hollow, solid at the base, glabrous,

**Leaf:** Simple, petiolate, hollow, exstipulate, alternate, broad, palmately lobed, usually 7-9 lobes, serrate, palmately reticulate divergent venation.

**Inflorescence**: Terminal panicle.

**Male Flower** Bracteate, ebracteolate, pedicellate, male flowers (open for one day) towards lower portion of the inflorescence, actinomorphic, incomplete.

**Perianth:** Tepals 5, apophyllous, uniseriate, green, valvate aestivation, odd tepal posterior in position.

**Androecium:** Stamens numerous (upto 1000) crowded and connate into about 8mm long cluster of stipitate phalanges, each stamen profusely branded, anthers globose basifixed.

**Gynocium:** usually absent rarely represented by pistillode.

**Female Flower** Bracteate, ebracteolate, pedicellate, female flowers (open for fourteen days) found towards the apical portion of inflorescence, actinomorphic, incomplete and hypogynous.

**Perianth:** Tepals 3, apophyllous, green valvate.

**Androecium**: Absent but staminode is present.

**Gynoecium**: Tricarpellary, syncarpous, ovary superior, distinctly trilobed, trilocular, covered with spiny outgrowth, single large ovule in each locule on axile placentation, style three with three bifid stigma.

**Fruit**: A schizocarp with spiny outgrowth, splits into three one seeded cocci.

**Seed:** Endospermous, knob-like caruncle develops from the micorpyle, that absorbs and temporarily retains water enabling germination.

**Floral Formula:**

**Male flower**: Br.,Ebrl.,$\oplus$,♂,$P_{(5)}$,$A_{\infty}$,$G_0$

**Female flower**: Br.,Ebrl.,$\oplus$,♀,$P_{(3)}$,$A_0$,$\underline{G}_{(3)}$

*Hevea brasiliensis*

*Euphorbia pulcherrima*

*Euphorbia splendens*

*Croton tiglium*

**Figure 5.23:** Selected plants belongs to the Family Euphorbiaceae

## Economic importance of the family Euphorbiaceae

| Economic importance | Binomial | Useful part | Uses |
|---|---|---|---|
| **Food plant** | *Emblica officinalis* (Nellikai)<br>*P. acidus* (அரைநெல்லி) | Fruits | Rich in vitamin C, which are edible and pickled. |
| | *Manihot esculenta* (Maravalli kizhanku / Tapioca) | Tuberous roots | Roots are rich in starch and used for preparing bread, biscuits, chips and other food stuffs. |
| | *Sauropus androgynous* | Leaves | Greens (multi vitamin plant) |
| **Oil plant** | | | |
| Croton oil | *Croton tiglium* | Seed | Used as a powerful purgative and also to treat skin diseases. |
| Castor Oil | *Ricinus communis* (Amanakku/Castor) | Seeds | Used as vegetable oil, ricinoleic acid present in this oil eliminate acne causing bacteria apart from that it acts as laxative and lubricant. |
| Jatropha Oil | *Jatropha curcas* (Kattamanakku) | Seeds | Used for biofuels. |
| **Rubber:** | *Hevea brasiliensis* (Para rubber)<br>*Manihot glaziovii* (Manicoba rubber) | Coagulated latex | Latex is used in rubber products like tube and tyre. |
| **Medicinal plants** | *Euphorbia resinifera* | Latex | *Euphorbium* drug is obtained from the latex and used as a purgative. |
| | *Euphorbia hirta* (அம்மான் பச்சரிசி) | Whole plant | Lactogogue |
| | *Mallotus philippenensis* | Fruits | Used as anthelmintic. |
| | *Phyllanthus amarus* (Keezhanelli) | Entire shoot system | Used to treat Jaundice. |

| Economic importance | Binomial | Useful part | Uses |
|---|---|---|---|
| | *Jatropha gossypifolia*<br><br>*Croton tiglium* (நேர்வாளம்)<br>*Ricinus communis* | Leaves and roots<br>Seed<br>Seed oil | Used in the treatment of leprosy and snakebite.<br>Purgative<br>Purgative |
| **Dye yielding plants**<br>**Kamela dye**,<br><br>**Blue dye**<br><br>**Purple dye**<br>**Red dye** | <br><br>*Mallotus philippenensis*<br><br>*Jatropha curcas*<br><br>*Chrozophora tinctoria*<br>*Phyllanthus reticulatus* | <br><br>Fruits<br><br>Bark<br><br>Bark<br>Roots | <br><br>Used for dyeing wool and silk.<br>Used for dyeing clothes and fishing nets.<br>Used in textile Industry<br>Used for tanning and *dyeing* fishing lines and nets |
| **Timber plant** | *Aporosa dioica*,<br>*Bischofia javanica*, (ரோமவிருட்சம்)<br>*Drypetes roxburghii* (வீரைமரம்) | Timber | Used for packing cases, tea boxes, veneers, plywood, match industry and several other similar purpose. |
| **Ornamental plant** | *Acalypha ciliata*,<br>*A. hispida*,<br>*Codiaeum varigatum*<br>*Croton tiglium*<br>*Euphorbia antiquorum*, *E.pulcherrima*, *E.splendens*.<br>*E. tirucalli*<br>*Jatropha gossypifolia* | Plants | Grown as ornamental plants. |

## 5.13.5 Family *Musaceae* – Banana Family

### Diagnostic Features

- Perennial giant herbs with pseudostems formed by leaf sheaths.
- Leaves are large with thick midrib, parallel venation.
- Flowers are zygomorphic, unisexual, inflorescence spadix covered by spathe.
- Corolla 2 lipped.
- Ovary tricarpellary, inferior.
- Fruit elongated berry.
- Septal nectaries are present.

**Systematic Position**

| APG Classification | | Bentham and Hooker Classification | |
|---|---|---|---|
| Kingdom | Plantae | Kingdom | Plantae |
| *Clade* | Angiosperms | Class: | Monocotyledonae |
| *Clade* | Monocots | Subclass | Zingiberidae |
| *Clade* | Commelinids | Series | Epigynae |
| Order | Zingiberales | Order | Zingiberales |
| Family | Musaceae | Family | Musaceae |

*Musa velutina*


***Rhizogram of the Zingiberales***

Note: Earlier Musaceae was a large family with 6 genera viz. *Musa, Ensete, Ravenala, Strelitzia, Orchidantha* and *Heliconia*. In APG only Musa and Ensete are retained while *Ravenala, Strelitzia, Orchidantha* and *Heleconia* are separated.

## General Characters

### Distribution

Musaceae includes only 2 genera (*Musa* and *Ensete*) and 81 species. The members of this family are mainly wet tropical lowlands from West Africa to Pacific (southern Japan to Queensland). (*Musa* is the most common plant of the family found in India)

**Habit:** Large perennial herbs perennating by means of rhizome ( *Musa paradisiaca*), raraly trees as in *Ravenala madagascariensis*.

**Root:** Fibrous adventitious root system.

**Stem:** In *Musa* the real stem is found underground called rhizomatous (dichotomously branching in atleast some spp). The apparent aerial erect, unbranched tall pseudostem is formed by the long stiff and sheathy leaf bases which are rolled around one another to form an aerial pseudostem. The central axis that is concealed at the bottom of the pseudostem in called shaft, which elongates and pierces through the pseudostem at the time of flowering and produces inflorescence terminally. **monocorpic** in *Musa*. (produces flowers and fruits once during its life time). Stem is aerial and woody in *Ravenala madagascariensis.*

**Leaf:** Simple with long and strong petiole the leaf blade is large and broad with sheathy leaf base. The leaf is exstipulate. Oval, obtuse or oblong with a stout midrib, entire, numerous parallel veins extending up to the margin, rolled in bud . Phyllotaxy is spiral in *Musa* and distichous i.e. leaves are arranged alternately in two opposite vertical rows in *Ravenala*.

**Inflorescence:** Terminal or axillary thyrse of one to many monochasial branched spadix in *Musa*, Usually the flowers are protected by large brightly coloured, spirally arranged, boat shaped bract called spathe. Compound cyme in *Ravenala*.

**Flowers:** Bracteate, ebracteolate, sessile, trimerours, unisexual, or bisexual or polygamous, when unisexual the flowers are monoecious. Flowers are zygyomorphic and epigynous. (In *Musa* flowers are polygamous i.e. staminate flowers, pistilate flowers and bisexual flowers are present in the same plant).

**Perianth:** Tepals 6, biseriate, arranged in two whorls of 3 each and homochlamydeous, 3 +3 syntepalous. In most of the species of *Musa*, the three outer tepals and two lateral tepals of the inner whorl are fused to form 5 toothed tube like structure called **abaxial lip**. The posterior inner median tepal alone is free, which is distinctly broad and membranous called **labellum**.

**Androecium:** Stamens 5 or 6, arranged in two whorls of 3 each opposite and adnate to the tepals. In *Musa* only 5 stamens are fertile and the inner posterior stamen is either absent or represented by a staminode. In *Ravenala* all the six stamens are fertile. Filaments free, anthers linear, dithecous dehisce by longitudinal slits, and with sticky pollen.

**Gynoecium:** Tricarpallary, syncarpous, the median carpel is anterior in position, trilocular ovary inferior, ovules many, placentation axile, style filiform, stigma three lobed septal nectaries are present.

**Fruit:** Elongated berry containing numerous seeds, fruits forming compact bunches, seeds with copious and small embryo in *Musa*. Capsule in *Ravenala.*

**Seed:** Starch rich endosperm and starchless perisperm. Species of *Ensete* are distinguished from those of *Musa* by their larger seeds.

### Botanical Description of *Musa paradisiaca.*

**Habit:** Monocarpic gigantic herb.

**Root:** Fibrous adventitious root system.

**Stem:** The real stem is underground called rhizomatous. The apparent, aerial erect unbranched pseudo stem is formed by the long, stiff and sheathy leaf bases which are rolled around one another to form an aerial pseudostem. The central

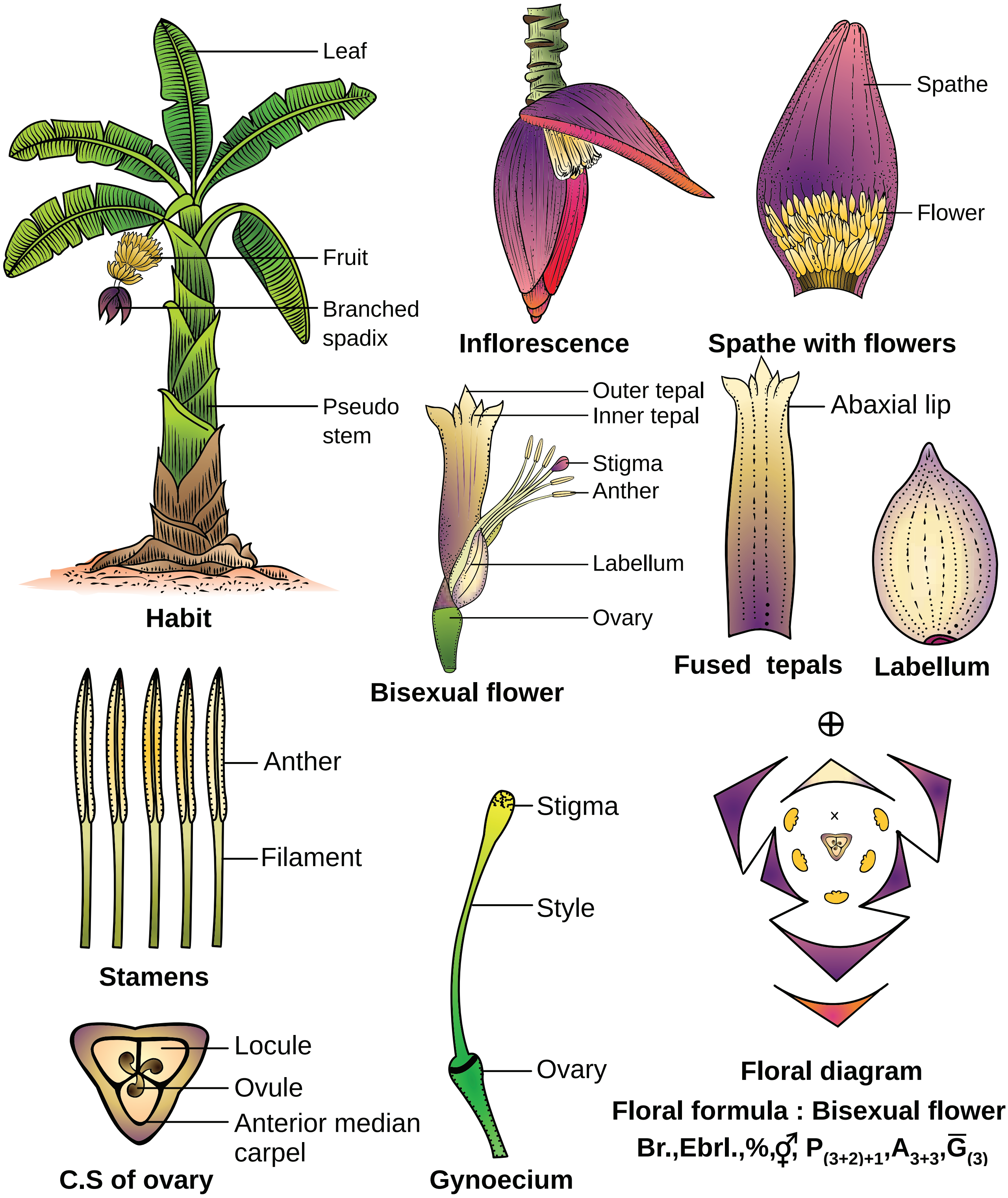



**Figure 5.24:** *Musa paradisiaca*

axis that is concealed at the bottom of the pseudostem is called shaft. The shaft elongates, pierces through the pseudostem and produces an inflorescence terminally.

**Leaf:** Simple with a long and strong petiole. The leaf blade is large and broad with sheathy leaf base. Leaf exstipulate and obtuse pinnately parallel venation which extends upto the leaf margin phyllotaxy is spiral.

**Inflorescence:** Terminal branched spadix. Flowers are protected by large, brightly coloured spirally arranged, boat shaped bracts called spathe. When the flowers open, spathe rolls back and falls off.

**Flower:** Bracteate, ebracteolate, sessile, trimerous, unisexual or bisexual, flowers are zygomorphic and epigynous.

**Perianth:** Tepals 6, biseriate, 3+3 syntepalous, arranged in two whorls of 3 each and homochlamydeous, the three tepals of the outer whorl and the two lateral tepals of the inner whol are fused by valvate aestivation to form 5 toothed tube like structure called abaxial lip, the posterior inner median tepal is distinctly broad membrancus and free called labellum.

**Androecium:** Stamens 6, arranged in two whorls of 3 each, arranged opposite to the tepals. Only five stamens are fertile and the inner posterior stamen is either absent or represented by staminode. Anthers are dithecous and they dehisce by vertical slits. Filament is simple and filiform and rudimentary ovary or pistillode is often present in the male flower.

**Gynoecium:** Tricarpellary, syncarpous, the median carpel anterior, trilocular, ovary inferior, numerous ovules on axile placentation. Style is simple and filiform, stigma trilobed. Septal nectaries are present.

**Fruit:** An elongated fleshy berry and seeds are not produced in cultivated varieties.

Floral Formula

Male flower:

$\mathbf{Br, Ebrl, \%, ♂, P_{(3+2)+1}, A_{3+3}, G_0.}$

Female flower:

$\mathbf{Br, Ebrl, \%, ♀, P_{(3+2)+1}, A_0, \overline{G}_{(3)}.}$

Bisexual flower:

$\mathbf{Br, Ebrl, \%, ⚥, P_{(3+2)+1}, A_{3+3}, \overline{G}_{(3)}.}$

*Ensete ventricosum*

*Ravenala madagascariensis*

*Strelitzia reginae*

*Heliconia spp*

**Figure 5.25:** Selected plants belongs to the Family Musaceae

**Economic Importance of The Family Musaceae**

| S.No | Economic importance | Binomial | Useful part | Uses |
|---|---|---|---|---|
| 1 | **Food plant** | *Musa paradisiaca.*<br><br>*Ensete ventricosa*<br><br>*Musa chinensis* (Chinea kela) | The raw (tender green) bananas, the shaft and male buds.<br>Leaves<br><br>Fruit<br><br>Flower stalk (Shaft)<br><br>Fruits | Cooked and eaten as vegetable.<br><br>Commonly used as plates on festive occasions and are widely used to wrap food items when cooking.<br>Crunchy and salty fried plantain chips are delicious.<br>Edible after cooking.<br>Edible bananas which are sweet, rich in starch and vitamins. |
| 2. | **Medicinal plant** | *Musa spp.* | Sap obtained from the sheathy leaf base. | Considered to be an antidote for cobra bite. |
| 3. | **Starch** | *Ensete ventricosum* (Ethiopean banana) | The swollen basal parts of leaf sheaths | Used as a source of starch and vitamins. |
| 4. | **Fibre yielding plant** | *Musa textilis* (Manila hemp) | Fibre | Fibre is woven and made into abaca cloth, also used for twine, bagging and wrapping paper. |
| 5. | **Ornamental plant** | *Musa coccinea* (a wild banana species).<br>(*M. acuminata*, *M. velutina* and *M. ornata*)<br>*Ensete ventricosum* | Plant | Have ornamental scarlet flowers.<br>Cultivated as ornamentals |

*Continued*

| | | | | |
|---|---|---|---|---|
| | | **Ravenala madagascariensis* (traveller's palm), **Strelitzia reginae* (bird of paradise ) and **Heliconia spp*. | Plant | Grown as ornamental plants |

## 5.13.6 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*.

**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.

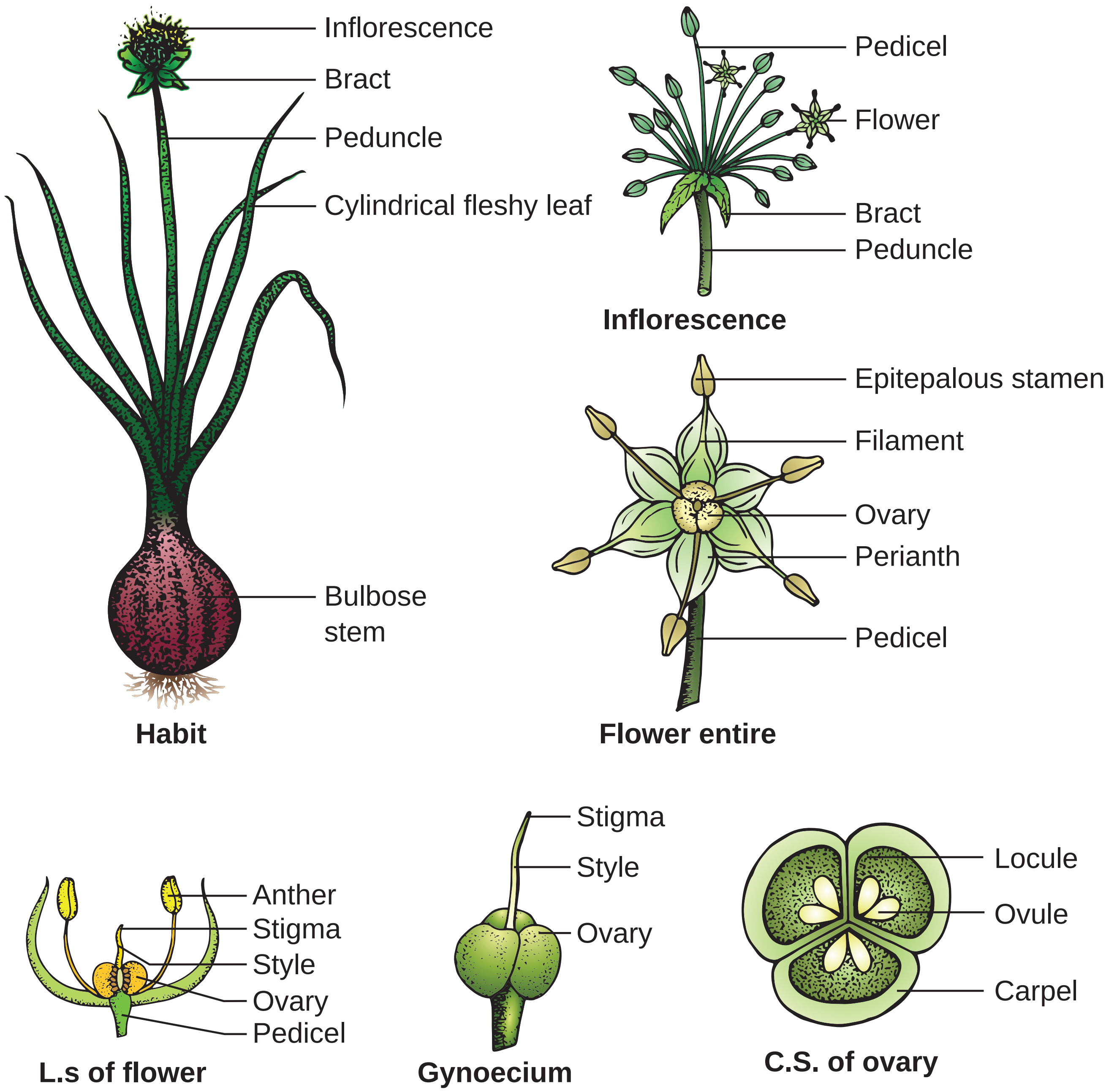
**Gynoecium:** Tricarpellary and syncarpous. Ovary superior, trilocular with two ovules in each locule on axile placentation. Style simple, slender with simple stigma.

**Fruit:** A loculicidal capsule.

**Seed:** Endospermous

**Floral Formula:**

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




**Floral formula**

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

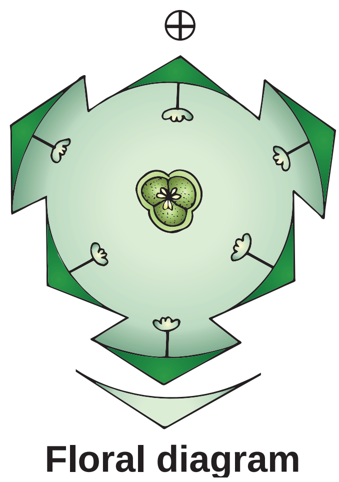



**Figure 5.26:** *Allium cepa*

## 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. |
| 4. | Fibre yielding plant | *Phormium tenax* | Fibre | Used for cordage, fishing net, mattings, twines |
| 5. | Raticides | *Urginea indica* | Bulbs | Used for killing rats |
| | Insecticides | *Veratrum album* | Bulbs | Used as insecticide. |

*Continued*

| S.No | Economic importance | Binomial | Useful part | Uses |
|---|---|---|---|---|
| 6. | Polyploidy | *Colchicum luteum* | Corm | Colchicine (alkaloid) used to induce polyploidy. |
| 7. | Ornamental plants | *Agapanthus africanus* (African Lilly)<br>*Hemerocallis fulva* (Orange Day Lilly)<br>*Gloriosa superba* (Malabar glory lilly)<br>*Lilium candidum*<br>*Lilium giganteum*<br>*Ruscus aculeatus* (Butchers Broom)<br>*Tulipa suaveolens*<br>*Yucca alcifolia* and *Y.gloriosa* | Plant | Some of the well known garden ornamentals.<br>**Can you identify this?**<br>a. Name the family.<br>b. Write the binomial.<br>c. List the economic uses.<br> |

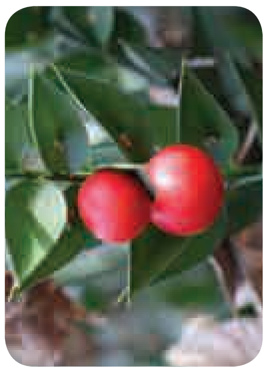
**DO YOU KNOW?**

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*

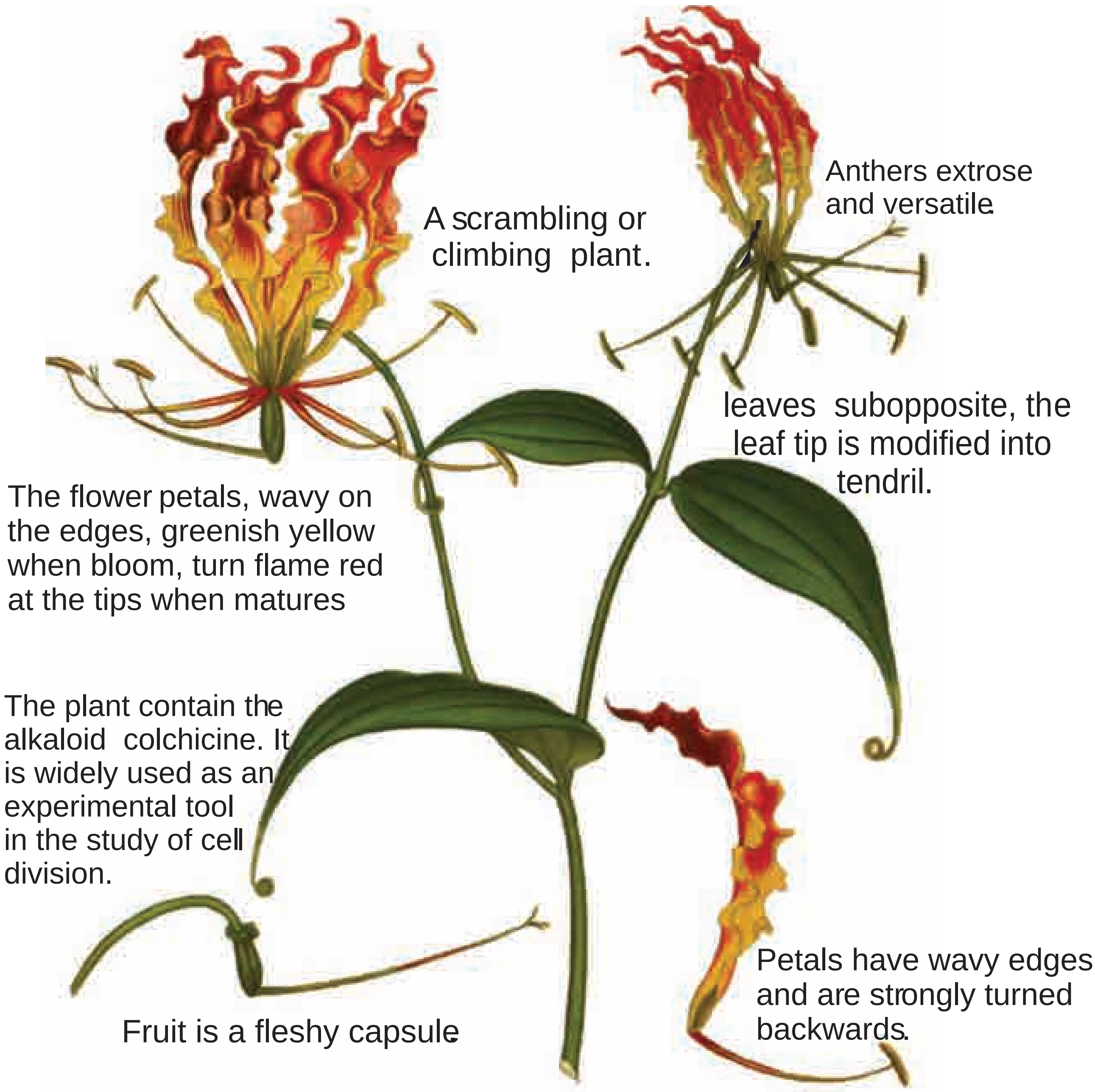
*Tulipa*



*Ruscus*

**Figure 5.27:** Selected plants belongs to the Family Liliaceae

## 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 also 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, mounting and labelling. 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 constructed 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
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

# Characteristics of flowers

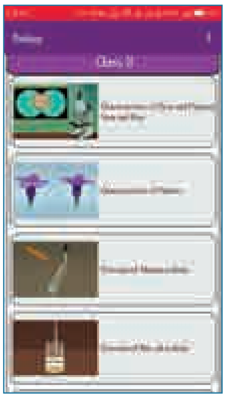
Look inside the **Flower.** →

### Steps

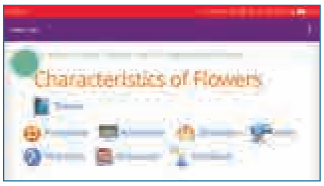
- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Character of flower
- Click theory to know the basic about Character of flower
- Register yourself with mail-id and create password to access online lab simulations

### Activity

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



Step 1

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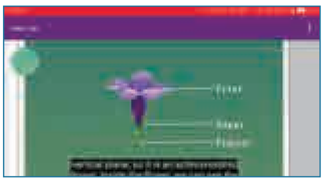

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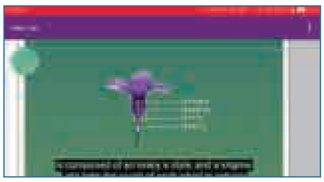

Step 4

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* 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

**6.1.** Discovery
**6.2.** Microscopy
**6.3.** Cell theory
**6.4.** Cell types
**6.5.** Plant cell and Animal cell
**6.6.** Cell organelles
**6.7.** Nucleus
**6.8.** Flagella
**6.9.** Cytological techniques

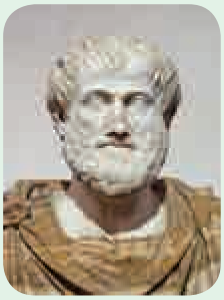
5QSR7L

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, $\lambda$= 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).

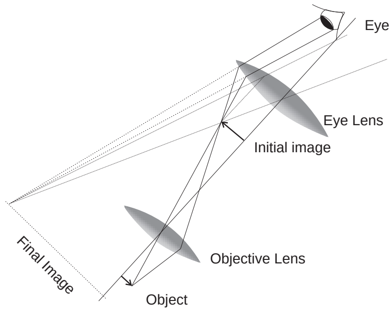
### 6.2.2 Dark Field Microscope

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).

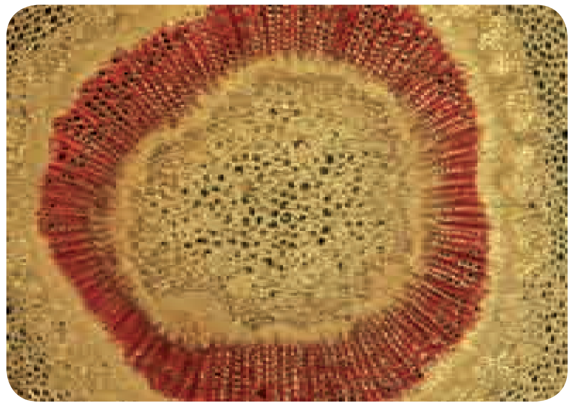
### 6.2.3 Phase contrast microscope

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.

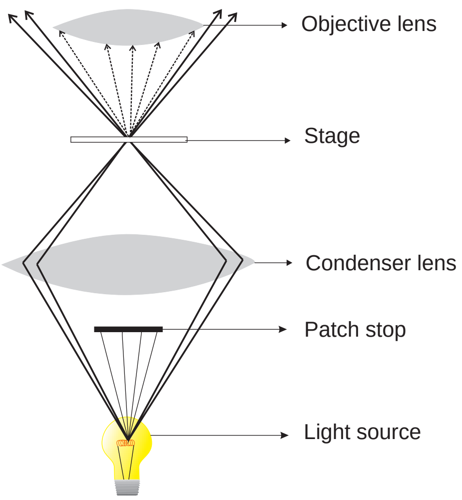
(a)



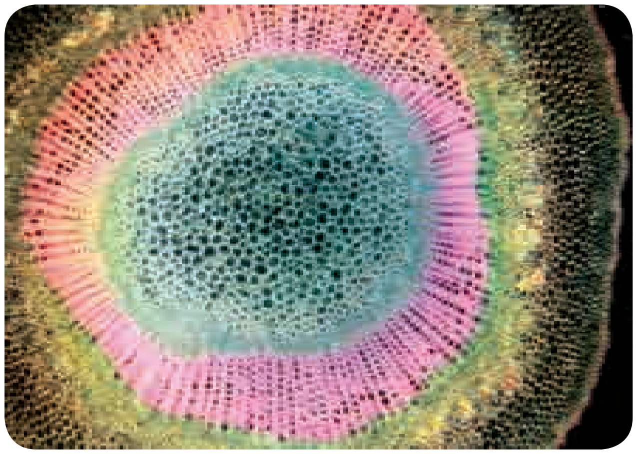

(b)



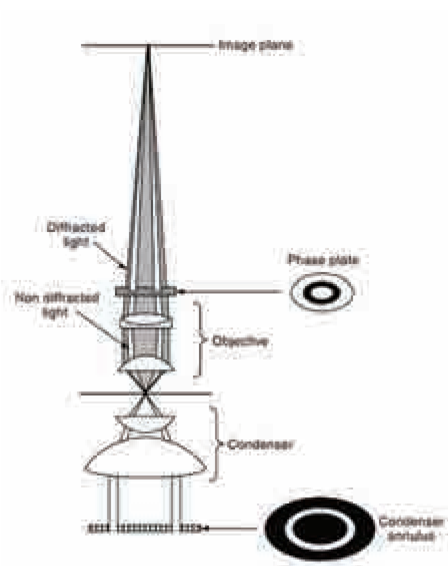
(c)




(d)



(e)




(f)

(g)

**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

**Microscopic measurements:**

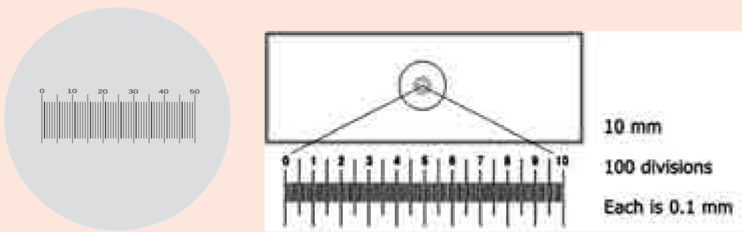
The microscope also has facility to measure microscopic objects through a technique called '**micrometry**'. There are two scales involved for measuring.

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.

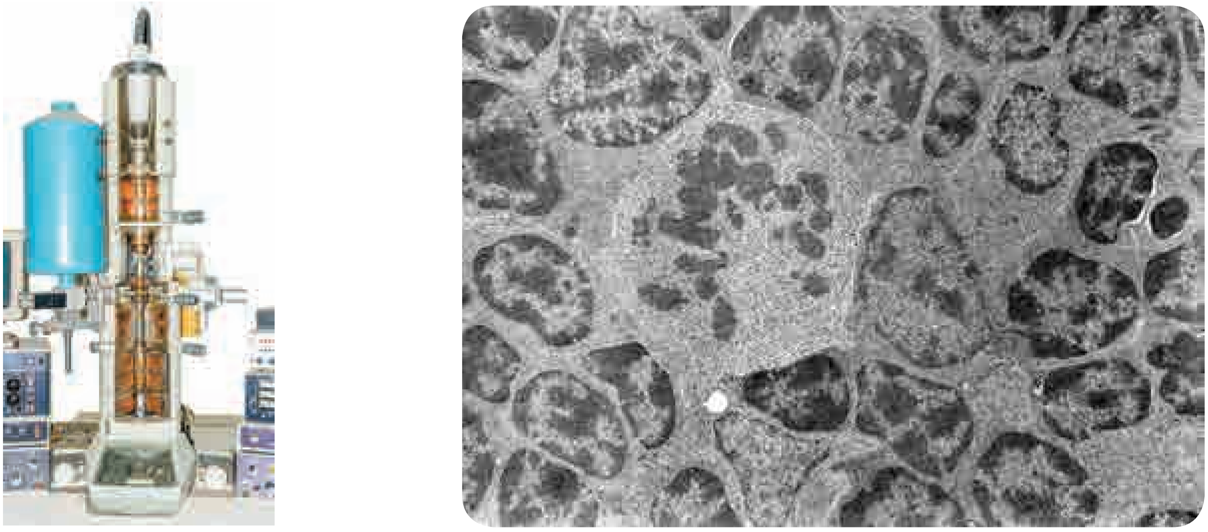
There are two kinds of electron microscopes namely

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

**1. Transmission electron microscope:**

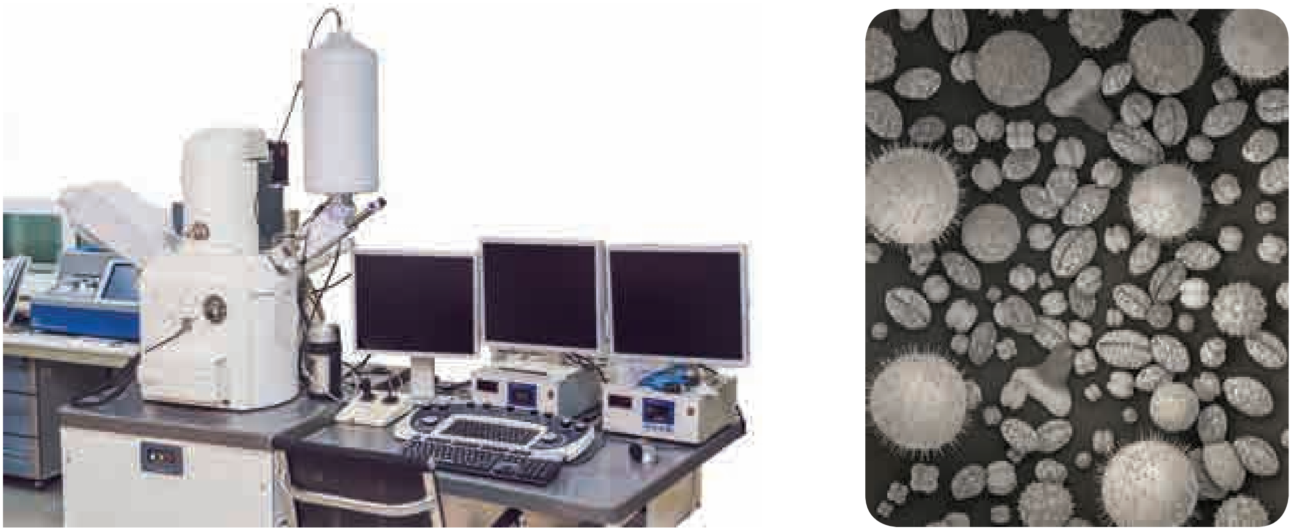
This is the most commonly used electron microscope which provides two dimensional image. The components of the microscope are as follows:

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

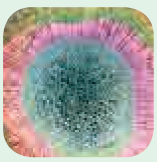
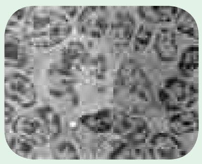
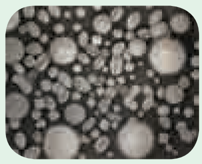


(a) (b)

**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 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.

These solutes may be homogeneous (soluble in water) or heterogeneous mass (insoluble in water) which forms the basis for its colloidal nature.

**Physical Properties of Protoplasm**

The protoplasm exist either in semisolid (jelly-like) state called '**gel**' due to suspended particles and various chemical bonds or may be liquid state called '**sol**'. The colloidal protoplasm which is in gel form can change into sol form by **solation** and the sol can change into gel by **gelation**. These gel-sol conditions of colloidal system are prime basis for mechanical behaviour of cytoplasm.

1. Protoplasm is translucent, odourless and polyphasic fluid.
2. It is a crystal colloid solution which is a mixture of chemical substances forming crystalloid i.e. true solution (sugars, salts, acids, bases) and others forming colloidal solution (Proteins and lipids)
3. It is the most important property of the protoplasm by which it exhibits three main phenomena namely Brownian movement, amoeboid movement and cytoplasmic streaming or cyclosis. Viscosity of protoplasm is 2–20 centipoises. The Refractive index of the protoplasm is 1.4.
4. The pH of the protoplasm is around 6.8, contain 90% water (10% in dormant seeds)
5. Approximately 34 elements are present in protoplasm but only 13 elements are main or universal elements i.e. C, H, O, N, Cl, Ca, P, Na, K, S, Mg, I and Fe. Carbon, Hydrogen, Oxygen and Nitrogen form the 96% of protoplasm.
6. Protoplasm is neither a good nor a bad conductor of electricity. It forms a delimiting membrane on coming in contact with water and solidifies when heated.
7. **Cohesiveness:** Particles or molecules of protoplasm are adhered with each other by forces, such as **Van der Waal's bonds**, that hold long chains of molecules together. This property varies with the strength of these forces.
8. **Contractility:** The contractility of protoplasm is important for the absorption and removal of water especially stomatal operations.
9. **Surface tension:** The proteins and lipids of the protoplasm have less surface tension, hence they are found at the surface forming the membrane. On the other hand the chemical substances (NaCl) have high surface tension, so they occur in deeper parts of the cell protoplasm.

### 6.3.4 Cell sizes and shapes

Cell greatly vary in size, shape and also in function. Group of cells with similar structures are called **tissue** they integrate together to perform similar function, group of tissue join together to perform similar function called **organ**, group of organs with related function called **organ system**, organ system coordinating together to form an **organism**.

**Shape**

The shape of cell vary greatly from organism to organism and within the organism itself. In bacteria cell shape

**DO YOU KNOW?**

| | |
|---|---|
| 1 cm | = 1/100 meter |
| 1 mm = 1/1000 meter | =1/10 cm |
| 1 µm = 1/1000,000 meter | = 1/10,000 cm |
| 1 nm = 1/1,000,000,000 meter | = 1/10,000,000 cm |
| 1 Å = 1/10,000,000,000 meter | =1/100,000,000 cm |

or

1 m = $10^2$cm = $10^3$mm = $10^6$µm = $10^9$nm = $10^{10}$Å

m = meter cm = centimetre mm = millimeter µm = micrometer
nm = nanometer Å=Angstrom

vary from round (**cocci**) to rectangular (**rod**). In virus, shape of the envelope varies from round to hexagonal or 'T' shaped. In fungi, globular to elongated cylindrical cells and the spores of fungi vary greatly in shape. In plants and animals cells vary in shape according to cell types such as parenchyma, mesophyll, palisade, tracheid, fiber, epithelium and others (Figure 6.6).

**Size:**

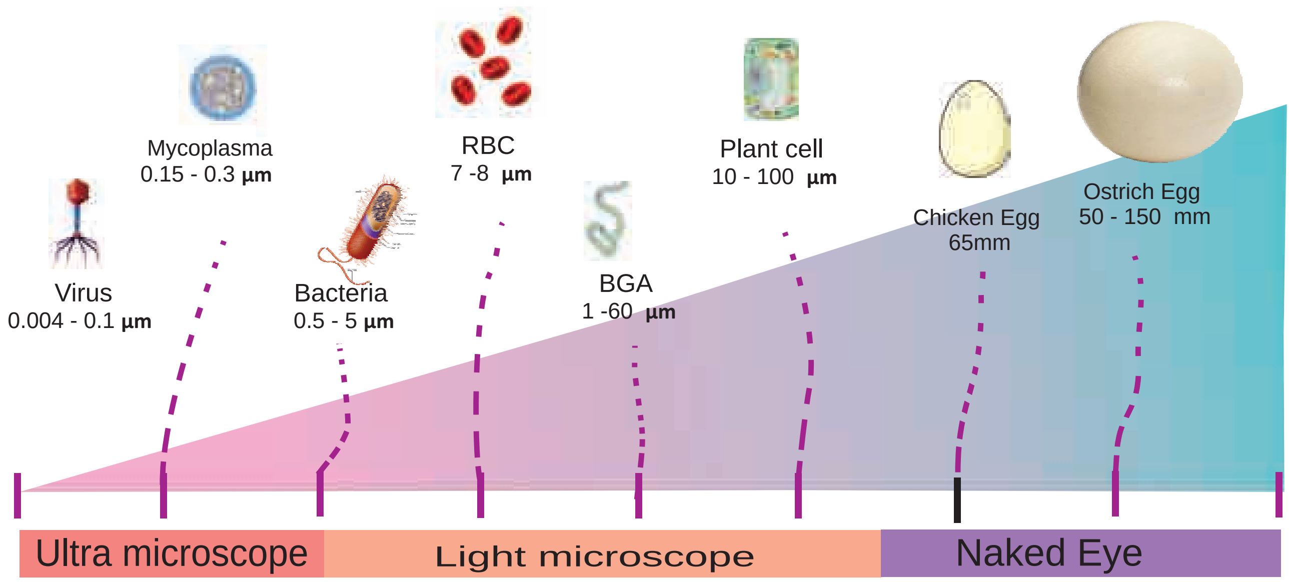



**Figure 6.6:** Cell size variation of few organisms

## 6.4. Types of cells

On the basis of the cellular organization and the nuclear characteristics, the cell can be divided into

- Prokaryotes
- Mesokaryotes and
- Eukaryotes

### 6.4.1 Prokaryotes

Those organisms with primitive nucleus are called as **prokaryotes** (*pro* – primitive; *karyon* – nucleus). The DNA lies in the 'nucleoid' which is not bound by the nuclear membrane and therefore it is not a true nucleus and is also a primitive type of nuclear material. The DNA is without histone proteins. Example: Bacteria, blue green algae, Mycoplasma, Rickettsiae and Spirochaetae.

### 6.4.2 Mesokaryotes

In the year 1966, scientist **Dodge** and his coworkersproposedanotherkindoforganisms called **mesokaryotes**. These organisms which shares some of the characters of both prokaryotes and eukaryotes. In other words these are organisms intermediate between pro and eukaryotes. These contains well organized nucleus with nuclear membrane and the DNA is organized into chromosomes but without histone protein components divides through amitosis similar with prokaryotes. Certain Protozoa like **Noctiluca**, some phytoplanktons like *Gymnodinium*, *Peridinium* and Dinoflagellates are representatives of mesokaryotes.

### 6.4.3 Eukaryotes

Those organisms which have true nucleus are called **Eukaryotes** (*Eu* – True; *karyon* – nucleus). The DNA is associated with protein bound histones forming the chromosomes. Membrane bound organelles are present. Few organelles may be arisen by **endosymbiosis** which is a cell living inside another cell. The organelles like mitochondria and chloroplast well support this theory.

## Comparison between types of cellular organisation

| Features | Prokaryotes | Mesokaryotes | Eukaryotes |
|---|---|---|---|
| **Size of the cell** | ~1-5µm | ~5-10µm | ~10-100µm |
| **Nuclear character** | Nucleoid, no true nucleus, | Nucleus with nuclear membrane | True nucleus with nuclear membrane |
| **DNA** | Usually circular without histone proteins | Usually linear but without histone proteins | Usually linear with histone proteins |
| **RNA/Protein synthesis** | Couples in cytoplasm | Similar with eukaryotes | RNA synthesis Inside nucleus/ Protein synthesis in cytoplasm |
| **Ribosomes** | 50S+ 30S | 60S + 40S | 60S + 40S |
| **Organelles** | Absent | Present | Numerous |
| **Cell movement** | Flagella | Gliding and flagella | Flagella and cilia |
| **Organization** | Usually single cell | Single and colony | Single, colonial and multicellular |
| **Cell division** | Binary fission | Binary fission | Mitosis and meiosis |
| **Examples** | Bacteria and Archaea | Dinoflagellate, Protozoa | Fungi, plants and animals |

**Origin of Eukaryotic cell:**

**Endosymbiont theory:** Two eukaryotic organelles believed to be the descendants of the endosymbiotic prokaryotes. The ancestors of the eukaryotic cell engulfed a bacterium and the bacteria continued to function inside the host cell.

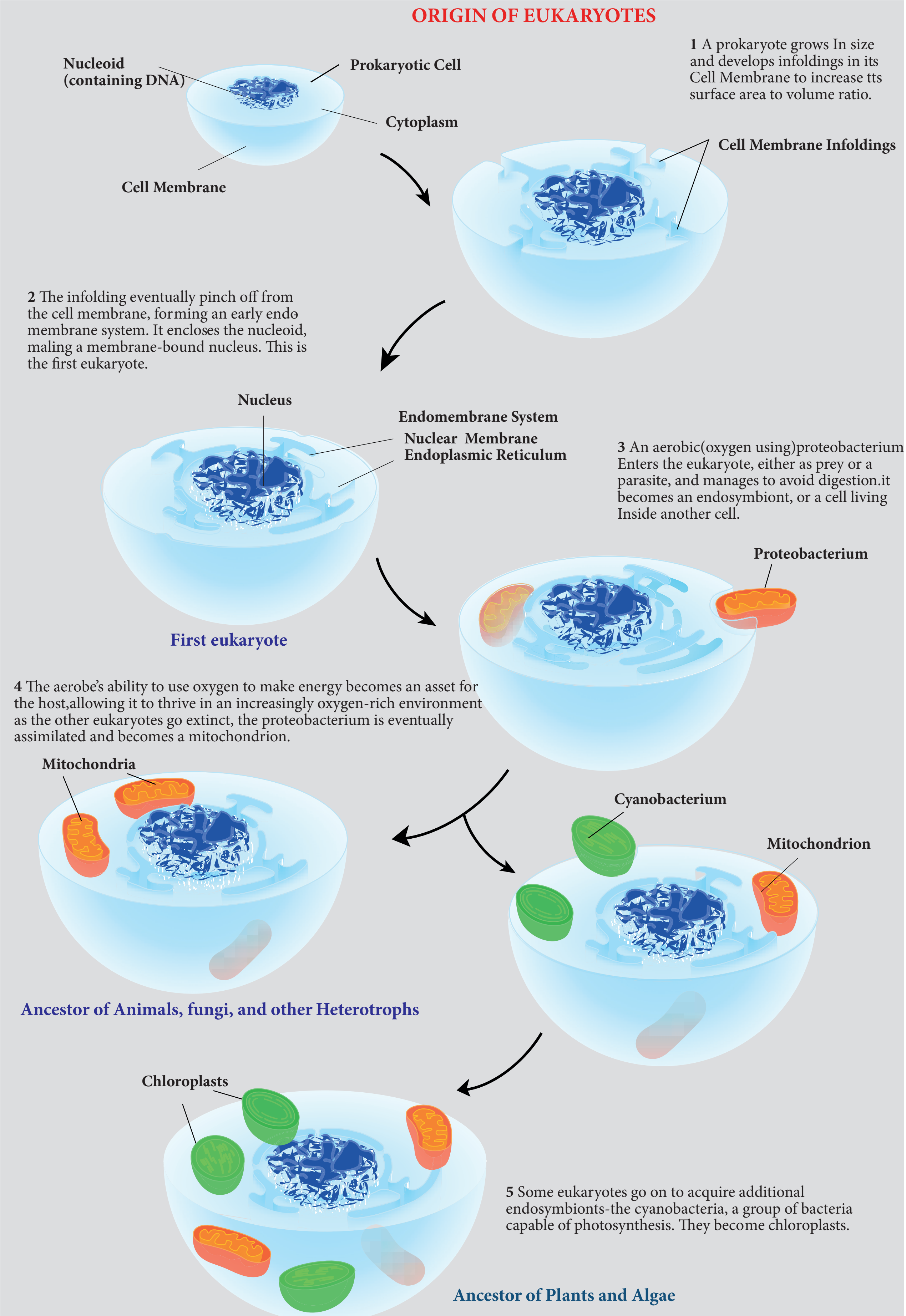



**Figure 6.7:** A model of endosymbiotic theory

The first cell might have evolved approximately 3.8 billion years ago. The primitive cell would have been similar to present day protists (Figure 6.7).

## 6.5. Plant and Animal cell

### 6.5.1 Ultra Structure of Eukaryotic Cell

The eukaryotic cell is highly distinct in its organisation. It shows several variations in different organisms. For instance, the eukaryotic cells in plants and animals vary greatly (Figure 6.8).

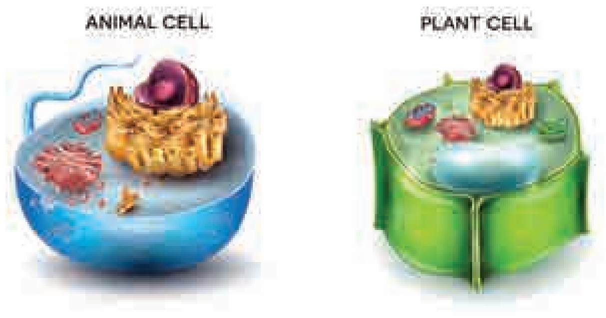



**Figure 6.8:** Animal and Plant cell

**Animal Cell**

Animal cells are surrounded by cell membrane or plasma membrane. Inside this membrane the gelatinous matrix called **protoplasm** is seen to contain nucleus and other organelles which include the endoplasmic reticulum, mitochondria, golgi bodies, centrioles, lysosomes, ribosomes and cytoskeleton.

**Plant cell**

A typical plant cell has prominent cell wall, a large central vacuole and plastids in addition to other organelles present in animal cell (Figure 6.9 and 6.10).

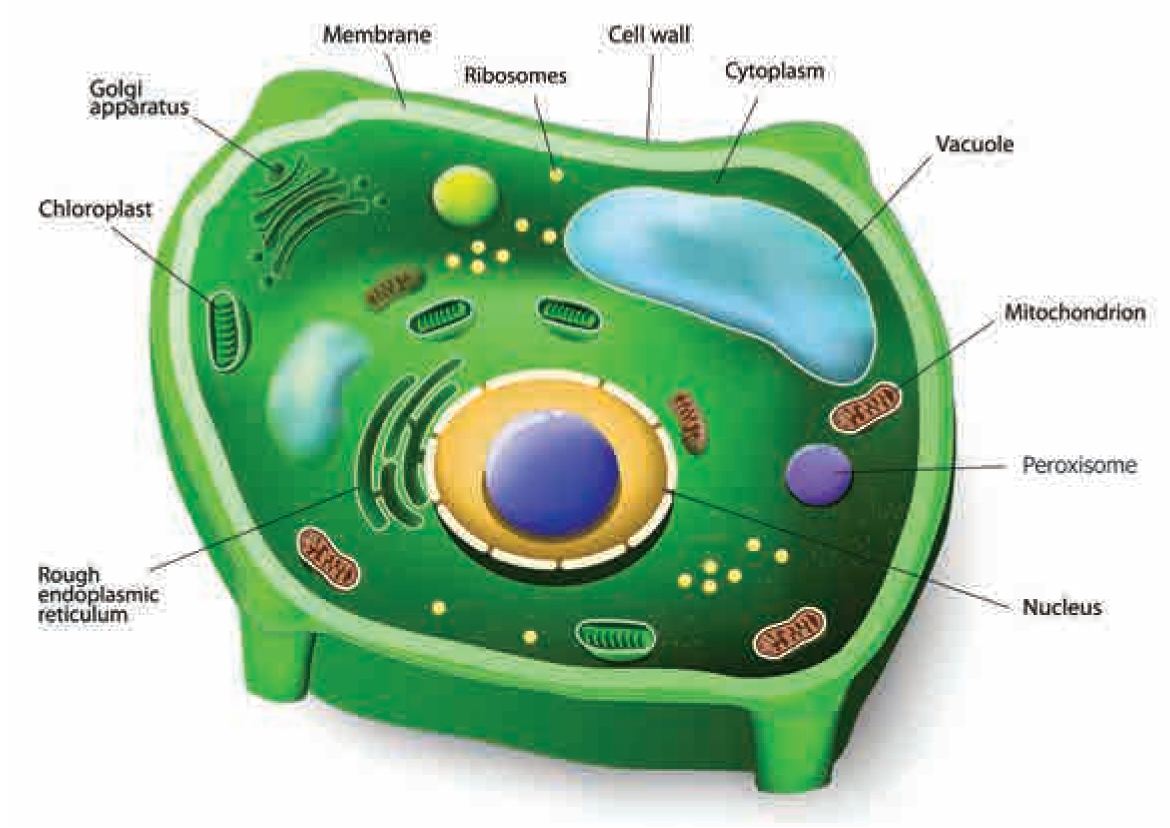



**Figure 6.9:** Ultra Structure of Plant Cell

## Difference between plant and animal cells

| S. No | Plant cell | Animal Cell |
|---|---|---|
| 1 | Usually they are larger than animal cells | Usually smaller than plant cells |
| 2 | Cell wall present in addition to plasma membrane and consists of middle lamellae, primary and secondary walls | Cell wall absent |
| 3 | Plasmodesmata present | Plasmodesmata absent |
| 4 | Chloroplast present | Chloroplast absent |
| 5 | Vacuole large and permanent | Vacuole small and temporary |
| 6 | Tonoplast present around vacuole | Tonoplast absent |
| 7 | Centrioles absent except motile cells of lower plants | Centrioles present |
| 8 | Nucleus present along the periphery of the cell | Nucleus at the centre of the cell |
| 9 | Lysosomes are rare | Lysosomes present |
| 10 | Storage material is starch grains | Storage material is a glycogen granules |

### 6.5.2 Protoplasm

Protoplasm is the living content of the cell that is surrounded by plasma membrane. It is a colourless material that exists throughout the cell together with the cytoplasm, nucleus and other organelles. Protoplasm is composed of a mixture of small particles, such as ions, amino acids, monosaccharides, water, macromolecules like nucleic acids, proteins, lipids and polysaccharides. It appears colourless, jelly like gelatinous, viscous elastic and granular. It appears foamy due to the presence of large number of vacuoles. It responds to the stimuli like heat, electric shock, chemicals and so on.

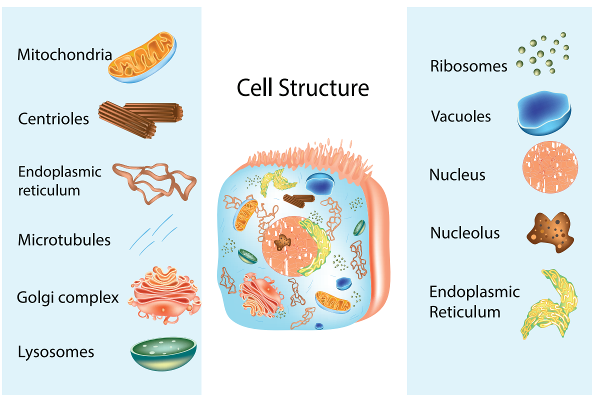



**Figure 6.10:** Cell structure and components

### 6.5.3 Cell Wall

Cell wall is the outermost protective cover of the cell. It is present in bacteria, fungi and plants whereas it is absent in animal cell. It was first observed by **Robert Hooke**. It is an actively growing portion. It is made up of different complex material in various organism. In bacteria it is composed of peptidoglycan, in fungi chitin and fungal cellulose, in algae cellulose, galactans and mannans. In plants it is made up of cellulose, hemicellulose, pectin, lignin, cutin, suberin and silica.

In plant, cell wall shows three distinct regions (a) Primary wall (b) Secondary wall (c) Middle lamellae (Figure 6.11).

**a. Primary wall**

It is the first layer inner to middle lamellae, primarily consisting of loose network of cellulose microfibrils in a gel matrix. It is thin, elastic and extensible. In most plants the microfibrils are made up of cellulose oriented differently based on shape and thickness of the wall. The matrix of the primary wall is composed of hemicellulose, pectin, glycoprotein and water. Hemicellulose binds the microfibrils with matrix and glycoproteins control the orientation of microfibrils while pectin serves as filling material of the matrix. Cells such as parenchyma and meristems have only primary wall.

**b. Secondary wall**

Secondary wall is laid during maturation. It plays a key role in determining the shape of a cell. It is thick, inelastic and is made up of cellulose and lignin. The secondary wall is divided into three sublayers termed as $S_1$, $S_2$ and $S_3$ where the cellulose microfibrils are compactly arranged with different orientation forming a laminated structure and the cell wall strength is increased.

**c. Middle lamellae**

It is the outermost layer made up of calcium and magnesium pectate, deposited at the time of cytokinesis. It is a thin amorphous layer which cements two adjacent cells. It is optically inactive (isotropic).

**Plasmodesmata and Pits**

Plasmodesmata act as a channel between the protoplasm of adjacent cells through which many substances pass through. Moreover, at few regions the secondary wall layer is laid unevenly whereas the primary wall and middle lamellae are laid continuously such regions are called **pits**. The pits of adjacent cells are opposite to each other. Each pit has a pit chamber and a pit membrane. The pit membrane has many minute pores and thus they are permeable. The pits are of two types namely simple and bordered pit.

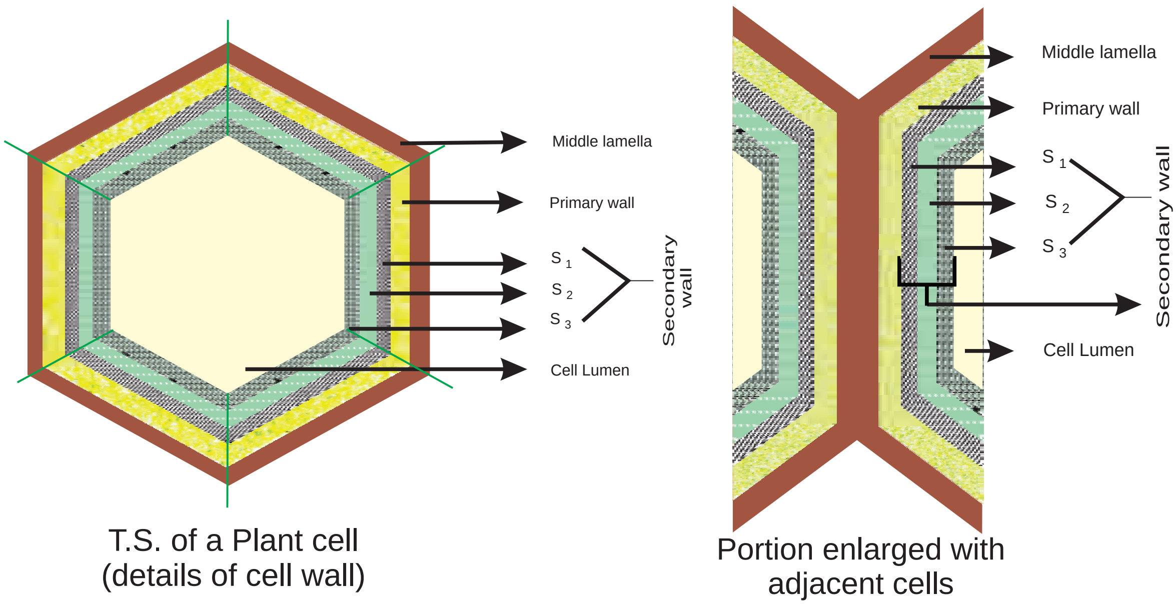



**Figure 6.11:** Plant cell wall

### Functions of cell wall

The cell wall plays a vital role in holding several important functions given below

1. Offers definite shape and rigidity to the cell.
2. Serves as barrier for several molecules to enter the cells.
3. Provides protection to the internal protoplasm against mechanical injury.
4. Prevents the bursting of cells by maintaining the osmotic pressure.
5. Plays a major role by acting as a mechanism of defense for the cells.

## 6.5.4 Cell Membrane

The cell membrane is also called **cell surface** (or) **plasma membrane**. It is a thin structure which holds the cytoplasmic content called '**cytosol**'. It is extremely thin (less than 10nm).

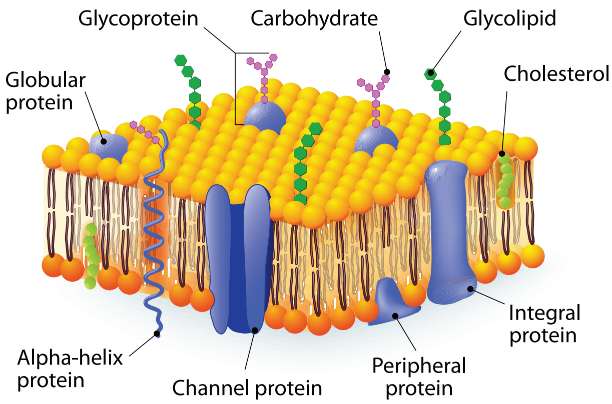



**Figure 6.12:** Model of Cell membrane

### Fluid Mosaic Model

**Jonathan Singer** and **Garth Nicolson** (1972) proposed fluid mosaic model.

It is made up of lipids and proteins together with a little amount of carbohydrate. The lipid membrane is made up of phospholipid. The phospholipid molecule has a hydrophobic tail and hydrophilic head. The hydrophobic tail repels water and hydrophilic head attracts water. The proteins of the membrane are globular proteins which are found intermingled between the lipid bilayer most of which are projecting beyond the lipid bilayer. These proteins are called as **integral proteins**. Few are superficially attached on either surface of the lipid bilayer which are called as **peripheral proteins**. The proteins are involved in transport of molecules across the membranes and also act as enzymes, receptors (or) antigens.

> **DO YOU KNOW?**
>
> Water-loving polar molecule are called hydrophilic molecule. They have polar phosphate group responsible for attracting water.
>
> Water hating non-polar molecule are called as hydrophobic molecule. They have fatty acid which is non-polar which cannot attract water

The Carbohydrate molecules of cell membrane are short chain polysaccharides. These are either bound with '**glycoproteins**' or '**glycolipids**' and form a '**glyocalyx**' (Figure 6.12).

The movement of membrane lipids from one side of the membrane to the other side by vertical movement is called **flip flopping** or **flip flop movement**. This movement takes place more slowly than lateral diffusion of lipid molecule. The phospholipids can have flip flop movement because the phospholipids have smaller polar regions, whereas the proteins cannot flip flop because the polar region is extensive.

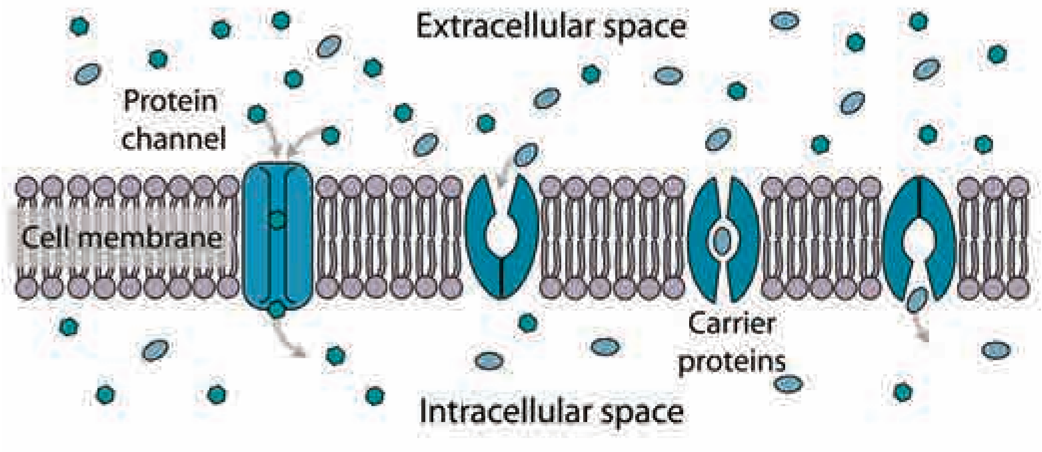



**Figure 6.13:** Transport of molecules through cell membrane

### Function of Cell Membrane

The functions of the cell membrane is enormous which includes cell signalling, transporting nutrients and water, preventing unwanted substances entering into the cell, and so on.

### Cell Transport

Cell membrane act as a channel of transport for molecules. The membrane is selectively permeable to molecules. It transports molecules through energy dependant process and energy independent process. The membrane proteins (channel and carrier) are involved in movement of ions and molecules across the membrane (Figure 6.13).

### Endocytosis and Exocytosis

Cell surface membrane are able to transport individual molecules and ions. There are processes in which a cell can transport a large quantity of solids and liquids into cell (**endocytosis**) or out of cell (**exocytosis**) (Figure 6.14).

**Endocytosis:** During endocytosis the cell wraps the cell surface membrane around the material and brings it into

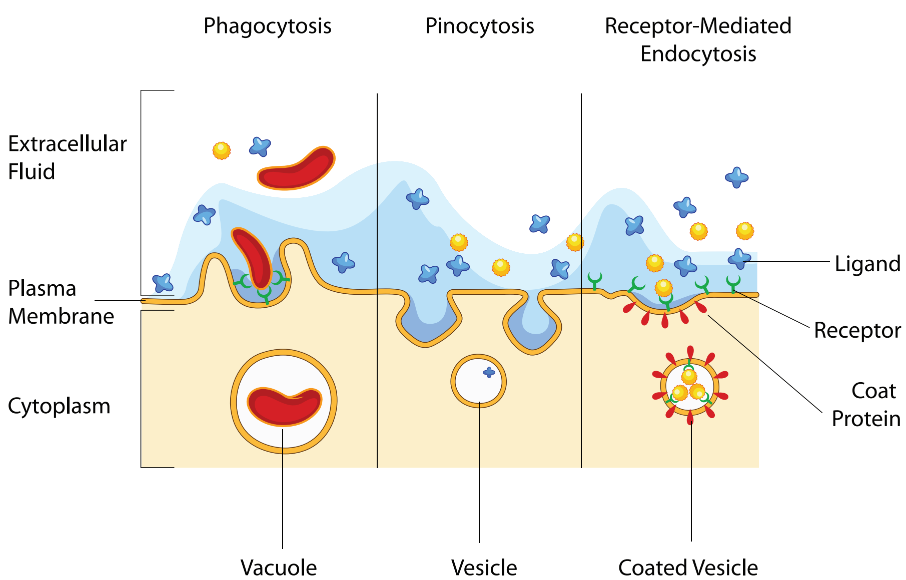



**Figure 6.14:** Endocytosis and exocytosis

cytoplasm inside a vesicle. There are two types of endocytosis:

1. **Phagocytosis** – Particle is engulfed by membrane, which folds around it and forms a vesicle. The enzymes digest the material and products are absorbed by cytoplasm.
2. **Pinocytosis** – Fluid droplets are engulfed by membrane, which forms vesicles around them.

**Exocytosis:** Vesicles fuse with plasma membrane and eject contents. This passage of material out of the cell is known as **exocytosis**. This material may be a secretion in the case of digestive enzymes, hormones or mucus.

### Signal Transduction

The process by which the cell receive information from outside and respond is called **signal transduction**. Plants, fungi and animal cell use nitric oxide as one of the many signalling molecules. The cell membrane is the site of chemical interactions of signal transduction. Receptors receives the information from first messenger and transmit the message through series of membrane proteins. It activates second messenger which stimulates the cell to carry out specific function.

## Cytoplasm

Cytoplasm is the main arena of various activities of a cell. It is the semifluid gelatinous substance that fills the cell. It is made up of eighty percent water and is usually clear and colourless. The cytoplasm is sometimes described as non nuclear content of protoplasm. The cytoplasm serves as a molecular soup where all the cellular organelles are suspended and bound together by a lipid bilayer plasma membrane. It constitutes dissolved nutrients, numerous salts and acids to dissolve waste products. It is a very good conductor of electricity. It gives support and protection to the cell organelles. It helps movement of the cellular materials around the cell through a process called **cytoplasmic streaming**. Further, most cellular activities such as many metabolic pathways including glycolysis and cell division occur in cytoplasm.

## 6.6 Cell Organelles

### 6.6.1 Endomembrane System

The system of membranes in a eukaryotic cell, comprising the plasma membrane, nuclear membrane, endoplasmic reticulum, golgi apparatus, lysosomes and vacuolar membranes (tonoplast). Endomembranes are made up of phospholipids with embedded proteins that are similar to cell membrane which occur within the cytoplasm. The endomembrane system is evolved from the inward growth of cell membrane in the ancestors of the first eukaryotes (Figure 6.15).

### 6.6.2 Endoplasmic Reticulum

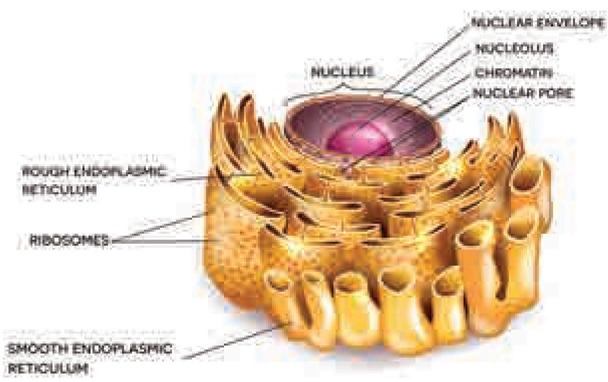



**Figure 6.15:** Structure of Endoplasmic reticulum

The largest of the internal membranes is called the **endoplasmic reticulum** (ER). The name endoplasmic reticulum was given by **K.R. Porter** (1948). It consists of double membrane. Morphologically the structure of endoplasmic reticulum consists of:

1. **Cisternae** are long, broad, flat, sac like structures arranged in parallel bundles or stacks to form lamella. The space between membranes of cisternae is filled with fluid.
2. **Vesicles** are oval membrane bound vacuolar structure.
3. **Tubules** are irregular shape, branched, smooth walled, enclosing a space

Endoplasmic reticulum is associated with nuclear membrane and cell surface membrane. It forms a network in cytoplasm and gives mechanical support to the cell. Its chemical environment enables protein folding and undergo modification necessary for their function. Misfolded proteins are pulled out and are degraded in endoplasmic reticulum. When ribosomes are present in the outer surface of the membrane it is called as **rough endoplasmic reticulum(RER)**, when the ribosomes are absent in the endoplasmic reticulum it is called as **smooth Endoplasmic reticulum(SER)**. Rough endoplasmic reticulum is involved in protein synthesis and smooth endoplasmic reticulum are the sites of lipid synthesis. The smooth endoplasmic reticulum contains enzymes that detoxify lipid soluble drugs, certain chemicals and other harmful compounds.

### 6.6.3 Golgi Body (Dictyosomes)

In 1898, **Camillo Golgi** visualized a netlike reticulum of fibrils near the nucleus, were named as **Golgi bodies.** In plant cells they are found as smaller vesicles termed as **dictyosomes**. Golgi apparatus is a stack of flat membrane enclosed sacs. It consist of cisternae, tubules, vesicles and golgi vacuoles. In plants the cisternae are 10-20 in number placed in piles separated from each other by a thin layer of inter cisternal cytoplasm often flat or curved. Peripheral edge of cisternae forms a network of tubules and vesicles. Tubules interconnect cisternae and are 30-50nm in dimension. Vesicles are large round or concave sac. They are pinched off from the tubules.They are smooth/secretary or coated type. Golgi vacuoles are large spherical filled with granular or amorphous substance, some function like lysosomes. The Golgi apparatus compartmentalises a series of steps leading to the production of functional protein.

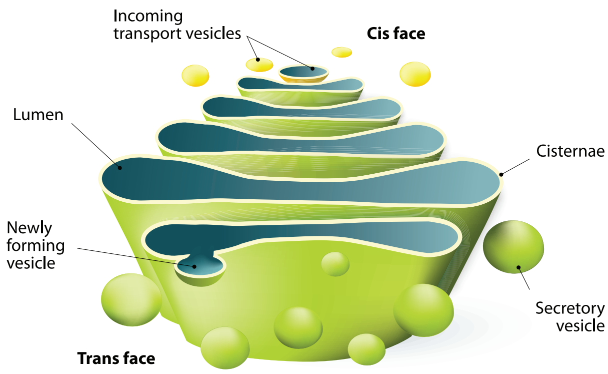



**Figure 6.16:** Structure of Golgi apparatus

Small pieces of rough endoplasmic reticulum are pinched off at the ends to form small vesicles. A number of these vesicles then join up and fuse together to make a Golgi body. Golgi complex plays a major role in post translational modification of proteins and glycosidation of lipids (Figure 6.16 and 6.17).

**Functions:**

- Glycoproteins and glycolipids are produced
- Transporting and storing lipids.

- Formation of lysosomes.
- Production of digestive enzymes.
- Cell plate and cell wall formation
- Secretion of Carbohydrates for the formation of plant cell walls and insect cuticles.
- **Zymogen granules** (proenzyme/pre-cursor of all enzyme) are synthesised.

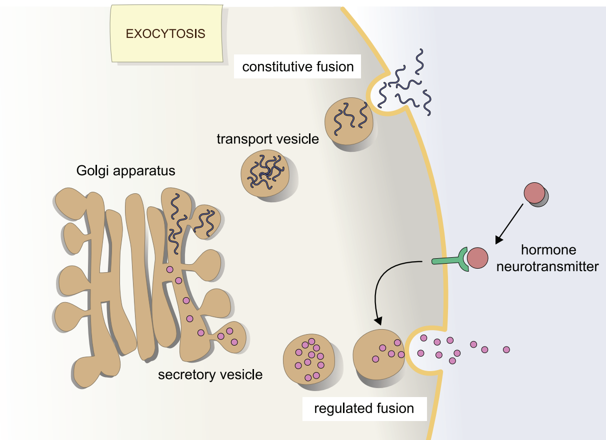



**Figure 6.17:** Exocytosis

### 6.6.4 Mitochondria

It was first observed by **A. Kolliker** (1880). **Altmann** (1894) named it as Bioplasts. **Later Benda** (1897, 1898), named as mitochondria. They are ovoid, rounded, rod shape and pleomorphic structures. Mitochondrion consists of double membrane, the outer and inner membrane. The outer membrane is smooth, highly permeable to small molecules and it contains proteins called **Porins**, which form channels that allows free diffusion of molecules smaller than about 1000 daltons and the inner membrane divides the mitochondrion into two compartments, outer chamber between two membranes and the inner chamber filled with matrix.

The inner membrane is convoluted (infoldings), called **crista** (plural: cristae). Cristae contain most of the enzymes for electron transport system. Inner chamber of the mitochondrion is filled with proteinaceous material called **mitochondrial matrix**. The inner membrane consists of stalked particles called **elementary particles** or **Fernandez Moran particles**, F1 particles or Oxysomes. Each particle consists of a base, stem and a round head. In the head ATP synthase is present for oxidative phosphorylation. Inner membrane is impermeable to most ions, small molecules and maintains the proton gradient that drives oxidative phosphorylation (Figure 6.18).

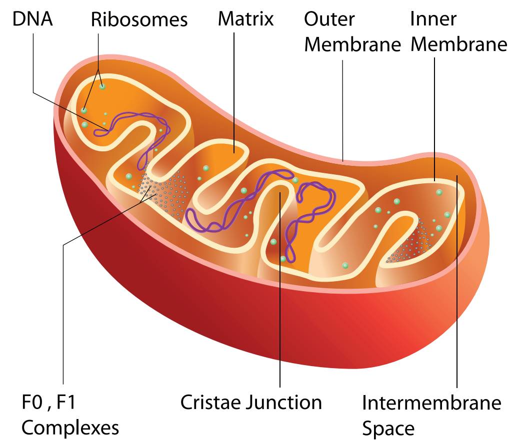



**Figure 6.18:** Structure of Mitochondria

Mitochondria contain 73% of proteins, 25-30% of lipids, 5-7 % of RNA, DNA (in traces) and enzymes (about 60 types). Mitochondria are called **Power house of a cell**, as they produce energy rich ATP.

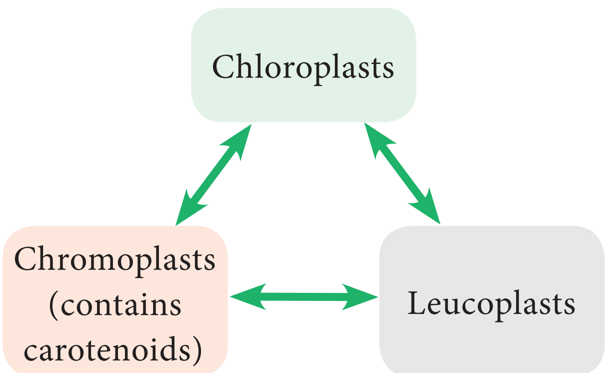
All the enzymes of Kreb's cycle are found in the matrix except succinate dehydrogenase. Mitochondria consist of circular DNA and 70S ribosome. They multiply by fission and replicates by strand displacement model. Because of the presence of DNA it is semi-autonomous organelle. Unique characteristic of mitochondria is that they are inherited from female parent only. Mitochondrial DNA comparisons are used to trace human origins. Mitochondrial DNA is used to track and date recent evolutionary time because it mutates 5 to 10 time faster than DNA in the nucleus.

### 6.6.5 Plastids

The term plastid is derived from the Greek word ***Platikas*** (formed/moulded) and used by **A.F.U. Schimper** in 1885. He classified plastids into following types according to their structure, pigments and function. Plastids multiply by fission.

| Plastids | |
|---|---|
| **Chromoplasts** | **Leucoplasts** |
| (Coloured Plastids) | (Colourless Plastids store food materials) |
| **Chloroplast**<br>Occurs in green algae and higher plants<br>Pigments chlorophyll *a* and *b* | **Amyloplast** – stores – starch |
| **Phaeoplast**<br>Brown algae and dinoflagellates<br>Pigment fucoxanthin | **Elaioplast** – store – lipids (oils)<br>Seed of monocot and dicots. |
| **Rhodoplast**<br>Red algae<br>Pigment Phycoerythrin | **Aleuroplast** (or) **Proteoplast**<br>store – Protein |

According to Schimper, different kind of plastids can transform into one another.




### 6.6.6 Chloroplast

Chloroplasts are vital organelle found in green plants. Chloroplast has a double membrane the outer membrane and the inner membrane separated by a space called **periplastidial space**. The space enclosed by the inner membrane of chloroplast is filled with gelatinous matrix, lipo-proteinaceous fluid called **stroma**. Inside the stroma there is flat interconnected sacs called **thylakoid**. The membrane of thylakoid enclose a space called **thylakoid lumen**.

**Grana** (singular: Granum) are formed when many of these thylakoids are stacked together like pile of coins. Light is absorbed and converted into chemical energy in the granum, which is used in stroma to prepare carbohydrates. Thylakoid contain chlorophyll pigments. The chloroplast contains osmophilic granules, 70s ribosomes, DNA (circular and non histone) and RNA. These chloroplast genome encodes approximately 30 proteins involved in photosynthesis including the components of photosystem I & II, cytochrome bf complex and ATP synthase. One of the subunits of Rubisco is encoded by chloroplast DNA. It is the major protein component of chloroplast stroma, single most abundant protein on earth. The thylakoid contain small, rounded photosynthetic units called **quantosomes**. It is a semi-autonomous organelle and divides by fission (Figure 6.19).

**Functions:**

- Photosynthesis
- Light reactions takes place in granum,
- Dark reactions take place in stroma,
- Chloroplast is involved in photo-respiration.

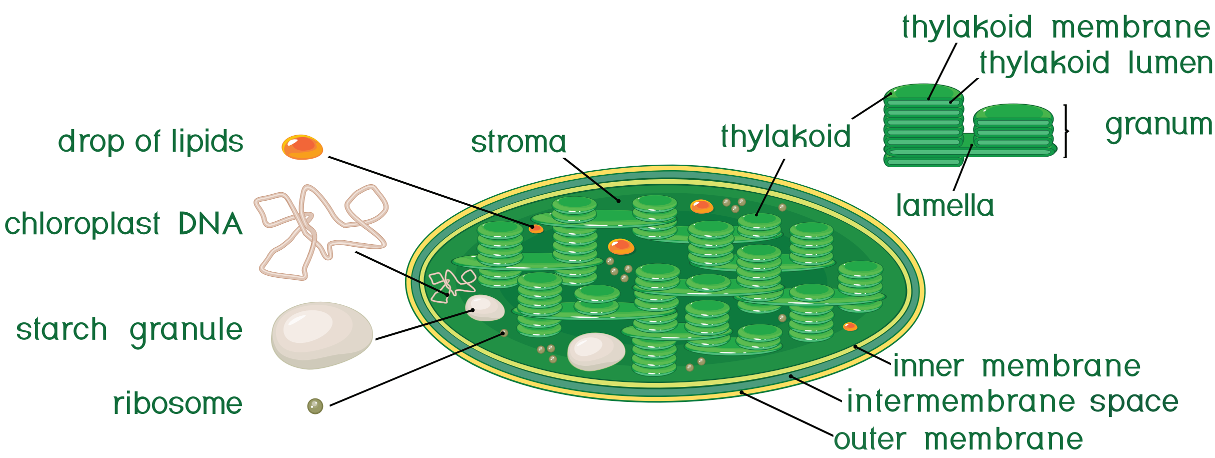



**Figure 6.19:** Structure of Chloroplast

### 6.6.7 Ribosome

Ribosomes were first observed by **George Palade** (1953) as dense particles or granules in the electron microscope. Electron microscopic observation reveals that ribosomes are composed of two rounded sub units, united together to form a complete unit. $Mg^{2+}$ is required for structural cohesion of ribosomes. Biogenesis of ribosome are *denova* formation, auto replication and nucleolar origin. Each ribosome is made up of one small and one large sub-unit Ribosomes are the sites of protein synthesis in the cell. Ribosome is not a membrane bound organelle (Figure 6.20).

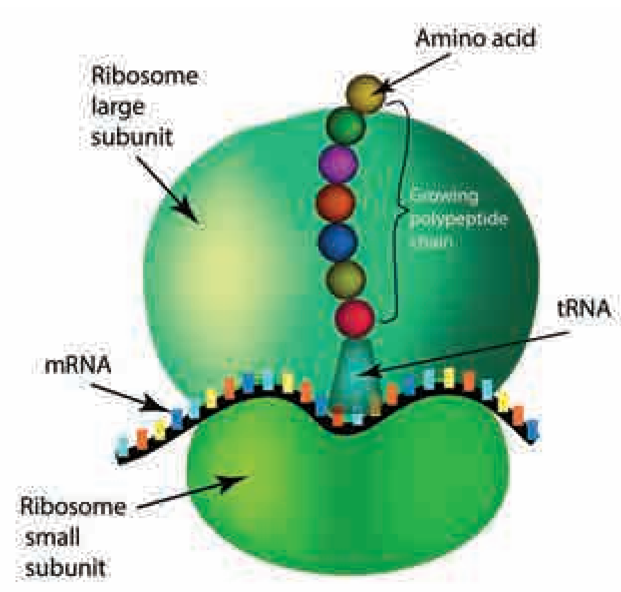



**Figure 6.20:** Structure of Ribosomes

**Types of Ribosomes**

| 70S Ribosomes (sub unit 30S and 50S) | 80S Ribosomes (sub units 40S and 60S) |
|---|---|
| 3 RNA molecule<br>(i) 16SrRNA in 30S subunit<br>(ii) 23S and 5S in 50S large subunit<br>**(Prokaryotic cells of Bluegreen algae Bacteria, Mitochondria and Chloroplast of many Algae and higher plants)** | 4 RNA molecule<br>(i) 18SrRNA in 40S small subunit<br>(ii) 28S, 5.8S and 5S in larger 60S subunit<br>**(Eukaryotic cells of Plants and animals)** |

DO YOU KNOW?

**Svedberg unit (s).**

The size of ribosomes and their subunits are usually given in Svedberg unit (named after Theoder Svedberg, Swedish Chemist Noble Laureate 1929), a measure of a particle size dependent on the speed with which particle sediment in the ultracentrifuge.

Ribosome consists of RNA and protein: RNA 60 % and Protein 40%. During protein synthesis many ribosomes are attached to the single mRNA is called **polysomes** or **polyribosomes**. The function of polysomes is the formation of several copies of a particular polypeptide during protein synthesis. They are free in non-protein synthesising cells. In protein synthesising cells they are linked together with the help of $Mg^{2+}$ ions.

### 6.6.8 Lysosomes (Suicidal Bags of Cell)

Lysosomes were discovered by **Christian de Duve** (1953), these are known as **suicidal bags**. They are spherical bodies enclosed by a single unit membrane. They are found in eukaryotic cell. Lysosomes are small vacuoles formed when small pieces of golgi body are pinched off from its tubules.

They contain a variety of hydrolytic enzymes, that can digest material within the cell. The membrane around lysosome prevent these enzymes from digesting the cell itself (Figure 6.21).

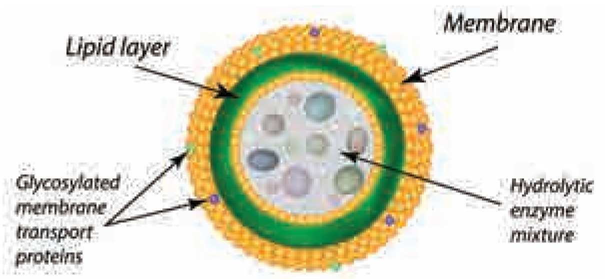



**Figure 6.21:** Structure of Lysosome

**Functions:**

- **Intracellular digestion:** They digest carbohydrates, proteins and lipids present in cytoplasm.
- **Autophagy:** During adverse condition they digest their own cell organelles like mitochondria and endoplasmic reticulum
- **Autolysis:** Lysosome causes self destruction of cell on insight of disease they destroy the cells.
- **Ageing:** Lysosomes have autolytic enzymes that disrupts intracellular molecules.
- **Phagocytosis:** Large cells or contents are engulfed and digested by macrophages, thus forming a phagosome in cytoplasm. These phagosome fuse with lysosome for further digestion.
- **Exocytosis:** Lysosomes release their enzymes outside the cell to digest other cells (Figure 6.22).

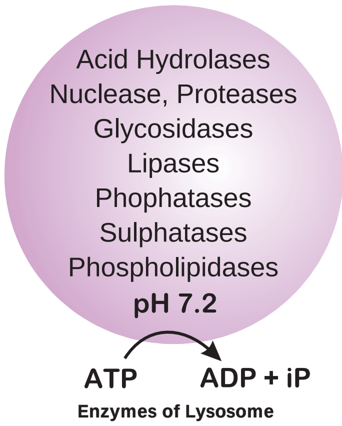



**Figure 6.22:** Enzymes of Lysosome

### 6.6.9 Peroxisomes

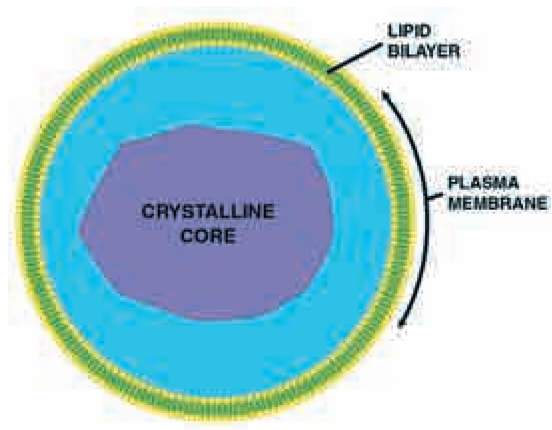



**Figure 6.23:** Structure of Peroxisome

Peroxisomes were identified as organelles by **Christian de Duve** (1967). Peroxisomes are small spherical bodies and single membrane bound organelle. It takes part in photorespiration and associated with glycolate metabolism. In plants, leaf cells have many peroxisomes. It is also commonly found in liver and kidney of mammals. These are also found in cells of protozoa and yeast (Figure 6.23).

### 6.6.10 Glyoxysomes

Glyoxysome was discovered by **Harry Beevers** (1961). Glyoxysome is a single membrane bound organelle. It is a sub cellular organelle and contains enzymes of glyoxylate pathway. β-oxidation of fatty acid occurs in glyoxysomes of germinating seeds Example: Castor seeds.

### 6.6.11 Microbodies

Eukaryotic cells contain many enzyme bearing membrane enclosed vesicles called **microbodies**. They are single unit membrane bound cell organelles: Example: peroxisomes and glyoxysomes.

### 6.6.12 Sphaerosomes

It is spherical in shape and enclosed by single unit membrane. Example: Storage of fat in the endosperm cells of oil seeds.

### 6.6.13 Centrioles

Centriole consist of nine triplet peripheral fibrils made up of tubulin. The central part of the centriole is called **hub**, is connected to the tubules of the peripheral triplets by radial spokes (9+0 pattern). The centriole form the basal body of cilia or flagella and spindle fibers which forms the spindle apparatus in animal cells. The membrane is absent in centriole (non-membranous organelle) (Figure 6.24).

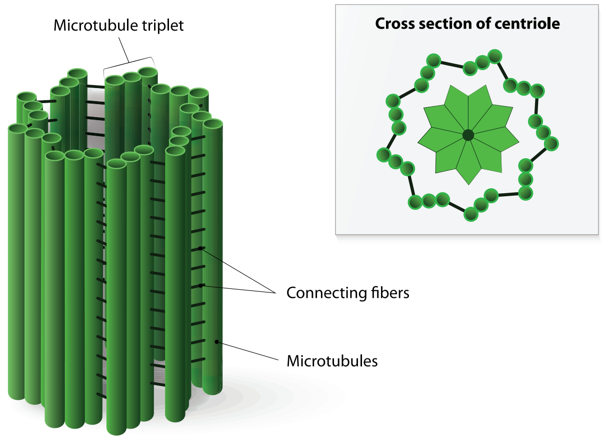



**Figure 6.24:** Structure of Centriole

### 6.6.14 Vacuoles

In plant cells vacuoles are large, bounded by a single unit membrane called **Tonoplast**. The vacuoles contain cell sap, which is a solution of sugars, amino acids, mineral salts, waste chemical and anthocyanin pigments. Beetroot cells contains anthocyanin pigments in their vacuoles. Vacuoles accumulate products like tannins. The osmotic expansion of a cell kept in water is chiefly regulated by vacuole and the water enters the vacuoles by osmosis.

The major function of plant vacuole is to maintain water pressure known as **turgor pressure**, which maintains the plant structure. Vacuoles organises itself into a storage/sequestration compartment. Example: Vacuoles store, most of the sucrose of the cell.

i. Sugar in *Sugar beet* and *Sugar cane.*
ii. Malic acid in Apple.
iii. Acids in *Citrus* fruits.
iv. Flavonoid pigment Cyanidin 3 rutinoside in the petals of *Antirrhinum*.

v. Tannins in *Mimosa pudica*.
vi. Raphide crystals in *Dieffenbachia*.
vii. Heavy metals in Mustard (*Brassica*).
viii. Latex in Rubber tree and *Dandelion stem*.

### Cell Inclusions

The cell inclusions are the non-living materials present in the cytoplasm. They are organic and inorganic compounds.

### Inclusions in prokaryotes

In prokaryotes, reserve materials such as phosphate granules, cyanophycean granules, glycogen granules, poly β-hydroxy butyrate granules, sulphur granules, carboxysomes and gas vacuoles are present. Inorganic inclusions in bacteria are polyphosphate granules (volutin granules) and sulphur granules. These granules are also known as **metachromatic granules.**

### Inclusions in Eukaryotes

- Reserve food materials: Starch grains, glycogen granules, aleurone grains, fat droplets
- Secretions in plant cells are essential oil, resins, gums, latex and tannins
- **Inorganic crystals** – plant cell have calcium carbonate, calcium oxalate and silica
- **Cystolith** – hypodermal leaf cells of *Ficus bengalensis*, calcium carbonate
- **Sphaeraphides** – star shaped calcium oxalate, *Colocasia*
- **Raphides** – calcium oxalate, *Eichhornia*
- **Prismatic crystals** – calcium oxalate, dry scales of *Allium cepa*

## 6.7. Nucleus

Nucleus is an important unit of cell which control all activities of the cell. Nucleus holds the hereditary information. It is the largest among all cell organelles. It may be spherical, cuboidal, ellipsoidal or discoidal.

It is surrounded by a double membrane structure called **nuclear envelope**, which has the inner and outer membrane. The inner membrane is smooth without ribosomes and the outer membrane is rough by the presence of ribosomes and is continues with irregular and infrequent intervals with the endoplasmic reticulum. The membrane is perforated by pores known as **nuclear pores** which allows materials such as mRNA, ribosomal units, proteins and other macromolecules to pass in and out of the nucleus. The pores enclosed by circular structures called **annuli**. The pore and annuli forms the **pore complex**. The space between two membranes is called **perinuclear space**.

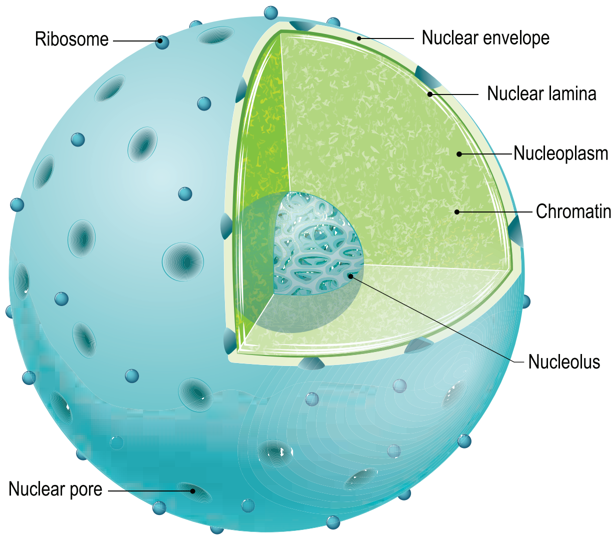



**Figure 6.25:** Structure of a Nucleus

Nuclear space is filled with **nucleoplasm**, a gelatinous matrix has uncondensed

**chromatin** network and a conspicuous **nucleoli**. The chromatin network is the uncoiled, indistinct and remain thread like during the interphase. It has little amount of RNA and DNA bound to histone proteins in eukaryotic cells (Figure 6.25).

> DO YOU KNOW?
>
> **Chromatin** is a viscous gelatinous substance that contains DNA, histone & non–histone proteins and RNA. H1, H2A, H2B, H3 and H4 are the different histones found in chromatin. It is formed by a series of repeated units called nucleosomes. Each nucleosome has a core of eight histone subunits.

During cell division chromatin is condensed into an organized form called **chromosome**. The portion of Eukaryotic chromosome which is transcribed into mRNA contains active genes that are not tightly condensed during interphase is called **Euchromatin**. The portion of a Eukaryotic chromosome that is not transcribed into mRNA which remains condensed during interphase and stains intensely is called **Heterochromatin.** I **Nucleolus** is a small, dense, spherical structure either present singly or in multiples inside nucleus and it's not membrane bound. Nucleoli possesses genes for rRNA and tRNA.

**Functions of the nucleus**

- Controlling all the cellular activities
- Storing the genetic or hereditary information.
- Coding the information in the DNA for the production of enzymes and proteins.
- DNA duplication and transcription takes place in the nucleus.
- In nucleolus ribosomal biogenesis takes place.

### 6.7.1 Chromosomes

**Strasburger** (1875) first reported its present in eukaryotic cell and the term 'chromosome' was introduced by **Waldeyer** in 1888. **Bridges** (1916) first proved that chromosomes are the physical carriers of genes. It is made up of DNA and associated proteins.

**Structure of chromosome**

The chromosomes are composed of thread like strands called **chromatin** which is made up of DNA, protein and RNA. Each chromosome consists of two symmetrical structures called **chromatids**. During cell division the chromatids forms well organized chromosomes with definite size and shape. They are identical and are called **sister chromatids**. A typical chromosome has narrow zones called **constrictions**. There are two types of constrictions namely primary constriction and secondary constriction. The **primary constriction** is made up of **centromere** and kinetochore. Both the chromatids are united at centromere, whose number varies. The **monocentric** chromosome has one centromere and the **polycentric** chromosome has many centromeres. The centromere contains a complex system of protein fibres called **kinetochore**. Kinetochore is the region of chromosome which is attached to the spindle fibre during mitosis.

Besides primary there are **secondary constrictions,** represented with few occurrence. Nucleoli develop from these secondary constrictions are called **nucleolar organizers**. Secondary constrictions contains the genes for ribosomal RNA which induce the formation of nucleoli and are called **nucleolar organizer regions** (Figure 6.26).

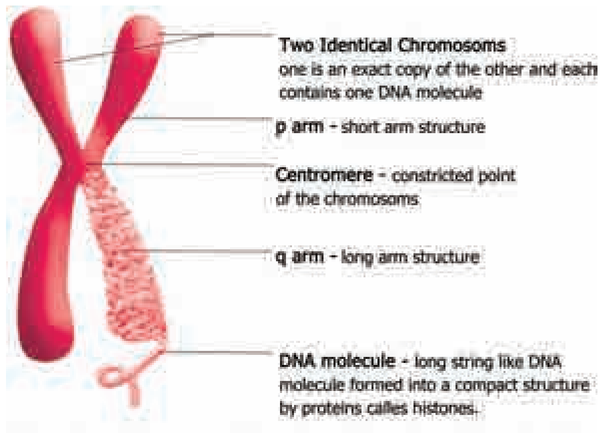



**Figure 6.26:** Structure of a Chromosome

A **satellite** or SAT Chromosome are short chromosomal segment or rounded body separated from main chromosome by a relatively elongated secondary constriction. It is a morphological entity in certain chromosomes.

Based on the position of centromere, chromosomes are called **telocentric** (terminal centromere), **Acrocentric** (terminal centromere capped by telomere), **Sub metacentric** (centromere subterminal) and **Metacentric** (centromere median). The eukaryotic chromosomes may be rod

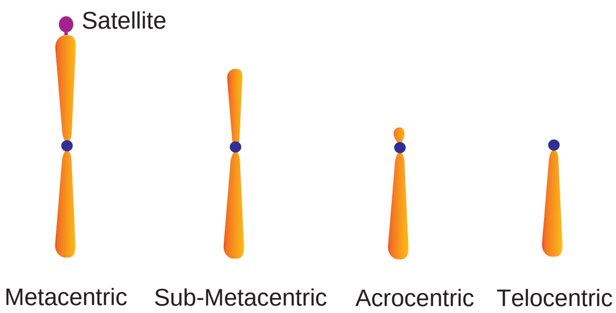



**Figure 6.27:** Types of chromosomes based on centromere

DO YOU KNOW?

**Chromonema fiber**: It is a chromatin fibre, 100 – 130 nm in diameter thought to be an element of higher order packing of chromatin within chromosome. During prophase the chromosomal material becomes visible as very thin filaments called chromonemata, which is called as chromatids in early stages of condensation. Chromatid and chromonema are the two names for the same structure a single linear DNA molecule with its associated proteins

**Chromomeres**: Chromomeres are bead like accumulations of chromatin material which are visible along interphase chromosomes. They can be seen in polytene chromosomes. At metaphase they are not visible.

shaped (telocentric and acrocentric), L-shaped (sub-metacentric) and V-shaped (metacentric) (Figure 6.27).

**Telomere** is the terminal part of chromosome. It offers stability to the chromosome. DNA of the telomere has specific sequence of nucleotides. Telomere in all eukaryotes are composed of many repeats of short DNA sequences (**5'TTAGGG3'** sequence in *Neurospora crassa* and human beings). Maintenance of telomeres appears to be an important factor in determining the life span and reproductive capacity of cells so studies of telomeres and telomerase have the promise of providing new insights into conditions such as ageing and cancer. Telomeres prevents the fusion of chromosomal ends with one another.

**Holocentric chromosomes** have centromere activity distributed along the whole surface of the chromosome during mitosis. Holocentric condition can be seen in *Caenorhabditis elegans* (nematode) and many insects. There are three types of centromere in eukaryotes. They are as follows:

**Point centromere:** the type of centromere in which the kinetochore is assembled as a result of protein recognition of specific DNA sequences. Kinetochores assembled on point centromere bind a single microtubule. It is also called as **localized centromere**. It occurs in budding yeasts

**Regional centromere:** In regional centromere where the kinetochore is assembled on a variable array of repeated DNA sequences. Kinetochore assembled on regional centromeres bind multiple microtubules. It occurs in fission yeast cell, humans and so on.

**Holocentromere**- The microtubules bind all along the mitotic chromosome. Example: *Caenorhabditis elegans* (nematode) and many insects.

Based on the functions of chromosome it can be divided into **autosomes** and **sex chromosomes**.

Autosomes are present in all cells controlling somatic characteristics of an organism. In human diploid cell, 44 chromosomes are autosomes whereas two are sex chromosomes. Sex chromosomes are involved in the determination of sex.

Special types of chromosomes are found only in certain special tissues. These chromosomes are larger in size and are called **giant chromosomes** in certain plants and they are found in the suspensors of the embryo. The polytene chromosome and lamp brush chromosome occur in animals and are also called as **giant chromosomes.**

**Polytene chromosomes** observed in the salivary glands of Drosophila (fruit fly) by **C.G. Balbiani** in 1881. In larvae of many flies, midges (*Dipthera*) and some insects the interphase chromosomes duplicates and reduplicates without nuclear division. A single chromosome which is present in multiple copies form a structure called **polytene chromosome** which can be seen in light microscope. They are genetically active. There is a distinct alternating dark bands and light inter-bands. About 95% of DNA are present in bands and 5% in inter-bands. The polytene chromosome has extremely large puff called **Balbiani rings** which is seen in Chironomous larvae. It is also known as **chromosomal puff**. Puffing of bands are the sites of intense RNA synthesis. As this chromosome occurs in the salivary gland it is known as **salivary gland chromosomes**. Polyteny is achieved by repeated replication of chromosomal DNA several times without nuclear division and the daughter chromatids aligned side by side and do not separate (called **endomitosis**). Gene expression, transcription of genes and RNA synthesis occurs in the bands along the polytene chromosomes. Maternal and paternal homologues remain associated side by side is called somatic pairing.

**Lampbrush chromosomes** occur at the diplotene stage of first meiotic prophase in oocytes of an animal **Salamandar** and in giant nucleus of the unicellular alga *Acetabularia*. It was first observed by **Flemming** in 1882. The highly condensed chromosome forms the chromosomal axis, from which lateral loops of DNA extend as a result of intense RNA synthesis.

## 6.8. Flagella

### 6.8.1 Prokaryotic Flagellum

**Check your grasp ?**

When E-coli are cultured in medium rich in glucose they lack flagella. When grown in nutritionally poor medium they possess flagella. What does this indicate about the value of flagella?

Flagella is essential to seek out a nutritionally more favourable environment

Bacterial flagella are helical appendages helps in motility. They are much thinner than flagella or cilia of eukaryotes. The filament contains a protein called **flagellin**. The structure consists of a basal body associated with cytoplasmic membrane and cell wall with short hook and helical filament. Bacteria rotates their helical flagella and propels rings present in the basal body which are involved in the rotary motor that spins the flagellum.

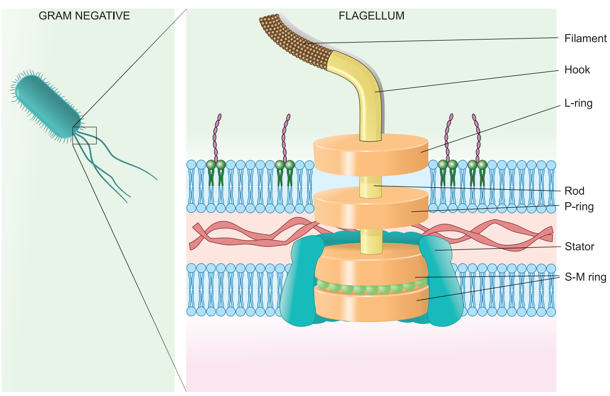



**Figure 6.28:** Structure of Bacterial Flagellum

**Structure of flagella in Bacteria**

The gram positive bacteria contain only two basal rings. S-ring is attached to the inside of peptidoglycan and M-ring is attached to the cell membrane. In Gram negative bacteria two pairs of rings proximal and distal ring are connected by a central rod. They are L-Lipopolysaccharide ring P-Peptidoglycan ring, S-Super membrane ring and M-membrane ring. The outer pair L and P rings is attached to cell wall and the inner pair S and M rings attached to cell membrane (Figure 6.28).

**Mechanism of flagellar movement – proton motive force**

In flagellar rotation only proton movements are involved and not ATP. Protons flowing back into the cell through the basal body rings of each flagellum drives it to rotate. These rings constitute the rotary motor. The proton motive force (The force derived from the electrical potential and the hydrogen ion gradient across the cytoplasmic membrane) drives the flagellar motor. For the rotation of flagellum the energy is derived from proton gradient across the plasma membrane generated by oxidative phosphorylation. In bacteria flagellar motor is located in the plasma membrane where the oxidative phosphorylation takes place. Therefore, plasma membrane is a site of generation of proton motive force.

### 6.8.2 Eukaryotic Flagellum– Cell Motility

**Structure**

**Eukaryotic Flagella** are enclosed by unit membrane and it arises from a basal body.

Flagella is composed of outer nine pairs of microtubules with two microtubules in its centre (9+2 arrangement). Flagella are microtubule projection of the plasma membrane. Flagellum is longer than cilium (as long as 200µm). The structure of flagellum has an axoneme made up microtubules and protein tubulin (Figure 6.29).

**Movement**

Outer microtubule doublet is associated with axonemal dynein which generates force for movement. The movement is ATP driven. The interaction between tubulin and dynein is the mechanism for the contraction of cilia and flagella. Dynein molecules uses energy from ATP to shift the adjacent microtubules. This movement bends the cilium or flagellum.

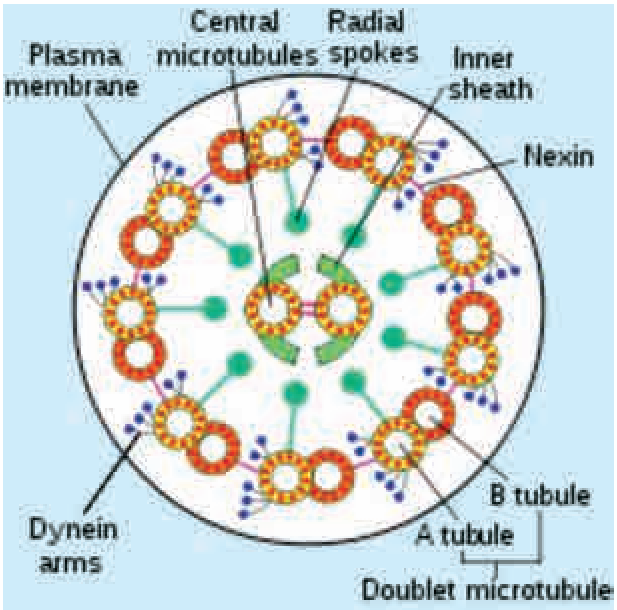



**Figure 6.29:** Structure of Eukaryotic flagellum

### 6.8.3 Cilia

Cilia (plural) are short cellular, numerous microtubule bound projections of plasma membrane. Cilium (singular) is membrane bound structure made up of basal body, rootlets, basal plate and shaft. The shaft or **axoneme** consists of nine pairs of microtubule doublets, arranged in a circle along the periphery with a two central tubules, (**9+2**) arrangement of microtubules is present. Microtubules are made up of tubulin. The motor protein **dynein** connects the outer microtubule pair and links them to the central pair. Nexin links the peripheral doublets of microtubules (Figure 6.30).

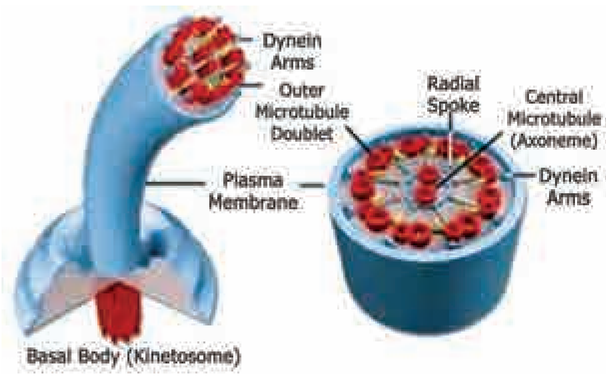



**Figure 6.30:** Structure of Cilia & flagella

## 6.9. Cytological Techniques

### 6.9.1 Preparation of Slides

5RBIAH

There are different types of mounting based on the portion of a specimen to be observed

a. **Whole mount:** The whole organism or smaller structure is mounted over a slide and observed.

b. **Squash**: Is a preparation where the material to be observed is crushed/ squashed on to a slide so as to reveal their contents. Example: Pollen grains, mitosis and meiosis in root tips and flower buds to observe chromosomes.

c. **Smears:** Here the specimen is in the fluid (blood, microbial cultures etc.,) are scraped, brushed or aspirated from surface of organ. Example: Epithelial cells.

d. **Sections:** Free hand sections from a specimen and thin sections are selected, stained and mounted on a slide. Example: Leaf and stem of plants.

### 6.9.2 Recording the Observations

The observations made through a microscope can be recorded by hand diagrams or through microphotographs.

**Hand diagrams**: Hand diagrams are drawn using ordinary pencil by observing the slide and drawing manually.

**Microphotograph**: Images of structures observed through microscopes can be further magnified, projected and saved by attaching a camera to the microscope by a microscope coupler or eyepiece adaptor. Picture taken using a inbuilt camera in a microscope is called **microphotography** or **microphotograph**.

### 6.9.3 Staining Techniques

Staining is very important to observe different components of the cell. Each component of the cell has different affinity towards different stains. The technique of staining the cells and tissue is called '**histochemical staining**' or '**histochemistry**'.

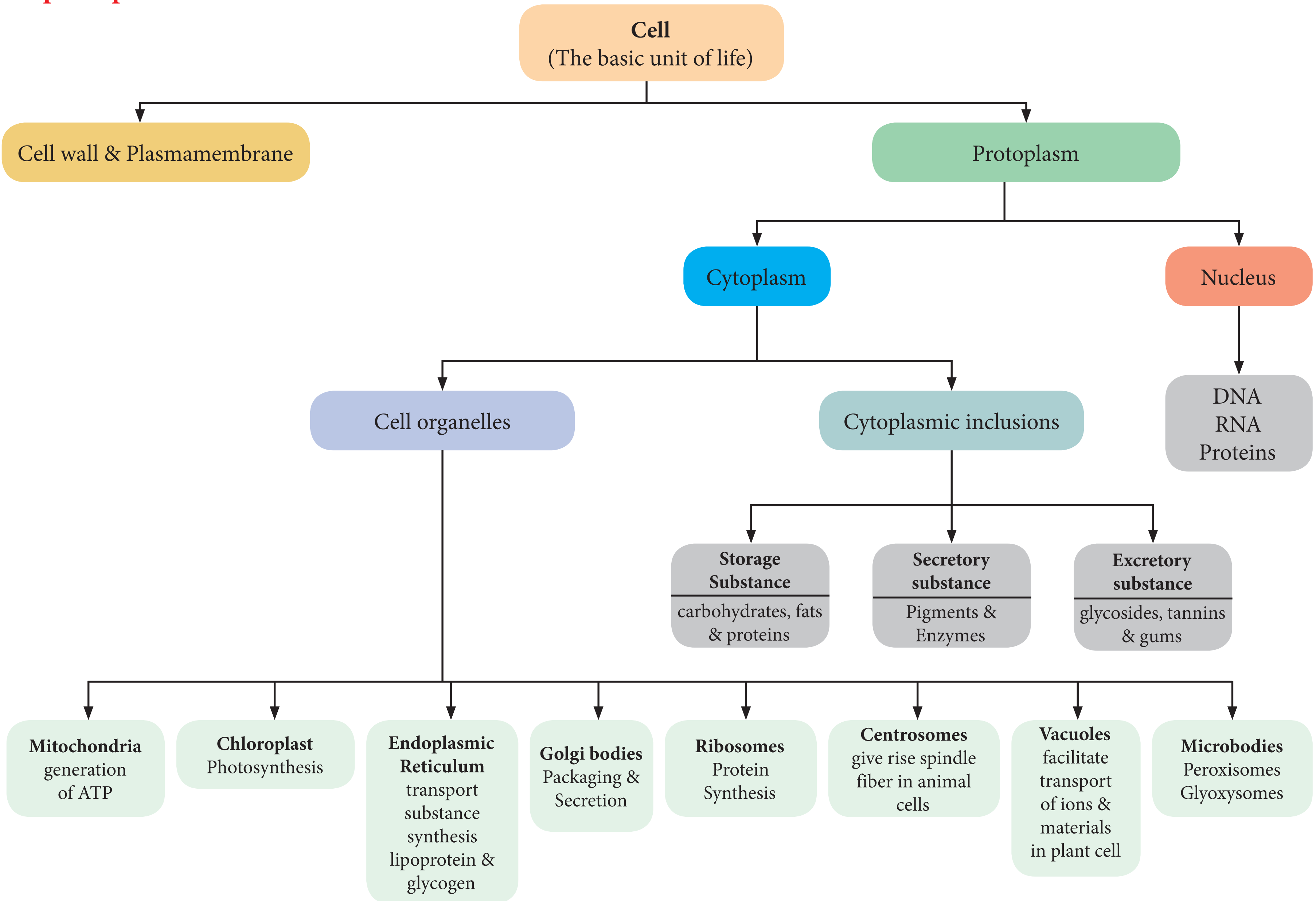
### Common stains used in Histochemistry

| S. No. | Stain | Colour of staining | Affinity |
|---|---|---|---|
| 1. | Eosin | Pink, Red | Cytoplasm, cellulose |
| 2. | Acetocarmine/ Haematoxylin | Pink/ Red | Nucleus, Chromosomes |
| 3. | Methylene Blue | Blue | Nucleus |
| 4. | Saffranine | Red | Cell wall (Lignin) |
| 5. | Cotton blue | Blue | Fungal Hyphae |
| 6. | Sudan IV, Sudan Black | Scarlet Red/Black | Lipids |
| 7. | Coomasie brilliant Blue | Blue | Protein |
| 8. | Janus Green | Greenish Blue | Mitochondria |
| 9. | $I_2KI$ | Bluish black to brown | Starch |
| 10. | Toluidine blue | Blue, greenish blue | Xylem, Parenchyma & Epidermis |

## Summary

Cell is the fundamental unit of all organisms which was identified 300 years ago. Microscope offers scope for observing smaller objects and organisms. It works on the principle of light and lenses. Different microscope offers clarity in observing objects depending on the features to be observed. Micrometric techniques are used in measurement of microscopic objects. Electron microscopes are used in understanding the ultra-structural details of cell. Cell theory and doctrine states that all organism are made up of cell and it contains genetic material. Protoplasm theory explains nature and different properties of protoplasm. Cell size and shape differ from type of tissue or organs and organisms. Based on cellular organization and nuclear characters the

## Concept Map


Cell
(The basic unit of life)
Cell wall & Plasmamembrane
Protoplasm
Cytoplasm
Nucleus
DNA
RNA
Proteins
Cell organelles
Cytoplasmic inclusions
Storage Substance
carbohydrates, fats & proteins
Secretory substance
Pigments & Enzymes
Excretory substance
glycosides, tannins & gums
Mitochondria
generation of ATP
Chloroplast
Photosynthesis
Endoplasmic Reticulum
transport substance synthesis lipoprotein & glycogen
Golgi bodies
Packaging & Secretion
Ribosomes
Protein Synthesis
Centrosomes
give rise spindle fiber in animal cells
Vacuoles
facilitate transport of ions & materials in plant cell
Microbodies
Peroxisomes
Glyoxysomes

organisms are classified into prokaryote, eukaryote and mesokaryote.

The eukaryotic cells originated by endosymbiosis of prokaryotic organism. Key difference between plant cell and animal cell is the cell wall. Protoplasm is the colourless mass includes the cytoplasm, cell organelles and nucleus. Cell wall is the outermost protective covering with three regions primary, secondary wall and middle lamellae. Cell membrane holds the cytoplasmic content called **cytosol**. Cytoplasm includes the matrix and the cell organelles excluding nucleus. Endomembrane system includes endoplasmic reticulum, golgi apparatus, chloroplast, lysosomes, vacuoles, nuclear membrane and plasma membrane. Nucleus is the control unit of the cell, it carries hereditary information. Chromosomes are made up of DNA and associated proteins. Bacterial flagella are made up of helical polymers of a protein called **flagellin**. Proton motive force are involved in flagellar rotation. In Eukaryotes flagella are made up microtubules and protein called **dynein** and **nexin** and the movement is driven by ATP. Cytological techniques include preparation of slides, staining and recording the observation.

5RKECJ

## Evaluation

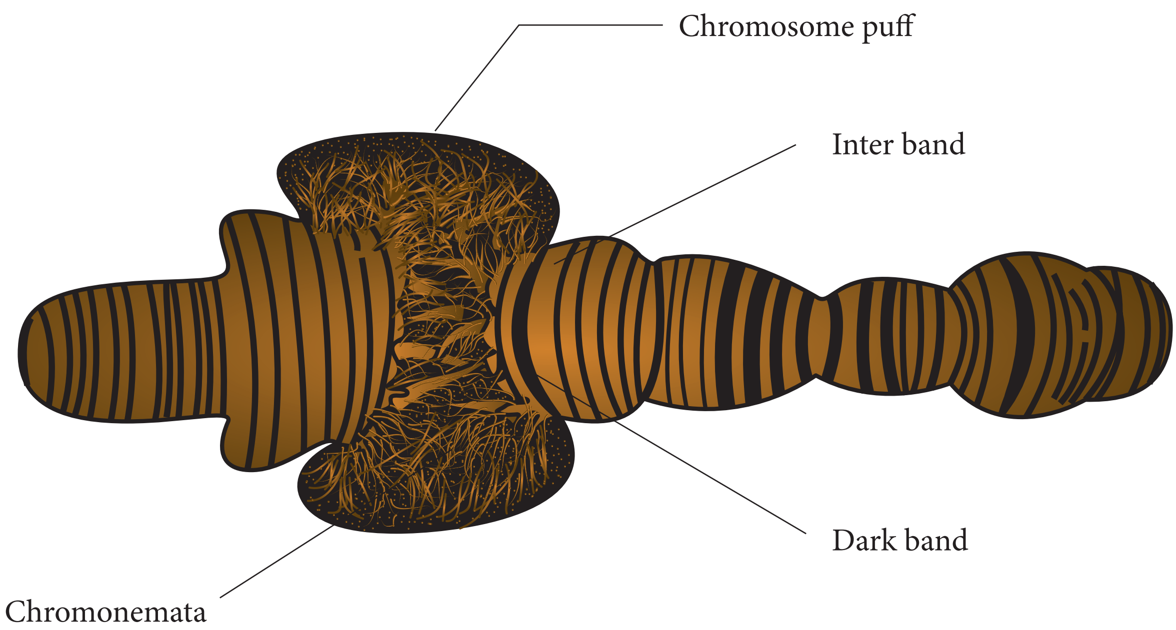
1. The two subunits of ribosomes remain united at critical ion level of
   a. Magnesium b. Calcium
   c. Sodium d. Ferrous
2. Sequences of which of the following is used to know the phylogeny
   a. mRNA b. rRNA
   c. tRNA d. Hn RNA
3. Many cells function properly and divide mitotically even though they do not have
   a. Plasma membrane b. cytoskeleton
   c. mitochondria d. Plastids
4. Keeping in view the fluid mosaic model for the structure of cell membrane, which one of the following statements is correct with respect to the movement of lipids and proteins from one lipid monolayer to the other
   a. Neither lipid nor proteins can flip-flop
   b. Both lipid and proteins can flip flop
   c. While lipids can rarely flip-flop proteins cannot
   d. While proteins can flip-flop lipids cannot
5. Match the columns and identify the correct option:

| Column-I | Column-II |
|---|---|
| (a) Thylakoids | (i) Disc-shaped sacs in Golgi apparatus |
| (b) Cristae | (ii) Condensed structure of DNA |
| (c) Cisternae | (iii) Flat membranous sacs in stroma |
| (d) Chromatin | (iv) Infoldings in mitochondria |

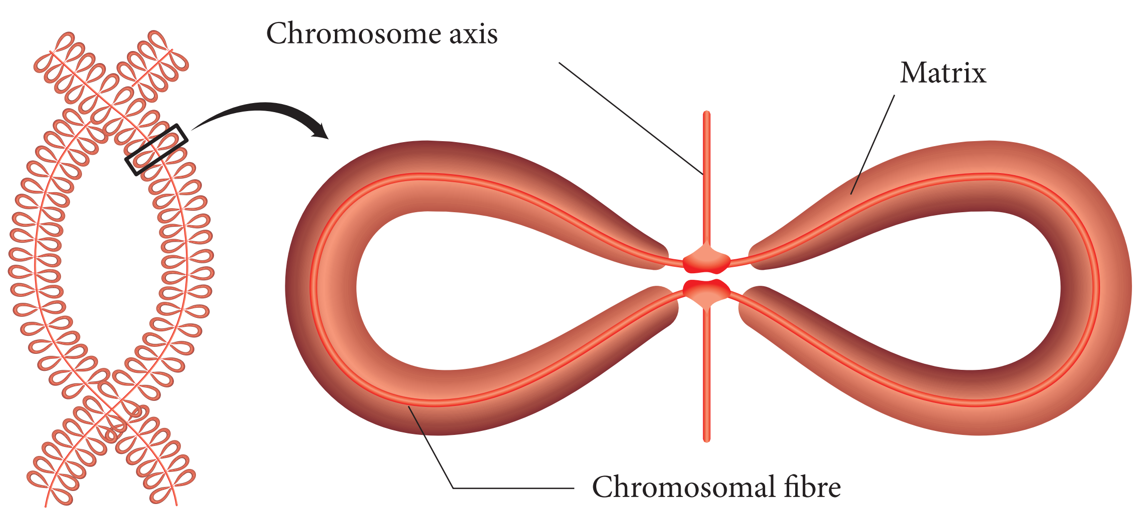
| | (a) | (b) | (c) | (d) |
|---|---|---|---|---|
| (1) | (iii) | (iv) | (ii) | (i) |
| (2) | (iv) | (iii) | (i) | (ii) |
| (3) | (iii) | (iv) | (i) | (ii) |
| (4) | (iii) | (i) | (iv) | (ii) |

6. Bring out the significance of phase contrast microscopy
7. State the protoplasm theory
8. Distinguish between prokaryotes and eukaryotes
9. Difference between plant and animal cell
10. Draw the ultra structure of plant cell

## Giant Chromosomes




**Polytene chromosomes**




**Lampbrush chromosomes**

# ICT Corner

## Cell structure

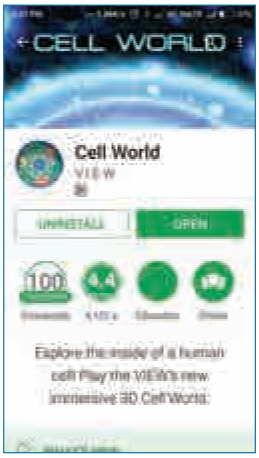
Cell-The unit of Life →

### Steps

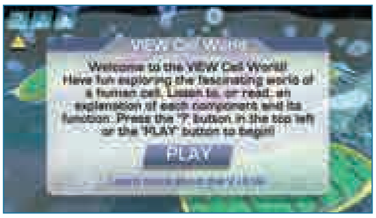
- Scan the QR code & install the app from Android app store
- Open the app & move the cell organelles by moving left bottom button
- Select the cell organelles by pointer
- Play the audio notes of cell organelles by click the right center button
- Use pointer & observe the structure of cell organelles

### Activity

- Observe the structures of cell organelles and record it.

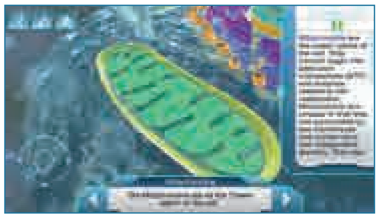



Step 1




Step 2

Step 3



Step 4

Step 5

URL:

https://play.google.com/store/apps/details?id=com.VIEW.CellWorld&hl=en

B181_11_BOT

* Pictures are indicative only

# Chapter 7

# Cell Cycle

## Learning Objectives

The learner will be able to,

- *Outline the cell cycle and different stages in cell division.*
- *Recognise the importance of mitosis in the production of genetically identical cells.*
- *Have an insight on the significant of mitosis and meiosis.*
- *Understand how a single cell divides to a whole organism.*
- *Familiarize the behaviour of chromosomes in plants and animal cells during meiosis.*
- *Know about crossing over and random assortment of homologous chromosomes and its importance.*

## Chapter Outline



5RUAE7

One of the most important features of the living cells is their power to grow and divide. New cells are formed by the division of pre-existing cells. Cells increase in number by cell division. The parent cell divides and passes on genetic material to the daughter cells.

**Edouard Van Beneden**, a Belgian cytologist, embryologist and marine biologist. He was Professor of Zoology at the University of Liège. He contributed to cytogenetics by his works on the roundworm *Ascaris*. In his work he discovered how chromosomes organized meiosis (the production of gametes).

**DO YOU KNOW?**

**Neurons can be replaced!**

**Stem cells in the human brain** - most neurons are in $G_0$ and do not divide. As neurons and neuroglia die or injured they are replaced by neural stem cells

## 7.1 History of a Cell

**Table 7.1: History of Cell**

| Year | Scientist | Events |
|---|---|---|
| 1665 | Robert Hooke | Coined word "Cell" |
| 1670–74 | Antonie van Leeuwenhoek | First living cells observed in microscope - Structure of bacteria |
| 1831–33 | Robert Brown | Presence of nucleus in cells of orchid roots |
| 1839 | Jan Evangelista Purkyne (J.E. Purkinje) | Coined "protoplasm" |
| 1838–39 | Schleiden & Schwann | Cell theory |
| 1858 | Rudolph Ludwig Carl Virchow | Cell theory '*omnis cellula e cellula*' |
| 1873 | Anton Schneider | Described chromosomes (Nuclear filaments) for the first time |
| 1882 | Walther Flemming | Coined the word mitosis; chromosome behaviour |
| 1883 | Edouard Van Beneden | Cell division in round worm |
| 1888 | Theodor Boveri | Centrosome; Chromosome Theory |

### 7.1.1 The Role of the Nucleus

As studied earlier, the nucleus is the organising centre of the cell. The information in the nucleus is contained within structures called **chromosomes**. These uniquely:

- Control activities of the cell.
- Genetic information copied from cell to cell while the cell divides.
- Hereditary characters are passed on to new individuals when gametic cells fuse together in sexual reproduction.

### 7.1.2 Chromosomes

At the time when a nucleus divides, the chromosomes become compact and multicoiled structure. Only in this condensed state do the chromosomes become clearly visible in cells. All other times, the chromosomes are very long, thin, uncoiled threads. In this condition they give the stained nucleus the granular appearance. The granules are called **chromatin**.

The four important features of the chromosome are:

- **The shape of the chromosome is specific:** The long, thin, lengthy structured chromosome contains a short, constricted region called **centromere**. A centromere may occur anywhere along the chromosome, but it is always in the same position on any given chromosome.
- **The number of chromosomes per species is fixed:** for example the mouse has 40 chromosomes, the onion has 16 and humans have 46.

- **Chromosomes occur in pairs:** The chromosomes of a cell occur in pairs, called **homologous pairs**. One of each pair come originally from each parent. Example, human has 46 chromosomes, 23 coming originally from each parent in the process of sexual reproduction.
- **Chromosomes are copied:** Between nuclear divisions, whilst the chromosomes are uncoiled and cannot be seen, each chromosome is copied. The two identical structures formed are called **chromatids**.

### 7.1.3 Nuclear Divisions

There are two types of nuclear division, as **mitosis** and **meiosis**. In mitosis, the daughter cells formed will have the same number of chromosomes as the parent cell, typically diploid (2n) state. Mitosis is the nuclear division that occurs when cells grow or when cells need to be replaced and when organism reproduces asexually.

In meiosis, the daughter cells contain half the number of chromosomes of the parent cell and is known as **haploid state (n)**.

Whichever division takes place, it is normally followed by division of the cytoplasm to form separate cells, called as **cytokinesis**.

## 7.2 Cell Cycle

**Definition:** A series of events leading to the formation of new cell is known as **cell cycle**. The phenomenonal changes leading to formation of new population take place in the cell cycle. It was discovered by **Prevost** and **Dumans** (1824). The series of events include several phases.

### 7.2.1 Duration of Cell Cycle

Different kinds of cells have varied duration for cell cycle phases. Eukaryotic cell divides every 24 hours. The cell cycle is divided into mitosis and interphase. In cell cycle 95% is spent for interphase whereas the mitosis and cytokinesis last only for an hour.

**Table 7.2: Cell cycle of a proliferating human cell**

| Phase | Time duration (in hrs) |
|---|---|
| $G_1$ | 11 |
| S | 8 |
| $G_2$ | 4 |
| M | 1 |

The different phases of cell cycle are as follows (Figure 7.1).

### 7.2.2 Interphase

Longest part of the cell cycle, but it is of extremely variable length. At first glance the nucleus appears to be resting but this is not the case at all. The chromosomes previously visible as thread like structure, have dispersed. Now they are actively involved in protein synthesis, at least for most of the interphase.

C-Value is the amount in picograms of DNA contained within a haploid nucleus.

### 7.2.3 $G_1$ Phase

The first gap phase – 2C amount of DNA in cells of $G_1$. The cells become metabolically active and grows by producing proteins, lipids, carbohydrates and cell organelles including mitochondria and endoplasmic reticulum. Many checkpoints control

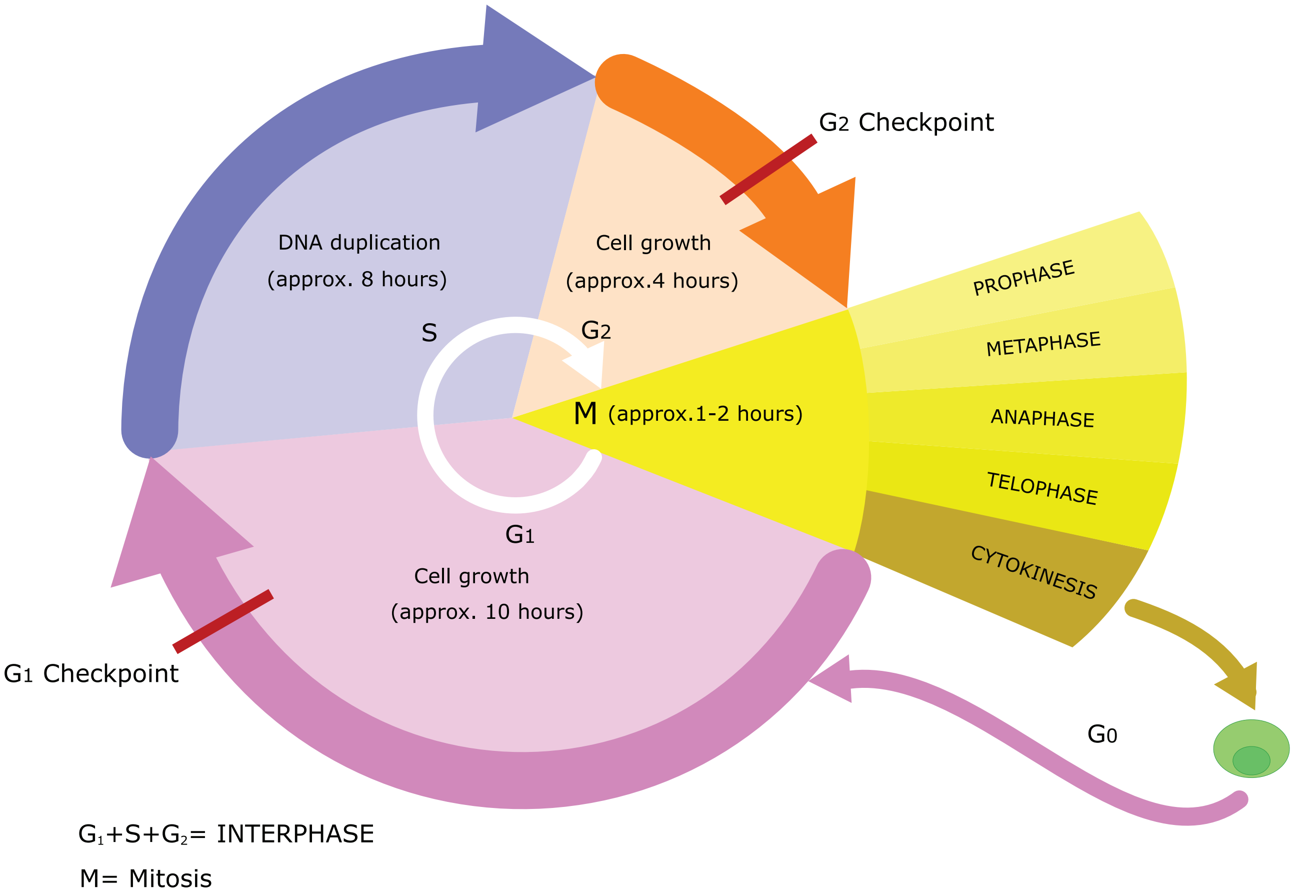



**Figure 7.1:** Cell cycle

the cell cycle. The checkpoint called the **restriction point** at the end of $G_1$, determines a cells fate whether it will continue in the cell cycle and divide or enter a stage called $\mathbf{G_0}$ as a quiescent stage and probably as specified cell or die. Cells are arrested in $G_1$ due to:

- Nutrient deprivation
- Lack of growth factors or density dependant inhibition
- Undergo metabolic changes and enter into $G_0$ state.

Biochemicals inside cells activates the cell division. The proteins called **kinases** and cyclins activate genes and their proteins to perform cell division. Cyclins act as major checkpoint which operates in $G_1$ to determine whether or not a cell divides.

DO YOU KNOW?

**Dolly**

Since the DNA of cells in $G_0$, do not replicate. The researcher are able to fuse the donor cells from a sheep's mammary glands into $G_0$ state by culturing in the nutrient free state. The $G_0$ donor nucleus synchronised with cytoplasm of the recipient egg, which developed into the clone Dolly.

### 7.2.4 $G_0$ Phase

Some cells exit $G_1$ and enters a quiescent stage called $\mathbf{G_0}$, where the cells remain metabolically active without proliferation. Cells can exist for long periods in $G_0$ phase. In $G_0$ cells cease growth with reduced rate of RNA and protein synthesis. The $G_0$ phase is not permanent. Mature neuron and skeletal muscle cell remain permanently in $G_0$. Many cells in animals remains in $G_0$ unless called on to proliferate by appropriate growth factors or other extracellular signals. $G_0$ cells are not dormant.

### 7.2.5 S phase – Synthesis phase – cells with intermediate amounts of DNA.

Growth of the cell continues as replication of DNA occur, protein molecules called **histones** are synthesised and attach to the DNA. The centrioles duplicate in the cytoplasm. DNA content increases from 2C to 4C.

### 7.2.6 $G_2$ – The second Gap phase – 4C amount of DNA in cells of $G_2$ and mitosis

Cell growth continues by protein and cell organelle synthesis, mitochondria and chloroplasts divide. DNA content remains as 4C. Tubulin is synthesised and microtubules are formed. Microtubles organise to form spindle fibre. The spindle begins to form and nuclear division follows.

One of the proteins synthesized only in the $G_2$ period is known as **Maturation Promoting Factor (MPF)**. It brings about condensation of interphase chromosomes into the mitotic form.

DNA damage checkpoints operates in $G_1$ S and $G_2$ phases of the cell cycle.

## 7.3 Cell Division

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### 7.3.1 Amitosis (Direct Cell Division)

Amitosis is also called **direct** or **incipient cell division**. Here there is no spindle formation and chromatin material does not condense. It consist of two steps: (Figure 7.2).

❖ **Karyokinesis:**

- Involves division of nucleus.
- Nucleus develops a constriction at the center and becomes dumbell shaped.
- Constriction deepens and divides the nucleus into two.

❖ **Cytokinesis:**

- Involves division of cytoplasm.
- Plasma membrane develops a constriction along nuclear constriction.
- It deepens centripetally and finally divides the cell into two cells.

Example: Cells of mammalian cartilage, macronucleus of *Paramecium* and old degenerating cells of higher plants.

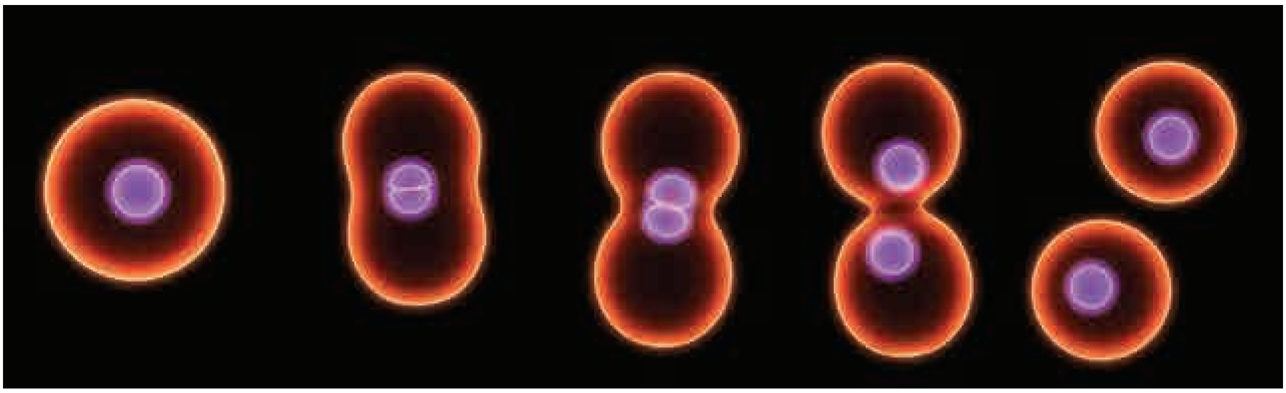


**Figure 7.2:** Amitosis

**Drawbacks of Amitosis**

- Causes unequal distribution of chromosomes.
- Can lead to abnormalities in metabolism and reproduction.

### 7.3.2 Mitosis

The most important part of cell division concerns events inside the nucleus. Mitosis occurs in shoot and root tips and other meristematic tissues of plants associated with growth. The number of chromosomes in the parent and the daughter (Progeny) cells remain the same so it is also called as **equational division**.

### 7.3.3 Closed and Open Mitosis

In closed mitosis, the nuclear envelope remains intact and chromosomes migrate to opposite poles of a spindle within the nucleus (Figure 7.3).

Example: Many single celled eukaryotes including yeast and slime molds.

In open mitosis, the nuclear envelope breaks down and then reforms around the 2 sets of separated chromosome.

Example: Most plants and animals

- Some animals are able to regenerate the whole parts of the body.

Mitosis is divided into four stages prophase, metaphase, anaphase and telophase (Figure 7.6).

**Prophase**

Prophase is the longest phase in mitosis. Chromosomes become visible as long thin thread like structure, condenses to form compact mitotic chromosomes. In plant cells initiation of spindle fibres takes place, nucleolus disappears. Nuclear envelope breaks down. Golgi apparatus and endoplasmic reticulum are not seen.

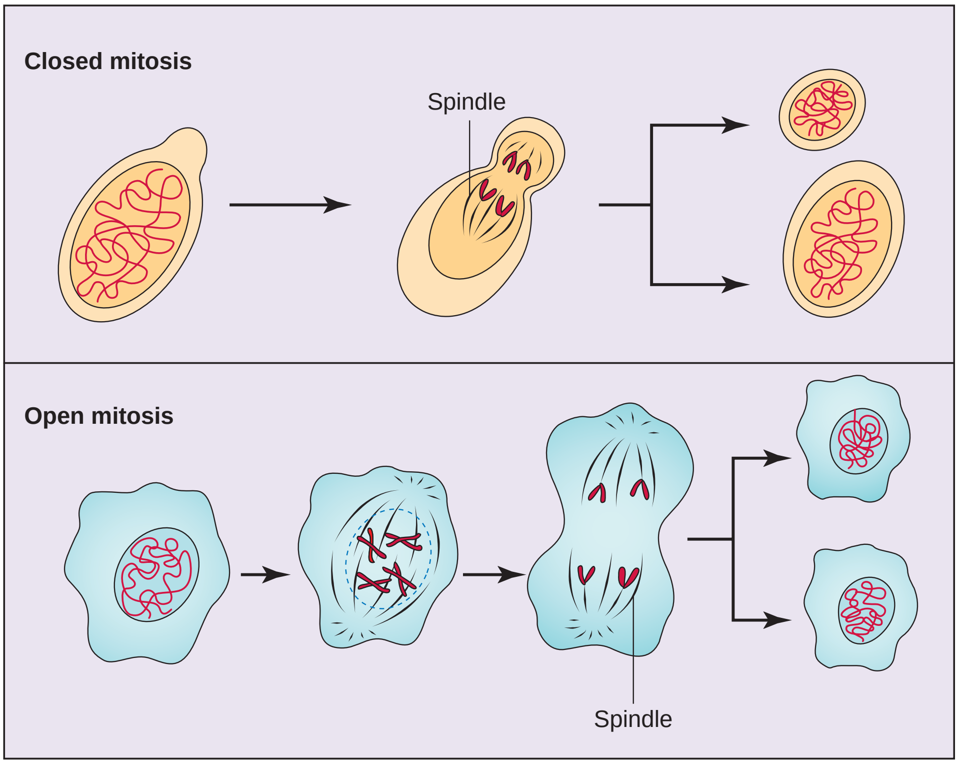



**Figure 7.3:** Closed and Open mitosis

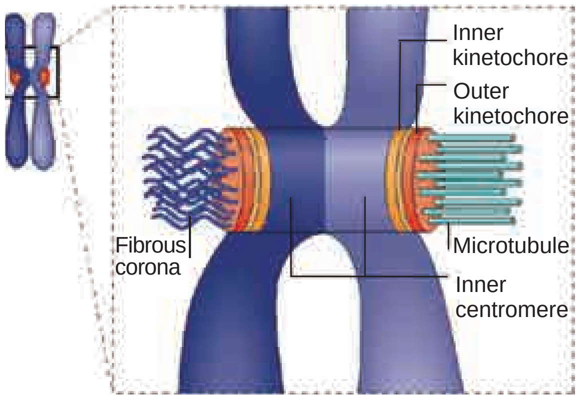



**Figure 7.4:** Centromere

In animal cell the centrioles extend a radial array of microtubules (Figure 7.4) towards the plasma membrane when they reach the poles of the cell. This arrangement of microtubules is called **an aster**. Plant cells do not form asters.

### Metaphase

Chromosomes (two sister chromatids) are attached to the spindle fibres by kinetochore of the centromere. The spindle fibres is made up of tubulin. The alignment of chromosome into compact group at the equator of the cell is known as **metaphase plate**. This is the stage where the chromosome morphology can be easily studied.

Kinetochore is a DNA–Protein complex present in the centromere DNA where the microtubules are attached. It is a trilaminar disc like plate.

The spindle assembly checkpoint which decides the cell to enter anaphase.

### Anaphase

Each chromosome split simultaneously and two daughter chromatids begins to migrate towards two opposite poles of a cell. Each centromere splits longitudinally into two, freeing the two sister chromatids from each other. Shortening of spindle fibre and longitudinal splitting of centromere creates a pull which divides chromosome into two halves. Each half receive two chromatids (that is sister chromatids are separated). When the sister chromatids separate the actual partitioning of the replicated genome is complete.

A ubiquitine ligase is activated called as the **anaphase-promoting complex cyclosome (APC/C)** leads to degradation of

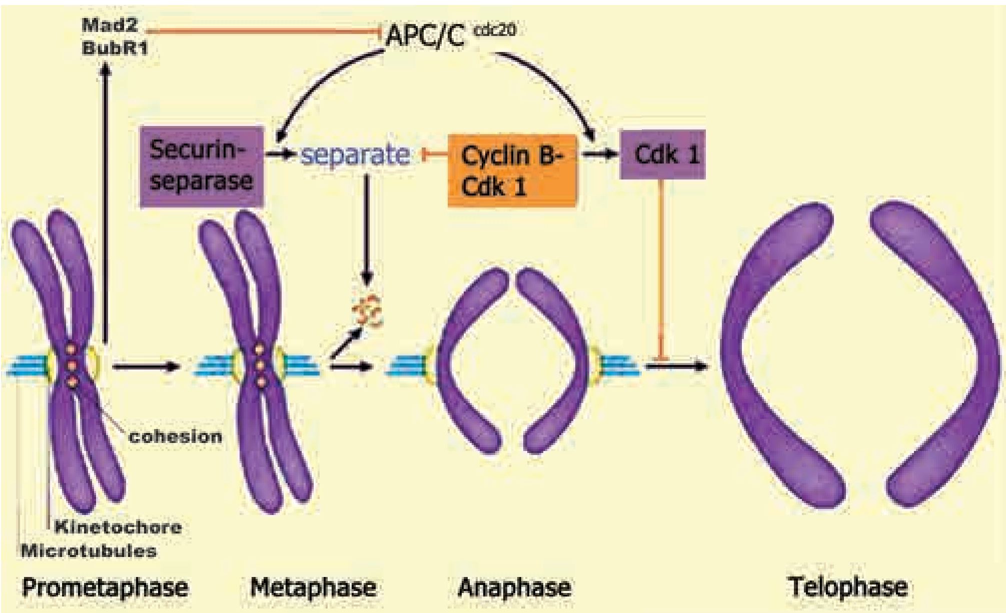



**Figure 7.5:** Anaphase promoting complex cyclosome

the key regulatory proteins at the transition of metaphase to anaphase. APC is a cluster of proteins that induces the breaking down of cohesion proteins which leads to the separation of chromatids during mitosis (Figure 7.5).

**Telophase**

Two sets of daughter chromosomes reach opposite poles of the cell, mitotic spindle disappears. Division of genetic material is completed after this karyokinesis, cytokinesis (division of cytoplasm) is completed, nucleolus and nuclear membranes reforms. Nuclear membranes form around each set of sister chromatids now called **chromosomes**, each has its own centromere. Now the chromosomes decondense. In plants, phragmoplast are formed between the daughter cells. Cell plate is formed between the two daughter cells, reconstruction of cell wall takes place. Finally the cells are separated by the distribution of organelles, macromolecules into two newly formed daughter cells.

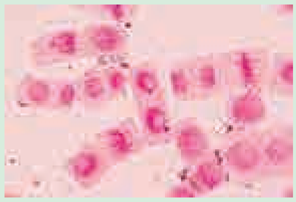
A Culture of animal cells in which the cell cycles were asynchronous was incubated with 3H-Thymidine for 10 minutes. Autoradiography showed that 50% of the cells were labelled. If the cell cycle time (generation time) was 16 hrs how long was the S period?

Length of the S period = Fraction of cells in DNA replication × generation time

Length of the S period = 0.5 × 16 hours = 8 hours

**Activity**

Squash preparation of onion root tip to visualize and study various stages of mitosis.



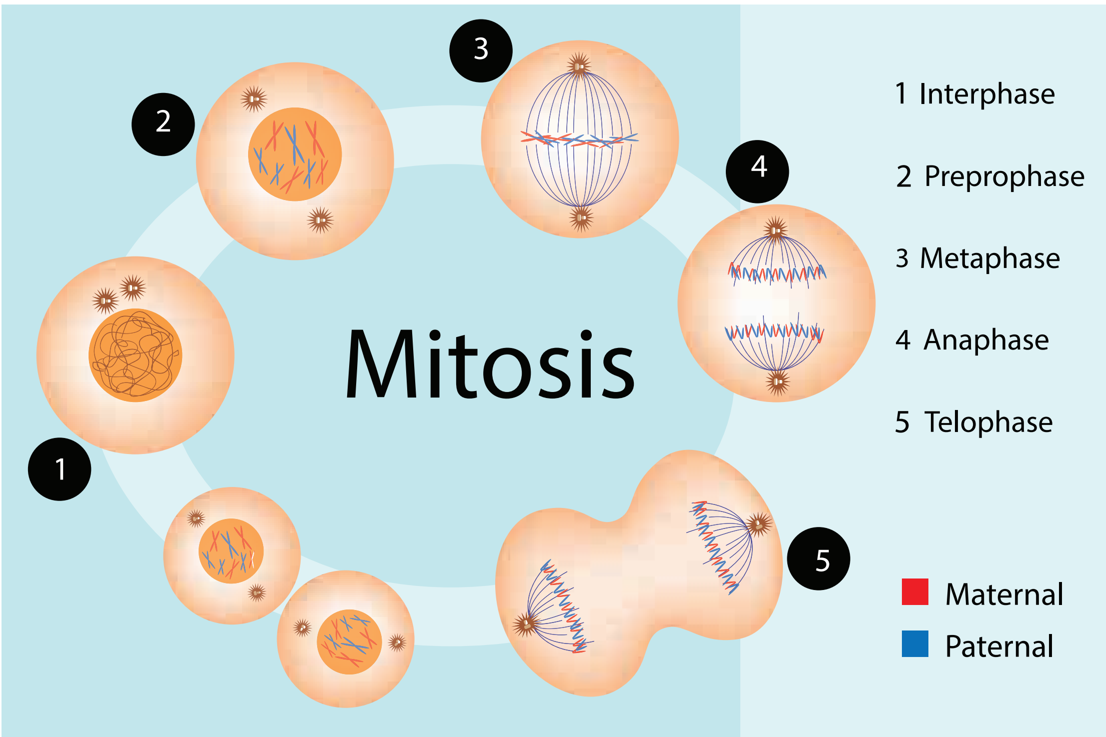



**Figure 7.6:** Mitosis

### 7.3.4 Cytokinesis

**Cytokinesis in Animal Cells**

It is a contractile process. The contractile mechanism contained in contractile ring located inside the plasma membrane. The ring consists of a bundle of microfilaments assembled from **actin** and **myosin**. This fibril helps for the generation of a contractile force. This force draws the contractile ring inward forming a cleavage furrow in the cell surface dividing the cell into two.

**Check your grasp!**

What effect does mitosis have on transcription?

During mitosis transcription stops.

**Cytokinesis in Plant Cell**

Division of the cytoplasm often starts during telophase. In plants, cytokinesis cell plate grows from centre towards lateral walls - centrifugal manner of cell plate formation.

Phragmoplast contains microtubules, actin filaments and vesicles from golgi apparatus and ER. The golgi vesicles contains carbohydrates such as pectin, hemicellulose which move along the microtubule of the pharagmoplast to the equator fuse, forming a new plasma membrane and the materials which are placed their becomes new cell wall. The first stage of cell wall construction is a line dividing the newly forming cells called a **cell plate**. The cell plate eventually stretches right across the cell forming the middle lamella. Cellulose builds up on each side of the middle lamella to form the cell walls of two new plant cells.

**DO YOU KNOW?**

Skin cells and the cells lining your gut are constantly dying and are being replaced by identical cells.

### 7.3.5 Significance of Mitosis

Exact copy of the parent cell is produced by mitosis (genetically identical).

1. **Genetic stability** – daughter cells are genetically identical to parent cells.
2. **Growth** – as multicellular organisms grow, the number of cells making up their tissue increases. The new cells must be identical to the existing ones.
3. **Repair of tissues** - damaged cells must be replaced by identical new cells by mitosis.
4. **Asexual reproduction** – asexual reproduction results in offspring that are identical to the parent. Example Yeast and Amoeba.
5. In flowering plants, structure such as bulbs, corms, tubers, rhizomes and runners are produced by mitotic division. When they separate from the parent, they form a new individual.

   The production of large numbers of offsprings in a short period of time, is possible only by mitosis. In genetic engineering and biotechnology, tissues are grown by mitosis (i.e. in tissue culture).
6. **Regeneration** – Arms of star fish

### 7.3.6 Meiosis

In Greek *meioum* means to reduce. Meiosis is unique because of synapsis, homologous recombination and reduction division. Meiosis takes place in the reproductive organs. It results in the formation of gametes with half the normal chromosome number.

Haploid sperms are made in testes; haploid eggs are made in ovaries of animals.

In flowering plants meiosis occurs during microsporogenesis in anthers and megasporogenesis in ovule. In contrast to mitosis, meiosis produces cells that are not genetically identical. So meiosis has a key role in producing new genetic types which results in genetic variation.

### Stages in Meiosis

Meiosis can be studied under two divisions i.e., meiosis I and meiosis II. As with mitosis, the cell is said to be in interphase when it is not dividing.

> *Prophase I is the longest and most complex stage in meiosis. Pairing of homologous chromosomes (bivalents).*

### Meiosis I-Reduction Division

**Prophase I** – Prophase I is of longer duration and it is divided into 5 substages – Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis (Figure 7.7).

**Leptotene** – Chromosomes are visible under light microscope. Condensation of chromosomes takes place. Paired sister chromatids begin to condense.

**Zygotene** – Pairing of homologous chromosomes takes place and it is known as **synapsis**. Chromosome synapsis is made by the formation of synaptonemal complex. The complex formed by the homologous chromosomes are called as **bivalent (tetrads)**.

**Pachytene** – At this stage bivalent chromosomes are clearly visible as tetrads. Bivalent of meiosis I consists of 4 chromatids and 2 centromeres. Synapsis is completed and recombination nodules appear at a site where crossing over takes place between non-sister chromatids of homologous chromosome. Recombination of homologous chromosomes is completed by the end of the stage but the chromosomes are linked at the sites of crossing over. This is mediated by the enzyme recombinase.

**Diplotene** – Synaptonemal complex disassembled and dissolves. The homologous chromosomes remain attached at one or more points where crossing over has taken place. These points of attachment where 'X' shaped structures occur at the sites of crossing over is called **Chiasmata**. Chiasmata are chromatin structures at sites where recombination has been taken place. They are specialised chromosomal structures that hold the homologous chromosomes together. Sister chromatids remain closely associated whereas the homologous chromosomes tend to separate from each other but are held together by chiasmata. This substage may last for days or years depending on the sex and organism. The chromosomes are very actively transcribed in females as the egg stores up materials for use during embryonic development. In animals, the chromosomes have prominent loops called **lampbrush chromosome**.

**Diakinesis** – Terminalisation of chiasmata. Spindle fibres assemble. Nuclear envelope breaks down. Homologous chromosomes become short and condensed. Nucleolus disappears.

### Metaphase I

Spindle fibres are attached to the centromeres of the two homologous chromosomes. Bivalent (pairs of homologous chromosomes) aligned at the

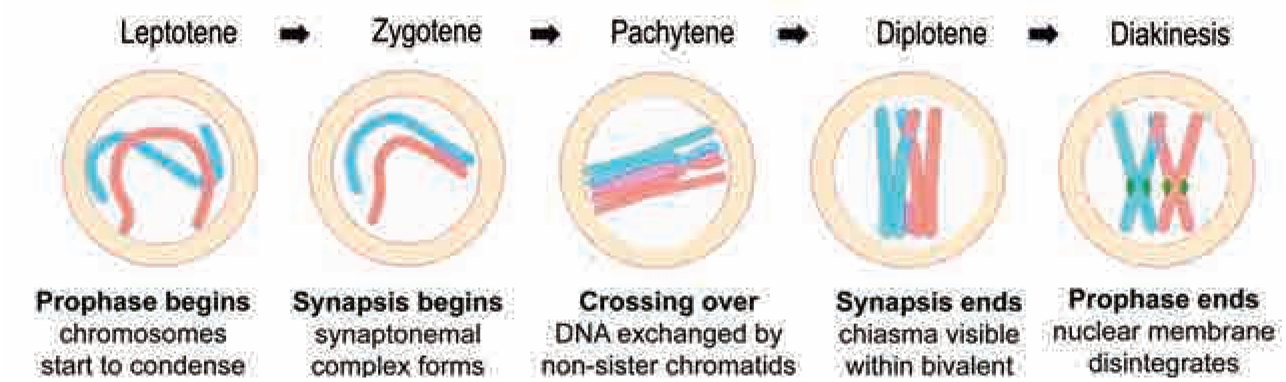



**Figure 7.7:** Prophase I

equator of the cell known as **metaphase plate**. Each bivalent consists of two centromeres and four chromatids.

The random distribution of homologous chromosomes in a cell in Metaphase I is called **independent assortment**.

### Anaphase I

Homologous chromosomes are separated from each other. Shortening of spindle fibers takes place. Each homologous chromosomes with its two chromatids and undivided centromere move towards the opposite poles of the cells. The actual reduction in the number of chromosomes takes place at this stage. Homologous chromosomes which move to the opposite poles are either paternal or maternal in origin. Sister chromatids remain attached with their centromeres.

### Telophase I

Haploid set of chromosomes are present at each pole. The formation of two daughter cells, each with haploid number of chromosomes. Nuclei are reassembled. Nuclear envelope forms around the chromosome and the chromosomes becomes uncoiled. Nucleolus reappears.

In plants, after karyokinesis cytokinesis takes place by which two daughter cells are formed by the cell plate between 2 groups of chromosomes known as **dyad of cells (haploid)**.

The stage between the two meiotic divisions is called **interkinesis** which is short-lived.

### Meiosis II – Equational division.

This division is otherwise called **mitotic meiosis**. Since it includes all the stages of mitotic divisions.

### Prophase II

The chromosome with 2 chromatids becomes short, condensed, thick and becomes visible. New spindle develops at right angles to the cell axis. Nuclear membrane and nucleolus disappear.

### Metaphase II

Chromosome arranged at the equatorial plane of the spindle. Microtubules of spindle gets attached to the centromere of sister chromatids.

### Anaphase II

Sister chromatids separate. The daughter chromosomes move to the opposite poles due to shortening of microtubules. Centromere of each chromosome split, allowing to move towards opposite poles of the cells holding the sister chromatids.

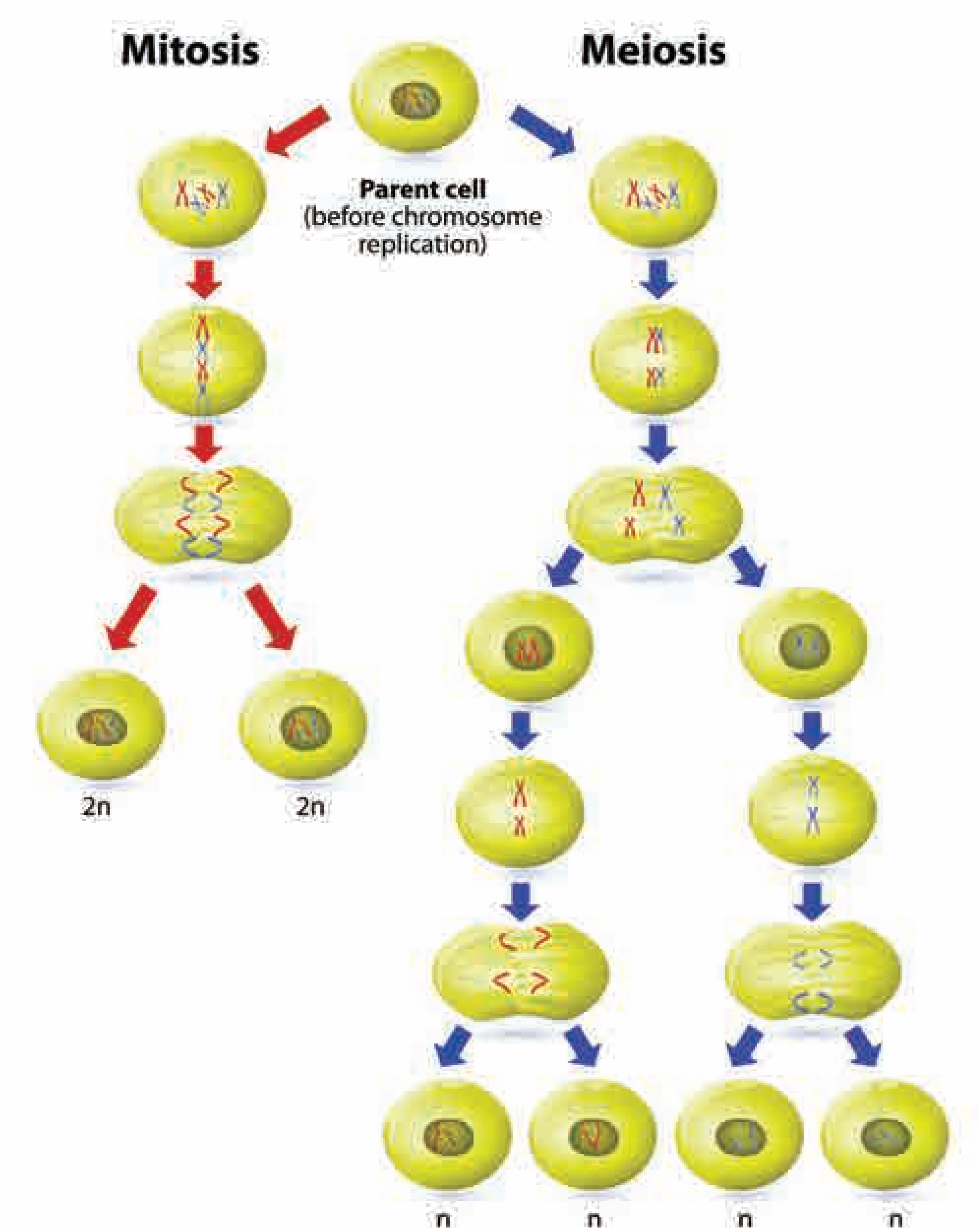



**Figure 7.8:** Meiosis

### Telophase II

Four groups of chromosomes are organised into four haploid nuclei. The spindle disappears. Nuclear envelope, nucleolus reappear.

After karyokinesis, cytokinesis follows and four haploid daughter cells are formed, called **tetrads**.

### 7.3.7 Significance of Meiosis

- This maintains a definite constant number of chromosomes in organisms.
- Crossing over takes place and exchange of genetic material leads to variations among species. These variations are the raw materials to evolution. Meiosis leads to genetic variability by partitioning different combinations of genes into gametes through independent assortment.
- Adaptation of organisms to various environmental stress.

## 7.4 Difference Between Mitosis and Meiosis

**Table 7.3: Difference between mitosis in Plants and Animals**

| Plants | Animals |
|---|---|
| Centrioles are absent | Centrioles are present |
| Asters are not formed | Asters are formed |
| Cell division involves formation of a cell plate | Cell division involves furrowing and cleavage of cytoplasm |
| Occurs mainly at meristem | Occurs in tissues throughout the body |

**Table 7.4: Difference Between Mitosis and Meiosis (Figure 7.8)**

| Mitosis | Meiosis |
|---|---|
| One division | Two divisions |
| Number of chromosomes remains the same | Number of chromosomes is halved |
| Homologous chromosomes line up separately on the metaphase plate | Homologous chromosomes line up in pairs at the metaphase plate |
| Homologous chromosome do not pair up | Homologous chromosome pairup to form bivalent |
| Chiasmata do not form and crossing over never occurs | Chiasmata form and crossingover occurs |
| Daughter cells are genetically identical | Daughter cells are genetically different from the parent cells |
| Two daughter cells are formed | Four daughter cells are formed |

## 7.5 Mitogens

The factors which promote cell cycle proliferation is called **mitogens**. Plant mitogens include gibberellin, ethylene, Indole acetic acid, kinetin. These increase mitotic rate.

### Mitotic Poisons (Mitotic Inhibitors)

Certain chemical components act as inhibitors of the mitotic cell division and they are called **mitotic poisons**.

### Endomitosis

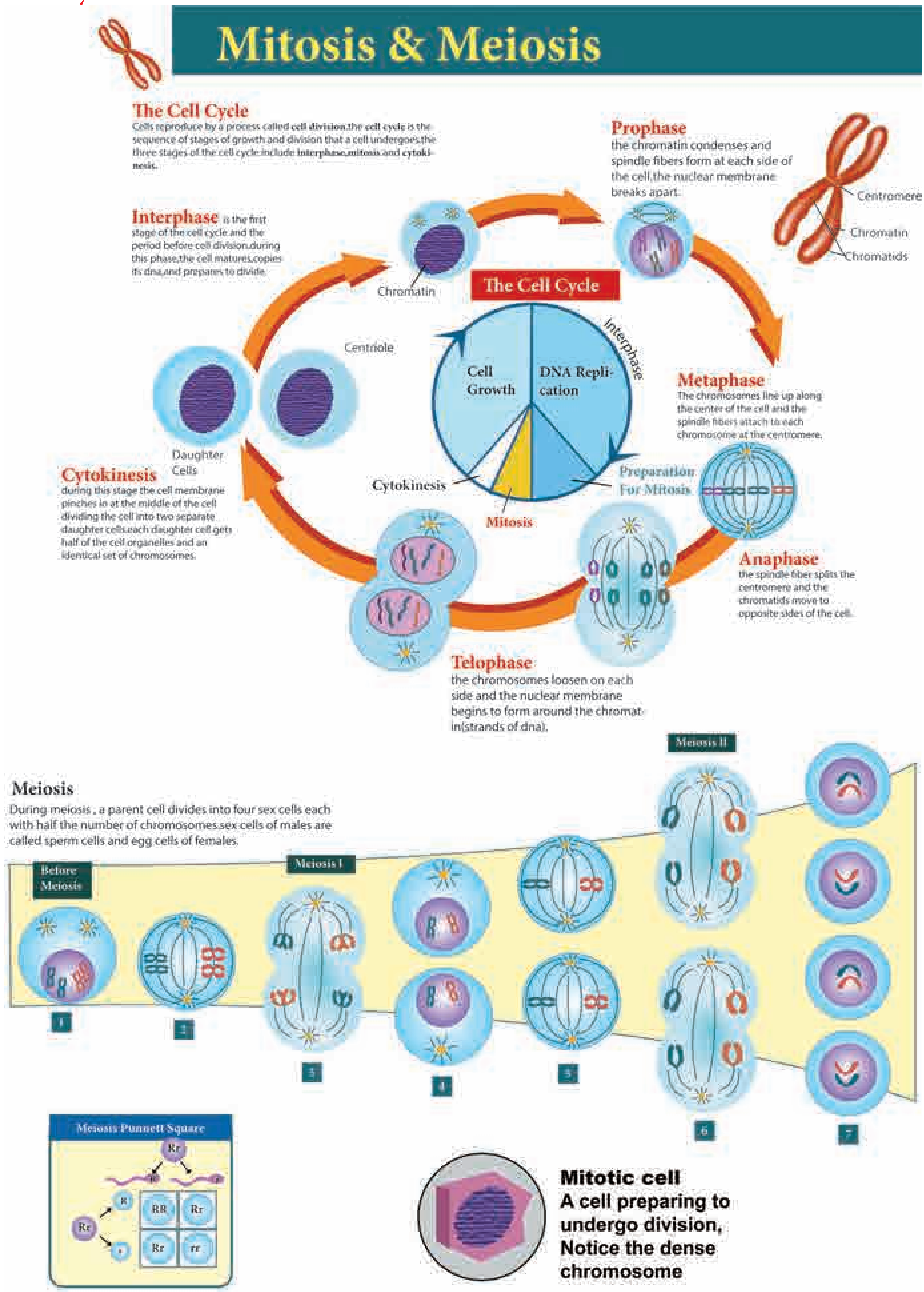
The replication of chromosomes in the absence of nuclear division and cytoplasmic division resulting in numerous copies within each cell is called **endomitosis**. Chromonema do not separate to form chromosomes, but remain closely associated with each other. Nuclear membrane does not rupture. So no spindle formation. It occurs notably in the salivary glands of *Drosophila* and other flies. Cells in these tissues contain giant chromosomes (polyteny), each consisting of over thousands of intimately associated, or synapsed, chromatids. Example: Polytene chromosome.

### Anastral

This is present only in plant cells. No asters or centrioles are formed only spindle fibres are formed during cell division.

### Amphiastral

Aster and centrioles are formed at each pole of the spindle during cell division. This is found in animal cells.


Mitosis & Meiosis
The Cell Cycle
Cells reproduce by a process called cell division.the cell cycle is the sequence of stages of growth and division that a cell undergoes.the three stages of the cell cycle include interphase,mitosis and cytokinesis.
Interphase is the first stage of the cell cycle.and the period before cell division.during this phase,the cell matures,copies its dna,and prepares to divide.
Chromatin
Centriole
Prophase
the chromatin condenses and spindle fibers form at each side of the cell,the nuclear membrane breaks apart.
Centromere
Chromatin
Chromatids
The Cell Cycle
Interphase
Cell Growth
DNA Replication
Cytokinesis
Mitosis
Preparation For Mitosis
Metaphase
The chromosomes line up along the center of the cell and the spindle fibers attach to each chromosome at the centromere.
Daughter Cells
Cytokinesis
during this stage the cell membrane pinches in at the middle of the cell dividing the cell into two separate daughter cells.each daughter cell gets half of the cell organelles and an identical set of chromosomes.
Anaphase
the spindle fiber splits the centromere and the chromatids move to opposite sides of the cell.
Telophase
the chromosomes loosen on each side and the nuclear membrane begins to form around the chromatin(strands of dna).
Meiosis
During meiosis , a parent cell divides into four sex cells each with half the number of chromosomes.sex cells of males are called sperm cells and egg cells of females.
Before Meiosis
Meiosis I
Meiosis II
1
2
3
4
5
6
7
Meiosis Punnett Square
Rr
R
r
RR
Rr
Rr
rr
Mitotic cell
A cell preparing to undergo division, Notice the dense chromosome

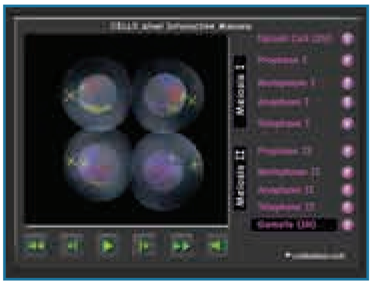
## Evaluation

1. The correct sequence in cell cycle is
   a. S-M-G1-G2
   b. S-G1-G2-M
   c. G1-S-G2-M
   d. M-G-G2-S
2. If cell division is restricted in G1 phase of the cell cycle then the condition is known as
   a. S Phase
   b. G2 Phase
   c. M Phase
   d. $G_0$ Phase
3. Anaphase promoting complex APC is a protein degradation machinery necessary for proper mitosis of animal cells. If APC is defective in human cell, which of the following is expected to occur?
   a. Chromosomes will be fragmented
   b. Chromosomes will not condense
   c. Chromosomes will not segregate
   d. Recombination of chromosomes will occur
4. In S phase of the cell cycle
   a. Amount of DNA doubles in each cell
   b. Amount of DNA remains same in each cell
   c. Chromosome number is increased
   d. Amount of DNA is reduced to half in each cell
5. Centromere is required for
   a. transcription
   b. crossing over
   c. Cytoplasmic cleavage
   d. movement of chromosome towards pole
6. Synapsis occur between
   a. mRNA and ribosomes
   b. spindle fibres and centromeres
   c. two homologous chromosomes
   d. a male and a female gamete
7. In meiosis crossing over is initiated at
   a. Diplotene
   b. Pachytene
   c. Leptotene
   d. Zygotene
8. Colchicine prevents the mitosis of the cells at which of the following stage
   a. Anaphase
   b. Metaphase
   c. Prophase
   d. interphase
9. The paring of homologous chromosomes on meiosis is known as
   a. Bivalent
   b. Synapsis
   c. Disjunction
   d. Synergids
10. Anastral mitosis is the characteristic feature of
    a. Lower animals
    b. Higher animals
    c. Higher plants
    d. All living organisms
11. Write any three significance of mitosis
12. Differentiate between mitosis and meiosis
13. Given an account of $G_0$ phase
14. Differentiate cytokinesis in plant cells and animal cells
15. Write about Pachytene and Diplotene of Prophase I

## ICT Corner

# Cell division

**How cells are multiply?** →

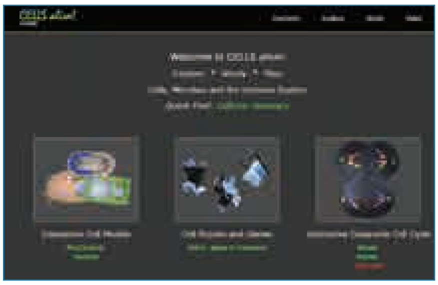


### Steps

- Scan the QR code
- Click Mitosis and start the animation press play
- Select mitosis in the top of the page – play it - use forward button to slow down
- Select meiosis in the top of the page – play it - use forward button to slow down

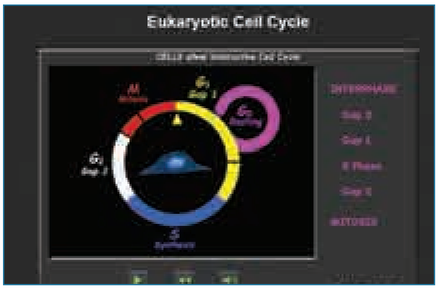
### Activity

- Select meiosis and cell cycle.
- Record your observations.



Step 1

Step 3




Step 2

Step 4

URL:

https://www.cellsalive.com/

* Pictures are indicative only

B181_11_BOT

# Chapter 8

# Biomolecules

## Learning Objectives

The learner will be able to,

- *List out the inorganic and organic components of a cell.*
- *Understand about bonding pattern of water and properties of water.*
- *Familiarise with the classification of carbohydrates and its functions.*
- *Recognise the basic structure of carbohydrates, proteins, lipids and nucleic acids and differentiate the various pattern of classification with respect to structure.*
- *Identify the structure and functions of carbohydrates.*
- *Familiarise with the general structure of amino acids and its classification based on the functional group.*
- *Comparative study of the primary, secondary, tertiary and quaternary structure of proteins.*
- *Know the structure and classification of enzymes.*
- *Know about the factors affecting the mode of action of enzymes with relevant examples.*
- *Understand lipids as a biomolecule and discuss the properties of lipids.*
- *Have a deeper knowledge about structure of nucleic acids.*
- *Recognize nucleic acids as a polymer which plays a vital role in carrying the genetic information.*
- *Learn about the different forms of DNA and types of RNA.*

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## Chapter Outline

**8.1** Water

**8.2** Primary and Secondary Metabolites

**8.3** Carbohydrates – Classification and Structure

**8.4** Lipids – Classification and Structure

**8.5** Proteins and Amino Acids – Classification and Structure,

**8.6** Enzymes – Classification, Nomenclature, Structure and Concepts, Mechanism of Enzyme Action, Activation energy, factors affecting enzyme action.

**8.7** Nucleic Acids general Structure and composition – Forms of DNA and Types of RNA.

## Biomolecules

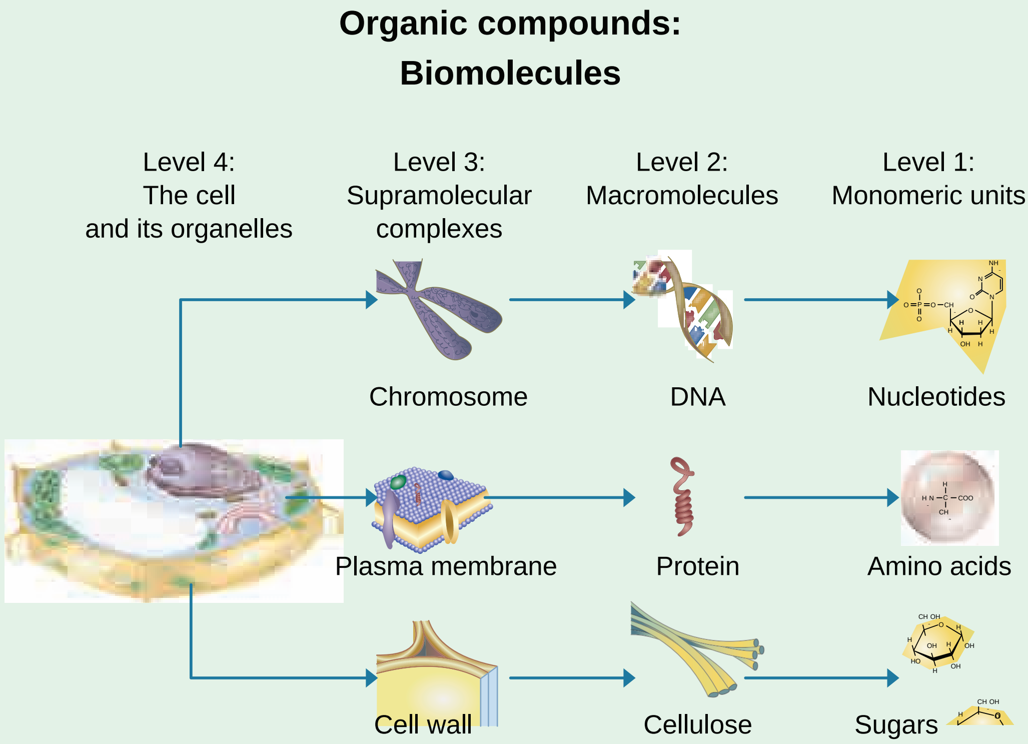



**Figure 8.1:** Components of cell

Having learnt the structure of the cell, we can now understand that each component of the cell is responsible for a specific function. The cell components are made of collection of molecules called as **cellular pool**, which consists of both inorganic and organic compounds. Inorganic compounds include salts, mineral ions and water.

Organic compounds are carbohydrates, lipids, amino acids, proteins, nucleotides, hormones and vitamins. Some organic molecules remain in colloidal form in the aqueous intracellular fluid. Others exist in non-aqueous phases like the lipid membrane and cell walls. The cell maintains this pool by the intake and elimination of specific molecules (Figure 8.1).

The minerals essential for plant growth are of two types: **macronutrients**, which are required in larger amounts (Eg. Potassium, phosphorus, calcium, magnesium, sulphur and iron) and **micronutrients**, which are required in trace amounts (Eg. Cobalt, zinc, boron, copper, molybdenum and manganese) and are essential for enzyme action. Example, Manganese is required for activity of enzyme needed for synthesis of oligosaccharides and glycoproteins. Molybdenum is necessary for fixation of nitrogen by enzyme nitrogenase.

| Component | % of the total cellular mass |
|---|---|
| Water | 70 |
| Proteins | 15 |
| Carbohydrates | 3 |
| Lipids | 2 |
| Nucleic acids | 6 |
| Ions | 4 |

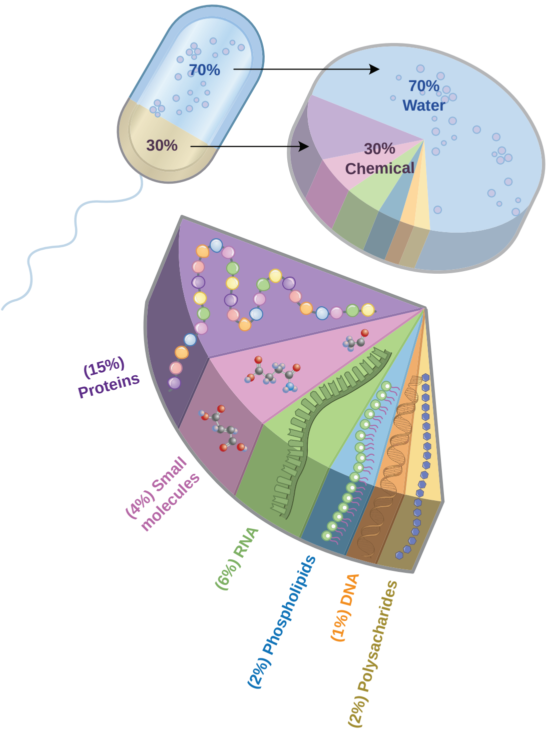



**Figure 8.2:** Percentage of biomolecules in cell

## 8.1 Water

Water is the most abundant component in living organisms. Life on earth is inevitably linked to water. Water makes up 70% of human cell and upto 95% of mass of a plant cell (Figure 8.2).

DO YOU KNOW?

Masaru Emoto discovered that crystals formed in frozen water reveal changes when specific, concentrated thoughts are directed toward them. This crystal structure shows joy mood

**Figure 8.3**

### 8.1.1 Chemistry of Water

Water is a tiny polar molecule and can readily pass through membranes. Two electronegative atoms of oxygen share a hydrogen bonds of two water molecule. Thus, they can stick together by cohesion and results in lattice formation (Figure 8.4).

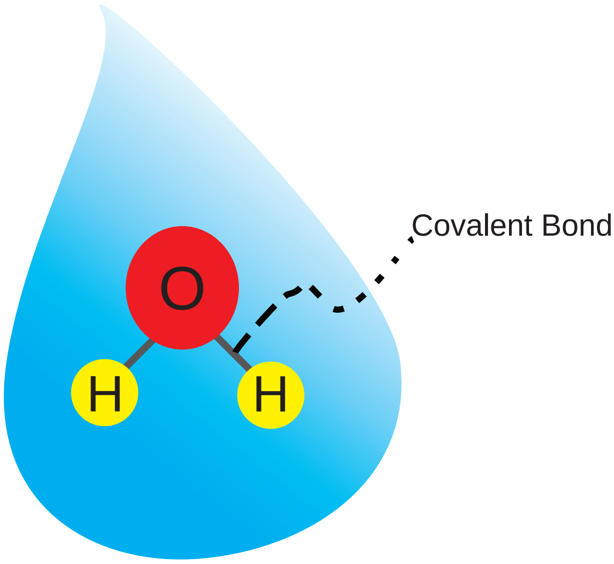



**Figure 8.4:** Water molecule

### 8.1.2 Properties of Water

- Adhesion and cohesion property
- High latent heat of vaporisation
- High melting and boiling point
- Universal solvent
- Specific heat capacity

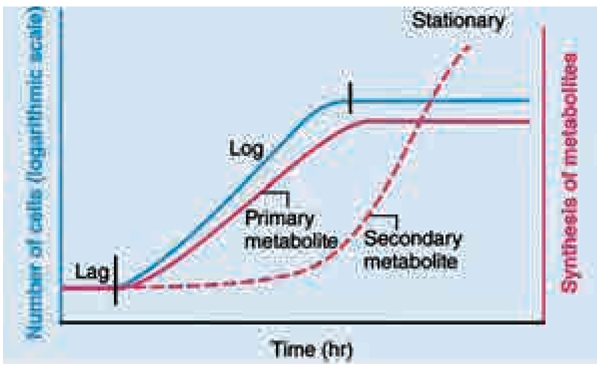



**Figure 8.5:** Synthesis of metabolites during growth

## 8.2 Primary and Secondary Metabolites

Most plants, fungi and other microbes synthesizes a number of organic compounds. These components are called as **metabolites** which are intermediates and products of metabolism. The term metabolite is usually restricted to small molecules. It can be catergorized into two types namely primary and secondary metabolites based on their role in metabolic process (Figure 8.5).

**Primary metabolites** are those that are required for the basic metabolic processes like photosynthesis, respiration, protein and lipid metabolism of living organisms.

**Secondary metabolites** does not show any direct function in growth and development of organisms.

| Metabolites | Examples |
|---|---|
| **Primary** | |
| Enzymes | Protease, lipase, peroxidase |
| Amino acid | Proline, leucine |
| Organic acid | Acetic acid, lactic acid |
| Vitamins | A, B, C |
| **Secondary** | |
| Pigments | Carotenoids, anthocyanins |
| Alkaloids | Morphine, codeine |
| Essential oil | Lemon grass oil, rose oil |
| Toxins | Abrin, ricin |
| Lectins | Concanavalin A |
| Drugs | Vinblastin, curcumin |
| Polymeric substances | Rubber, gums, cellulose |

DO YOU KNOW?

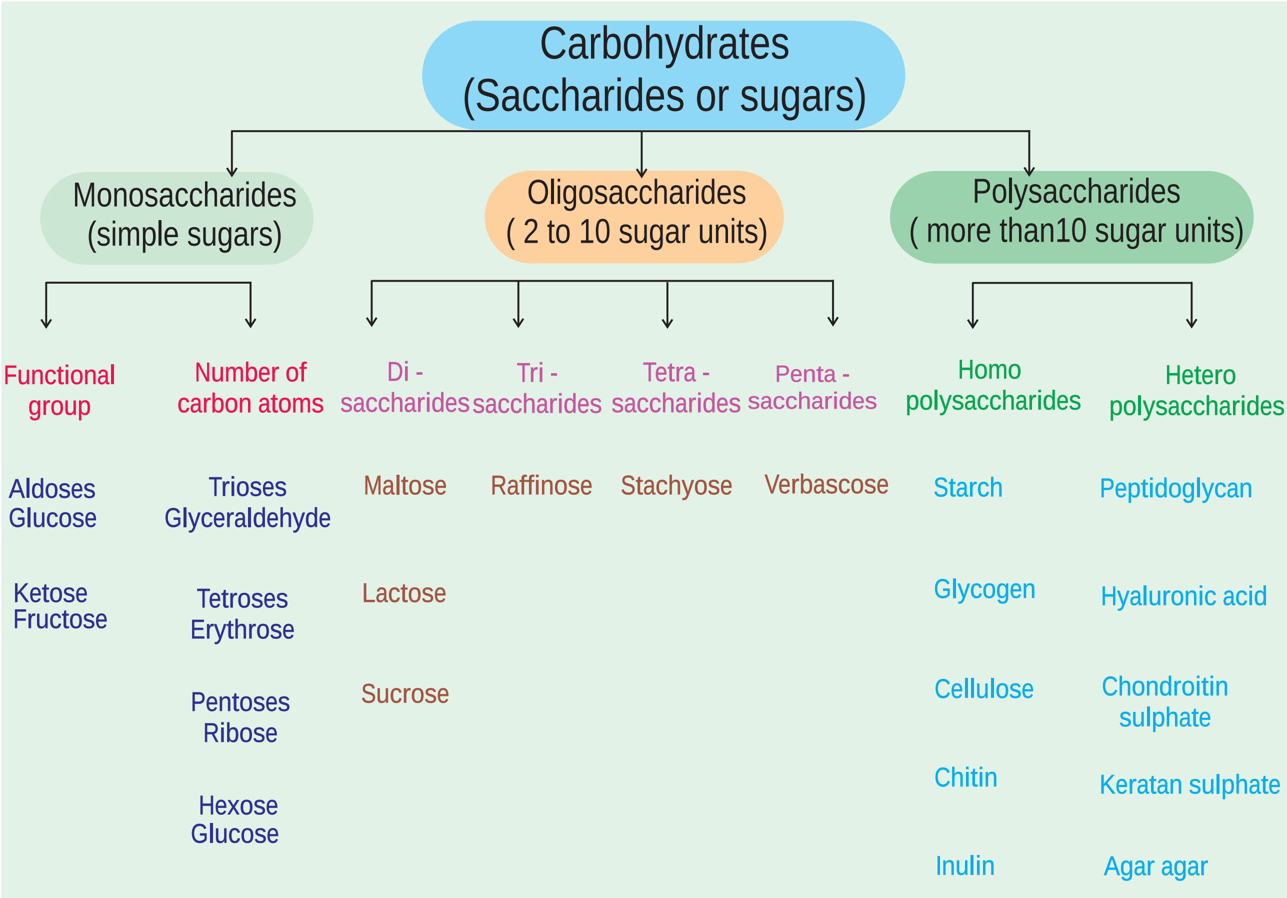
**Morphine** is the first alkaloid to be found. It comes from the plant Opium poppy (*Papaver somniferum*). It is used as a pain reliever in patients with severe pain levels and cough suppressant.

### 8.2.1 Organic Molecules

Organic molecules may be small and simple. These simple molecules assemble and form large and complex molecules called **macromolecules**. These include four main classes – carbohydrates, lipids, proteins and nucleic acids. All macromolecules except lipids are formed by the process of polymerisation, a process in which repeating subunits termed monomers are bound into chains of different lengths. These chains of monomers are called **polymers**.

## 8.3 Carbohydrates

Carbohydrates are organic compounds made of carbon and water. Thus one molecule of water combines with a carbon atom to form $CH_2O$ and is repeated several (n) times to form $\mathbf{(CH_2O)_n}$ where n is an integer ranging from 3–7. These are also called as **saccharides**. The common term sugar refers to a simple carbohydrate such as a monosaccharide or disaccharide that tastes sweet are soluble in water (Figure 8.7).




## 8.3.1 Monosaccharides – The Simple Sugars

**Monosaccharides** are relatively small molecules constituting single sugar unit. Glucose has a chemical formula of $C_6H_{12}O_6$. It is a six carbon molecule and hence is called as **hexose** (Figure 8.6).

All monosaccharides contain one of two functional groups. Some are aldehydes, like glucose and are referred as **aldoses**; other are ketones, like fructose and are referred as **ketoses**.

**DO YOU KNOW?**

Glucose is one of the most well-known molecules due to its nature as an essential nutrient for human health. You ingest glucose in your food, and then your body uses blood to carry the glucose to the cells of every organ for the purpose of energy production.

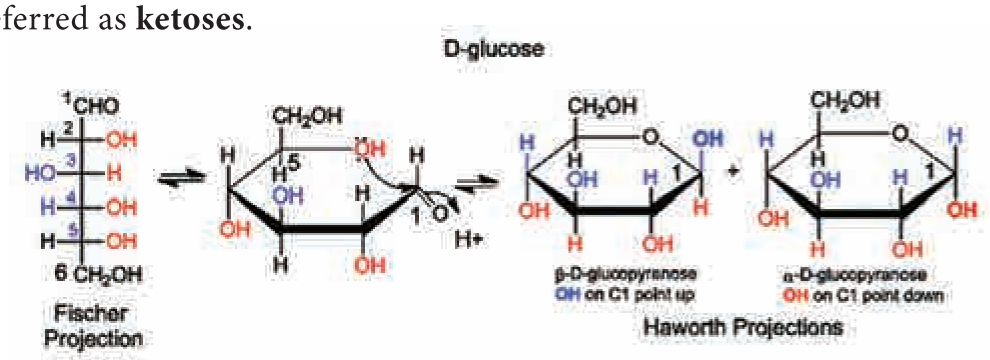



**Figure 8.6:** Structure of Glucose

### 8.3.2 Disaccharides

Disaccharides are formed when **two monosaccharides** join together. An example is **sucrose**. Sucrose is formed from a molecule of α-glucose and a molecule of fructose. This is a condensation reaction releasing water. The bond formed between the glucose and fructose molecule by removal of water is called **glycosidic bond**. This is another example of strong, covalent bond.

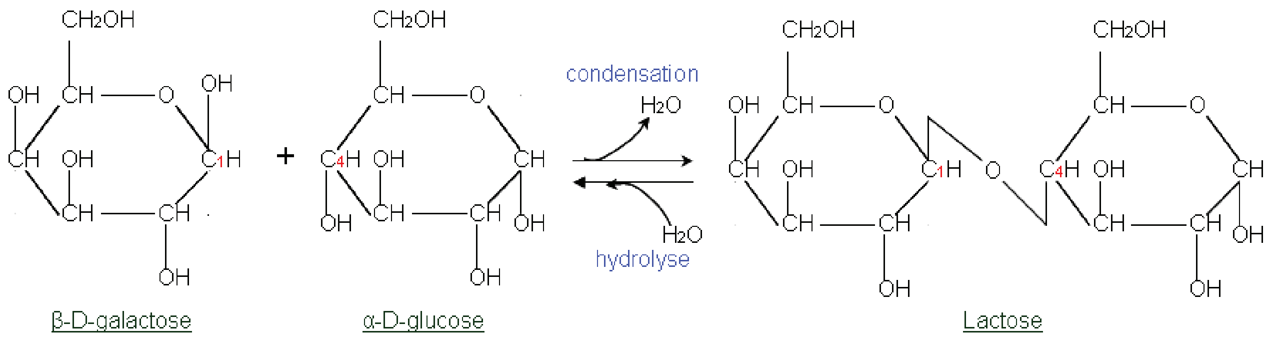



**Figure 8.7:** structure of carbohydrates

In the reverse process, a disaccharide is digested to the component monosaccharide in a hydrolysis reaction. This reaction involves addition of a water (hydro) molecule and splitting (lysis) of the glycosidic bond.

### 8.3.3 Polysaccharides

These are made of **hundreds of monosaccharide units**. Polysaccharides also called "**Glycans**". Long chain of branched or unbranched monosaccharides are held together by glycosidic bonds. Polysaccharide is an example of giant molecule, a macromolecule and consists of only one type of monomer. Polysaccharides are insoluble in water and are sweetless. **Cellulose** is an example built from repeated units of glucose monomer.

Depending on the function, polysaccharides are of two types - **storage polysaccharide and structural polysaccharide** (Figure 8.8)**.**

### 8.3.4 Starch

Starch is a storage polysaccharides made up of repeated units of **amylose and amylopectin**. Starch grains are made up of successive layers of amylose and amylopectin, which can be seen as growth rings. Amylose is a linear, unbranched polymer which makes up 80% of starch. Amylopectin is a polymer with some 1, 6 linkages that gives it a branched structure.


**Figure 8.8:** Branched and linear polysaccharides

### 8.3.5 Test for Starch

We test the presence of starch by adding a solution of iodine in potassium iodide. Iodine molecules fit nearly into the starch helix, creating a **blue-black colour** (Figure 8.9).

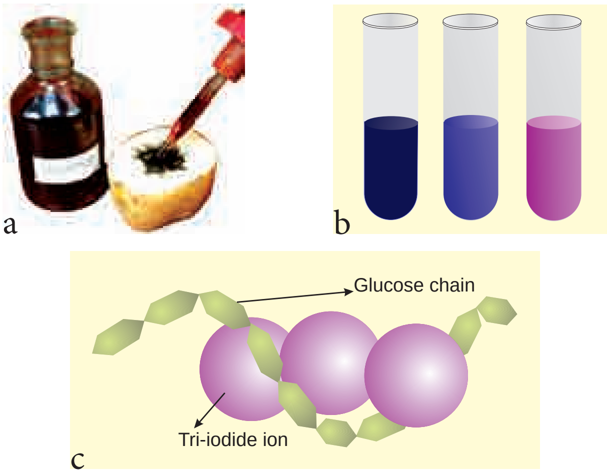



**Figure 8.9:** Test for starch

a. Test on potato; b. test on starch at varied concentrations; c. starch – iodine reaction

### 8.3.6 Glycogen

Glycogen is also a storage polysaccharide otherwise called as **animal starch**. It is the only carbohydrate stored in animals and fungi. Like amylopectin glycogen is a polymer of glucose with (α1-6) linked branches. Glycogen is seen in liver cells, skeletal muscle fibre and throughout the human body except brain (Figure 8.10).

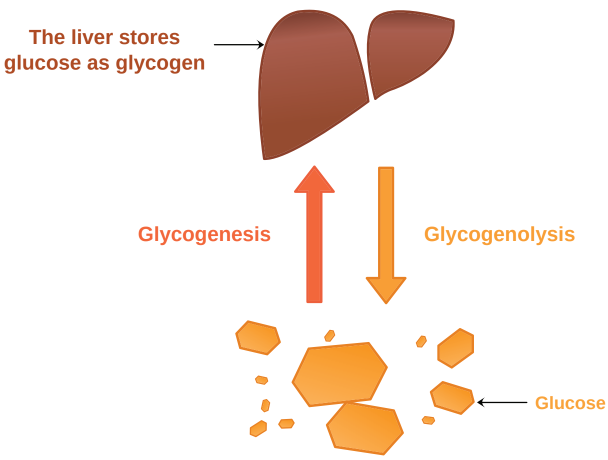



**Figure 8.10:** Glycogen: Glycogen in liver

### 8.3.7 Celluloses

Cellulose is a structural polysaccharide made up of thousands of glucose units. In this case, β-glucose units are held together by 1,4 glycosidic linkage, forming long unbranched chains. Cellulose fibres are straight and uncoiled. It has many industrial uses which include cellulose fibres as cotton, nitrocellulose for explosives, cellulose acetate for fibres of multiple uses and cellophane for packing (Figure 8.11).

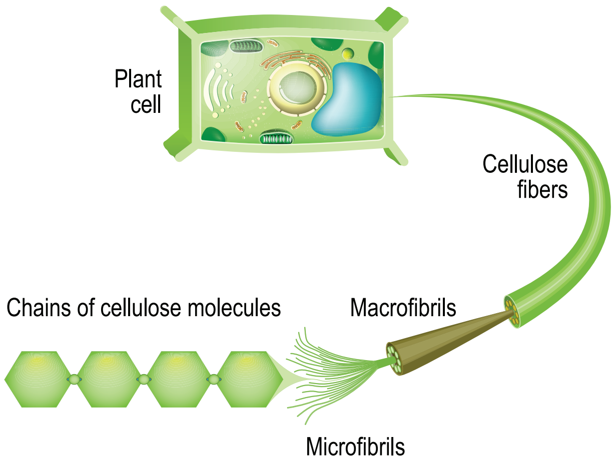



**Figure 8.11:** Cellulose molecule


**Most herbivores have a problem:**

- Cellulose is one of the most abundant organic compound in the biosphere.
- eat grass: principle component is cellulose
- cannot produce cellulase

**Solution:** Mutualistic bacteria in digestive system produce cellulases.

### 8.3.8 Chitin

Chitin is a homo polysaccharide with amino acids added to form **mucopolysaccharide.** The basic unit is a nitrogen containing glucose derivative known as **N-acetyl glucosamine.** It forms the exoskeleton of insects and other arthropods. It is also present in the cell walls of fungi (Figure 8.12).

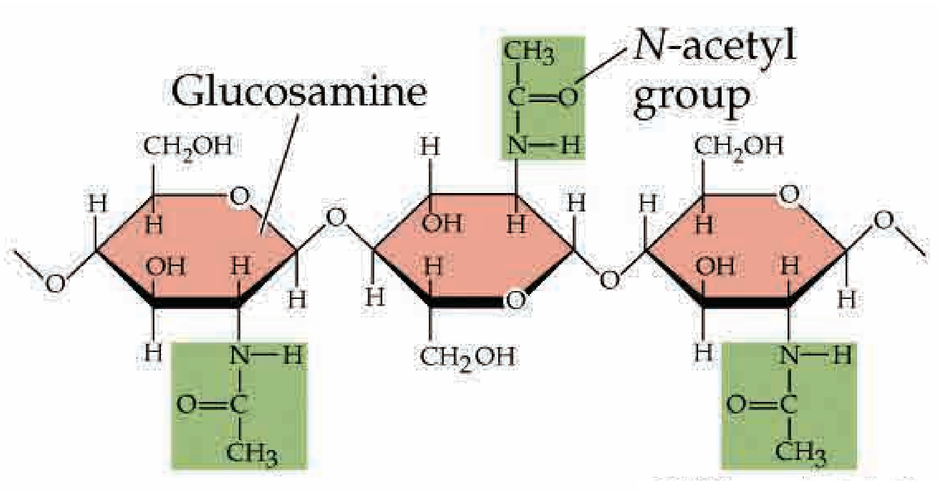



**Figure 8.12:** Structure of Chitin molecule

DO YOU KNOW?

**Does mushroom cells have cell wall?**

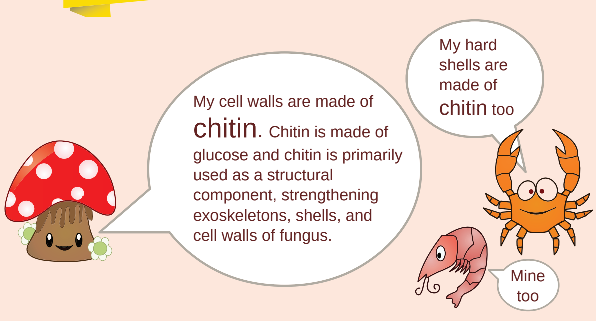



**Figure 8.13**

### 8.3.9 Test for Reducing Sugars

Aldoses and ketoses are reducing sugars. This means that, when heated with an alkaline solution of copper (II) sulphate (a blue solution called **benedict's solution**), the aldehyde or ketone group reduces $Cu^{2+}$ ions to $Cu^{+}$ ions forming brick red precipitate of copper(I) oxide. In the process, the aldehyde or ketone group is oxidised to a carboxyl group (–COOH). This reaction is used as test for reducing sugar and is known as **Benedict's test.** The results of benedict's test depends on concentration of the sugar. If there is no reducing sugar it remains blue (Figure 8.14).

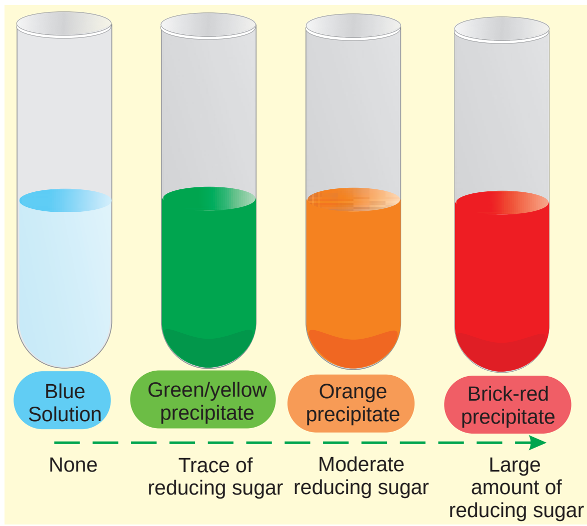



**Figure 8.14:** Test for sugar

- Sucrose is not a reducing sugar
- The greater the concentration of reducing sugar, the more is the precipitate formed and greater is the colour change.

### Other Sugar Compounds

| Other Polysaccharides | Structure | Functions |
|---|---|---|
| Inulin | Polymer of fructose | It is not metabolised in the human body and is readily filtered through the kidney |
| Hyaluronic acid | Heteropolymer of d glucuronic acid and D-N acetyl glucosamine | It accounts for the toughness and flexibility of cartilage and tendon |
| Agar | Mucopolysaccharide from red algae | Used as solidifying agent in culture medium in laboratory |
| Heparin | Glycosamino glycan contains variably sulphated disaccharide unit present in liver | Used as an anticoagulant |
| Chondroitin sulphate | Sulphated glycosaminoglycan composed of altering sugars (N-acetylglucosamine and glucuronic acid) | Dietery supplement for treatment of osteoarthritis |
| Keratan sulphate | Sulphated glycosaminoglycan and is a structural carbohydrate | Acts as cushion to absorb mechanical shock |

**DO YOU KNOW?**

Human can't digest cellulose but herbivores can digest them with the help of bacteria present in the gut which produces enzyme **cellulase.** This is an example of **mutualism.**

## 8.4 Lipids

The term lipid is derived from *greek* word lipos, meaning fat. These substances are not soluble in polar solvent such as water but dissolve in non-polar solvents such as benzene, ether, chloroform. This is because they contain long hydrocarbon chains that are non-polar and thus hydrophobic. The main groups of compounds classified as lipids are triglycerides, phospholipids, steroids and waxes.

### 8.4.1 Triglycerides

Triglycerides are composed of single molecule of glycerol bound to 3 fatty acids. These include fats and oils. Fatty acids are long chain hydrocarbons with a carboxyl group at one end which binds to one of the hydroxyl groups of glycerol, thus forming an ester bond. Fatty acids are structural unit of lipids and are carboxylic acid of long chain hydrocarbons. The hydrocarbon can vary in length from 4 – 24 carbons and the fat may be saturated or unsaturated. In saturated fatty acids the hydrocarbon chain is single bonded (Eg. palmitic acid, stearic acid) and in unsaturated fatty acids (Eg. Oleic acid, linoleic acid) the hydrocarbon chain is double bonded (one/two/three). In general solid fats are saturated and oils are unsaturated, in which most are globules.

### 8.4.2 Membrane Lipids

A class of lipids that serves as major structural component of cell membrane is **phospholipids**. These contain only 2 fatty acids attached to the glycerol, while the third glycerol binding site holds a phosphate group. This phosphate group is in turn bonded to an alcohol. These lipids have both hydrophobic and hydrophilic regions. The structure of lipid bilayer helps the membrane in function such as selective permeability and fluid nature (Figure 8.15).

### 8.4.3 Steroids

These are complex compounds commonly found in cell membrane and animal hormones. Eg. Cholesterol which reinforces the structure of the cell membrane in animal cells and in an unusual group of cell wall deficient bacteria – Mycoplasma.

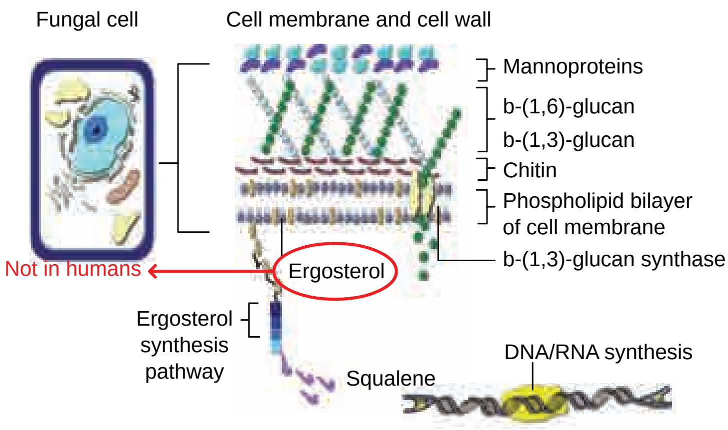



**Figure 8.15:** Complex molecules in cell wall

### 8.4.4 Waxes

These are esters formed between a long chain alcohol and saturated fatty acids. Fur, feathers, fruits, leaves, skin and insect exoskeleton are naturally waterproofed with a coating of wax (Figure 8.16 and 8.17).


**Figure 8.16:** Lecithin

Lecithin is a food additive and dietery supplement

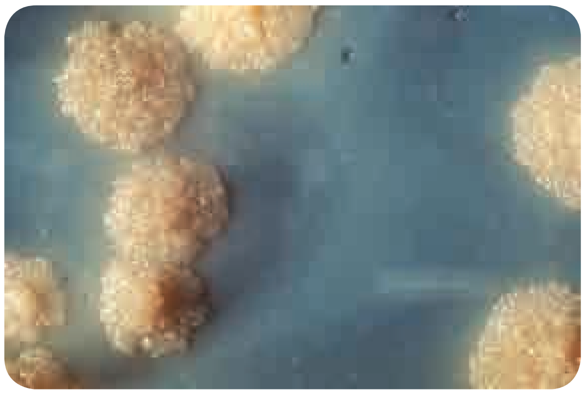
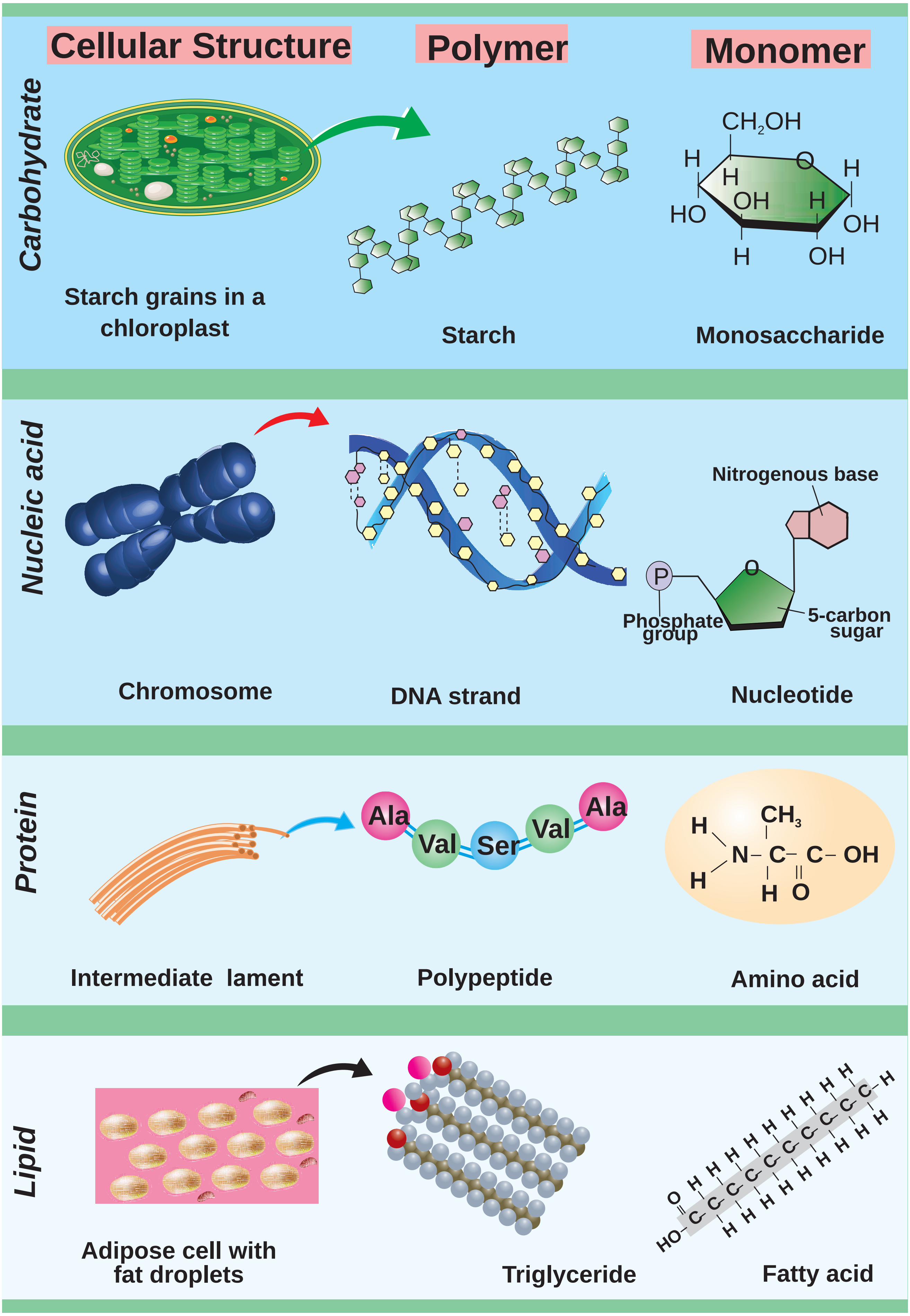


**Figure 8.17:** Wax D present in cell wall of TB and Leprosy causing bacteria is infectious



Cellular Structure
Polymer
Monomer
Carbohydrate
Starch grains in a chloroplast
Starch
CH2OH
H
O
H
H
OH
H
HO
OH
H
OH
Monosaccharide
Nucleic acid
Nitrogenous base
P
O
Phosphate group
5-carbon sugar
Chromosome
DNA strand
Nucleotide
Protein
Ala
Val
Ser
Val
Ala
CH3
H
N- C- C- OH
H
H O
Intermediate lament
Polypeptide
Amino acid
Lipid
Adipose cell with fat droplets
Triglyceride
Fatty acid

## 8.5 Proteins

Proteins are the most diverse of all macromolecule. Proteins make up 2/3 of total dry mass of a cell. The term protein was coined by **Gerardus Johannes Mulder** and is derived form a *greek* word proteos which means of the first rank.

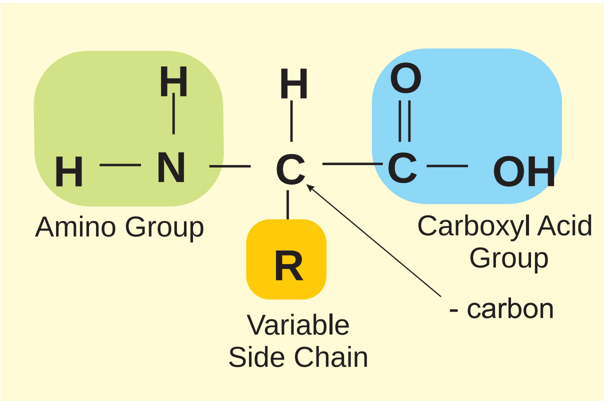



**Figure 8.18:** Structure of basic amino acid

Amino acids are building blocks of proteins. There are about 20 different amino acids exist naturally. All amino acids have a basic skeleton consisting of a carbon (a-carbon) linked to a basic amino group.

($NH_2$), an acidic carboxylic group (COOH) and a hydrogen atom (H) and side chain or variable R group. The amino acid is both an acid and a base and is called **amphoteric**.

A **zwitterion** also called as **dipolar ion**, is a molecule with two or more functional groups, of which at least one has a positive and other has a negative electrical charge and the net charge of the entire molecule is zero. The pH at which this happens is known as the **isoelectric point** (Figure 8.19).

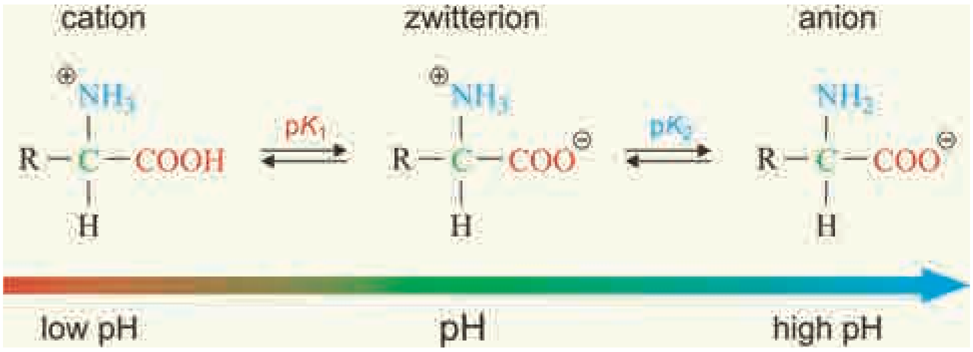



**Figure 8.19:** Structure of amino acid

### 8.5.1 Classification of Amino acids

Based on the R group amino acids are classified as acidic, basic, polar, non-polar.

The amino group of one amino acid reacts with carboxyl group of other amino acid, forming a **peptide bond**. Two amino acids can react together with the loss of water to form a **dipeptide**. Long strings of amino acids linked by peptide bonds are called **polypeptides**. In 1953 Fred Sanger first sequenced the Insulin protein (Figure 8.18 and 8.20 a and b).

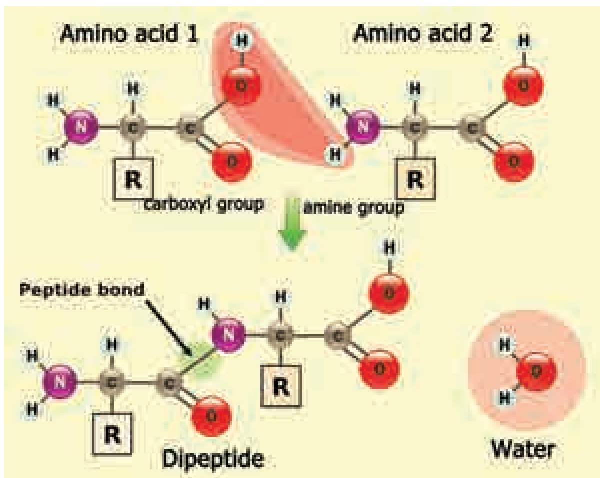



**Figure 8.20(a):** Amino acid reaction

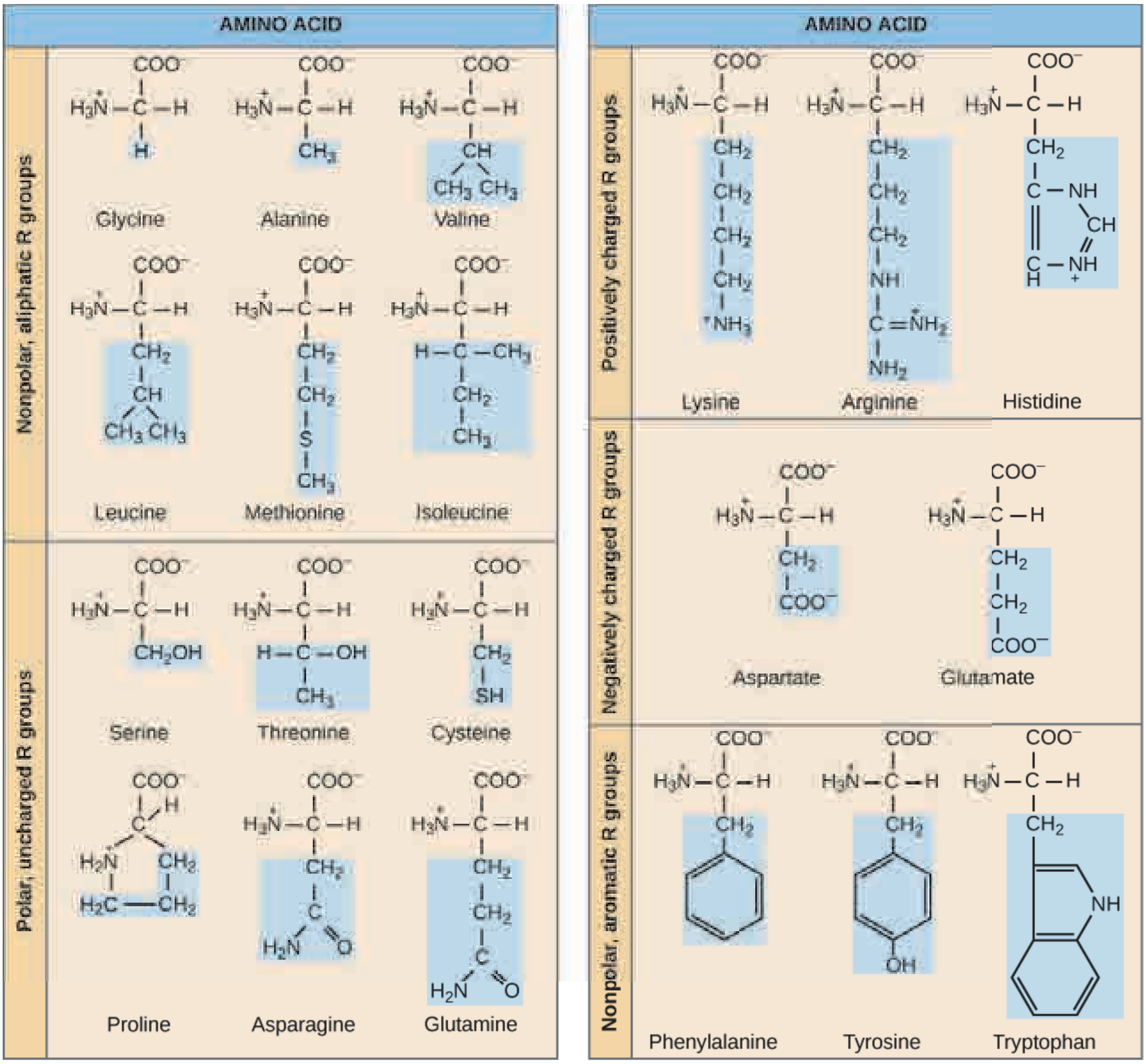



**Figure 8.20(b):** Classification of Amino Acids

DO YOU KNOW?

First protein Insulin was sequenced by Fred Sanger

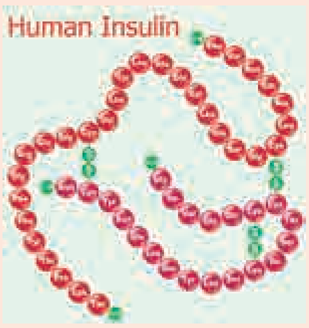



**Figure 8.21**

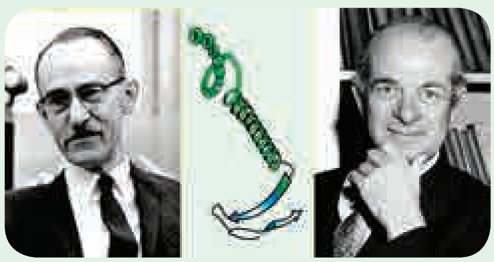


**Figure 8.22**

Linus Pauling and Robert Corey in 1951 proposed the α-helix and β sheet secondary structures of proteins. They were awarded nobel prize in 1954

### 8.5.2 Structure of Protein

Protein is synthesised on the ribosome as a linear sequence of amino acids which are held together by peptide bonds. After synthesis, the protein attains conformational change into a specific 3D form for proper functioning. According to the mode of folding, four levels of protein organisation have been recognised namely primary, secondary, tertiary and quaternary (Figure 8.23).

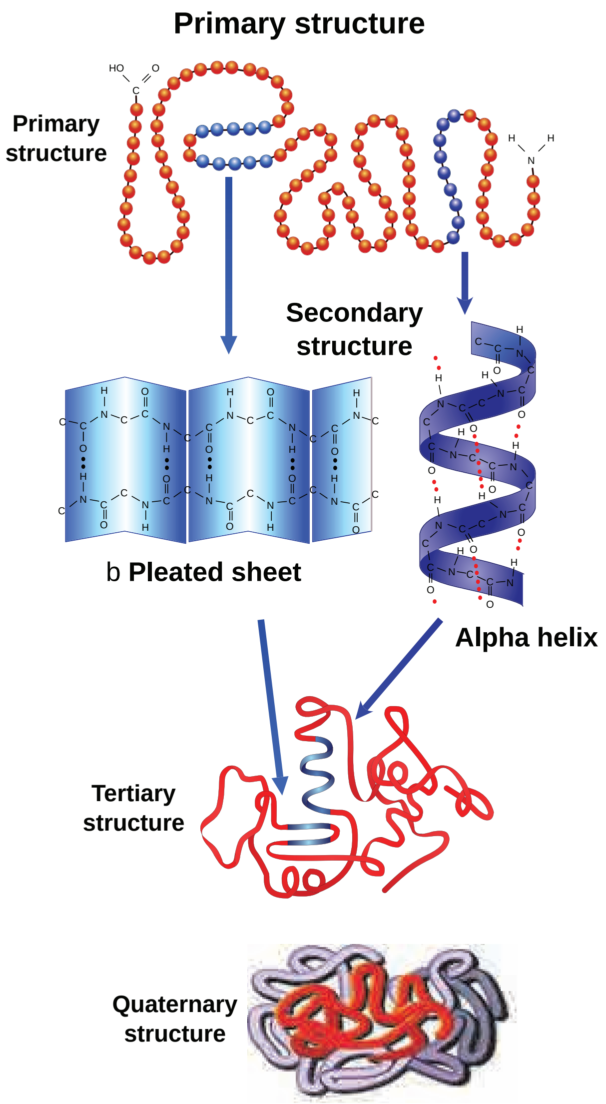



**Figure 8.23:** Structure of Protein

- The **primary structure** is linear arrangement of amino acids in a polypeptide chain.
- **Secondary structure** arises when various functional groups are exposed on outer surface of the molecular interaction by forming hydrogen bonds. This causes the aminoacid chain to twist into coiled configuration called α-**helix** or to fold into a flat β-pleated sheets.
- **Tertiary protein structure** arises when the secondary level proteins fold into globular structure called domains.
- **Quaternary protein structure** may be assumed by some complex proteins in which more than one polypeptide forms a large multiunit protein. The individual polypeptide chains of the protein are called **subunits** and the active protein itself is called a **multimer.**

For example: Enzymes serve as catalyst for chemical reactions in cell and are non-specific. Antibodies are complex glycoproteins with specific regions of attachment for various organisms.

### 8.5.3 Protein Denaturation

Denaturation is the loss of 3D structure of protein. Exposure to heat causes atoms to vibrate violently, and this disrupts the hydrogen and ionic bonds. Under these conditions, protein molecules become elongated, disorganised strands. Agents such as soap, detergents, acid, alcohol and some disinfectants disrupt the interchain bond and cause the molecule to be non-functional (Figure 8.25).

Christian Anfinsen explained denaturation of proteins by heat treatment leading to breakage of non-covalent bond.

**Figure 8.24**

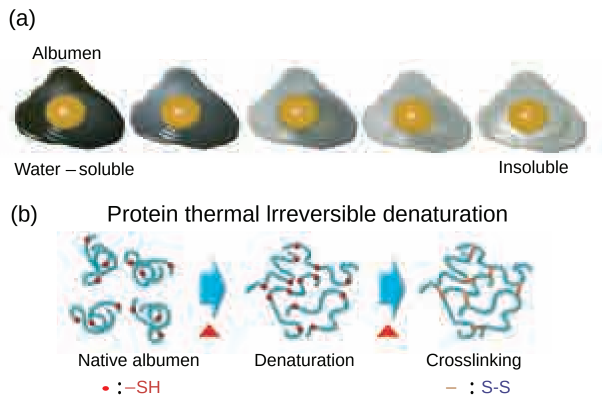



**Figure 8.25:** Protein denaturation

## 8.5.4 Protein Bonding

There are three types of chemical bonding

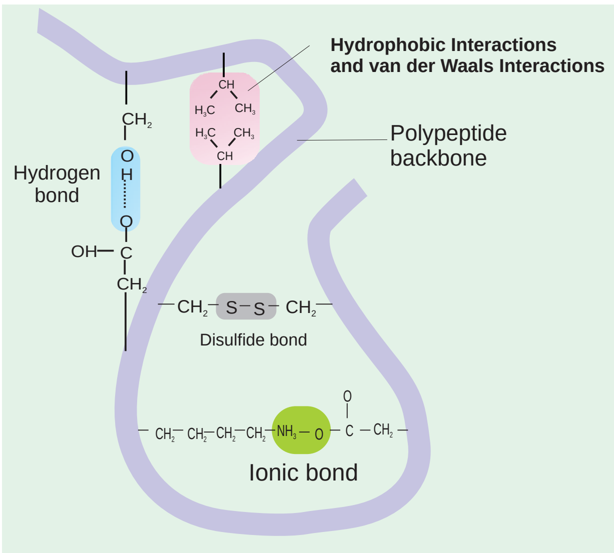



**Figure 8.26:** Protein bonding

### Hydrogen Bond

It is formed between some hydrogen atoms of oxygen and nitrogen in polypeptide chain. The hydrogen atoms have a small positive charge and oxygen and nitrogen have small negative charge. Opposite charges attract to form hydrogen bonds.

Though these bonds are weak, large number of them maintains the molecule in 3D shape (Figure 8.26).

### Ionic Bond

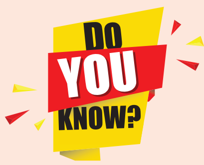
It is formed between any charged groups that are not joined together by peptide bond. It is stronger than hydrogen bond and can be broken by changes in pH and temperature.

### Disulfide Bond

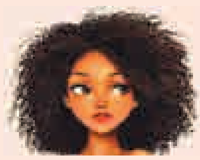
Some amino acids like cysteine and methionine have sulphur. These form disulphide bridge between sulphur atoms and amino acids.

### Hydrophobic Bond

This bond helps some protein to maintain structure. When globular proteins are in solution, their hydrophobic groups point inwards away from water.




The more the distance between the sulphur atoms, the more the proteins bend; the more the hair curls.



## 8.5.5 Test for Proteins

The biuret test is used as an indicator of the presence of protein because it gives a purple colour in the presence of peptide bonds (–C–N–). To a protein solution an equal quantity of sodium hydroxide solution is added and mixed. Then a few drops of 0.5% copper (II) sulphate is added with gentle mixing. A distinct purple colour develops without heating (Figure 8.27 a and b).

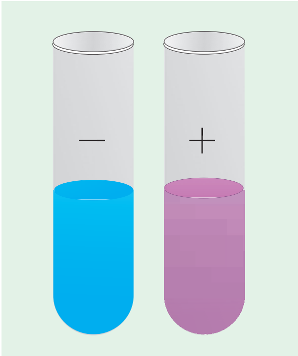



**Figure 8.27(a):** Biuret test

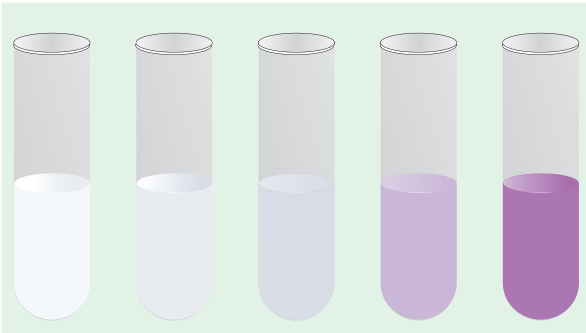


**Figure 8.27(b):** Colour intensity increases with increase in concentration

## 8.6 Enzymes

Enzymes are globular proteins that catalyse the many thousands of metabolic reactions taking place within cells and organism. The molecules involved in such reactions are metabolites. Metabolism consists of chains and cycles of enzyme-catalysed reactions, such as respiration, photosynthesis, protein synthesis and other pathways. These reactions are classified as

- **anabolic** (building up of organic molecules). Synthesis of proteins from amino acids and synthesis of polysaccharides from simple sugars are examples of anabolic reactions.
- **catabolic** (breaking down of larger molecules). Digestion of complex foods and the breaking down of sugar in respiration are examples of catabolic reactions (Figure 8.28).

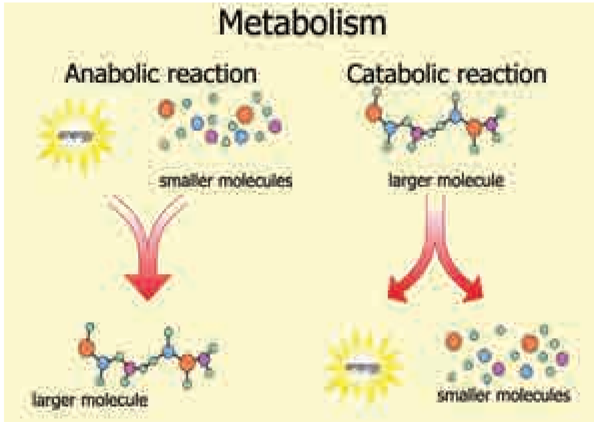



**Figure 8.28:** Enzyme reaction

Enzymes can be **extracellular enzyme** as secreted and work externally exported from cells. Eg. digestive enzymes; or **intracellular enzymes** that remain within cells and work there. These are found inside organelles or within cells. Eg. insulin

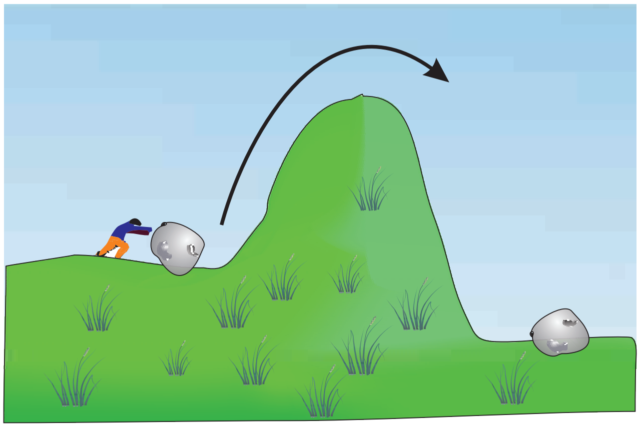
### 8.6.1 Properties of Enzyme

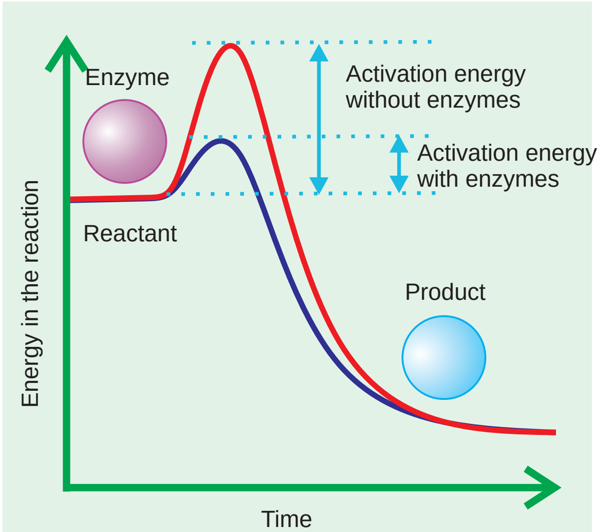
- All are globular proteins.
- They act as catalysts and effective even in small quantity.
- They remain unchanged at the end of the reaction.
- They are highly specific.
- They have an active site where the reaction takes place.
- Enzymes lower activation energy of the reaction they catalyse.

DO YOU KNOW?

**RUBISCO** is the abundant protein in the whole biosphere

As molecules react they become unstable, high energy intermediates, but they are in this transition state only momentarily. Energy is required to raise molecules to this transition state and this minimum energy needed is called the **activation energy**. This could be explained schematically by 'boulder on hillside' model of activation energy (Figure 8.29).






This graph shows the activation energies of a reaction with and without enzymes

**Figure 8.29:** Activation energy

### 8.6.2 Lock and Key Mechanism of Enzyme

In a enzyme catalysed reaction, the starting substance is the substrate. It is converted to the product. The substrate binds to the specially formed pocket in the enzyme – **the active site**, this is called **lock and key mechanism** of enzyme action. As the enzyme and substrate form a **ES complex**, the substrate is raised in energy to a transition state and then breaks down into products plus unchanged enzyme (Figure 8.30).

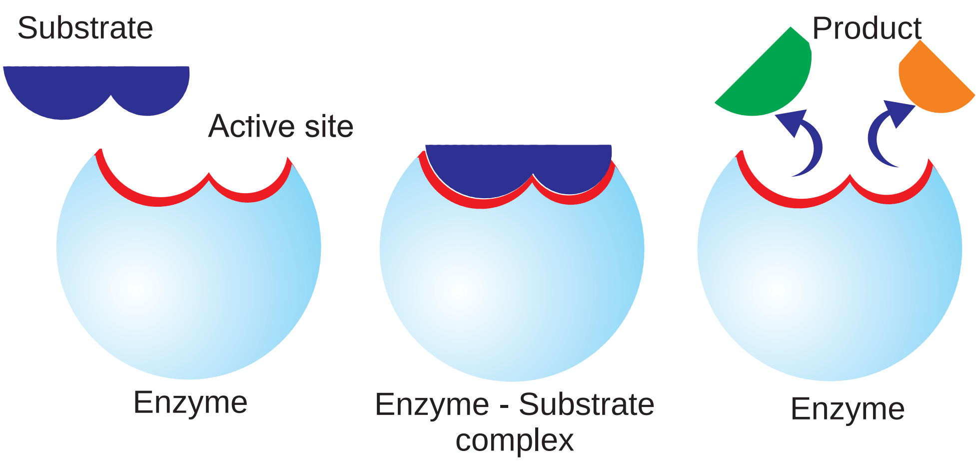



**Figure 8.30:** Enzyme mechanism

### 8.6.3 Factors Affecting the Rate of Enzyme Reactions

Enzymes are sensitive to environmental condition. It could be affected by temperature, pH, substrate concentration and enzyme concentration.

The rate of enzyme reaction is measured by the amount of substrate changed or amount of product formed, during a period of time.

### 8.6.4 Temperature

Heating increases molecular motion. Thus the molecules of the substrate and enzyme move more quickly resulting in a greater probability of occurence of the reaction. The temperature that promotes maximum activity is referred to as optimum temperature (Figure 8.31a).

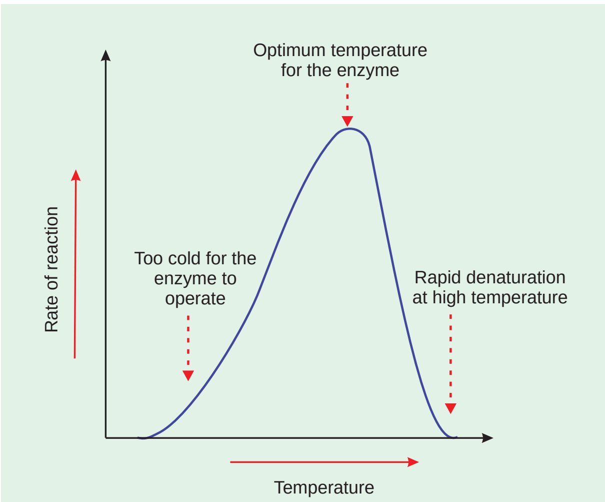



**Figure 8.31(a):** Temperature

### 8.6.5 pH

The optimum pH is that at which the maximum rate of reaction occurs. Thus the pH change leads to an alteration of enzyme shape, including the active site. If extremes of pH are encountered by an enzyme, then it will be denatured (Figure 8.31b).

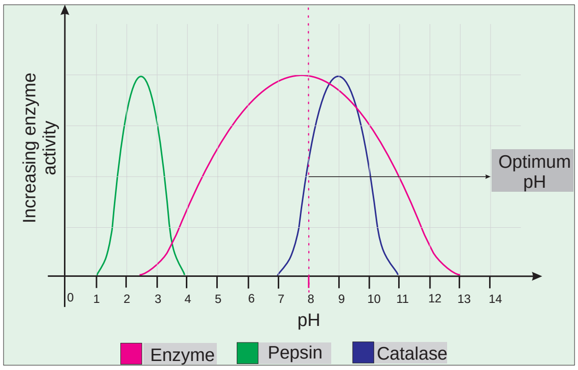



**Figure 8.31(b):** pH

### 8.6.6 Substrate Concentration

For a given enzyme concentration, the rate of an enzyme reaction increases with increasing substrate concentration (Figure 8.32).

### 8.6.7 Enzyme Concentration

The rate of reaction is directly proportional to the enzyme concentration.

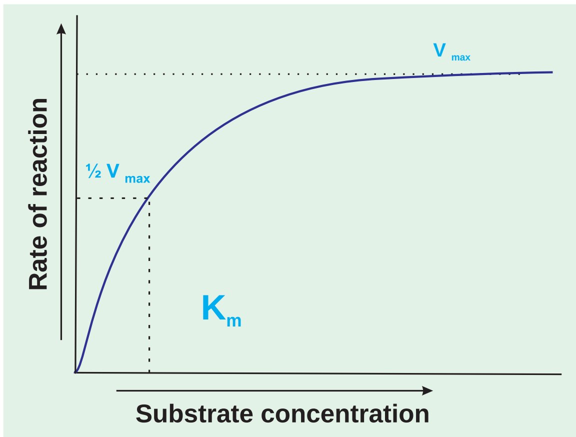



**Figure 8.32:** Rate of enzyme reaction

### 8.6.8 Introducing the Michaelis-Menton Constant (Km) and Its Significance

When the initial rate of reaction of an enzyme is measured over a range of substrate concentrations (with a fixed amount of enzyme) and the results plotted on a graph. With increasing substrate concentration, the velocity increases – rapidly at lower substrate concentration.

However the rate increases progressively, above a certain concentration of the substrate the curve flattened out. No further increase in rate occurs.

This shows that the enzyme is working at maximum velocity at this point. On the graph, this point of maximum velocity is shown as $V_{max}$.

### 8.6.9 Inhibitors of Enzyme

Certain substances present in the cells may react with the enzyme and lower the rate of reaction. These substances are called **inhibitors**. It is of two types **competitive and non-competitive** (Figure 8.33).

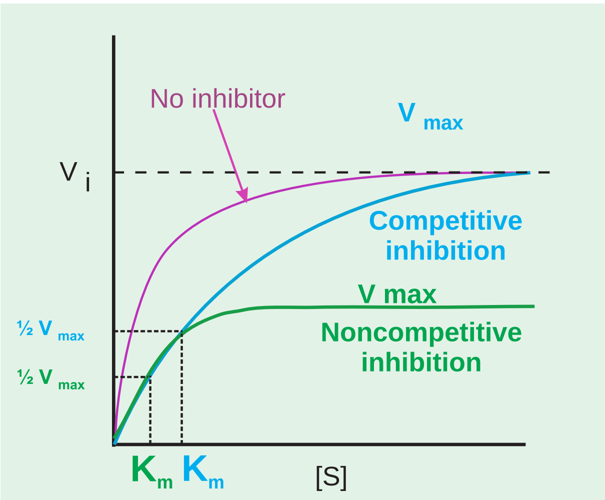



**Figure 8.33:** Enzyme inhibitors

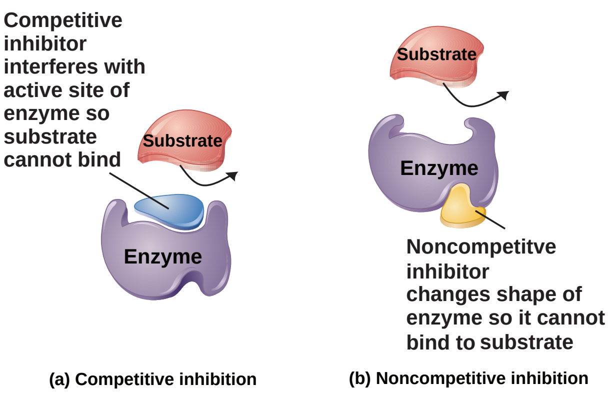



**Figure 8.34:** Action of Enzyme inhibitors

### 8.6.10 Competitive Inhibitor

Molecules that resemble the shape of the substrate and may compete to occupy the active site of enzyme are known as **competitive inhibitors**. For Example: the enzyme that catalyses the reaction between carbon di oxide and the $CO_2$ acceptor molecule in photosynthesis, known as **ribulose biphosphate carboxylase oxygenase (RUBISCO)** is competitively inhibited by **oxygen/carbon-di-oxide** in the chloroplast. The competitive inhibitor is **malonate** for **succinic dehydrogenase** (Figure 8.34).

### 8.6.11 Non-competitive Inhibitors

There are certain inhibitors which may be unlike the substrate molecule but still combines with the enzyme. This either blocks the attachment of the substrate to active site or change the shape so that it is unable to accept the substrate. For example the effect of the amino acids alanine on the enzyme pyruvate kinase in the final step of glycolysis.

Certain **non-reversible/irreversible inhibitors** bind tightly and permanently to an enzyme and destroy its catalytic properties entirely. These could also be termed as **poisons**. Example – **cyanide ions** which blocks **cytochrome oxidase** in terminal oxidation in cell aerobic respiration, the **nerve gas sarin** blocks a neurotransmitter in synapse transmission.

### 8.6.12 Allosteric Enzymes

They modify enzyme activity by causing a reversible change in the structure of the enzyme active site. This in turn affects the ability of the substrate to bind to the enzyme. Such compounds are called

**allosteric inhibitors**. Eg. The enzyme hexokinase which catalysis glucose to glucose-6 phosphate in glycolysis is inhibited by glucose 6 phosphate. This is an example for **feedback allosteric inhibitor**.

### 8.6.13 End Product Inhibition (Negative Feedback Inhibition)

When the end product of a metabolic pathway begins to accumulate, it may act as an allosteric inhibitor of the enzyme controlling the first step of the pathway. Thus the product starts to switch off its own production as it builds up. The process is self – regulatory. As the product is used up, its production is switched on once again. This is called **end-product inhibition** (Figure 8.35).

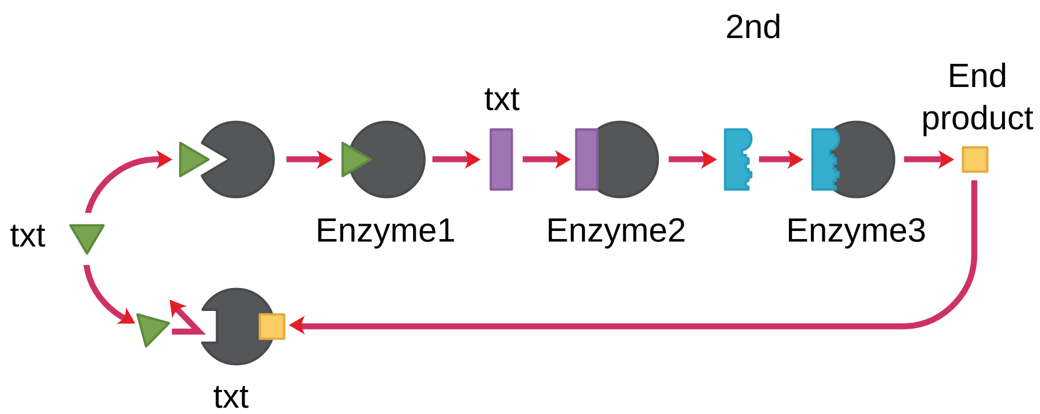



**Figure 8.35:** Negative feedback inhibition of enzyme

### 8.6.14 Enzyme Cofactors

Many enzymes require non-protein components called **cofactors** for their efficient activity. Cofactors may vary from simple inorganic ions to complex organic molecules. They are of three types: **inorganic ions, prosthetic groups and coenzymes** (Figure 8.36).

- **Holoenzyme** – active enzyme with its non protein component.

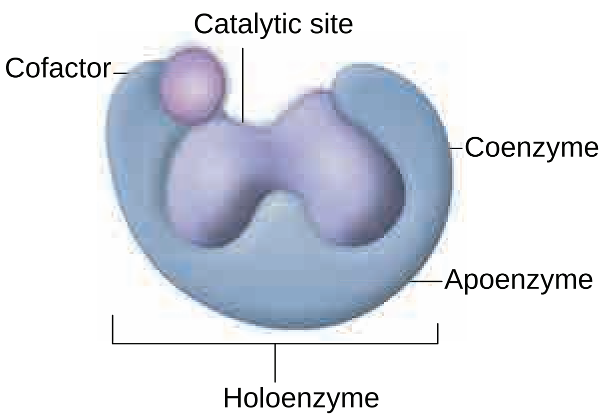



**Figure 8.36:** Enzyme components

- **Apoenzyme** – the inactive enzyme without its non protein component.
- **Inorganic ions** help to increase the rate of reaction catalysed by enzymes. Example: Salivary amylase activity is increased in the presence of chloride ions.
- **Prosthetic groups** are organic molecules that assist in catalytic function of an enzyme. Flavin adenine dinucleotide (FAD) contains riboflavin (vit B2), the function of which is to accept hydrogen. 'Haem' is an iron-containing prosthetic group with an iron atom at its centre.
- **Coenzymes** are organic compounds which act as cofactors but do not remain attached to the enzyme. The essential chemical components of many coenzymes are vitamins. Eg. NAD, NADP, Coenzyme A, ATP

DO YOU KNOW?

**Ribozyme – Non Protein Enzyme**

A Ribozyme, also called as **catalytic RNA**; is a ribonucleic acid that acts as enzyme. It is found in ribosomes.

### 8.6.15 Nomenclature of Enzymes

Most of the enzymes have a name based on their substrate with the ending **–ase**. For example lactase hydrolyses lactose and amylase hydrolyses amylose. Other enzymes like renin, trypsin do not depict any relation with their function.

### 8.6.16 Classification of Enzymes

Enzymes are classified into six groups based on their mode of action**.**

| Enzymes | Mode of action | General scheme of reaction | Example |
|---|---|---|---|
| Oxidoreductase | Oxidation and reduction (redox) reactions | $A_{red} + B_{ox} \longrightarrow A_{ox} + B_{red}$ | Dehydrogenase |
| Transferase | Transfer a group of atoms from one molecule to another | $A - B + C \longrightarrow A + C - B$ | Transaminase, phosphotransferase |
| Hydrolases | Hydrolysis of substrate by addition of water molecule | $A - B + H_2O \longrightarrow A - H + B - OH$ | Digestive enzymes |
| Isomerase | Control the conversion of one isomer to another by transferring a group of atoms from one molecule to another | $A - B - C \longrightarrow A - C - B$ | Isomerase |

*(Continued)*

| Enzymes | Mode of action | General scheme of reaction | Example |
|---|---|---|---|
| Lyase | Break chemical bond without addition of water | $A - B \longrightarrow A + B$ | Decarboxylase |
| Ligase | Formation of new chemical bonds using ATP as a source of energy | $A + B + ATP \longrightarrow A - B + ADP + Pi$ | DNA ligase |

DO YOU KNOW?

**Telomerase – A Ribonucleo Protein**

Telomere protects the end of the chromosome from damage. Telomerase is a ribonucleo protein also called as *terminal transferase*.

### 8.6.17 Uses of Enzymes

| Enzyme | Source | Application |
|---|---|---|
| Bacterial protease | Bacillus | Biological detergents |
| Bacterial glucose isomerase | Bacillus | Fructose syrup manufacture |
| Fungal lactase | Kluyveromyces | Breaking down of lactose to glucose and galactose |
| Amylases | Aspergillus | Removal of starch in woven cloth production |

## 8.7 Nucleic Acids

As we know DNA and RNA are the two kinds of nucleic acids. These were originally isolated from cell nucleus. They are present in all known **cells** and **viruses** with special coded genetic programme with detailed and specific instructions for each organism heredity.

DO YOU KNOW?

**Friedrich Miescher** *was the first to isolate a non-protein substance in nuclei of pus cells and named it as '***Nuclein***'.*

DNA and RNA are polymers of monomers called **nucleotides**, each of which is composed of a nitrogen base, a pentose sugar and a phosphate. A purine or a pyrimidine and a ribose or deoxyribose sugar is called **nucleoside**. A nitrogenous base is linked to pentose sugar through n-glycosidic linkage and forms a nucleoside. When a phosphate group is attached to a nucleoside it is called a **nucleotide**. The nitrogen base is a heterocyclic compound that can be either a **purine** (two rings) or a **pyrimidine** (one ring). There are **2 types of purines – adenine** (A) **and guanine** (G) **and 3 types of pyrimidines – cytosine** (C)**, thymine** (T) **and uracil** (U) (Figure 8.38)**.**

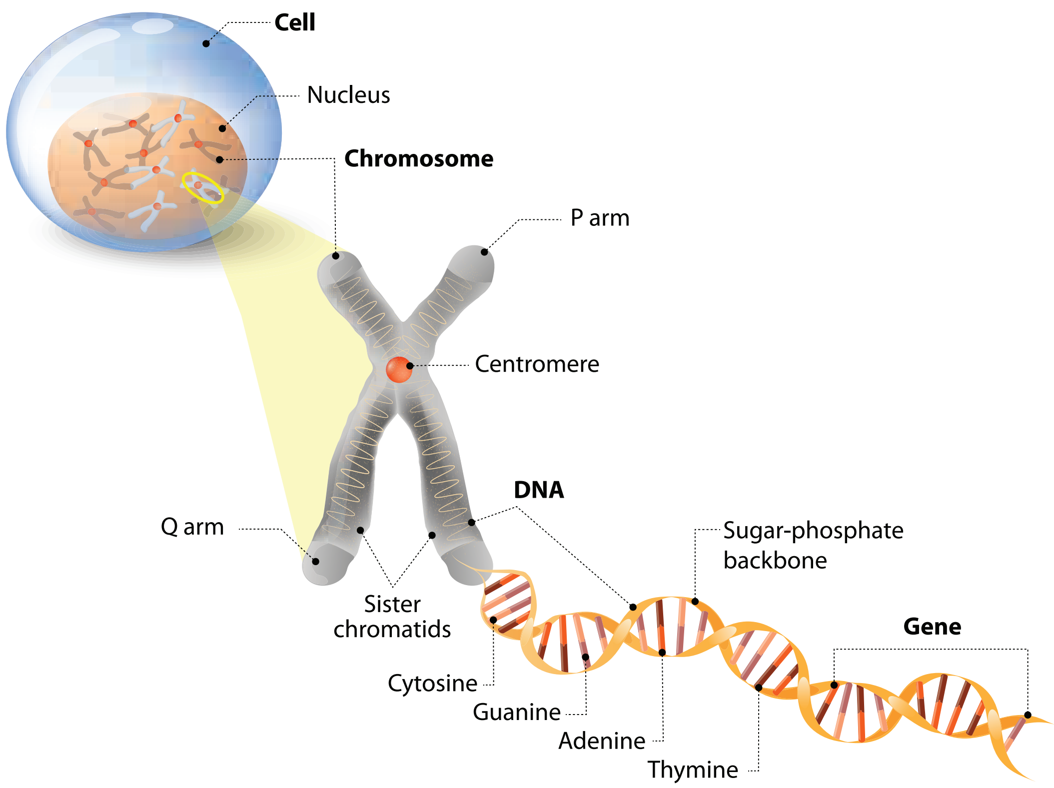



**Figure 8.37:** Position of DNA in the cell

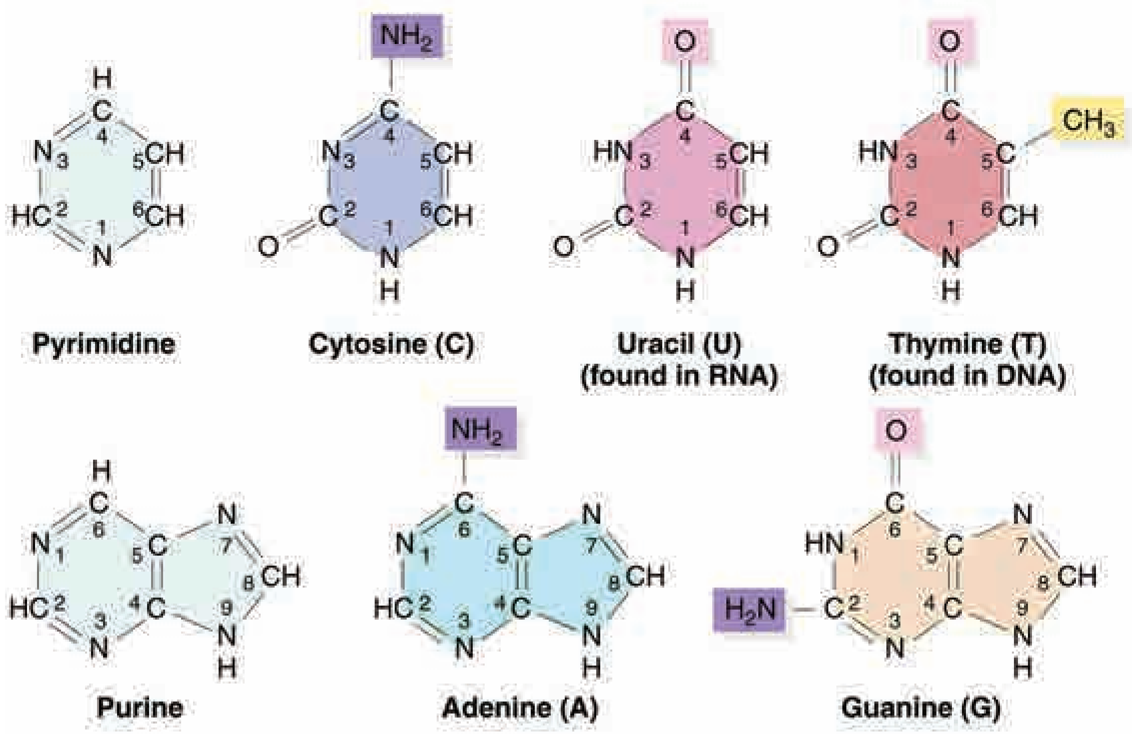



**Figure 8.38:** Structure of nucleic acid component

A characteristic feature that differentiates DNA from RNA is that DNA contains nitrogen bases such as Adenine, guanine, thymine (5-methyl uracil) and cytosine and the RNA contains nitrogen bases such as adenine, guanine, cytosine and uracil instead of thymine. The nitrogen base is covalently bonded to the sugar ribose in RNA and to deoxyribose (ribose with one oxygen removed from $C_2$) in DNA. Phosphate group is a derivative of ($PO_4^{3-}$) phosphoric acid, and forms phosphodiester linkages with sugar molecule (Figure 8.39).

### 8.7.1 Formation of Dinucleotide and Polynucleotide

Two nucleotides join to form **dinucleotide** that are linked through 3′-5′ phosphodiester linkage by condensation between phosphate groups of one with sugar of other. This is repeated many times to make **polynucleotide**.

| Nucleoside | Nucleotide |
|---|---|
| It is a combination of base and sugar. | It is a combination of nucleoside and phosphoric acid. |
| **Examples** | **Examples** |
| Adenosine = Adenine + Ribose | Adenylic acid = Adenosine + Phosphoric acid |
| Guanosine = Guanine + Ribose | Guanylic acid = Guanosine + Phosphoric acid |
| Cytidine = Cytosine + Ribose | Cytidylic acid = Cytidine + Phosphoric acid |
| Deoxythymidine = Thymine + Deoxyribose | Uridylic acid = Uridine + Phosphoric acid |

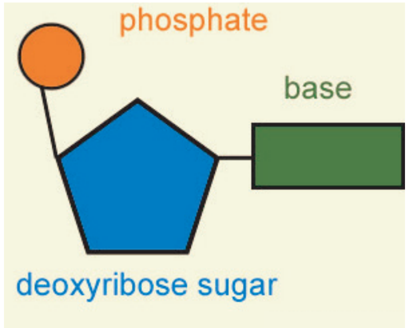



**Figure 8.39:** Basic component of DNA and RNA

### 8.7.2 Structure of DNA

Watson and Crick shared the **Nobel Prize** in **1962** for their discovery, along with **Maurice Wilkins**, who had produced the crystallographic data supporting the model. **Rosalind Franklin** (1920–1958) had earlier produced the first clear crystallographic evidence for a helical structure. **James Watson** and **Francis Crick** (Figure 8.40) of Cavendish laboratory in Cambridge built a scale model of double helical structure of DNA which is the most prevalent form of DNA, the **B-DNA**. This is the secondary structure of DNA.

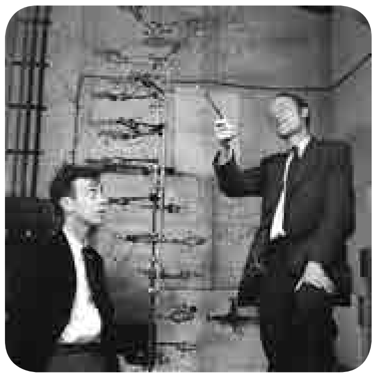


**Figure 8.40:** Watson and Crick

As proposed by **James Watson and Francis Crick**, DNA consists of right handed double helix with 2 helical polynucleotide chains that are coiled around a common axis to form right handed B form of DNA. The coils are held together by hydrogen bonds which occur between complementary pairs of nitrogenous bases. The sugar is called **2′-deoxyribose** because there is no hydroxyl at position 2′. Adenine and thiamine base pairs has two hydrogen bonds while guanine and cytosine base pairs have three hydrogen bonds.

**Chargaff's Rule:**

- A = T; G ≡ C
- A + G = T + C
- A : T = G : C = 1

As published by **Erwin Chargaff** in 1949, a purine pairs with pyrimidine and vice versa. Adenine (A) always pairs with Thymine (T) by double bond and Guanine (G) always pairs with Cytosine (C) by triple bond.

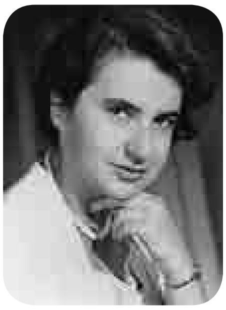


**Figure 8.41:** Rosalind franklin

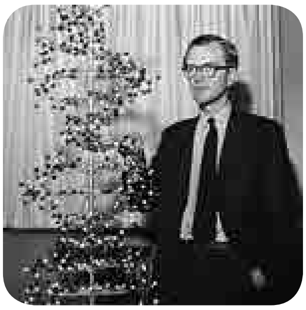
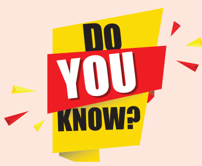


**Figure 8.42:** Erwin Chargaff




*In 1950s,* ***Maurice Wilkins and Rosalind Franklin*** *of Kings College, London studied the X-ray crystallography and revealed experimental data on the structure of DNA*

### 8.7.3 Features of DNA

- If one strand runs in the 5′-3′ direction, the other runs in 3′-5′ direction and thus are antiparallel (they run in opposite direction). The 5′ end has the phosphate group and 3'end has the OH group.
- The angle at which the two sugars protrude from the base pairs is about 120°, for the narrow angle and 240° for the wide angle. The narrow angle between the sugars generates a **minor groove** and the large angle on the other edge generates **major groove.**
- Each base is 0.34 nm apart and a complete turn of the helix comprises 3.4 nm or 10 base pairs per turn in the predominant B form of DNA.
- DNA helical structure has a diameter of 20 A° and a pitch of about 34 A°. X-ray crystal study of DNA takes a stack of about 10 bp to go completely around the helix (360°).
- Thermodynamic stability of the helix and specificity of base pairing includes (i) the hydrogen bonds between the complementary bases of the double helix (ii) stacking interaction between bases tend to stack about each other perpendicular to the direction of helical axis. Electron cloud interactions (Π – Π) between the bases in the helical stacks contribute to the stability of the double helix.
- The phosphodiester linkages gives an inherent polarity to the DNA helix. They form strong covalent bonds, gives the strength and stability to the polynucleotide chain (Figure 8.43).

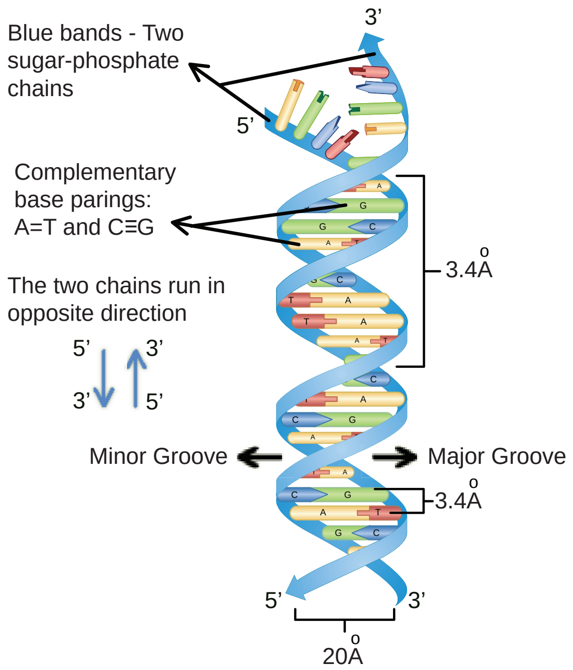



**Figure 8.43:** Structure of DNA

- Plectonemic coiling - the two strands of the DNA are wrapped around each other in a helix, making it impossible to simply move them apart without breaking the entire structure. Whereas in paranemic coiling the two strands simply lie alongside one another, making them easier to pull apart.
- Based on the helix and the distance between each turns, the DNA is of three forms – **A DNA, B DNA and Z DNA** (Figure 8.43) .

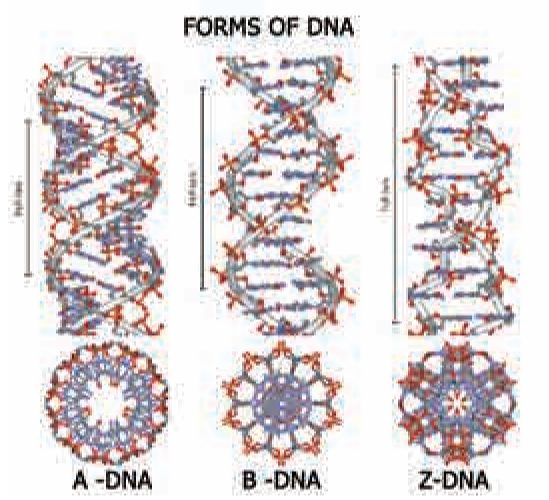



**Figure 8.44:** Forms of DNA

| Feature | B-DNA | A-DNA | Z-DNA |
|---|---|---|---|
| Type of helix | Right-handed | Right-handed | Left-handed |
| Helical diameter (nm) | 2.37 | 2.55 | 1.84 |
| Rise per base pair (nm) | 0.34 | 0.29 | 0.37 |
| Distance per complete turn (pitch) (nm) | 3.4 | 3.2 | 4.5 |
| Number of base pairs per complete turn | 10 | 11 | 12 |
| Topology of major groove | Wide, deep | Narrow, deep | Flat |
| Topology of minor groove | Narrow, shallow | Broad, shallow | Narrow, deep |

### 8.7.4 Ribonucleic Acid (RNA)

**Ribonucleic acid** (**RNA**) is a polymeric molecule essential in various biological roles in coding, decoding, regulation and expression of genes. RNA is single stranded and is unstable when compared to DNA (Figure 8.45).

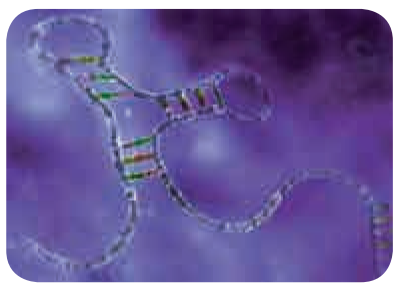


**Figure 8.45:** Structure of RNA

### 8.7.5 Types of RNA

- **mRNA (messenger RNA):** Single stranded, carries a copy of instructions for assembling amino acids into proteins. It is very unstable and comprises 5% of total RNA polymer. Prokaryotic mRNA (Polycistronic) carry coding sequences for many polypeptides. Eukaryotic mRNA (Monocistronic) contains information for only one polypeptide.
- **tRNA (transfer RNA):** Translates the code from mRNA and transfers amino acids to the ribosome to build proteins. It is highly folded into an elaborate 3D structure and comprises about 15% of total RNA. It is also called as **soluble RNA**.
- **rRNA (ribosomal RNA):** Single stranded, metabolically stable, make up the two subunits of ribosomes. It constitutes 80% of the total RNA. It is a polymer with varied length from 120–3000 nucleotides and gives ribosomes their shape. Genes for rRNA are highly conserved and employed for phylogenetic studies (Figure 8.46).

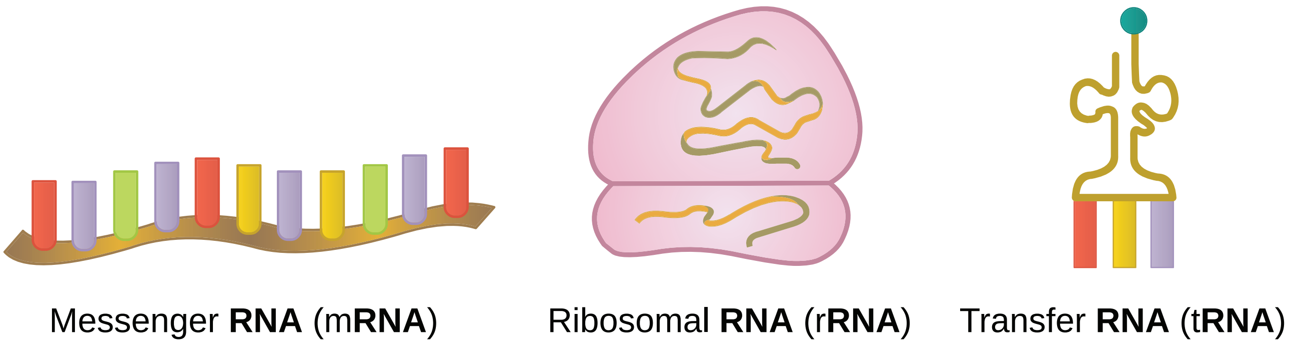



**Figure 8.46:** Types of RNA

## Summary

- **Cells** are composed of water, inorganic compounds and organic molecules. The biomolecules of the cells include carbohydrates, lipids, proteins, enzymes and nucleic acids.
- **Carbohydrates** include simple sugars (monosaccharides) and polysaccharides. Polysaccharide serve as storage forms of sugar and structural components of cell.
- **Lipids** are the principle components of cell membrane, and they serve as energy storage and signalling molecules.
- **Proteins** are polymers of 20 different amino acids, each of which has a distinct side chain with specific chemical properties. Each protein has a unique aminoacid sequence which determines its 3D structure.
- **Nucleic acids** are the principle information molecules of the cell. Both DNA and RNA are polymers of purine and pyrimidine nucleotides. Hydrogen bonding between complementary base pairs allows nucleic acids to direct their self replication.

## Evaluation

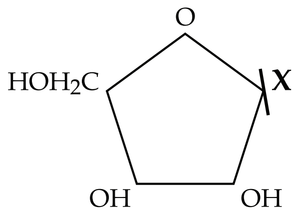
1. The most basic amino acid is
   a. Arginine
   b. Histidine
   c. Glycine
   d. Glutamine

2. An example of feedback inhibition is
   a. Cyanide action on cytochrome
   b. Sulpha drug on folic acid synthesiser bacteria
   c. Allosteric inhibition of hexokinase by glucose-6-phosphate
   d. The inhibition of succinic dehydrogenase by malonate

3. Enzymes that catalyse interconversion of optical, geometrical or positional isomers are
   a. Ligases
   b. Lyases
   c. Hydrolases
   d. Isomerases

4. Proteins perform many physiological functions. For example some functions as enzymes. One of the following represents an additional function that some proteins discharge:
   a. Antibiotics
   b. Pigment conferring colour to skin
   c. Pigments making colours of flowers
   d. Hormones

5. Given below is the diagrammatic representation of one of the categories of small molecular weight organic compounds in the living tissues. Identify the category shown & one blank component " X" in it




| Category | Compound |
|---|---|
| Cholesterol | Guanine |
| Amino acid | $NH_2$ |
| Nucleotide | Adenine |
| Nucleoside | Uracil |

6. Distinguish between nitrogenous base and a base found in inorganic chemistry.
7. What are the factors affecting the rate of enzyme reaction?
8. Briefly outline the classification of enzymes
9. Write the characteristic feature of DNA
10. Explain the structure and function of different types of RNA

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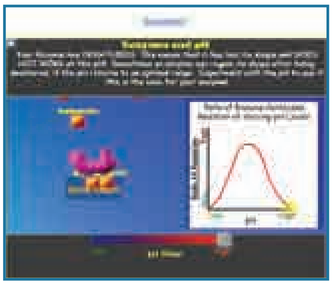
## ICT Corner

# ENZYMES

**Bio Catalyst** →



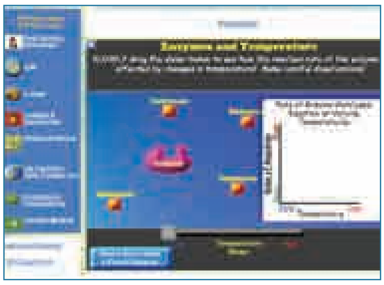
### Steps

- Scan the QR code
- Click Enzymatic
- Start a new game
- Select yes if you using touch screen mobile / tablet
- Tap or click here
- Click experiments

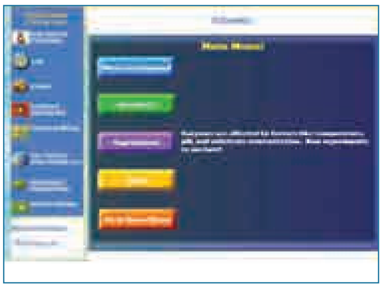
### Activity

- Move the slide to change temperature
- Go to next concept
- Try Quiz  after experiments

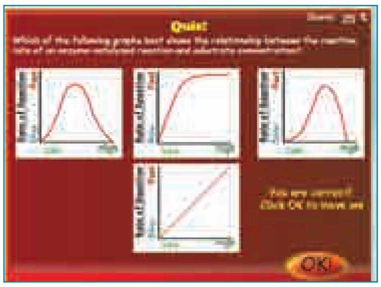
**Step 1**




**Step 3**



**Step 2**




**Step 4**

URL:

https://www.biomanbio.com/HTML5GamesandLabs/LifeChemgames/lifechem.html

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* Pictures are indicative only

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## Glossary

| | |
|---|---|
| **Acetyl CoA** | Small, water-soluble metabolite comprising an acetyl group linked to coenzyme A (CoA). |
| **Active site** | Region of an enzyme molecule where the substrate binds and undergoes a catalyzed reaction. |
| **Akinetes** | Thick walled, dormant, non motile asexual spores. |
| **Aleurone** | Outer layer of the endosperm |
| **Anamorph** | Asexual or imperfect state of fungi |
| **Anisogamy** | Fusion of morphologically and physiologically dissimilar gametes |
| **Apogamy** | Formation of sporophyte from the gametophytic tissue without the fusion of gametes. |
| **Apospory** | Development of the gametophyte from the sporophyte without the formation of spores |
| **Balausto** | Fleshy in dehiscent fruit |
| **Basal body** | Structure at the base of cilia and flagella from which microtubules forming the axoneme radiate |
| **Biosphere** | The region of earth on which life exist |
| **Buffer** | A solution of the acid and base form of a compound that undergoes little change in pH when small quantities of strong acid or base are added. |
| **Carcinogen** | Any chemical or physical agent that can cause cancer when cells or organism s are exposed to it. |
| **Chemotaxonomy** | Classification based on the biochemical constituents of plants |
| **Clades** | Group of species comprising common ancestor and its descendants |
| **Cladistics** | Methodology used to classify organisms into monophyletic group |
| **Codon** | Sequence of three nucleotides in DNA or mRNA that specifies a particular amino acid during protein synthesis; also called triplet |
| **Coenocytic condition** | Aseptate, multinucleate condition |
| **Dalton** | Unit of molecular mass approximately equal to the mass of a hydrogen atom (1.66 × 10–24 g) |
| **Endosperm** | Nutritive tissue for the embryo |
| **Endospore** | Thick walled, resting spores |
| **Eusporangiate** | Sporangium formed from a group of initials |
| **Fossil** | The remains or impression of plant or animal of the past geological age |
| **Gametophyte** | The haploid plant body |
| **Genome** | Complete set of genes in an organism |
| **Germ** | Protein rich embryo |

| | |
|---|---|
| **Heterospory** | Production of spores of different sizes: megaspores and microspores |
| **Karyogamy** | Fusion of nucleus |
| **Karyotype** | Number, sizes, and shapes of the entire set of metaphase chromosomes of a eukaryotic cell. |
| **Km** | A parameter that describes the affinity of an enzyme for its substrate and equals the substrate concentration that yields the half-maximal reaction rate; |
| **Leptosporangiate** | Sporangium formed from a single initial |
| **Merosity** | Number of parts per whorls |
| **Microgreens** | Young vegetable greens add flavour in culinary |
| **Monograph** | Complete account of a taxon of any rank |
| **Monosulcate** | Pollen grain with single furrow or pores |
| **Mycobank** | Online database documenting new mycological names |
| **Nucleoid** | Genetic material of bacterium |
| **Oogamy** | Fusion of morphologically and physiologically dissimilar gametes |
| **Parthenocarphy** | Fruit developed without fertilization |
| **Pendulous** | Hanging downward loosely or freely (like catkin) |
| **Petrifaction** | A process of fossil formation through infiltration of minerals over a long period |
| **pH** | A measure of the acidity or alkalinity of a solution defined as the negative logarithm of the hydrogen ion concentration in moles per liter |
| **Phylogeny** | Evolution of group of organisms |
| **Pistillode** | Sterile pistil |
| **Plasmogamy** | Fusion of cytoplasm |
| **Pluriocular** | An ovary with two or more locus |
| **Prophage** | The integrated phage DNA with host DNA |
| **Protologue** | Set of information associated with the scientific name of a taxon at its first valid publication containing the entire original material regarding the taxon |
| **Rachilla** | Central axis of a spikelet |
| **Sporophyte** | Diploid plant body |
| **Teloemorph** | Sexual or perfect state of the fungi |
| **Thallospores** | Asedual spores formed due to the fragmentation of hyphae |
| **Triplicate** | Pollen grain with three furrows or pores |
| **X-Ray crystallography** | Most commonly used technique for determining the three-dimensional structure of macromolecules (particularly proteins and nucleic acids) by passing x-rays |
| **Zoospore** | Motile, asexual spores |
| **Zygospore** | Thick walled diploid resting spores |

## English – Tamil Terminology

| | |
|---|---|
| Acropetal succession (arrangement) | நுனி நோக்கிய வரிசை |
| Aggregatte fruit | திரள்கனி |
| Akinetes | உறக்க நகராவித்து |
| Anamorph | பாலிலாநிலை |
| Anisogamy | சமமற்ற கேமீட்களின் இணைவு |
| Anthrophytes | பூக்கும் தாவரங்களின் முன்னோடிகள் |
| Apogamy | பாலிணைவின்மை |
| Apospory | குன்றலில்லா வித்துத்தன்மை |
| Arbitary marker | தன்னிச்சையான குறிப்பான் |
| Basipetal succession | அடி நோக்கிய வரிசை |
| Biosphere | உயிர்க்கோளம் |
| Buttress root | பலகை வேர் |
| Centrifugal | மையம் விலகியது |
| Centripetal | மையம் நோக்கியது |
| Cladogram | கிளை வரைபடம் |
| Coenocytic | பல்உட்கரு நிலை |
| Conjugation | இணைவு |
| Cotyledons | விதையிலைகள் |
| Dry dehiscent fruit | உலர் வெடிகனி |
| Dry indehiscent fruit | உலர் வெடியாக்கனி |
| Embryo | கரு |
| Endosperm | கருவூண்திசு |
| Endospores | அகவித்துகள் |
| Eukaryote | உண்மை உட்கரு உயிரி |
| Eusporangiate | உண்மை வித்தகத்தன்மை |
| Fossil | தொல்லுயிரெச்சம் |
| Funicle | சூல்காம்பு |
| Gametophyte | கேமீட்டக தாவரம் |
| Gene marker | மரபணு குறிப்பான் |
| Genome | மரபணுத் தொகுப்பு |
| Geocarpic fruit | புவிபுதை கனி/நிலத்தகத்துக் கனி |
| Geophytes | நிலத்தகத்துத் தூண்சேர் தாவரம் |
| Gynobasic | சூற்பை அடி சூலகத்தண்டு |
| Heterospory | மாற்று வித்தகத்தன்மை |
| Homeostasis | சமச்சீர் நிலை |
| Hydrochory | நீர்மூலம் பரவுதல் |
| Indeterminate | வரம்பற்ற வளர்ச்சி |
| Irritability | உறுத்துணர்ச்சி |
| Isogamy | ஒத்த கேமீட்களின் இணைவு |
| Karyogamy | உட்கரு இணைவு |
| Karyokinesis | காரியோகைனசிஸ் |
| Leaf primodium | இலைத்தோற்றுவி |
| Legume / Pod | விதைப்பை |

| | |
|---|---|
| Leptosporangiate | மெலி வித்தகத்தன்மை |
| Maturation promoting factor (MPF) | முதிர்ச்சியை ஊக்கப்படுத்தும் காரணி |
| Merosity | எண்ணிக்கை அமைவு |
| Metabolism | வளர்சிதைமாற்றம் |
| Middle Lamella | இடைமென் அடுக்கு |
| Monograph | தனிக்கட்டுரை |
| Multiple fruit | கூட்டுக்கனி |
| Mycobank | பூஞ்சை வங்கி |
| Nuclear envelope | நியூக்ளியர் உறை |
| Nuclear organizer | நியுக்ளியோலார் அமைப்பான்கள் |
| Nucleoid | உட்கரு ஒத்த அமைப்பு |
| Oogamy | முட்டை கருவுறுதல் |
| Pendulous | தொங்குகின்ற |
| Pericarp | கனி உறை |
| Petrification | கல்லாதல் |
| Pili or Fimbriae | நுண் சிலும்புகள் |
| Pistillode | மலட்டு சூலகம் |
| Plasmogamy | சைட்டோபிளாச இணைவு |
| Plumule | முளைக்குருத்து |
| Plurilocular | பல்லறை சூற்பை |
| Polymorphism | பலபடிவுடமை |
| Primary adapter | முதன்மை மாற்றி |
| Probe | ஆய்வி |
| Prokaryote | தொல்லுட்கரு உயிரி |
| Prophage | ஃபாஜ் முன்னோடி |
| Rachilla | சிறுகதிரின் மையஅச்சு |
| Radicle | முளை வேர் |
| Restriction site | வரையறு தளம் |
| Seed | விதை |
| Seed coat | விதை உறை |
| Serotaxonomy | ஊநீர் வகைப்பாட்டியல் |
| Sporophyte | வித்தகத்தாவரம் |
| Synaptonemal complex | சைனாப்டினிமல் தொகுதி |
| Systematics | முறைப்பாட்டு தாவரவியல் |
| Tandem repeat | ஒருசெயல நிகழும் மாறிகள் |
| Taxon | வகைப்பாட்டுத் தொகுதி |
| Telomorph | பால்நிலை |
| Thallospores | உடல வித்துகள் |
| Transduction | மரபணு ஊடுகடத்தல் |
| Transformation | மரபணு மாற்றம் |
| True fruit | மெய்க்கனி |
| Zoospore | இயங்கு வித்து |
| Zygospore | உறக்க கருமுட்டை |

# Competitive Examination Questions

## Unit – 1 Diversity of Living World

1. Which of the following are found in extreme saline conditions? (NEET-2017)
   **a. Archaebacteria**
   b. Eubacteria
   c. Cyanobacteria
   d. Mycobacteria

2. Select the mismatch (NEET – 2017)

| | |
|---|---|
| a. *Frankia* | *Alnus* |
| **b. *Rhodospirillum*** | ***Mycorrhiza*** |
| c. *Anabaena* | *Nitrogen fixer* |
| d. *Rhizobium* | *Alfalfa* |

3. Which among the following are the smallest living cells, known without a definite cell wall, pathogenic to plants as well as animals and can survive without oxygen? (NEET – 2017)
   a. *Bacillus* b. *Pseudomonas*
   **c. Mycoplasma** d. *Nostoc*

4. Read the following statements ( A to E ) and select the option with all correct statements (AIPMT – 2015)
   A. Mosses and Lichens are the first organisms to colonise a bare rock.
   B. *Selaginella* is a homosporous pteridophyte.
   C. Coralloid roots in *Cycas* have VAM.
   D. Main plant body in bryophytes is gametophytic, whereas in pteridophytes it is sporophytic.
   E. In gymnosperms, male and female gametophytes are present within sporangia located on sporophyte.
   a. B, C and E
   b. A, C and D
   c. B, C and D
   **d. A, D and E**

5. An example of colonial alga is (NEET – 2017)
   a. *Chlorella* **b. *Volvox***
   c. *Ulothrix* d. *Spirogyra*

6. Five kingdom system of classification suggested by R.H. Whittaker is not based on (AIPMT – 2014)
   **a. Presence or absence of a well defined nucleus**
   b. Mode of reproduction
   c. Mode of nutrition
   d. Complexity of body organisation

7. Mycorrhizae are the example of (NEET – 2017)
   ` a. Fungitasis c. Amensalism
   b. Antibiosis **d. Mutualism**

8. Which of the following shows coiled RNA strand and capsomeres? (AIPMT – 2014)
   a. Polio virus
   **b. Tobacco mosaic virus**
   c. Measles virus
   d. Retrovirus

9. Viroids differ from viruses in having : (NEET – 2017)
   a. DNA molecules with protein coat
   b. DNA molecules without protein coat
   c. RNA molecules with protein coat
   **d. RNA molecules without protein coat**

10. Select the mismatch (NEET – 2017)

| | | |
|---|---|---|
| **a. *Pinus*** | **—** | **Dioecious** |
| b. Cycas | — | Dioecious |
| c. *Salvinia* | — | Heterosporous |
| d. *Equisetum* | — | Homosporous |

11. Life cycle of *Ectocarpus* and *Fucus* respectively are (NEET – 2017)
    a. Haplontic, Diplontic
    b. Diplontic, Haplodiplontic
    **c. Haplodiplontic, Diplontic**
    d. Haplodiplontic, Halplontic

12. Zygote meiosis is characterisitic of (NEET – 2017)
    a. *Marchantia* b. *Fucus*
    c. *Funaria* **d. *Chlamydomonas***

13. Which of the following is correctly matched for the product produced by them? (NEET – 2017)
    a. *Acetobacter acetic* : Antibiotics
    b. *Methanobacterium* : Lactic acid
    c. *Penicillium notatum* : Acetic acid
    **d. *Saccharomyces cerevisiae* : Ethanol**

14. Which of the following components provides sticky character to the bacterial cell? (NEET – 2017)
    a. Cell wall b. Nuclear membrane
    c. Plasma membrane **d. Glycocalyx**

15. Which of the following statements is wrong for viroids? (NEET – 2016)
    a. They lack a protein coat
    b. They are smaller than viruses
    c. They causes infections
    **d. Their RNA is a high molecular weigh**t

16. In bryophytes and pteridophytes, transport of male gametes require (NEET – 2016)
    a. Wind b. Insects
    c. Birds **d. Water**

17. How many organisms in the list below are autotrophs? (AIPMT Mains 2012)
    *Lactobacillus, Nostoc, Chara, Nitrosomonas, Nitrobacter, Streptomyces, Saccharomyces, Trypanosoma, Porphyra, Wolffia*
    a. Four b. Five
    **c. Six** d. Three

18. Which of the following would appear as the pioneer organisms on bare rocks? (NEET – 2016)
    **a. Lichens** b. Liverworts
    c. Mosses d. Green algae

19. Monoecious plant of *Chara* shows occurrence of (NEET-2013)
    a. Stamen and carpel on the same plant
    b. Upper antheridium and lower oogonium on the same plant
    **c. Upper oogonium and lower antheridium on the same plant**
    d. Antheridiophore and archegoniophore on the same plant

20. Read the following five statement (A-E) and answer as asked next to them (AIPMT Prelims – 2012)
    a. In *Equisetum*, the female gametophyte is retained on the parent sporophyte
    b. In *Ginkgo*, male gametophyte is not independent
    c. The sporophyte in *Riccia* is more developed than that in *Polytrichum*
    d. Sexual reproduction in *Volvox* is isogamous
    e. The spores of slime moulds lack cell walls

    How many of the above statement are correct? (AIPMT Prelims – 2012)
    a. Two b. Three
    c. Four **d. One**

21 One of the major components of cell wall of most fungi is (NEET – 2016)
    **a. Chitin** b. Peptidoglycan
    c. Cellulose d. Hemicellulose

22. Which one of the following statements is wrong? (NEET – 2016)
    a. Cyanobacteria are also called blue-green algae
    b. Golden algae are also called desmids
    **c. Eubacteria are also called false bacteria**
    d. Phycomycetes are also called algal fungi

23. Flagellated male gametes are present in all the three of which one of the following sets? (AIPMT Prelims – 2007
    **a. *Riccia, Dryopteris* and *Cycas***
    b. *Anthoceros, Funaria* and *Spirogyra*
    c. *Zygnema, Saprolegnia* and *Hydrilla*
    d. *Fucus, Marsilea* and *Calotropis*

24. Ectophloic siphonostele is found in (AIPMT Prelims – 2005)
    a. *Adiantum* and Cucurbitaceae
    **b. *Osmunda* and *Equisetum***
    c. *Marsilea* and *Botrychium*
    d. *Dicksonia* and maiden hair fern

25. Which part of the tobacco plant is infected by *Meloidogyne incognita*? (NEET – 2016)
    a. Flower    b. Leaf
    c. Stem    **d. Root**

26. Select the correct statement (NEET – 2016)
    a. Gymnosperms are both homosporous and heterosporous
    b *Salvinia, Ginkgo* and *Pinus* all are gymnosperms
    **c. *Sequoia* is one of the tallest trees**
    d. The leaves of gymnosperms are not well adapted to extremes of climate

27. Seed formation without fertilization in flowering plants involves the process of (NEET – 2016)
    a. Sporulation
    b. Budding
    c. Somatic hybridization
    **d. Apomixis**

28. Chrysophytes, Euglenoids, Dinoflagellates and Slime moulds are included in the kingdom (NEET – 2016)
    a. Animalia    **b, Monera**
    c. Protista    d. Fungi

29. The primitive prokaryotes responsible for the production of biogas from the dung of ruminant animals, include the (NEET – 2016)
    a. Halophiles    b. Thermoacidophiles
    **c. Methanogens**    d. Eubacteria

## Unit – 2 Plant Morphology and Taxonomy of Angiosperm

1. Leaves become modified into spines in [AIPMT-2015]
   a. Silk Cotton    **b. *Opuntia***
   c. Pea    d. Onion

2. Keel is the characteristic feature of flower of [AIPMT-2015]
   a. Tomato    b. Tulip
   **c. *Indigofera***    d. *Aloe*

3. Perigynous flowers are found in [AIPMT-2015]
   **a. Rose**    b. Guava
   c. Cucumber    d. China rose

4. Which one of the following statements is correct [AIPMT-2014]
   a. The seed in grasses is not endospermic
   b. Mango is a parthenocarpic fruit

**c. A proteinaceous aleurone layer is present in maize grain**
d. A sterile pistil is called a staminode

5. An example of edible underground stem is [AIPMT-2014]
   a. Carrot b. Groundnut
   c. Sweet potato **d. Potato**

6. Placenta and pericarp are both edible portions in [AIPMT-2014]
   a. Apple b. Banana
   **c. Tomato** d. Potato

7. When the margins of sepals or petals overlap one another without any particular direction, the condition is termed as [AIPMT-2014]
   a. Vexillary **b. Imbricate**
   c. Twisted d. Valvate

8. An aggregate fruit is one which develops from [AIPMT-2014]
   a. Multicarpellary syncarpous gynoecium
   **b. Multicarpellary apocarpous gynoecium**
   c. Complete inflorescence
   d. Multicarpellary superior ovary

9. Non-albuminous seed is produced in [AIPMT-2014]
   a. Maize b. Castor
   c. Wheat **d. Pea**

10. Seed coat is not thin, membranous in [NEET-2013]
    **a. Coconut** b. Groundnut
    c. Gram d. Maize

11. In china rose the flower are [NEET-2013]
    a. Actinomorphic. Epigynous with valvate aestivation
    b. Zygomorphic, hypogynous with imbricate aestivation
    c. Zygomorphic, epigynous with twisted aestivation
    **d. Actinomorphic, hypogynous with twisted aestivation**

12. Placentation in tomato and lemon is [AIPMT Prelims-2012]
    a. Marginal **b. Axile**
    c. Parietal d. Free central

13. Vexillary aestivation is characteristic of the family [AIPMT Prelims-2012]
    a. Solanaceae b. Brassicaceae
    **c. Fabaceae** d. Asteraceae

14. Phyllode is present in [AIPMT Prelims-2012]
    **a. Australian *Acacia*** b. *Opuntia*
    c. *Asparagus* d. *Euphorbia*

15. How many plants in the list given below have composite fruits that develop from an inflorescence? Walnut, poppy, radish, pineapple, apple, tomato. [AIPMT Prelims-2012]
    a. Two **b. Three**
    c. Four d. Five

16. Cymose inflorescence is present in [AIPMT Prelims-2012]
    a. *Trifolium* b. *Brassica*
    **c. *Solanum*** d. *Sesbania*

17. Which one of the following organism is correctly matched with its three characteristics? [AIPMT Mains -2012]
    a. Pea : C3 pathway, Endospermic seed, Vexillary aestivation
    b. Tomato : Twisted aestivation, Axile placentation, Berry
    c. Onion: Bulb, Imbricate aestivation, Axile placentation
    **d. Maize : C3 pathway, Closed vascular bundles, scutellum**

18. How many plants in the list given below have marginal placentation?
Mustard, Gram, Tulip, *Asparagus,* Arhar, sun hemp, Chilli, *Colchicine,* Onion, Moong, Pea, Tobacco, Lupin [AIPMT Mains -2012]
a. Four b. Five
**c. Six** d. Three

19. The Eyes of the potato tuber are [AIPMT Prelims-2011]
**a. Axillary buds** b. Root buds
c. Flower buds d. Shoot buds

20. Which one of the following statements is correct? [AIPMT Prelims-2011]
a. Flower of tulip is a modified shoot
b. In tomato, fruit is a capsule
c. Seeds of orchids have oil – rich endosperm
**d. Placentation in primrose is basal**

21. A drup develops in [AIPMT Prelims-2011]
a. Tomato **b. Mango**
c. Wheat d. Pea

## Unit 3 Cell biology and Biomolecules

1. Who invented electron microscope? (2010 AIIMS, 2008 JIPMER)
a. Janssen b. Edison
**c. Knoll and Ruska** d. Landsteiner

2. Specific proteins responsible for the flow of materials and information into the cell are called (2009 AIIMS)
a. Membrane receptors
**b. carrier proteins**
c. integeral proteins
d. none of these

3. Omnis-cellula-e-cellula was given by (2007 AIIMS)
**a. Virchow** b. Hooke
c. Leeuwenhoek d. Robert Brown

4. Which of the following is responsible for the mechanical support, protein synthesis and enzyme transport (2007 AIIMS)
a. cell membrane
b. mitochondria
c. dictyosomes
**d. endoplasmic reticulum**

5. Genes present in the cytoplasm of eukaryotic cells are found in (2006 AIIMS)
**a. mitochondria and inherited via egg cytoplasm**
b. lysosomes and peroxisomes
c. Golgi bodies and smooth endoplasmic reticulum
d. Plastids inherited via male gametes

6. In which one the following would you expect to find glyoxysomes(2005 AIIMS)
a. Endosperm of wheat
**b. endosperm of castor**
c. Palisade cells in leaf
d. Root hairs

7. A quantosome is present in (JIPMER 2012)
a. Mitochondria **b. Chloroplast**
c. Golgi bodies d. ER

8. In mitochondria the enzyme cytochrome oxidase is present in (2012 JIPMER)
a. Outer mitochondrial membrane
**b. inner mitochondrial membrane**
c. Stroma d. Grana

9. Which organelle is present in higher number in secretory cell (2008 JIPMER)
a. Mitochondria b. Chloroplast
c. Nucleus **d. Dictyosomes**

10. Major site for the synthesis of lipids (2013 NEET)
a. Rough ER **b. smooth ER**
c. Centriole d. Lysosome

11. Golgi complex plays a major role in. (2013 NEET)
    **a. post translational modification of proteins and glycosidation of lipids**
    b. translation of proteins
    c. Transcription of proteins
    d. Synthesis of lipid

12. Main arena of various types of activities of a cell is (2010 AIPMT)
    a. Nucleus b. Mitochondria
    **c. Cytoplasm** d. Chloroplast

13. The thylakoids in chloroplast are arranged in (2005 JIPMER)
    a. regular rings b. linear array
    c. diagonal direction **d. stacked discs**

14. Sequences of which of the following is used to know the phylogeny (2002 JIPMER)
    a. mRNA **b. rRNA** c. tRNA d. Hn RNA

15. Structures between two adjacent cells which is an effective transport pathway- (2010 AIPMT)
    **a. Plasmodesmata**
    b. Middle lamella
    c. Secondary wall layer
    d. Primary wall layer

16. In active transport carrier proteins are used, which use energy in the form of ATP to
    a. transport molecules against concentration gradient of cell wall
    b. transport molecules along concentration gradient of cell membrane
    **c. transport molecules against concentration gradient of cell membrane**
    d. transport molecules along concentration gradient of cell wall

17. The main organelle involved in modification and routing of newly synthesised protein to their destinations is (AIPMT 2005)
    a. Mitochondria
    b. Glyoxysomes
    c. Spherosomes
    **d. Endoplasmic reticulum**

18. Algae have cell wall made up of (AIPMT 2010)
    **a. Cellulose, galactans and mannans**
    b. Cellulose, chitin and glucan
    c. Cellulose, Mannan and peptidoglycan
    d. Muramic acid and galactans

# BOTANICAL NAMES AND COMMON NAMES

| S.No | Botanical name | Common name | Tamil name |
|---|---|---|---|
| 1 | *Abrus precatorius* | Crab's eye | குன்றிமணி |
| 2 | *Acacia nilotica* | Babul tree | கருவேலம் |
| 3 | *Acalypha indica* | Indian Acalypha | குப்பைமேனி |
| 4 | *Achyranthes aspera* | Chaff flower | நாயுருவி |
| 5 | *Albizia lebbeck* | Indian siris | வாகை |
| 6 | *Allium cepa* | Onion | வெங்காயம் |
| 7 | *Allium sativum* | Garlic | வெள்ளைப்பூண்டு |
| 8 | *Aloe vera* | Indian aloe | சோற்றுக்கற்றாழை |
| 9 | *Alstonia scholaris* | Devilwood | ஏழிலைப்பாலை |
| 10 | *Amorphophallus paeoniifolius* | Elephant foot yam | கருணைக் கிழங்கு |
| 11 | *Argemone mexicana* | Mexican poppy | குடியோட்டிப் பூண்டு |
| 12 | *Areca catechu* | Betel nut | பாக்கு / கமுகு |
| 13 | *Avicennia marina* | White mangrove | வெள்ளை அலையாற்றி |
| 14 | *Azadirachta indica* | Neem | வேம்பு |
| 15 | *Beta vulgaris* | Beetroot | பீட்ருட் |
| 16 | *Bombax ceiba* | White Silk cotton | இலவம் பஞ்சு |
| 17 | *Bambosa bambos* | Bamboo | மூங்கில் |
| 18 | *Borassus flabellifer* | Palmyra palm | பனை |
| 19 | *Bougainvillea* | Paper flower | காகிதப்பூ |
| 20 | *Brassica juncea* | Mustard | கடுகு |
| 21 | *Brassica oleracea var. botrytis* | Cauliflower | காலிஃபிளவர் |
| 22 | *Brassica oleracea var. capitata* | Cabbage | முட்டைக்கோசு |
| 23 | *Caesalpinia pulcherrima* | Peacock flower | மயிற்கொன்றை |
| 24 | *Calotropis gigantea* | Giant milkweed | எருக்கு |
| 25 | *Canna indica* | Canna | கல்வாழை |
| 26 | *Carica papaya* | Papaya | பப்பாளி |
| 27 | *Cassia auriculata* | Avaram | ஆவாரை |
| 28 | *Cassia fistula* | Indian laburnum | கொன்றை |
| 29 | *Casuarina equisetifolia* | Whistling pine | சவுக்கு |

| | | | |
|---|---|---|---|
| 30 | *Ceiba pentandra* | Red silk cotton | செவ்விலவ மரம் |
| 31 | *Centella asiatica* | Indian penny wort | வல்லாரை |
| 32 | *Chrysanthemum indicum* | Chrysanthemum | சாமந்தி |
| 33 | *Cinnamomum zeylanicum* | Cinnamon | பட்டை |
| 34 | *Cocos nucifera* | Coconut | தென்னை |
| 35 | *Coffea arabica* | Coffee plant | காஃபி தாவரம் |
| 36 | *Colocasia esculenta* | Cocoyam | சேனைக் கிழங்கு |
| 37 | *Coriandrum sativum.* | Coriander | கொத்துமல்லி |
| 38 | *Corypha umbraculifera* | Talipot palm | தாழிப்பனை |
| 39 | *Couroupita guianensis* | Cannonball tree | நாகலிங்கமரம் |
| 40 | *Crotalaria retusa* | Rattle weed | கிலுகிலுப்பை |
| 41 | *Cucumis sativus* | Cucumber | வெள்ளரி |
| 42 | *Curcuma amada* | Mango ginger | மா இஞ்சி |
| 43 | *Cuscuta reflexa* | Dodder plant | அம்மையார் கூந்தல் |
| 44 | *Daucus carota* | Carrot | காரட் |
| 45 | *Delonix regia* | Gulmohar,flame tree. | செம்மயிற்கொன்றை. |
| 46 | *Dioscorea bulbifera* | Potato yam | கொடிக்கிழங்கு |
| 47 | *Dolichos biflorus* | Horsegram | கொள்ளு |
| 48 | *Eugenia jambolana* | Jamun | நாவல் |
| 49 | *Ficus benghalensis* | Banyan. | ஆலமரம் |
| 50 | *Ficus carica* | Common fig | சீமை அத்தி |
| 51 | *Ficus racemosa* | Indian fig | அத்தி |
| 52 | *Ficus religiosa* | Peepal. | அரச மரம் |
| 53 | *Gloriosa superba* | Malabar glory lilly | செங்காந்தள் |
| 54 | *Gossypium herbaceum* | Cotton | பருத்தி |
| 55 | *Hibiscus rosa-sinensis* | Shoe flower, China rose. | செம்பருத்தி |
| 56 | *Hiptage benghalensis* | Clustered hiptage | மாதவிக்கொடி |
| 57 | *Hordeum vulgare.* | Barley | பார்லி |
| 58 | *Jasminum officinale* | Jasmine | மல்லிகை |
| 59 | *Mangifera indica* | Mango | மா |
| 60 | *Mimosa pudica* | Touch me not plant | தொட்டாற்சுருங்கி |
| 61 | *Mitrogyna parvifolia* | Kadamb | கடம்பு |
| 62 | *Moringa oleifera* | Drumstick | முருங்கை |
| 63 | *Murraya koenigii* | Curry leaf | கறிவேப்பிலை |

| | | | |
|---|---|---|---|
| 64 | *Musa paradisiaca* | Banana | வாழை |
| 65 | *Nelumbo nucifera* | Indian lotus | தாமரை |
| 66 | *Neolamarckia cadamba* | Ven Kadambu | வெண்கடம்ப மரம் |
| 67 | *Nerium oleander* | Oleander | அரளி |
| 68 | *Numphaea rubra* | Red Water lilly | செவ்வல்லி |
| 69 | *Nymphaea nouchali* | Blue water lilly | நீல ஆம்பல் |
| 70 | *Nymphaea pubescens* | White water lilly | வெள்ளை அல்லி, நெய்தல் |
| 71 | *Ocimum sanctum* | Tulsi | துளசி |
| 72 | *Ocimum tenuiflorum* | Tulsi | கருந்துளசி |
| 73 | *Oryza sativa* | Paddy, Rice | நெல் |
| 74 | *Phaseolus vulgaris.* | Beans | பீன்ஸ் |
| 75 | *Physalis angulata* | Balloon cherry | சொடக்குத்தக்காளி |
| 76 | *Piper nigrum* | Pepper | மிளகு |
| 77 | *Prosopis juliflora* | Honey mesquite | சீமைக்கருவேலம் |
| 78 | *Raphanus sativus* | Radish | முள்ளங்கி |
| 79 | *Saraca indica* | Ashoka | அசோக மரம் |
| 80 | *Solanum nigrum* | Black night shade | மணித்தக்காளி |
| 81 | *Solanum lycopersicum* | Tomato | தக்காளி |
| 82 | *Solanum melongena* | Brinjal | கத்திரி |
| 83 | *Solanum tuberosum* | Potato | உருளை |
| 84 | *Sorghum bicolor* | Sorghum | சோளம் |
| 85 | *Theobroma cacao* | Cocoa tree | கொக்கோ மரம் |
| 86 | *Triticum aestivum* | Wheat | கோதுமை |
| 87 | *Vitis vinifera* | Grapes | திராட்சை |
| 88 | *Zea mays* | Maize, corn | மக்காச்சோளம் |
| 89 | *Zingiber officinale* | Ginger | இஞ்சி |
| 90 | *Zizyphus jujuba* | Jujube | இலந்தை |

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