The learner will be able to,

- Explore the parts of the flowering plants
- Differentiate vegetative morphology and reproductive morphology
- Compare various root systems and their modifications
- Understand the stem modifications and functions
- Interpret the structure of leaf and functions of leaf

**Learning Objectives**

The study of various external features of the organism is known as **morphology**. **Plant morphology** also known as **external morphology** deals with the study of shape, size and structure of plants and their parts (roots, stems, leaves, flowers, fruits and seeds). Study of morphology is important in taxonomy. Morphological features are important in determining productivity of crops. Morphological characters indicate the specific habitats of living as well as the fossil plants and help to correlate the distribution in space and time of fossil plants. Morphological features are also significant for phylogeny.

**Plant Morphology can be studied under two broad categories:**

A. **Vegetative morphology** - It includes shoot system and root system

B. **Reproductive morphology** - It includes Flower/inflorescence, Fruit and Seed

A. **Vegetative morphology**

**Vegetative morphology** deals with the study of shape, size and structure of plants and their parts roots, stems and leaves. To understand the vegetative morphology the following important components are to be studied. They are, 1) Habit, 2) Habitat and 3) Lifespan.
3.1 Habit
The general form of a plant is referred to as habit. Based on habit plants are classified into herbs, shrubs, climbers (vines) and trees.

I. Herbs
Herbs are soft stemmed plants with less wood or no wood. According to the duration of their life they may be classified as annuals, biennials and perennials. Perennial herbs having a bulb, corm, rhizome or tuber as the underground stem are termed as geophytes. Example: Phyllanthus amarus, Cleome viscosa.

II. Shrubs
A shrub is a perennial, woody plant with several main stems arising from the ground level. Example: Hibiscus

III. Climbers (Vine)
An elongated weak stem generally supported by means of climbing devices are called Climbers (vines) which may be annual or perennial, herbaceous or woody. Liana is a vine that is perennial and woody. Liana’s are major components in the tree canopy layer of some tropical forests. Example: Ventilago, Entada, Bougainvillea.

IV. Trees
A tree is a stout, tall, perennial, woody plant having one main stem called trunk with many lateral branches. Example: mango, sapota, jack, fig, teak. If the trunk remains unbranched it is said to be caudex. Example: Palmyra, coconut.

3.2 Plant habitat
Depending upon where plants grow habitats may be classified into major categories: I. Terrestrial and II. Aquatic.

I. Terrestrial
Plants growing on land are called terrestrial plants. The following table illustrate the types of terrestrial plants classified based on their environmental adaptation.

II. Aquatic
Plants that are living in water environment are called aquatic plants or hydrophytes.

3.3 Life Span
Based on life span plants are classified into 3 types. They are annual, biennial and perennial
consisting of an axis with an underground “Root system” and an aerial “Shoot System”. The shoot system has a stem, branches and leaves. The root system consists of root and its lateral branches.

### I. Annual (Therophyte or Ephemerals)
A plant that completes its life cycle in one growing season. Example: Peas, maize, water melon, groundnut, sunflower, rice and so on.

### II. Biennial
A plant that lives for two seasons, growing vegetatively during the first season and flowering and fruiting during the second season. Example: Onion, Lettuce, Fennel, Carrot, Radish, Cabbage and Spinach.

### III. Perennial (Geophyte)
A plant that grows for many years that flowers and set fruits for several seasons during the life span. When they bear fruits every year, they are called polycarpic. Example: mango, sapota. Some plants produce flowers and fruits only once and die after a vegetative growth of several years. These plants are called monocarpic. Example: Bamboo, Agave, Musa, Talipot palm.

### 3.4 Parts of a flowering plant
Flowering plants are called “Angiosperms” or Magnoliophytes. They are sporophytes

### 3.5 Root System
The root is non-green, cylindrical descending axis of the plant that usually grows into the soil (positively geotropic). It develops from the radicle which is the first structure that comes out when a seed is placed in the soil. Root is responsible for absorption of water and nutrients and anchoring the plant.
I. Characteristic features

- Root is the descending portion of the plant axis.
- Generally non-green in colour as it lacks chlorophyll.
- Does not possess nodes, internodes and buds (Exception in sweet potato and members of Rutaceae, roots bear buds which help in vegetative propagation)
- It bears root hairs (To absorb water and minerals from the soil)
- It is positively geotropic and negatively phototropic in nature.

II. Regions of root

Root tip is covered by a dome shaped parenchymatous cells called root cap. It protects the meristematic cells in the apex. In Pandanus multiple root cap is present. In Pistia instead of root cap root pocket is present. A few millimeters above the root cap the following three distinct zones have been classified based on their meristematic activity.

1. Meristematic Zone
2. Zone of Elongation
3. Zone of Maturation

![Figure 3.2: Regions of root](image)

<table>
<thead>
<tr>
<th>Feature</th>
<th>1. Meristematic Zone</th>
<th>2. Zone of Elongation</th>
<th>3. Zone of Maturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>It lies just above the root cap</td>
<td>It lies just above the meristematic zone</td>
<td>It lies above the zone of elongation.</td>
</tr>
<tr>
<td>Types of cells</td>
<td>Meristematic cells, actively divide and continuously increase in number</td>
<td>Elongated cells</td>
<td>Mature differentiated cells</td>
</tr>
<tr>
<td>Functions</td>
<td>This is the main growing tip of the root</td>
<td>The cells increase the length and cause enlargement of the root.</td>
<td>The cells differentiate into various tissues like epidermis, cortex and vascular bundles. It also produces root hairs which absorb water and minerals from the soil</td>
</tr>
</tbody>
</table>
3.5.1 Types of root

Tap root system  
Fibrous root system

Figure 3.3: Types of root system

I. Tap root system

Primary root is the direct prolongation of the radicle. When the primary root persists and continues to grow as in dicotyledons, it forms the main root of the plant and is called the tap root. Tap root produces lateral roots that further branches into finer roots. Lateral roots along with its branches together called as secondary roots.

II. Adventitious root system

Root developing from any part of the plant other than radicle is called adventitious root. It may develop from the base of the stem or nodes or internodes. Example: Monstera deliciosa, Ficus benghalensis, Piper nigrum. In most of the monocots the primary root of the seedling is short lived and lateral roots arise from various regions of the plant body. These are bunch of thread-like roots equal in size which are collectively called fibrous root system generally found in grasses. Example: Oryza sativa, Eleusine coracana, Pennisetum americanum.

III. Functions of root

Root performs two kinds of functions namely primary and secondary functions.

Primary function
1. Absorb water and minerals from soil.
2. Help to anchor the plant firmly in the soil.

Secondary function
In some plants roots perform additional functions. These are called secondary functions. To perform additional functions, these roots are modified in their structure.

Root modification

- Tap root modification
  - Storage
    - i. Conical
    - ii. Fusiform
    - iii. Napiform
  - Breathing root
    - i. Tuberous root
    - ii. Fasciculated root
    - iii. Nodulose root
    - iv. Moniliform root
    - v. Annulated root

- Adventitious root modification
  - Storage
  - Mechanical support
    - i. Prop root
    - ii. Stilt root
    - iii. Climbing root
    - iv. Buttress root
  - Vital function
    - i. Epiphytic root
    - ii. Foliar root
    - iii. Sucking root
    - iv. Photosynthetic root
3.5.2 Modifications of root

I. Tap root modification

a. Storage roots

1. Conical Root
These are cone like, broad at the base and gradually tapering towards the apex. Example: *Daucus carota*.

2. Fusiform root
These roots are swollen in the middle and tapering towards both ends. Example: *Raphanus sativus*.

3. Napiform root
It is very broad and suddenly tapers like a tail at the apex. Example: *Beta vulgaris*.

b. Breathing root
Some mangrove plants like *Avicennia*, *Rhizophora*, *Bruguiera* develop special kinds of roots (Negatively geotropic) for respiration because the soil becomes saturated with water and aeration is very poor. They have a large number of breathing pores or pneumatophores for exchange of gases.

II. Adventitious root modification

a. Storage roots

1. Tuberous root
These roots are swollen without any definite shape. Tuberous roots are produced singly and not in clusters. Example: *Ipomoea batatas*.

2. Fasciculated root
These roots are in cluster from the base of the stem. Example: *Dahlia, Asparagus, Ruellia*.

3. Nodulose root
In this type of roots swelling occurs only near the tips. Example: *Maranta* (arrow root) *Curcuma amada* (mango ginger), *Curcuma longa* (turmeric).

4. Moniliform or Beaded root
These roots swell at frequent intervals giving them a beaded appearance. Example: *Vitis, Portulaca, Momordica* Indian spinach.

5. Annulated root
These roots have a series of ring-like swellings on their surface at regular intervals. Example: *Ipecac (Psychotria)*

b. Mechanical support

1. Prop (Pillar) root
These roots grow vertically downward from the lateral branches into the soil.
Example: *Ficus benghalensis* (banyan tree), Indian rubber.

2. **Stilt (Brace) root**
   These are thick roots growing obliquely from the basal nodes of the main stem. These provide mechanical support. Example: *Saccharum officinarum, Zeamays* and *Pandanus, Rhizophora*.

3. **Climbing (clasping or clinging) roots**
   These roots are produced from the nodes of the stem which attach themselves to the support and help in climbing. To ensure a foothold on the support they secrete a sticky juice which dries up in air, attaching the roots to the support. Example: *Epipremnum pinnatum, Piper betel, Ficus pumila*.

4. **Buttress root**
   In certain trees broad plank like outgrowths develop towards the base all around the trunk. They grow obliquely downwards and give support to huge trunks of trees. This is an adaptation for tall rain forest trees. Example: silk cotton tree (*Bombax*), white cotton tree (*kapok, Terminalia arjuna, Delonix regia, Pterygota alata*).

c. **Vital functions**

1. **Epiphytic or velamen root**
   Some epiphytic orchids develop a special kind of aerial roots which hang freely in the air. These roots develop a spongy tissue called *velamen* which helps in absorption of moisture from the surrounding air. Example: *Vanda, Dendrobium, Aerides*.

2. **Foliar root**
   Roots are produced from the veins or lamina of the leaf for the formation of new plant. Example: *Bryophyllum, Begonia, Zamioculcas*.
3. Sucking or Haustorial roots
These roots are found in parasitic plants. Parasites develop adventitious roots from stem which penetrate into the tissue of the host plant and suck nutrients.
Example: Cuscuta (dodder), Cassytha, Orobanche (broomrape), Viscum (mistletoe), Dendrophthoe.

4. Photosynthetic or assimilatory roots
Roots of some climbing or epiphytic plants develop chlorophyll and turn green which help in photosynthesis. Example: Tinospora, Trapa natans (water chestnut), Taeniophyllum.

3.6 Shoot system
The plumule of the embryo of a germinating seed grows into stem. The epicotyl elongates after embryo growth into the axis (the stem) that bears leaves from its tip, which contain the actively dividing cells of the shoot called apical meristem. Further cell divisions and growth result in the formation of mass of tissue called a leaf primordium. The point from which the leaf arises is called node. The region between two adjacent nodes is called internode.

I. Characteristic features of the stem
1. The stem is usually the aerial portion of the plant
2. It is positively phototropic and negatively geotropic
3. It has nodes and internodes.
4. Stem bears vegetative bud for vegetative growth of the plant, and floral buds for reproduction, and ends in a terminal bud.
5. The young stem is green and thus carries out photosynthesis.
6. During reproductive growth stem bears flowers and fruits.
7. Branches arise exogenously
8. Some stems bears multicellular hairs of different kinds.

II. Functions of the stem
Primary functions
1. Provides support and bears leaves, flowers and fruits.
2. It transports water and mineral nutrients to the other parts from the root.
3. It transports food prepared by leaves to other parts of the plant body.

Figure 3.7: Adventitious Root Modification for Vital Functions
3. **Extra axillary bud**: These buds are formed at nodes but outside the axil of the leaf as in *Solanum americanum*.

4. **Accessory bud**: An extra bud on either side (collateral bud) or above (superposed bud or serial bud) the axillary bud. Example: *Citrus* and *Duranta*.

5. **Adventitious buds**: Buds arising at any part other than stem are known as *adventitious bud*. **Radical buds** are those that arises from the lateral roots which grow into plantlets. Example: *Millingtonia*, *Bergera koenigii* (*Murraya koenigii*), *Coffea arabica* and *Aegle marmelos*. **Foliar buds** are those that grow on leaves from veins or from margins of the leaves. Example: *Begonia* (Elephant ear plant) and *Bryophyllum* (Sprout leaf plant). **Cauline buds** arise directly from the stem either from cut, pruned ends or from branches. Adventitious buds function as propagules which are produced on the stem as tuberous structures. Example: *Dioscorea*, *Agave*.

6. **Bulbils (or specialized buds)**: Bulbils are modified and enlarged bud, meant for propagation. When bulbils detach from parent plant and fall on the ground, they germinate into new plants and serve as a means of vegetative propagation. In *Agave* and *Allium proliferum* floral buds get modified into bulbils. In *Lilium bulbiferum* and *Dioscorea bulbifera*, the bulbils develop in axil of leaves. In *Oxalis*, they develop just above the swollen root.
3.6.2 Types of Stem

Majority of angiosperm possess upright, vertically growing erect stem. They are (i) Excurrent, (ii) Decurrent, (iii) Caudex, (iv) Culm.

i. Excurrent

The main axis shows continuous growth and the lateral branches gradually becoming shorter towards the apex which gives a conical appearance to the trees. Example: Polyalthia longifolia, Casuarina.

ii. Decurrent

The growth of lateral branch is more vigorous than that of main axis. The tree has a rounded or spreading appearance. Example: Mangifera indica, Azadirachta indica, Tamarindus indicus, Aegle marmelos.

iii. Caudex

It’s an unbranched, stout, cylindrical stem, marked with scars of fallen leaves. Example: Cocus nucifera, Borassus flabelliformis, Areca catechu.

iv. Culm

Erect stems with distinct nodes and usually hollow internodes clasped by leaf sheaths. Example: Majority of grasses including Bamboo.

3.6.3 Modification of Stem

I. Aerial modification of stem

1. Creepers

These are plants growing closer (horizontally) to the ground and produces roots at each node. Example: Cynodon dactylon, Oxalis, Centella.

2. Trailers (Stragglers)

It is a weak stem that spreads over the surface of the ground without rooting at nodes. They are divided into 3 types,

i. Prostrate (Procumbent): A stem that grows flat on the ground. Example: Evolvulus alsinoides, Indigofera prostrata.

ii. Decumbent: A stem that grows flat but becomes erect during reproductive stage. Example: Portulaca, Tridax, Lindenber gia.


3. Climbers

These plants have long weak stem and produce special organs for attachment for climbing over a support. Climbing helps to display the leaves towards sunlight and to position the flower for effective pollination.

i. Root climbers

Plants climbing with the help of adventitious roots (arise from nodes) as in species of Piper betel, Piper nigrum, Hedera helix, Pothos, Hoya.

ii. Stem climbers (twiners)

These climbers lack specialised structure for climbing and the stem itself coils around the support. Example: Ipomoea, Convolvulus, Dolichos, Clitoria, Quisqualis.

Stem climbers may coil around the support clockwise or anti-clockwise. Clockwise coiling climbers are called dextrose. Example: Dioscorea alata. Anti-clockwise coiling climbers are called sinistrose. Example: Dioscorea bulbifera.
iii. Hook climbers
These plants produce specialized hook like structures which are the modification of various organs of the plant. In *Artabotrys* inflorescence axis is modified into hook. In *calamus* (curved hook) leaf tip is modified into hook. In *Bignonia unguis-cati* the leaflets are modified into curved hook. In *Hugonia* the axillary buds modified into hook.

iv. Thorn climbers
Climbing or reclining on the support with the help of thorns as in *Bougainvillea* and *Carissa*.

v. Lianas (woody stem climber)
Woody perennial climbers found in tropical forests are lianas. They twine themselves around tall trees to get light. Example: *Hiptage benghalensis*, *Bauhinia vahlii*, *Entada pursaetha*.

vi. Tendril climbers
Tendrils are thread-like coiling structures which help the plants in climbing. Tendrils may be modifications of Stem – as in *Passiflora*, *Vitis* and *Cissus quadrangularis*; Inflorescence axis – *Antigonon*; Leaf – *Lathyrus*; Leaflets - *Pisum sativum*; Petiole – *Clematis*; Leaftip – *Gloriosa*; Stipules – *Smilax*. In pitcher plant (*Nepenthes*) the midrib of the leaf often coils around a support like a tendril and holds the pitcher in a vertical position.

Phylloclade
This is a green, flattened cylindrical or angled stem or branch of unlimited growth, consisting of a series of nodes and internodes at long or short intervals. Phylloclade is characteristic adaptation of xerophytes where the leaves often fall off early and modified into spines or scales to reduce transpiration. The phylloclade takes over all the functions of leaves, particularly photosynthesis. The phylloclade is also called as cladophyll. Example: *Opuntia*, *Phyllocactus*, *Muehlenbergia* (flattened phylloclade) *Casuarina*, *Euphorbia tirucalli*, *Euphorbia antiquorum* (cylindrical phylloclade).
2. Stolon
This is also a slender, lateral branch originating from the base of the stem. But it first grows obliquely above the ground, produces a loop and bends down towards the ground. When touches the ground it produces roots and becomes an independent plantlet. Example: *Mentha piperita* (peppermint), *Fragaria indica* (wild strawberry).

3. Sucker
Sucker develops from a underground stem and grows obliquely upwards and gives rise to a separate plantlet or new plant. Example: *Chrysanthemum, Musa, Bambusa*.

4. Offset
Offset is similar to runner but found in aquatic plants especially in rosette leaved forms. A short thick lateral branch arises from the lower axil and grows horizontally leafless for a short distance, then it produces a bunch of rosette leaves and

III. Underground stem modifications

Perennial and some biennial herbs have underground stems, which are generally known as root stocks. Rootstock functions as a storage and protective organ. It remains alive below the ground during unfavourable conditions and resumes growth during the favourable conditions.

Underground stems are not roots because they possess nodes, internodes, scale-leaves and buds. Rootstock also lack root cap and root hairs but they possess terminal bud which is a characteristics of stem.

1. **Bulb**

   It is a condensed conical or convex stem surrounded by fleshy scale leaves. They are of two types 1. Tunicated (coated) bulb: In which the stem is much condensed and surrounded by several concentric layers of scale leaves. The inner scales commonly fleshy, the outer ones dry. These are two types (a) Simple Tunicated bulb Example: *Allium cepa* (b) Compound Tunicated bulb. Example: *Allium sativum*. 2. Scaly bulb: They are narrow, partially overlap each other by their margins only. Example: *Tulipa spp.*

   Pseudobulb is a short erect aerial storage or propagating stem of certain epiphytic and terrestrial sympodial orchids. Example: *Bulbophyllum.*

2. **Corm**

   This is a succulent underground stem with an erect growing tip. The corm is surrounded by scale leaves and internodes. Example: *Amorphophallus, Gladiolus, Colocasia, Crocus, Colchicum*

3. **Rhizome**

   This is a underground stem grows horizontally with several lateral growing tips. Rhizome posses conspicuous nodes and internodes covered by scale leaves. Example: *Zingiber officinale, Canna, Curcuma longa, Maranta arundinacea, Nymphaea, Nelumbo.*
4. Tuber
This is a succulent underground spherical or globose stem with many embedded axillary buds called “eyes”. Example: *Solanum tuberosum, Helianthus tuberosus*

IV. Stem Branching
Branching pattern is determined by the relative activity of apical meristems. The mode of arrangement of branches on a stem is known as branching. There are two main types of branching, 1. Lateral branching and 2. Dichotomous branching. Based on growth pattern stems may show indeterminate or determinate growth.

1. Indeterminate: The terminal bud grows uninterrupted and produce several lateral branches. This type of growth is also known as **monopodial branching**. Example: *Polyalthia, Swietenia, Antiaris*.

2. Determinate: The terminal bud ceases to grow after a period of growth and the further growth is taken care by successive or several lateral meristem or buds. This type of growth is also known as **sympodial branching**. Example: *Cycas*.

3.7 Leaf
Leaves are green, thin flattened lateral outgrowths of the stem and exogenous in origin. They arise from the nodes of the stem and have limited growth and life span. Leaves are the primary photosynthetic organs and the main site of transpiration. All the leaves of a plant together are referred to as **phyllome**.

I. Characteristics of leaf
1. Leaf is a lateral appendage of the stem.
2. It is borne at the node of the stem.
numerous lateral veins and thin veinlets. The lamina shows great variations in its shape, margin, surface, texture, colour, venation and incision.

Stipules
In most of the dicotyledonous plants, the leaf base bears one or two lateral appendages called the stipules. Leaves with stipules are called stipulate. The leaves without stipules are called estipulate or exstipulate. The stipules are commonly found in dicotyledons. In some grasses (Monocots) an additional outgrowth is present between leaf base and lamina. It is called Ligule. Sometimes, small stipule like outgrowths are found at the base of leaflets of a compound leaf. They are called stipels. The main function of the stipule is to protect the leaf in the bud condition.

3.7.2 Venation
The arrangement of veins and veinlets on the leaf blade or lamina is called venation. Internally, the vein contains vascular tissues. Conventionally venation is classified into two types namely, Reticulate venation and Parallel venation.

I. Reticulate venation
In this type of venation leaf contain a prominent midrib from which several secondary veins arise that branch and anastomose like a network. This type of venation is common in all dicot leaves. It is of two types.

1. Pinnately reticulate venation (unicostate): In this type of venation there is only one midrib in the centre which forms many lateral branches to form a network. Example: Mangifera indica, Ficus religiosa, Nerium.

Sheathing leafbase: In many monocot families such as Arecaceae, Musaceae, Zingiberaceae and Poaceae the leafbase extends into a sheath and clasps part or whole of the internode. Such leafbase also leave permanent scars on the stem when they fall. Example: Arecaceae

II. Petiole (stipe or mesopodium)
It is the bridge between leaf and stem. Petiole or leaf stalk is a cylindrical or sub cylindrical or flattened structure of a leaf which joins the lamina with the stem. A leaf with petiole is said to be petiolate. Example: Ficus, Hibiscus, Mangifera, Psidium. Leaves that do not possess petiole is said to be sessile. Example: Calotropis, Gloriosa.

III. Lamina (Leaf blade)
The expanded flat green portion of the leaf is the blade or lamina. It is the seat of photosynthesis, gaseous exchange, transpiration and most of the metabolic reactions of the plant. The lamina is traversed by the midrib from which arise

Figure 3.11: (a) Parts of the leaf (b) Pulvinus leaf base (c) Sheathing leaf base
2. Palmate Parallel Venation (multicostate): In this type of venation there are two or more principal veins arising from a single point and they proceed outwards or upwards. The two types of palmate reticulate venation are

i. Divergent type: When all principal veins originate from the base and diverge from one another towards the margin of the leaf as in Cucurbita, Luffia, Carica papaya, etc.,

ii. Convergent: When the veins converge to the apex of the leaf, as in Indian plum (Zizyphus), bay leaf (Cinnamomum)

Figure 3.12: Types of reticulate venation
(a) Pinnately reticulate
(b) Palmately reticulate (Divergent)
(c) Palmately reticulate (Convergent)

II. Parallel venation

Veins run parallel to each other and do not form a prominent reticulum. It is a characteristic feature of monocot leaves. It is classified into two sub types.

1. Pinnately Parallel Venation (Unicostate)

When there is a prominent midrib in the center, from which arise many veins perpendicularly and run parallel to each other. Example: Musa, Zinger, Curcuma, Canna.

2. Palmate Parallel Venation (Multicostate)

In this type several veins arise from the tip of the petiole and they all run parallel to each other and unite at the apex. It is of two sub types.

i. Divergent type: All principal veins originate from the base and diverge towards the margin, the margin of the leaf as in fan palm (Borassus flabelliformis)

ii. Convergent type: All principal veins run parallel to each other from the base of the lamina and join at the apex as in Bamboos, rice, water hyacinth.

(a) Canna (b) Bamboo (c) Borassus

Figure 3.13: Types of Parallel venation
(a) Pinnately parallel venation
(b) Palmately parallel (Convergent)
(c) Palmately parallel (Divergent)

3.7.3 Phyllotaxy

The mode of arrangement of leaves on the stem is known as phyllotaxy (Gk. Phyllon = leaf; taxis = arrangement). Phyllotaxy is to avoid over crowding of leaves and expose the leaves maximum to the sunlight for photosynthesis. The four main types of phyllotaxy are (1) Alternate (2) Opposite (3) Ternate (4) Whorled.

1. Alternate phyllotaxy

In this type there is only
Modern morphologist Hickey (1973) and Hickey and Wolf (1975) classified the venation into following major types based on the pattern of primary, secondary and tertiary venation.

- Craspedodromous – In which secondary veins terminate at the leaf margin. (sub types are simplecraspedodromous, semicraspedodromous, mixed craspedodromous).
- Camptodromous – In which secondary veins do not terminate at the margin. (sub types are brochidodromous, eucamptodromous, cladodromous, reticulodromous).
- Hyphodromous – With only the primary midrib vein present or evident and secondary veins either absent, very reduced or hidden with the leaf mesophyll.
- Parallelodromous – Venation is equivalent to parallel in which two or more primary or secondary veins run parallel to one another, converging at the apex.
- Actinodromous – If three or more primary veins diverge from one point.
- Palinoactinodromous – Similar to actinodromous, but the primary veins have additional branch in above the main point of divergence of the primaries.
- Flabellate – Venation is that in which several equal, fine veins branch toward the apex of the leaf.
- Campylodromous – Venation is that in which several primary veins run in prominent, recurved arches at the base, curving upward to converge at the leaf apex.
- Acrodromous – If two or more primary veins run in convergent arches toward the leaf apex.

one leaf per node and the leaves on the successive nodes are arranged alternate to each other. Spiral arrangement of leaves show vertical rows are called **orthostichies**. They are two types.

a) **Alternate spiral**: In which the leaves are arranged alternatively in a spiral manner. Example: *Hibiscus, Ficus*.

b) **Alternate distichous or Bifarious**: In which the leaves are organized alternatively in two rows on either side of the stem. Example: *Monoon longifolium* (*polyalthia longifolia*).

### 2. Opposite phyllotaxy

In this type each node possess two leaves opposite to each other. They are organized in two different types.

i. **Opposite superposed**: The pair of leaves arranged in succession are in the same direction, that is two opposite leaves at a node lie exactly above those at the lower node. Example: *Psidium* (Guava), *Eugenia jambolana* (Jamun), *Quisqualis* (Rangoon creeper).

ii. **Opposite decussate**: In this type of phyllotaxy one pair of leaves is placed at right angles to the next upper or lower pair of leaves. Example: *Calotropis, Zinnia, Ocimum*

### 3. Ternate phyllotaxy

In this type there are three leaves attached at each node. Example: *Nerium*
4. **Whorled (verticillate) type of phyllotaxy**

In this type more than three leaves are present in a whorl at each node forming a circle or whorl. Example: *Allamanda, Alstonia scholaris*.

3.7.4 **Leaf mosaic**

In leaf mosaic leaves tend to fit in with one another and adjust themselves in such a way that they may secure the maximum amount of sunlight with minimum amount of overlapping. The lower leaves have longer petioles and successive upper leaves possess decreasing length petioles. Example: *Acalypha, Begonia*.

3.7.5 **Leaf type**

The pattern of division of a leaf into discrete components or segments is termed leaf type.

Based on the number of segments

I. **Simple leaf**

A leaf is said to be simple when the petiole bears a single lamina; lamina may be entire (undivided) Example: Mango or incised to any depth but not upto the midrib or petiole. Example: *Cucurbita*.

II. **Compound leaf**

Compound leaf is one in which the main rachis bears more than one lamina surface, called leaflets. Compound leaves have evolved to increase total lamina surface. There is one axillary bud in the axil of the whole compound leaf. The leaflets however, do not possess axillary buds.

1. **Pinnately compound leaf**

A pinnately compound leaf is defined as one in which the rachis, bears laterally a number of leaflets, arranged alternately or in an opposite manner, as in tamarind, *Cassia*.

i. **Unipinnate**: The rachis is simple and unbranched which bears leaflets directly on its sides in alternate or opposite manner. Example: *Rose, Neem, Azadirachta, Chinese box (Murraya)*.

ii. **Bipinnate**: The primary rachis produces secondary rachii which bear the leaflets. The secondary rachii are known as pinnae. Number of pinnae varies depending on the species. Example: *Delonix, Mimosa, Acacia nilotica, Caesalpinia*.
• **Foliage leaves** — are ordinary green, flat, lateral appendages of the stem or the branch borne at the node.

• **Cotyledons or seed leaves** — are attached to the axis of the embryo of the seed. As the seed germinates, they usually turn green and become leaf-like.

• **Cataphylls or scale leaves** — are reduced forms of leaves, stalkless and often brownish. They are the bud-scales, scales on the rhizome (underground stems), and also on other parts of the plant body (Bamboo).

• **Prophylls** — the first formed leaves are called prophylls.

• **Floral leaves** — are members of a flower, forming into two accessory whorls (calyx and corolla), two essential whorls (androecium and gynoecium).

• **Hypsophylls or bract leaves** — these leaves cover the flower or an inflorescence in their axil. The main function of these leaves is to protect the flower buds.

iii. **Tripinnate**: When the rachis branches thrice the leaf is called tripinnate. (i.e) the secondary rachii produce the tertiary rachii which bear the leaflets. Example: *Moringa, Oroxylum*.

iv. **Decompound**: When the rachis of leaf is branched several times it is called decompound. Example: *Daucus carota, Coriandrum sativum, Foeniculum vulgare*.

2. **Palmately compound leaf**

A palmately compound leaf is defined as one in which the petiole bears terminally, one or more leaflets which seem to be radiating from a common point like fingers from the palm.

i. **Unifoliolate**: When a single leaflet is articulated to the petiole is said to be unifoliolate. Example: *Citrus, Desmodium gangeticum*.

ii. **Bifoliolate**: When there are two leaflets articulated to the petiole it is said to be bifoliolate. Example: *Balanites roxburghii, Hardwickia binata, Zornia diphylla*.

iii. **Trifoliolate**: There are three leaflets articulated to the petiole it is said to be trifoliolate. Example: wood apple (*Aegle marmelos*), Clover (*Trifolium*), Lablab, Oxalis.

iv. **Quadrifoliolate**: There are four leaflets articulated to the petiole it is said to be quadrifoliolate. Example: wood apple (*Aegle marmelos*), Clover (*Trifolium*), Lablab, Oxalis.

Figure 3.15: Types of pinnately compound leaves

(a) Unipinnate (Paripinnate)- *Tamarindus*  (b) Unipinnate (Imparipinnate)- *Azadirachta*

(c) Bipinnate- *Caesalpinia*  (d) Tripinnate- *Moringa*  (e) Decompound- *Coriandrum*
elegant climber, the terminal leaflets become modified into three, very sharp, stiff and curved hooks, very much like the nails of a cat. These hooks cling to the bark of a tree and act as organs of support for climbing. The leaf spines of Asparagus also act as hooks.

3.7.6 Modification of Leaf

The main function of the leaf is food preparation by photosynthesis. Leaves also modified to perform some specialized functions. They are described below.

I. Leaf tendrils

In some plants Stem is very weak and hence they have some special organs for attachment to the support. So some leaves are partially or wholly modified into tendril. Tendril is a slender wiry coiled structure which helps in climbing the support. Some of the modification of leaf tendrils are given below:


II. Leaf hooks

In some plants, leaves are modified into hook-like structures and help the plant to climb. In cat's nail (Bignonia unguis-cati) an elegant climber, the terminal leaflets become modified into three, very sharp, stiff and curved hooks, very much like the nails of a cat. These hooks cling to the bark of a tree and act as organs of support for climbing. The leaf spines of Asparagus also act as hooks.

III. Leaf Spines and Prickles

Leaves of certain plants develop spinesent structures. Either on the surface or on the margins as an adaptation to herbivory and xeric conditions. Example: Argemone mexicana (Prickly poppy), Solanum trilobatum, Solanum virginianum. In xerophytes such as Opuntia (Prickly pear) and Euphorbia leaves and stipules are modified into spines.
Prickles are small, sharp structures which are the outgrowths from epidermal cells of stem or leaf. It helps the plant in scrambling over other plants. It is also protective against herbivory. Example: *Rosa* spp, *Rubus* spp.

**IV. Storage Leaves**

Some plants of saline and xerophytic habitats and members of the family Crassulaceae commonly have fleshy or swollen leaves. These succulent leaves store water, mucilage or food material. Such storage leaves resist desiccation. Example: *Aloe*, *Agave*, *Bryophyllum*, *Kalanchoe*, *Sedum*, *Sueada*, *Brassica oleracea* (cabbage-variety capitata).

**V. Phyllode**

Phyllodes are flat, green-coloured leaf-like modifications of petioles or rachis. The leaflets or lamina of the leaf are highly reduced or caducous. The phyllodes perform photosynthesis and other functions of leaf. Example: *Acacia auriculiformis* (Australian *Acacia*), *Parkinsonia*.

**VI. Pitcher**

The leaf becomes modified into a pitcher in *Nepenthes* and *Sarracenia*. In *Nepenthes* the basal part of the leaf is laminar and the midrib continues as a coiled tendril-like structure. The apical part of the leaf as modified into a pitcher the mouth of the pitcher is closed by a lid which is the modification of leaf apex.

**VII. Bladder**

In bladderwort (*Utricularia*), a rootless free-floating or slightly submerged plant common in many water bodies, the leaf is very much segmented. Some of these segments are modified to form bladder-like structures, with a trap-door entrance that traps aquatic animalcules.

**VIII. Floral leaves**

Floral parts such as sepals, petals, stamens and carpels are modified leaves. Sepals and petals are leafy. They are protective in function and considered non-essential reproductive parts. Petals are usually coloured which attract the insects for pollination. Stamens are considered pollen bearing microsporophylls and carpels are ovule bearing megasporophylls.

3.7.7 Ptyxis

Rolling or folding of individual leaves may be as follows:

1. **Reclinate** - when the upper half of the leaf blade is bent upon the lower half as in loquat (*Eriobotrya japonica*).
2. **Conduplicate** - when the leaf is folded lengthwise along the mid-rib, as in guava, sweet potato and camel’s foot tree (*Bauhinia*).
3. **Plicate or plaited** – when the leaf is repeatedly folded longitudinally along ribs in a zig-zag manner, as in *Borassus flabellifer*.

4. **Circinate** - when the leaf is rolled from the apex towards the base like the tail of a dog, as in ferns.

5. **Convolute** - when the leaf is rolled from one margin to the other, as in banana, aroids and Indian pennywort. *Musa* and members of Araceae.

6. **Involute** - when the two margins are rolled on the upper surface of the leaf towards the midrib or the centre of the leaf, as in water lily, lotus, Sandwich Island Climber (*Antigonon*) and *Plumbago*.

7. **Crumpled** - when the leaf is irregularly folded as in cabbage.

### 3.7.8 Leaf duration

Leaves may stay and function for few days to many years, largely determined by the adaptations to climatic conditions.

**Cauducous (Fagacious)**

Falling off soon after formation. Example: *Opuntia, Cissus quadrangularis*.

**Deciduous**

Falling at the end of growing season so that the plant (tree or shrub) is leafless in winter/summer season. Example: *Maple, Plumeria, Launea, Erythrina*.

**Evergreen**

Leaves persist throughout the year, falling regularly so that tree is never leafless. Example: *Mimusops, Calophyllum*.

**Marcescent**

Leaves not falling but withering on the plant as in several members of Fagaceae.

### 3.7.9 Leaf symmetry

1. **Dorsiventral leaf**

When the leaf is flat, with the blade placed horizontally, showing a distinct upper surface and a lower surface, as in most dicotyledons, it is said to be dorsiventral. Example: *Tridax*.

2. **Isobilateral leaf**

When the leaf is directed vertically upwards, as in many monocotyledons, it is said to be isobilateral leaf. Example: *Grass*.

3. **Centric leaf**

When the leaf is more or less cylindrical and directed upwards or downwards, as in pine, onion, etc., the leaf is said to be centric.

4. **Heterophylly**

Occurrence of two different kinds of leaves in the same plant is called **heterophylly**. Heterophylly is found in many aquatic plants. Here, the floating or aerial leaves and the submerged leaves are of different kinds. The former are generally broad, often fully expanded, and undivided or merely lobed, while the latter are narrow, ribbon-shaped, linear or much dissected. Heterophylly in water plants is, thus, an adaptation to two different conditions of the environment. Example: water crowfoot (*Ranunculus aquatilis*), water plantain (*Alisma plantago*), arrowhead (*Sagittaria*), *Limnophila heterophylla*.

Terrestrial (land) plants also exhibit this phenomenon. Among them *Sterculia villosa*, jack (in early stages), *Ficus heterophylla* show leaves varying from entire to variously lobed structures during different developmental stages. Young leaves are usually lobed or dissected and the mature leaves are entire. Such type is known as **developmental heterophylly**. Example: *Eucalyptus, Artocarpus heterophyllus*. 

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Summary

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

Evaluation

1. Roots are
   a. Descending, negatively geotropic, positively phototropic
   b. Descending, positively geotropic, negatively phototropic
   c. Ascending, positively geotropic, negatively phototropic
   d. Ascending, negatively geotropic, positively phototropic

2. When the root is thick and fleshy, but does not take a definite shape, it said to be
   a. Nodulose root
   b. Tubercular root
   c. Moniliform root
   d. Fasciculated root

3. Example for negatively geotropic roots
   a. Ipomoea, Dahlia
   b. Asparagus, Ruellia
   c. Vitis, Portulaca
   d. Avicennia, Rhizophora

4. Curcuma amada, Curcuma domestica, Asparagus, Maranta are example of
   a. Tuberous root
   b. Beaded root
   c. Moniliform root
   d. Nodulose root

5. Bryophyllum and Dioscorea are example for
   a. Foliar bud, apical bud
   b. Foliar bud, cauline bud
   c. Cauline bud, apical bud
   d. Cauline bud, foliar bud

6. Why lateral roots are endogenous?

Activity

2. Prepare a report of traditional medicines.
3. Classroom level exhibition on Siddha and Ayurvedic medicine prepared from root, leaf, stem.
4. Growing micro greens in class room – project work. (Green seed sprouts)
7. Write the similarities and differences between
   1. *Avicennia* and *Trapa*
   2. Banyan and silk cotton
   3. Fusiform and Napiform root

8. How root climbers differ from stem climbers?

9. Compare sympodial branching with monopodial branching.

10. Compare pinnate unicostate and palmate multicostate venation?

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**ICT Corner**

**Monocot and Dicot plants**

Is plants differ **morphologically**?

**Steps**

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

**Activity**

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

![Steps Image]

URL:


* Pictures are indicative only