SHRI CHHATRAPATI SHIVAJI COLLEGE, OMERGA

# Morphology of Angiosperms

Notes for B. Sc. I (Botany) Paper II

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# B. Sc. I Year (Botany Syllabus)

## Semester - I Paper - II Morphology of Angiosperms

UNIT – 1

**1.1** Basic body plan of flowering plant, modular type of growth, diversity of plant forms – Herbs, Shrubs, Trees, Climbers; annuals, biennials and perennials.

**1.2 Morphology of Vegetative Organs**

**a) Root**- Characteristics, functions, regions of root, types – tap and adventitious, modification of root for storage, mechanical support (stilt root) and vital functions (Pneumatophore).

**b) Stem**- Characteristics, functions, modification – underground, sub aerial and aerial

**c) Leaf**- Parts of typical leaf, phyllotaxy, types (simple and compound), diversity in shape and size, venation and modifications of leaf.

# Morphology of Angiosperms

## Basic Body Plan

The plant body consists of a number of organs, i.e., root, stem, leaf and flower. The flower consists of sepals, petals, stamens, carpels and sometimes also sterile members. Each organ is made up of a number of tissues. Each tissue consists of many cells of one kind. The complex multicellular body of the seed plant is a result of evolutionary specialization of long duration. This specialization has given rise to the establishment of morphological and physiological differences between the various parts of the plant body and also caused the development of the concept of plant organs.

The organization of the plant body of the oldest known land plants, the Psilophytales, suggests that the differentiation of the vegetative plant into leaf, stem and root is a result of evolutionary development from an originally simple axial structure (Arnold, 1947; Eames, 1936). As regards the morphologic nature of the flower it is thought that the flower is homologous with a shoot and the floral parts with leaves.

## Fundamental Parts

The axis, consists of two parts—that portion which is normally aerial is known as the stem, and the portion which is subterranean is called the root. There are three types of appendages arising from the axis (Fig. 1). These are -

- **Leaves :** The strands of vascular tissue pass through the leaves. The leaves are characteristic of the stem and do not occur on the root. The leaves are found to be arranged on the stem in a definite manner, and bear an intimate structural relation to the skeleton of the axis. The leaf is looked upon as the lateral expansion of the stem, continuous with it. All fundamental parts of the stem are concerned with the formation of the leaf.
- **Emergences :** In the appendages of the second rank only the outermost layers of stem, the cortex and the epidermis, are usually present which are known as emergences. The prickles of the rose make a good example of it.
- **Hairs :** The appendages of the third rank are hairs. These are projections of the outermost layer of the cells. The emergences and hairs occur on both axis and leaves, usually without definite arrangement.

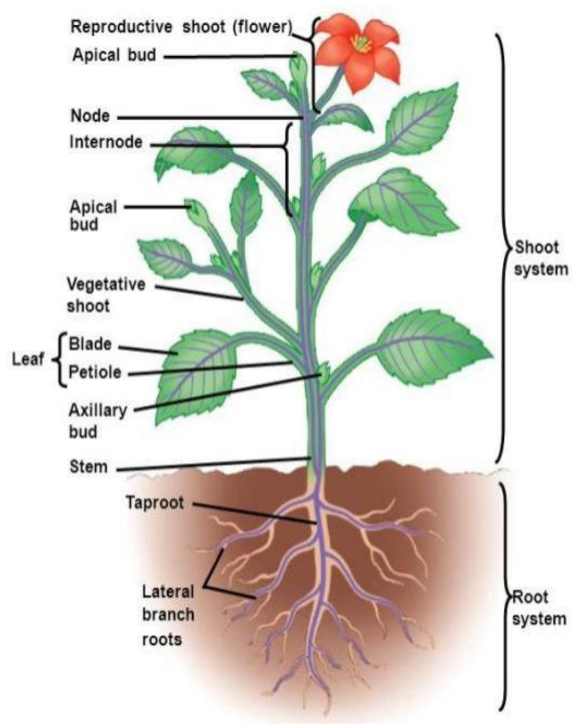



**Fig. 1. Typical body plan of Angiospermic plant**

## Development of the Plant Body

A vascular plant begins its existence as a morphologically simple unicellular zygote (2n). The zygote develops into the embryo and thereafter into the mature sporophyte. The development of the sporophyte involves division and differentiation of cells, and an organization of cells into the tissues and tissue systems. The embryo of the seed plant possesses relatively a simple structure as compared with the mature sporophyte. The embryo bears a limited number of parts - generally only an axis bearing one or more cotyledons. The cells and tissues of this structure are less differentiated.

However the embryo grows further, because of the presence of meristems, at two opposite ends of the axis, of future shoot and root. After the germination of the seed, during the development of shoot and root, the new apical meristems appear which cause a repetitive branching of these organs. After a certain period of vegetative growth, the reproductive stage of the plant is attained (Fig. 2).

## Primary and Secondary Growth

The first-formed plant body is known as the primary plant body, since it is built up by means of first or primary growth. The tissues of this first-formed body are known as primary tissues; for example the first-formed xylem is called primary xylem. In most vascular cryptogams and monocotyledons, the entire life cycle of the sporophyte is completed in a primary plant body. The gymnosperms, most dicotyledons, and some monocotyledons show an increase in thickness of stem and root by means of secondary growth. The tissues formed as the result of secondary growth are called secondary tissues. Generally the new types of cells are not formed by means of secondary growth. The bulk of the plant increases because of secondary growth. Especially the vascular tissues are developed which provide new conducting cells and additional support and protection. The secondary growth does not fundamentally change the structure of the primary body. The primary growth increases the length of the axis, forms the branches and builds up the new or young parts of the plant body. Thus, a secondary body composed of secondary tissues is added to the primary body composed of primary tissues.

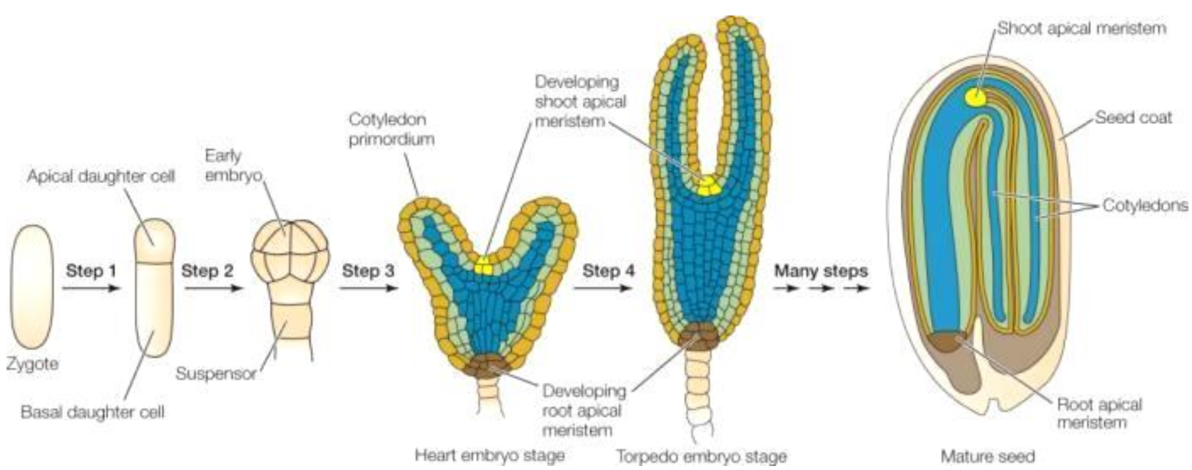



**Fig. 2 : Typical angiospermic embryo development**

A special meristem, the cambium, is concerned with the secondary thickening. The cambium arises between the primary xylem and the primary phloem, and lays down new xylem and phloem adjacent to these. Thus the secondary masses of xylem and phloem are found entirely within the central cylinder and between the primary xylem. The newly formed secondary xylem cloaks and ultimately surrounds the primary xylem and the pith. During this process the primary structure is not changed but engulfed intact within secondary xylem. The primary phloem and all other tissues outside the cambium are forced outward by secondary growth and ultimately crushed or destroyed.

In addition, a cork cambium or phellogen commonly develops the peripheral region of the axis and produces a periderm, a secondary tissue system assuming a protective function when the primary epidermal layer is disrupted during the secondary growth in thickness.

### Meristems Based on Position

As regards their position in plant body, the meristems may be classified into three groups apical meristem, intercalary meristem and lateral meristem(Fig. 3).

### Apical Meristem

The apical meristem lies at the apex of the stem and the root of vascular plants. Very often they are also found at the apices of the leaves. Due to the activity of these meristems, the organs increase in length. The initiation of growth takes place by one or more cells situated at the tip of the organ. These cells always maintain their individuality and position and are called 'apical cells' or 'apical initials'. Solitary apical cells occur in pteridophytes, whereas in higher vascular plants they occur in groups which may be terminal or terminal and sub-terminal in position.

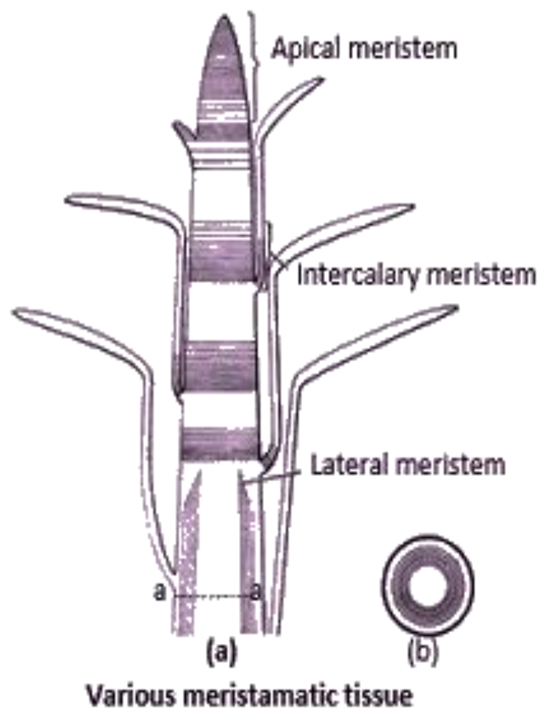



**Fig. 3 : Meristems based on position**

### Intercalary Meristems

The intercalary meristems are merely portions of apical meristems that have become separated from the apex during development by layers of more mature or permanent tissues and left behind as the apical meristem moves on in growth. The intercalary meristems are inter-nodal in their position.

In early stages, the internode is wholly or partially meristematic, but later on some of its part becomes mature more rapidly than the rest and in the internode a definite continuous sequence of development is maintained. The intercalary meristems are found lying in between masses of permanent tissues either at the leaf base or at the base of internode. Such meristems are commonly found in the stems of grasses and other monocotyledonous plants and horsetails, where they are basal. Leaves of many monocotyledons (grasses) and some other plants, such as Pinus, have basal meristematic regions. These meristematic regions are short living and ultimately disappear; ultimately, they become permanent tissues.

**Lateral Meristems**

The lateral meristems are composed of such initials which divide mainly in one plane (periclinally) and increase the diameter of an organ. They add to the bulk of existing tissues or give rise to new tissues. These tissues are responsible for growth in thickness of plant body. The cambium and the cork cambium are the examples of this type. The cambium does not fall definitely in either group (primary and secondary). It arises from apical meristem of which it is late and specialized stage. However, the accessory cambia are secondary. The tissues formed by the cambium are secondary, whereas the primary meristems form only primary tissues. The primary growth of an axis is completed in a relatively short period, whereas the secondary growth persists for a longer period and in a perennial axis the secondary growth continues indefinitely.

The stem apex like the root apex consists of a meristematic zone of cells that remain in a continuous and rapid state of division. This is called promeristem having cells with very thin walls. Immediately beneath the promeristem there is zone of determination which has no visible boundary with the promeristem. In the dicots, this zone has a group of conspicuous cells with dense cytoplasm. These cells in a transverse section are arranged in a circle (Fig. 31.4.). It is a remnant of a primordial meristem, which remains behind in a maturing segment, and it retained its activity to divide. Due to its circular appearance it is also called the ring meristem. The cells in the centre are protopith and those that are external to the ring meristem are the protocortex.

The cells of protocortex and protopith divide and build up the mass of ground tissue. The cells of the ring meristem divide longitudinally and form elongated cells that later on develop in vascular bundles and are known as procambical strands. The first formed phloem elements and so the xylem elements differentiate from the pro-cambial strands.

## Internal **Organization of Vascular Plant**

The cells or the morphologic units of the plant body are associated in various ways with each other forming tissues. In the plant body the cells are of several kinds and their combinations into tissues are such that different parts of the same organ may differ from one another. The larger units of tissues may show topographic continuity or physiologic similarity, or both together. Such tissue units are called tissue systems. Thus, the complex structure of the plant body results from variation in the form and function of cells and also from differences in the type of combination of cells into tissues and tissue systems.

As pointed out by Sachs (1875), the plant body of a vascular plant is composed of three systems of tissues (1) The dermal, (2) The vascular and (3) The fundamental or ground system.

The three vegetative organs, i.e., stem, root and leaf, are distinguished by the relative distribution of the vascular and ground tissues. The vascular system of the stem is found between the epidermis and the centre of the axis. In such type of arrangement the cortex (ground tissue) is found between the epidermis and the vascular region and the pith in the centre of the stem (Fig. 4).

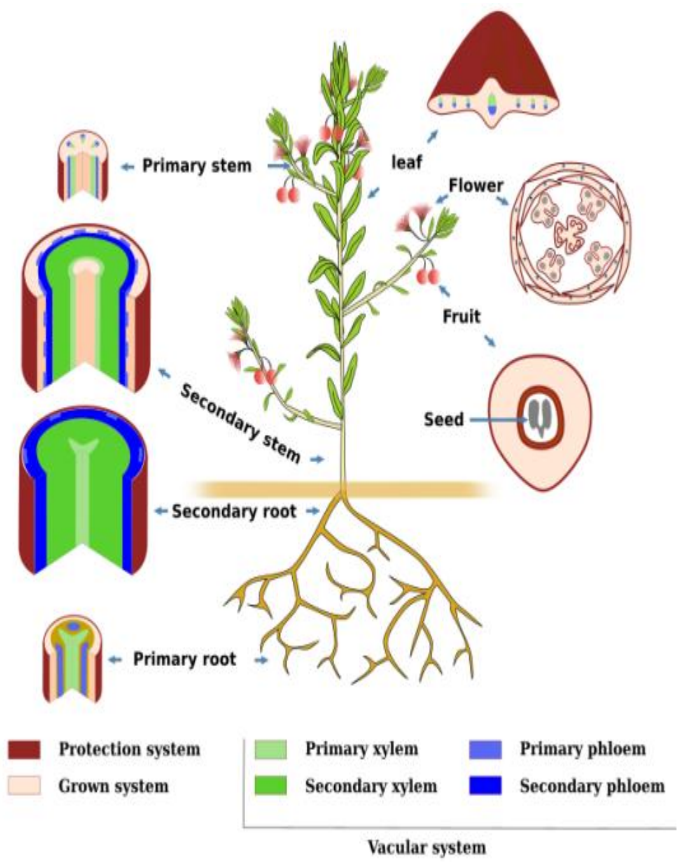



**Fig. 4 : Vascular organization in plants**

In the root, the pith may be absent, and the cortex is generally shed during secondary growth. The primary vascular tissues are commonly being arranged in the form of a ring of bundles as seen in transverse section of stem. During secondary growth the original primary vascular system may be obscured by secondary vascular tissues between the primary xylem and the primary phloem. In the leaf the vascular system consists of many interconnected strands (bundles) found in the ground tissue. In the case of leaf the ground tissue consists of photosynthetic parenchyma, and is known as mesophyll.

The above mentioned tissue systems of the primary plant body are derived from the apical meristems. The partly differentiated derivatives from these meristems may be classified as—protoderm, procambium and ground meristem. They make the meristematic precursors of the dermal, vascular and fundamental (ground) systems, respectively. The vascular tissue system enlarges by secondary growth which takes place in the vascular cambium. The periderm may be derived from a separate meristem, the phellogen or cork cambium.

# Modular Growth of Plant Body

Variation in organizational form that arises from size dependent relationship among parts is a fundamental aspect of development and evolutionary change. Allometric analysis is one of the earliest morphometric tools that help in revealing ontogenetic or evolutionary changes in shape as a consequence of changes in organ or body size (Gayon, 2000).

In plant population the individuals change widely in size may be due to asymmetric competition for light (Weimer, et al, 2001) or meager distribution of other resources. The variability is dependent on the way plants are constructed. Plants grow through the repeated addition of similar morphological sub-units called metamers and modules.

Module is a product of an apical meristem; while metamers are serially homologous repeated units along an axis and are generally sub-units of modules. A vegetative metamer consists of a leaf, the segment of stem subtending it and its axillary meristem (Fig. 5).

## Types of Modularity

On developmental genetics modules refer to largely autonomous developmentally and functionally integrated units (Carrol, 2001). According to comparative morphology the modular growth occurs through the retention of the same few types of structures, e.g., branches and flowers in plants. In contrast to developmental genetic modules, the modular subunits comprising an organism are similar to each other, i.e., serially homologous and loosely analogous to individuals in population.

## Modularity in Plants

In plants, module is the product of apical meristem, e.g., branches, cones or flowers. Vegetative modules produce new meristem that may give rise to additional vegetative or reproductive modules, creating a modular hierarchy. Usually modules themselves are composed of repeated units or metamers. For example, a typical vegetative metamer consists of a node and an internode, a leaf and an axillary meristem.

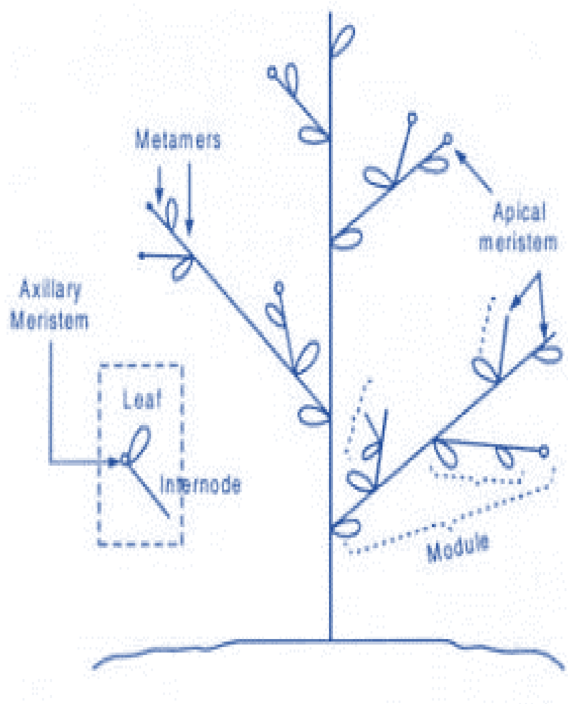



Fig. 5 : Modular Construction of Plant

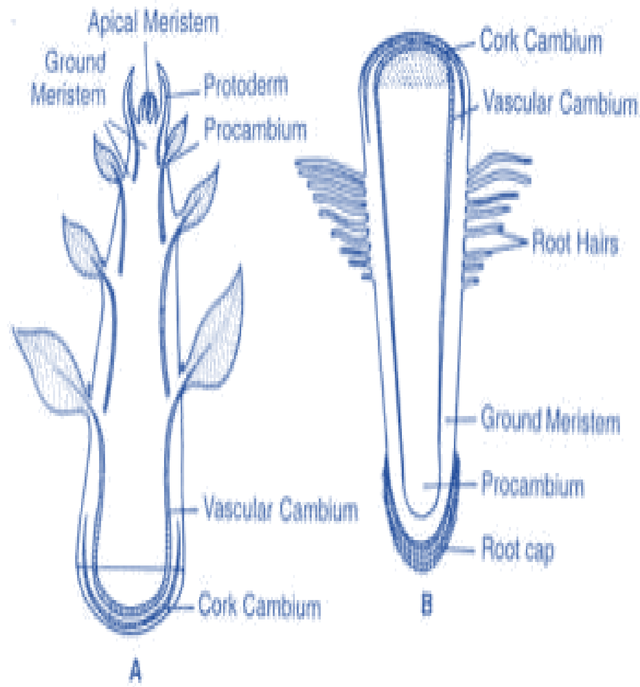



Fig. 6 : Modular Development of A. Stem and B. Root

## Modular Development

In seed plants, e.g., gymnosperms or angiosperms, the plant body is essentially modularly organized. The smallest elementary unit of construction in the shoot system is called a metamer. Metamers make branches and branches construct branching system. Each shoot apex is a potential point of further development. Development is iterative or repetitive process. The finite bit of programme is repeated to add new metamers.

The number of iterations can be infinite in some species. In annual plants iterations certainly terminate, but their number is not strictly defined and may depend on environment (Schlichting and Smith, 2002). The number of leaves of a tree can vary with age and habitat conditions. It is due to capability of formation of organs continuously. Organs, metamers and branches' are disposable without death of organism.

## Shoot System Modules

For the first time, the term metamer was used in animals. Metamers unite to form module. Modules divide due to outgrowths of axillary buds or adventitious buds. When the axillary bud grows continually without undergoing rest period is called sylleptic sub-module while the axillary bud that undergoes some dormancy period is called proleptic sub-module. The activity of module is directly related with that of apical meristem. After getting a stimulus, the axillary bud activates and module branches. New modules may arise some time playing an important role in regeneration, e.g., in Eucalyptus, after fire new modules grow out rapidly from hidden buds produced by modification of the base of stem. Any module or sub-module terminates in a flower or inflorescence depending upon the portion or orientation of metamers in shoot apex (Fig. 6).

### Root System Modules

Primary and lateral roots are modules of root system. Lateral roots are well developed in herbs. Various types of roots, such as respiratory roots, storage roots, etc., are types of modules (Fig. 6).

## Diversity of Plant Forms

### Habitat of Angiosperms

Habitat is the natural living place or locality of plant, i.e., aquatic, terrestrial, marshy, etc. whether cultivated as an ornamental plant, a food crop or occurs in a wild state.

### Habit of Angiosperms

- **Herb** - Plant with no persistent parts above ground, as distinct from shrubs and trees, e.g., *Ranunculus* of Ranunculaceae, *Mentha* of Fabaceae.
- **Shrub** - Perennial woody plant, typically with several stems arising from or near the ground, e.g., *Capparis* of Capparidaceae, *Thuja*.
- **Tree** - A perennial woody plant with a single trunk, e.g., *Melia* of Meliaceae, Mango of Anacardiaceae.

**Herb : Mentha**

**Shrub: Thuja**

**Tree : Mango**

- **Annual** - Plant that completes its life-cycle, from seed germination to seed production, followed by death within a single season, e.g., *Brassica* of Brassicaseae.
- **Biennial** - Plant that continues its growth from year to year. In herbaceous perennials serial parts die away in autumn, replaced by new shoots in the following year from underground structures, e.g., Delphinium, in woody perennials, permanent woody stems above ground from starting point for each New Year's growth, a characteristic that enables some of them to reach a large size, e.g., shrubs and trees.
- **Parasite** - Plant living in or on another plant (its host) from which it obtains food, e.g., *Cuscuta* of Convolvulaceae.

- **Epiphyte** - Plant attached to another plant, not growing parasitically upon it but merely using it for support, e.g., *Vanda* (an orchid) of Orchidaceae.
- **Mesophyte** - Plant growing under average conditions of water supply.
- **Hydrophyte** - Plant whose habitat is water or very wet places, e.g., *Ranunculus aquatilis* of Ranunculaceae; *Neptunia oleracea* of Mimosaceae.
- **Xerophyte** - Plant of dry habitat able to endure conditions of prolonged drought, e.g., *Capparis decidua* of Capparidaceae.
- **Saprophyte** - Plant which obtains organic matter in solution from dead and decaying tissues of plants (or animals), e.g., *Monotropa*.

## Morphology of Vegetative Organs

### Characteristics, Types, Structure and Functions of Root

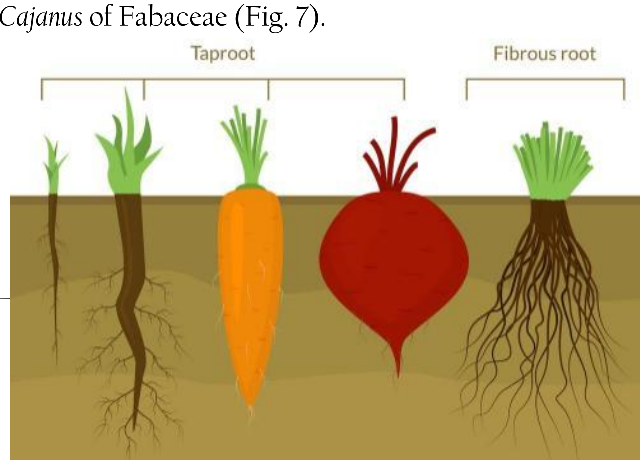
Major observable characteristics are as follows-

1. Root is the descending or underground part of the plant axis.
2. Root is usually positively geotropic (i.e. grows downward into the soil) and positively hydrotropic (i.e. grows towards the source of water) but negatively phototropic (i.e. grows away from sunlight).
3. Root is usually cylindrical and non-green (i.e. lack chlorophylls), but sometimes green as in Trapa and Taeniophylum.
4. Root does not bear nodes, internodes, leaves or buds (exceptions are sweet potato, wood apple etc.)
5. The growing point of root tip is sub-terminal and protected by a root cap or calyptra.
6. Unicellular root hairs present just behind the root caps which increase the absorptive surface area of roots,
7. Lateral roots are endogenous in origin i.e. arise from pericycle of the main root.

## Root of Angiosperms

Root is the part of vascular plants that usually grow downwards into the soil, anchoring plant and absorbing water and nutrient salts.

- **Tap** - Root system with a prominent main root, directed vertically downwards and bearing smaller lateral roots, e.g., most of dicots; *Cajanus* of Fabaceae (Fig. 7).
- **Adventitious**- Root developing from part of plant other than roots, e.g., from stem or leaf cutting; of buds, developing from part of plant other

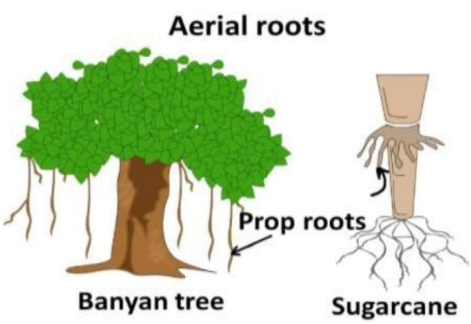


than in axil of leaf, e.g., from root, most of monocots (Fig.7 ).

- **Branched**- Roots possessing branches.
- **Un-branched**- Roots without branches.
- **Fibrous**- A fibrous root system consists of a tuft of adventitious roots of more or less equal diameter, arising from stem base or hypocot eat, strawberry.

**Fig. 7 : Tap Root and Adventitious Root**

- **Prop**- Hanging aerial roots of *Ficus* (Fig.8).




- **Stilt**- Such roots arise from the nodes of the stem above the soil, e.g., *Saccharum*.
- **Aerial**- Hanging aerial roots, e.g., Orchids.
- **Climbing**- The roots that help in climbing of plants, e.g., *Tecoma*, *Piper*, *Pothos*.
- **Respiratory**- Spongy roots, e.g., *Jussiaea*.
- **Pneumatophores**- Special root branch produced in large numbers by some vascular plants growing in water or in tidal swamps, e.g. Mangrove; grows erect, projecting into the air above and contains well developed intercellular system of air spaces in communication with atmosphere through pores o aerial portion (Fig. 8).
- **Tuberous**- Irregularly swollen roots laden with starch, e.g., *Ipomoea batatas* of Convolvulaceae.
- **Parasitic**- The sucking roots of parasites, e.g., *Cuscuta, Dendrophthoe, Viscum, Orobanche*.
- **Epipliytic**- Hanging aerial roots of Orchids.
- **Assimilatory**- The aerial roots with chlorophyll, e.g., *Tinospora*.
- **Aquatic**- The roots found in water plant. They do not possess root caps and root hairs, e.g., *Pistia*.

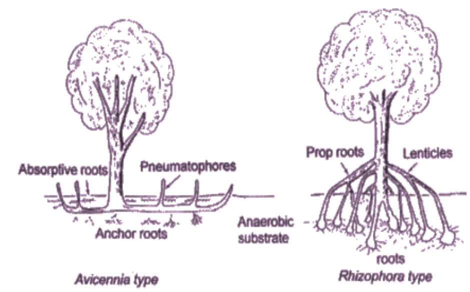
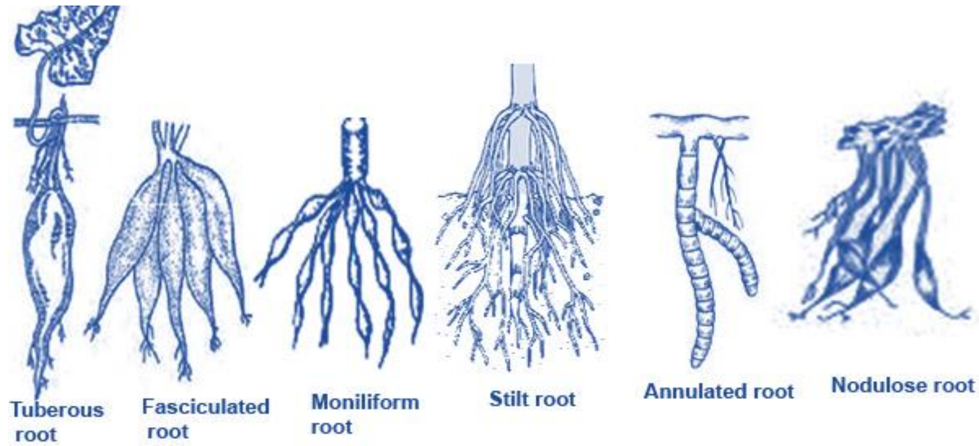



**Fig. 8: Prop Roots & Pneumatophore**

- **Conical**- Cone like fleshy roots, e.g., carrot.
- **Fusiform**- Fusiform, e.g., fleshy root of radish (*Raphanus sativus* of Brassicaceae).
- **Napiform**- Napiform. e.g., fleshy root of turnip.
- **Fasciculated**- Clusters of fleshy roots, e.g., *Asparagus*.
- **Nodulated** The nodules of the roots contain bacteria, e.g., Leguminous roots; *Cicer, Arachis, Trifolium*.
- **Beaded or Moniliform**- The roots possessing beaded structures, e.g., *Vitis*.
- **Annulated**- When the root has a series of ring-like swellings on its body, e.g., *Ipecacuanha*.
- **Nodulose**- When the slender root becomes suddenly swollen near the apex, e.g., Curcuma amada (Am-haldi).




## Rootless Plants

Many plants growing in aquatic habitats do not possess roots because there is little requirement for absorption of water and mineral salts, e.g., *Wolffia*, *Utricularia*, *Myriophyllum*, *Ceratophyllum*. In other aquatic plants, roots develop only for balancing (e.g., *Lemna*, *Pistia*) and fixation (e.g., *Hydrilla*).

## Root Structure

### (a) Root Cap (Calyptra)

It is a cap like protective structure of the growing root tip. In *Pandanus* (Screwpine) multiple root caps present while in aquatic plants (*Pistia*, *Eichhornia*, *Lemna*) root pockets present instead of root cap.

**Functions -**

- Protects root meristem,
- Secrete mucilage that help tender root to penetrate the hard soil,
- Helps in perception of gravity (Darwin, 1880),
- Root packet s functions as balances.

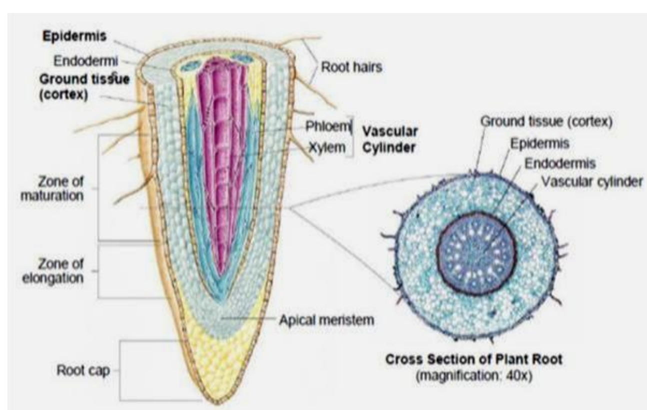



**Fig.9 : Various Zones of Meristematic Cells**

### (b) Meristematic Zone

It is about 0.25-1.0 mm long, lies just behind the root cap and thus sub-terminal in position. Its shape is like an inverted concave dome of cells. The central rarely dividing cells are called quiescent centre (Fig. 9).

**Function-** Root meristem adds cells to root cap and the basal region of the root.

### (c) Zone of elongation

It is about 1-10 mm long and lies just behind the meristematic zone. As the name implies, it is the site of rapid and extensive cell elongation. This zone increases length of the root. The external cells can absorb water and minerals from the soil.

**(d) Root hair Zone or Zone of differentiation**

It is about 1-6 cm long. It is the zone where cell differentiate to form epiblema, cortex, endodermis, pericycle, xylem and phloem. Many cells of epiblema elongate to form unicellular root hairs. As the root grows, new root hairs develop and older one shrivel and sloughed off (Fig. 9).

**Function-** Root hairs increase the absorptive surface area of root.

### (e) Zone of maturation

In constitute the major portion of the root. The cells attain maturity when they reach this zone.

**Function-**

(i) Lateral roots may emerge from pericycle
(ii) Radial differentiation of tissues causes' secondary growth in dicots.

### Functions of Root

Roots perform two kinds of functions — Primary and Secondary. The primary functions are performed by all kinds of roots, and they are structurally adapted to per-form these functions. The secondary functions are specialized one and are performed only by those roots which are modified accordingly (Fig. 9).

**The primary functions of roots are-**

1. Anchorage or fixing the plant firmly to the soil so that they are not easily uprooted.
2. Absorption and translocation of water and minerals from the soil to the aerial parts of the plant.
3. Prevent soil erosion by holding the soil particles.

In many plants, roots are modified to serve many secondary functions like food storage, mechanical support and various physiological activities other than absorption.

## Stem of Angiosperms

### Function and Types

The stem is the ascending part of the plant formed by the elongation of the plumule of the embryo. It bears leaves, branches and flowers. It is generally erect, strong and usually grows away from the soil (negatively geotropic). There are several plants in which the stem is weak and it either trails on the ground or twines around a support. Stems are differentiated into regions called nodes. Leaves and branches arise from nodes. The portion between the nodes is called the Internode. The growing apex of the stem is covered by numerous, tiny, developing leaves and is called the apical bud. Buds also arise in the axils of leaves; they are termed axillary or Lateral buds. These buds give rise to branches or flowers.

Plants have been classified on the basis of the height and strength of stem and their life- span. Herbs are small plants with a soft stem. Medium-sized plants with woody stems that branches profusely from the base and attain a bushy appearance are called Shrubs. Trees have a stout and tall trunk with profuse branching. Plants which complete their life cycle within one season are termed annuals such as agricultural crops (rice, groundnut etc.). Biennials complete their life cycle in two seasons (radish, cabbage). Plants that usually survive for a number of years and produce flowers and fruits during specific seasons are termed perennials (mango, apple etc.).Besides bearing branches, leaves and flowers, stems perform other functions such as presentation, vegetative propagation and storage of reserve food.

## Functions of stem

**Primary or main functions**

- It supports and holds leaves, flowers and fruits.
- Leaves are borne on stem in such a fashion that they are able to carry on the important function efficiently just like to receive the light and to carry on the gaseous exchange.
- The stem conducts the water and minerals from roots to leaves and fruits.
- Stem bears flowers and fruits in position to facilitate the processes of pollination and fertilization.

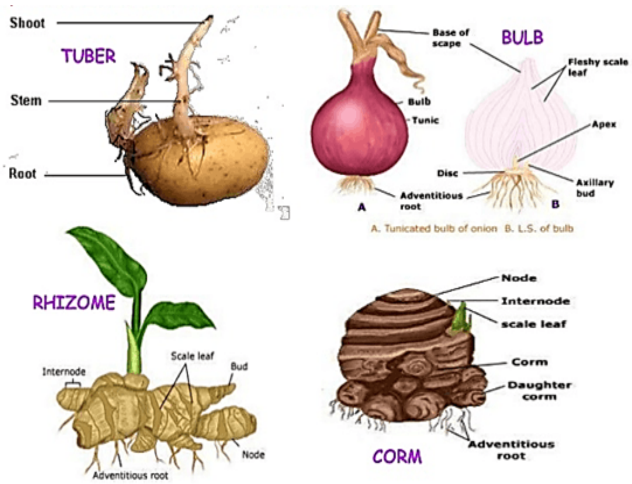
**Secondary or Accessory functions**

- Perennation
- Storage of food
- Photosynthesis
- Vegetative propagation
- As climbers

There are three types of stem Underground stem, Aerial stem and Sub- aerial stem.

## 1. Underground stem

Stems of some plants remain in the ground and serve the function of perennation and storage of food. They produce aerial shoots annually. They resemble roots superficially but are distinguishable by the presence of scale leaves and buds at nodes. Such stem also act as a means of vegetative propagation. The modified underground stems are the following




- **Rhizome-** It is a thickened, prostrate, underground stem having distinct nodes and internodes, scaly leaves at the nodes, axillary and terminal buds present; may be branched or un-branched; sometimes adventitious roots also arise, e.g. Ginger.

- **Tuber-** The underground stem becomes enlarged at the growing tips by the accumulation of stored food, commonly starch, tubers are produced e.g. Potato. The eyes of potato are nodes at each of which 1-3 buds are produced in the axils of small scaly like leaves.

- **Bulb-** Bulb is a short underground stem with fleshy leaf base called scales. Stem is very much reduced and becomes disc like. The discoid stem in convex or conical in shape and bears highly compressed internodes. These node bear fleshy scales. On the upper side, disc bears terminal bud surrounded by number of leaves. The axillary buds are present between the axis of leaves. The adventitious roots are borne on the lower side of the disc. Eg. Onion.

- **Corm-** Corm is short, thick and un-branched underground stem with stored food material. It grows vertically and covered by thin sheathing leaf bases of dead leaves called scales. The corm bears buds at their nodes. These buds are responsible for giving off adventitious roots. Corm serves the functions of food storage, vegetative propagation and perennation. Corm is more or less rounded in shape or often somewhat flattened from top to bottom, e.g. *Colocasia*.

## 2. Sub-aerial stems

Lower buds of the stem in some plants grow out into short, lateral branches. These are named according to their origin, nature and mode of reproduction.


**Fig. 10 : Sub aerial stems Offset (*Pistia, Eichornia*) , Stolon (*Mentha*) Runner (Strawberry)**

- **Runner-** It grows prostrate in all directions above the soil level. Nodes bear scale leaves. It has a creeping stem with long internodes. On the lower sides, nodes bear adventitious roots. Runner develops from the axils of lower leaves of aerial stem which sends slender horizontal branches in the form of runners. When older parts of plant die, the branches separate from parent plant and form independent plants e.g. Doob grass.

- **Stolon**- It is a slender lateral branch which appears from the lower part of main axis. This lateral branch grows aerially for some distance and becomes arched and finally touches the ground to give rise to new shoot with the help of its terminal bud. It also bears roots to get fixed with the soil e.g. Jasmine.

- **Offset**- Offset is shorter and thicker. It is usually found in aquatic plants like water hyacinth and *Pistia*. It bears a cluster of leaves near the water or ground level and gives adventitious roots inside water or ground from all nodes, e.g. *Pistia*.

- **Sucker**- Like the stolon the sucker is also a lateral branch but it grows obliquely upwards and gives rise to a new plants e.g. *Mentha*.

### 3. Aerial stems

These modified aerial stems perform unusual functions. Different forms of these stems are the following -

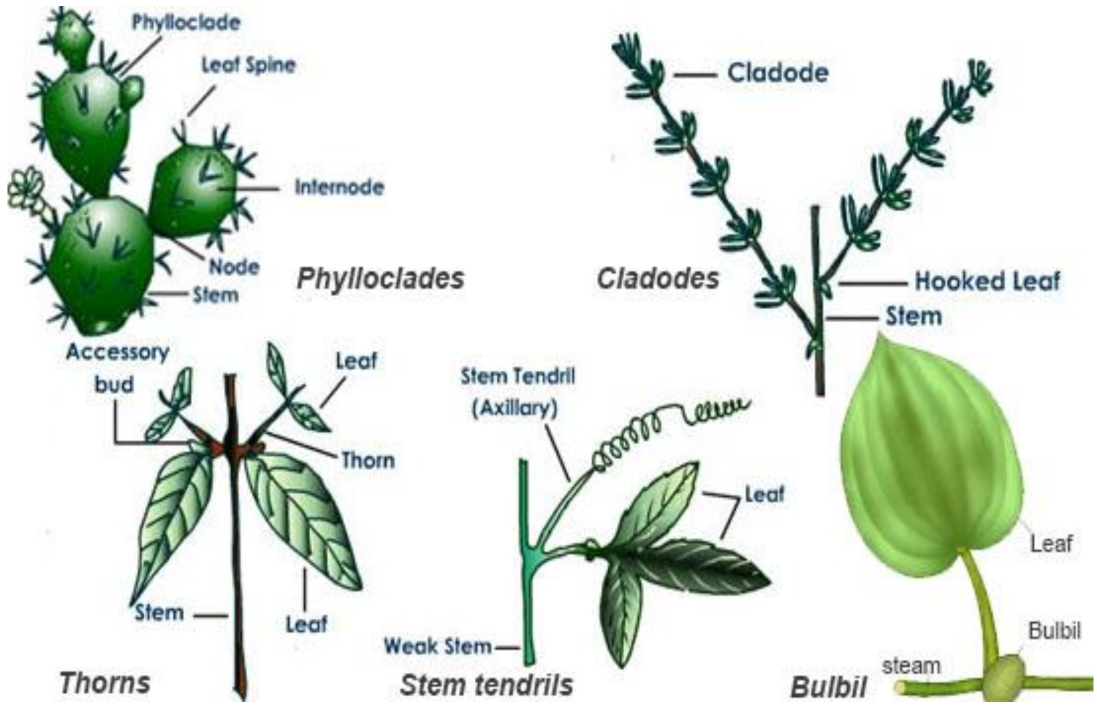
- **Stem tendril**- It is a leafless, spirally coiled branch formed in some climbers and helps them in climbing neighbouring objects; they may be modification of axillary bud, e.g. *Passiflora*.

- **Stem thorn**- Stem thorn is a hard, straight and pointed structure; it is a defensive organ; also helps in climbing; originates from axillary or terminal bud, e.g. *Duranta*.

- **Pylloclade**- It is a green, flattened or cylindrical stem which takes the form and function of leaf. It contains chlorophyll and is responsible for carrying on photosynthesis. It bears succession of nodes and intemodes at long or short intervals. Phylloclades are found in xerophytic plants where the leaves either grow feebly or fall off early or modified into spines e.g. *Opuntia*,**Cladode**- Phylloclade with one or two internodes is called cladode e.g. Asparagus. In Asparagus cladodes are needle-like, slightly flattened green structures which appear in cluster in the axils of a scaly leaf. Main stem bears leaf spines at its nodes. A scale leaf is found just above the spine. Every branch on main stem bears only scale leaves. In the axils of scale leaves cluster of cladodes appear

- **Bulbil**- Bulbil is the modification of vegetative or floral bud. It is swollen due to storage of food. It can function as an organ of vegetative propagation e.g. *Dioscorea*.

Normally aerial part of axis of vascular plants, bearing leaves and buds at definite positions (nodes) and reproductive structures, e.g., flowers.




## Important Terminologies

- **Erect**- Rigid, strong and upright stem.
- **Prostrate**- Trailing stem lying flat on the ground, e.g., *Portulaca*.
- **Twiner**- Long, slender and branched stem climbing by twining its body round the support, e.g., *Cuscuta*.
- **Climbers**- A weak stem attaching itself to any neighbouring support by means of special structures such as rootlets, hooks, leaf tendrils, stem tendrils, stipular tendrils, etc.
- **Rhizome**- Underground stem, bearing buds in axils of reduced scale-like leaves; saving as a means of perennation vegetative propagation, e.g., *Zingiber, Mentha*.
- **Bulb**- Modified shoot consisting of very much shortened stem enclosed by fleshy, scale leaves, e.g., *Allium cepa*.
- **Corm**- Swollen stem base containing food material and bearing buds in the axils of scale like remains of leaves of previous season's growth, e.g. *Colocasia, Amorphophallus, Gladiolus*.
- **Tuber**- Swollen end of underground stem bearing buds in axils of scale-like rudimentary leaves (stem tuber), e.g., Potato.
- **Offset**- A horizontal, short, more or less apex a tuft of leaves above and a cluster of thickened, prostrate branch producing at the small roots beneath, e.g., *Pistia*.
- **Stolon**- Horizontally growing stem that roots at nodes, e.g., strawberry runner, *Colocasia*.
- **Runner**- Stolon that roots at tip forming new plant that eventually is freed from connection with parent by decay of runner, e.g., *Oxalis*.
- **Sucker**- A creeping stem but growing obliquely upwards directly giving rise to a leafy shoot, e.g., Chrysanthemum.
- **Phylloclade**- Modified stem having appearance and function of a leaf e g *Ruscuscocoloba*.
- **Cladode**- A phylloclade of single internode, e.g., *Asparagus*.

- **Branched**- Stem possessing branches, e.g., Neem tree.


Cuscuta (Parasite)


Orobanche (Partial Parasite)


Viscum (Epiphyte)


Vanda (Epiphyte)


Dioscorea (Bulbil)


Vitis (Stem tendril)

### Un-branched

Stem having no branches, e.g., Palm. If branched whether racemose or cymose type of branching, If cymose whether uniparous, biparous or multiparous.

- **Herbaceous**- Having the characters of a herb, e.g., *Ranunculus*.
- **Woody**- Having the characters of a shrub and tree, e.g., *Capparis, Melia*.
- **Solid**- Interior portion of the stem is filled up with matter.
- **Fistular**- A stem having hollow interior, e.g., wheat, bamboo.
- **Cylindrical (terete)** - Circular stem as seen in T.S.
- **Angular**- A stem shows many angles in T.S., e.g., *Cucurbita*.
- **Flattened**- Flat stem in T.S.
- **Hairy**- Stem possessing hairs on its surface.
- **Glabrous**- Smooth stem.
- **Waxy**- Stem having wax coating, e.g., *Calotropis*.
- **Spiny**- Stem having spines.
- **Colour**- Whether green, grey, etc.

## Leaf of Angiosperms

### Characteristics & Functions of Leaf

Leaf is a green, dissimilar exogenous lateral flattened outgrowth which is borne on the node of a stem or its branch and is specialized to perform photosynthesis. Typically it is a thin expanded green structure which bears a bud in its axil. The green color of the leaf is due to the presence of chlorophyll. Leaves are arranged in acropetal order. They develop as lateral outgrowth from shoot apical meristem. They are important vegetative organs which are specialized for photosynthesis. All the green leaves of a plant are collectively called foliage.

## Importance of Leaf Morphology

Leaf morphology is employed in taxonomy for accurate description, identification and classification of plants. For this the leaves show specific variations in shape, apex, base, margin, phyllotaxy, venation, etc. Crop productivity is determined by rate of leaf production, periods for which they are retained on the plants, their orientation to light, shape, area, etc. Some plants show developmental heterophylly. In such plants shape of the leaves indicates the stage of plant maturity, e.g., Cotton, Eucalyptus. Any peculiarity of shape, size, and colour including variegation of leaves is picked up by horticulturists for propagation. Foliage plants are grown for adorning our verandahs and passages. The foliage of some plants is economically important, e.g., Tea.

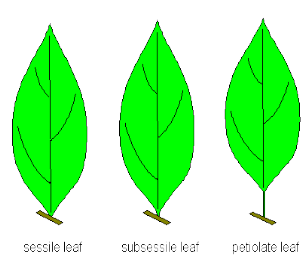
## Characteristics of Leaf

- It is dissimilar lateral flattened outgrowth of the stem,
- The leaf is exogenous in origin,
- It is borne on the stem in the region of a node,
- An axillary bud is often present in the axil of the leaf,
- Leaf has limited growth,
- An apical bud or a regular growing point is absent,
- The leaf base may possess two lateral outgrowths called stipules,
- A leaf is differentiated into three parts— leaf base, petiole and lamina,
- The lamina possesses prominent vascular strands called veins,
- It is green and specialised to perform photosynthesis,
- Leaf bears abundant stomata for exchange of gases,
- It is the major seat of transpiration.

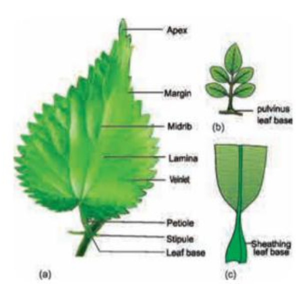
## Parts of a Leaf

A leaf consists of three parts - leaf base, petiole and lamina. Lamina or leaf blade is the terminal thin, expanded, green and conspicuous part of the leaf which is specialized to perform photosynthesis. The flattened lamina or leaf blade is supported by veins and veinlets which contain vascular tissues for conduction of water, mineral salts and prepared food.


Typical Leaf & its parts

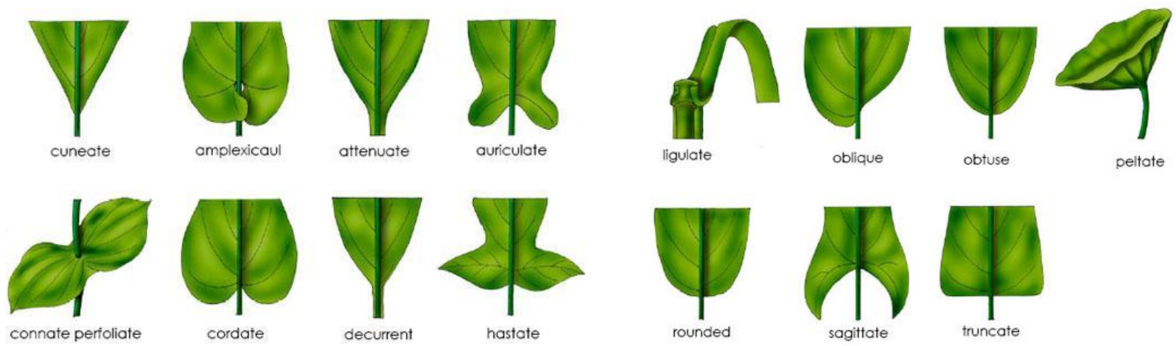



Petiole Types




Leaf Bases a. Simple b. Pulvinus c. Sheathing

There are two surfaces - adaxial (ventral, upper) towards the upper part of stem and abaxial (dorsal, lower) towards the lower part of stem. The two surfaces are quite distinct in dorsiventral leaves (most dicot leaves) but are quite similar in isobilateral leaves (most monocot leaves). Petiole is a cylindrical or sub-cylindrical smooth or grooved stalk of the leaf which lifts the lamina above the level of stem so as to provide it with maximum exposure. Leaf having petiole is called petiolate. It is termed sessile if the petiole is absent.




Leaf base is the lowermost part of the leaf by which the leaf is joined to the node of the stem. It protects the young axillary bud. Leaf base is often indistinguishable from the petiole. In many legumes it is swollen. The swollen leaf base is known as pulvinus. It is responsible for sleep and shock movements of certain leaves, e.g., *Mimosa pudica*. Leaf base may be broadened to enclose the stem. It is called sheathing leaf base. The latter is of two types - amplexicaul (enclosing stem completely as in Grasses, Wheat) and semiamplexicaul (enclosing the stem partially, e.g., Buttercup).

Leaf base often contains two small lateral outgrowths called stipules. A leaf with stipules is called stipulate while the one without stipules is termed as exstipulate. In grasses an outgrowth is present between leaf base and lamina. It is called ligule. The leaf with ligule is called ligulate.

**I. Stipules**

They are two small lateral outgrowths of the leaf base which protect the young leaf and its axillary bud in the young state. In some compound leaves, the leaflets bear basal lateral outgrowths named stipels, e.g., Bean, *Clitoria*, *Vicia*.

**Different types of stipules are-**

- **Free Lateral** - Small, free, green outgrowths, e.g., Shoe-flower (*Hibiscus rosa-sinensis*),
- **Scaly** - Very small dry membranous stipules, e.g., *Cassia fistula*,
- **Axillary or Intrapetiolar**- Stipules are fused from their inner margins to become axillary, e.g., *Gardenia*,
- **Opposite**- Stipules are fused from their outer margins to become opposite the leaf, e.g., Castor,
- **Interpetiolar**- Adjacent stipules of opposite leaves are fused to appear in between the petioles, e.g., *Anthocephalus* (Kadam), *Ixora*.
- **Adnate or Petiolar**- Stipules fused with petiole, e.g., Rose, Groundnut,
- **Ochreate** - Stipules fuse to form a sheath or ochrea around the stem, e.g., *Rumex*, *Polygonum*,

- **Bud Scales**- Stipules of young leaves connate to protect bud, e.g., *Ficus*,
- **Foliaceous** - Large and green, e.g., *Pisum*.
- **Stipular Spines** - Stipules are transformed into spines, e.g., *Acacia*, *Zizyphus*. The two stipular spines of *Zizyphus* are unequal with one straight and second bonked
- **Stipular Tendrils**- Stipules are modified into tendrils, e.g., Smilax for climbing.

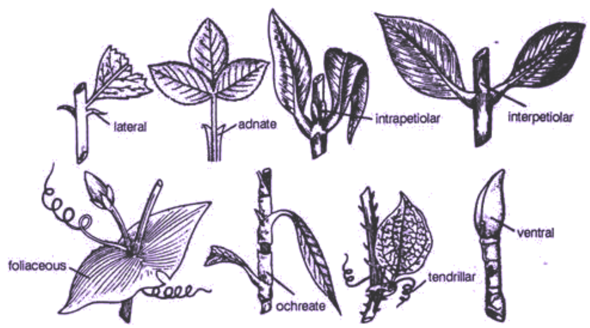


*Fig. 74. Kinds of stipules.*

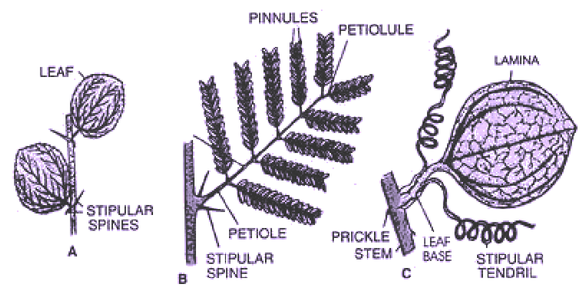


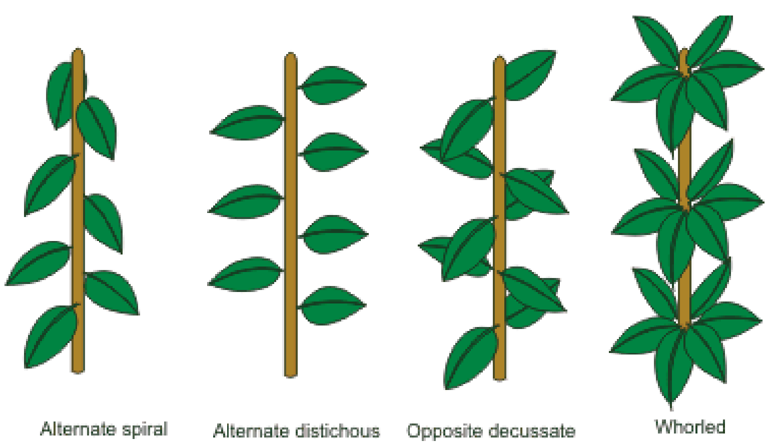
Fig. 5.52. A-B Stipular spines. A, *Zizyphus*. B, *Acacia*. C, Stipular tendrils of *Smilax*.

It is the arrangement of leaves on the stem or its branches (Gk. phyllon- leaf, taxis- arrangement). The purpose or function of phyllotaxy is to arrange leaves in such a way that all of them get proper exposure to sunlight.

## Phyllotaxy

### 1. Spiral

Only one leaf is borne on a node and the leaves of the adjacent nodes roughly lie towards the opposite sides (e.g., Shoe Flower). The simplest type of such a phyllotaxy is alternate or spiral distichous in which the leaves of a branch form two alternate rows (e.g., Grass).




In others, leaves form 3, 4, 5 or several rows called orthostichies. The condition is called tristichous, tetrastichous, pentastichous, etc. In such cases phyllotaxy is determined by passing a thread along the bases of successively higher leaves till a leaf comes to lie exactly above the first one (which is counted as zero).

The spiral made by the thread is called genetic spiral. Phyllotaxy is written by taking the number of circles as numerator and the number of leaves as denominator, e.g., 1/3, 2/5, 3/8, 5/13, 8/21.

These phyllotaxic series are also called Schimper-Brown series in which each member of the series is the sum total of numerators and denominators of the two previous ones. Angle between two successive leaves or angular divergence is calculated by multiplying the phyllotaxy with 360, e.g., 1/3 x 360 = 120.

**2. Opposite** - Two leaves are borne on the opposite sides of a single node.

**Opposite phyllotaxy is of two types-**

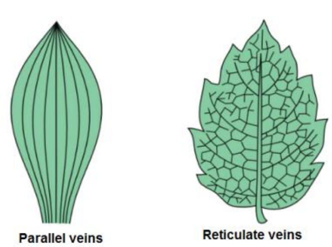
- **Opposite and Superposed**- Leaves of the successive nodes lie in the same plane so that only two rows are formed on the stem, e.g., *Quisqualis* (Rangoon Creeper), *Syzygium* (=*Eugenia, jambolana*, vem, jamun).

- **Opposite and Decussate**-The opposite leaves of the adjacent nodes lie at right angles so that four rows of leaves are formed on the stem, e.g., *Calotropis* (vern Ak), Sacred Basil (vern. Tulsi), Zinnia, Guava.
- **Whorled or Verticillate** - Three (e.g., *Nerium* or Oleander, vern. Kaner) or more than three (e.g., Alstonia) leaves develop from a single node. The leaves of one whorl generally alternate with those of the adjacent whorls in order to provide for maximum exposure. Cyclic phyllotaxy includes both opposite and whorled types of phyllotaxy.

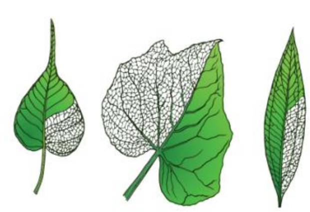
## II. Venation

The arrangement of veins and veinlet's on the lamina of a leaf is called venation. Veins and veinlet's are skeletal as well as conducting prominences visible on the surface of lamina, especially the under surface in dorsiventral leaves. **Their important functions are-**

- Conduction of water through xylem.
- Providing channels for translocation of organic nutrients,
- Conduction of minerals,
- By their large number, the veins and veinlet's provide skeletal support to the lamina so that it can remain stretched for its optimum functioning,
- Veins and veinlet's reduce the effect of wilting. Venation is of three main types- reticulate, parallel and furcate.

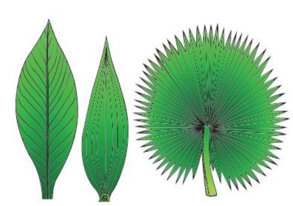



**Basic Types of Venation**



(a) *Ficus* (b) *Cucurbita* (c) *Cinnamomum*

**Reticulate Venation**



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

**Parallel Venation**

## I. Reticulate Venation

The veinlet's form a reticulum or network. Reticulate venation is found in dicots (exceptions; *Calophyllum*, *Corymbium*, *Eryngium*). It has two sub-types -

### (i) Pinnate or Unicostate Reticulate Venation

The lamina has a single principal vein or midrib which extends from its base to apex. It gives rise to lateral veins along its entire length Tike the plumes of a feather. Veins bear veinlet's. The veinlet's form reticulations, e.g., Peepal (*Ficus religiosa*), Shoe-Flower (*Hibiscus rosa-sinensis*).

### (ii) Palmate or Multicostate Reticulate Venation

A number of prominent or principal veins arise from the tip of the petiole and reach either the apex or margins of the lamina. They give rise to lateral veins connected by reticulations of veinlets.

**Multicostate venation is of two forms**

- **Convergent** - The principal veins converge towards the apex of the lamina, e.g., *Zizyphus*, *Smilax*.
- **Divergent** - The principal veins diverge towards the margins, e.g., Castor (*Ricinus*), *Luffa*, *Vitis* (Grape Vine), etc.

## II. Parallel Venation

Veinlet's are inconspicuous. Reticulations are absent. The veins run parallel to one another. Parallel venation is characteristic of monocots with the exception of a few (e.g., *Smilax*, *Colocasia*, *Alocasia*, *Dioscorea*). Parallel venation is of two subtypes-

- **Pinnate or Unicostate Parallel Venation**

There is single principal vein or midrib that runs from base to the apex of the lamina. The lateral veins run parallel to one another without forming anastomoses, e.g., Banana (Musa paradisiaca), Canna.

- **(ii) Palmate or Multicostate Parallel Venation**

Several parallel principal veins arise from the base of the lamina. Depending upon their orientation there are two forms-

- **Convergent** - The principal veins converge towards the apex, e.g., Bamboo, Grass,
- **Divergent**- The principal veins proceed towards the margins, e.g., Fan Palm (*Livistonia*).

## 3. Furcate Venation

The veins branch dichotomously. The finer branches do not form a reticulum. It is common in ferns (e.g., *Adiantum*). Among higher plants furcate venation is found in *Circeaster*.

## III. Pinnate Leaf

The plan of venation is similar to that of a feather. The simple leaf is unicostate, that is, it has a single principal vein or midrib. When Compound, the leaf bears leaflets on an elongated axis derived from midrib and called rachis.

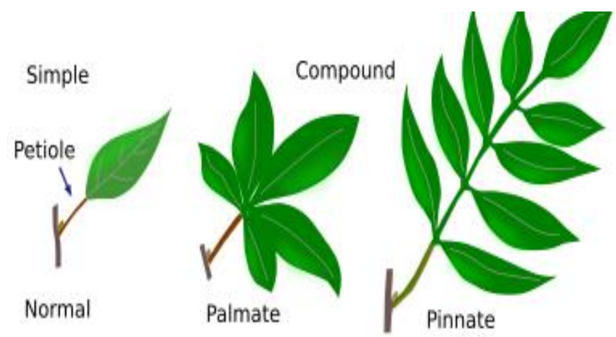
## IV. Palmate Leaf

The plan of venation is similar to a hand. When simple, leaf is multicosatate, that is, it has a number of principal veins, In compound leaf, leaflets are borne jointly on the tip of the petiole.

## V. Simple Leaf

A leaf having a single or undivided lamina is called simple leaf. The lamina can have various types of incions, which may reach up to half (-fid), more than half (-partite) or near the base of midrib (-sect). Depending upon the pinnate or palmate venation, the incisions are known as pinnatifid, palmatifid, pinnatipartite, palmatipartite, pinnatisect and palmatisect (Fig. 5.57).

## VI. Compound Leaf




A compound leaf is that where the lamina is completely broken up into distinct segments or leaflets which are separately articulated at the base. The leaflets resemble leaf in having base, stalk and blade. The leaflets (pinnae or pinnules) differ from the whole leaves in the absence of axillary buds, basal stipules and origin in the same plane.

**The compound leaves are of two types**

## 1. Pinnate Compound Leaves

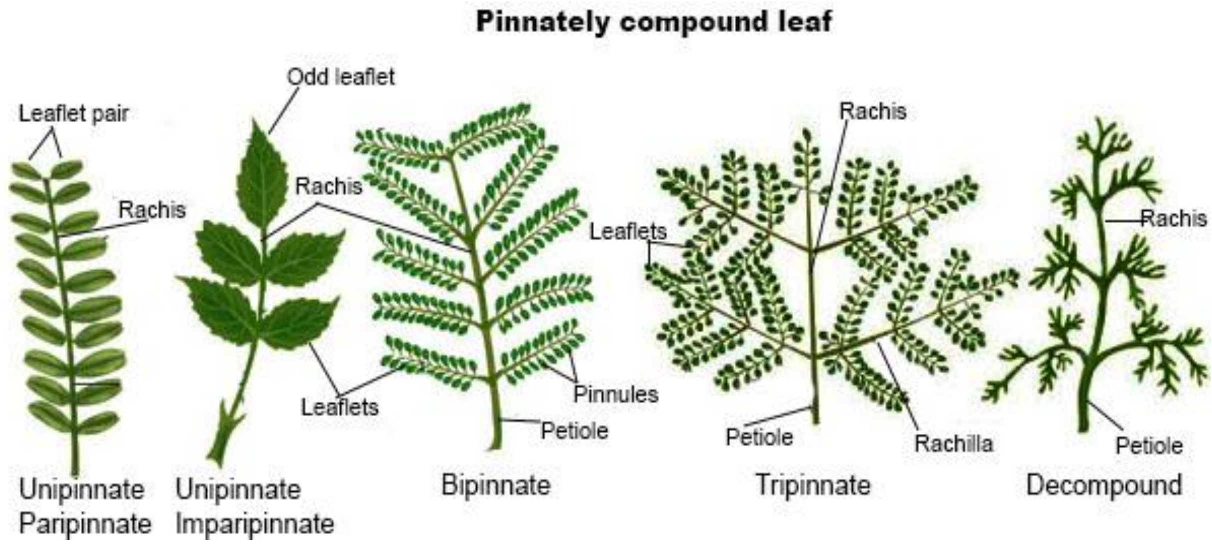
Here the leaflets are borne laterally on an elongated axis. The axis may represent the midrib or lateral vein of a simple leaf. The various kinds of pinnate compound leaves are as follows-

### (i) Unipinnate

The leaf is divided only once in a pinnate fashion. The leaflets or pinnae are attached on an axis which is a continuation of the petiole. It is called rachis. The leaflets are commonly borne in opposite or sub-opposite (e.g., *Murraya*) pairs.

- **Paripinnate :** The leaflets of this unipinnate leaf are even in number, e.g., cassia fistula (vern. Amaltas), *Sesbania*, Tamarind (vern. Imli).

- **Imparipinnate** : The leaflets are odd in number with a terminal unpaired leaflet, e.g., Rose, *Murraya*, Neem (*Azadirachta indica*).




**(ii) Bipinnate**

Here the pinnate leaf is divided twice pinnately. The leaflets called pinnules, are borne on the secondary axes known as rachillae or rachules. The rachillae are arranged in a pinnate fashion on the Primary axis or rachis, e.g., *Acacia nilotica* (vern. Kikar), *Mimosa pudica* (Sensitive Plant), *Albizzia* (Sirin, Siris).

**(iii) Tripinnate**

The leaf is thrice pinnate. The leaflets or pinnules are borne on tertiary axes, e.g., *Moringa* (vern. Sahinjana, Soanjana), *Melia azedarac* (vern. Dharek, Drek).

**(iv) Decompound**

In this type the leaf is more than thrice pinnate, e g Fennel Coriander (vern. Dhania), Carrot (vern. Gaajar). In several such cases the development of lamina is suppressed and the compound branches of the rachis remain green carrying on the function of photosynthesis.

## III. Pinnate Leaf

The plan of venation is similar to that of a feather. The simple leaf is unicostate, that is, it has a single principal vein or midrib. When Compound, the leaf bears leaflets on an elongated axis derived from midrib and called rachis.

## IV. Palmate Leaf

The plan of venation is similar to a hand. When simple, leaf is multicostate, that is, it has a number of principal veins, In compound leaf, leaflets are borne jointly on the tip of the petiole.

## 2. Palmate Compound Leaves

The palmate compound leaf is one in which the petiole bears leaflets at the tip like the fingers of the palm. A joint may be present between the tip of the petiole and the leaflets. Depending upon the number of the leaflets present, a palmate compound leaf is called-

- **Multifoliolate or digitate** (five or more leaflets, present at the tip of petiole, e.g., *Bombax* (Red Silk Cotton, vern. Simbal), *Cleome*;
- **Quadrifoliolate or quadrinate** (four leaflets attached to tip of petiole, e.g., *Paris quadrifolia; Marsilea* also seems to have quadrifoliolate leaves, although in reality its leaves are pinnately divided;
- **Trifoliolate or ternate** (three leaflets), e.g., *Aegle marmelos* (Wood Apple, vern. Bael), *Butea* (Dhak), *Oxalis*;
- **Bifoliolate or binate** (two leaflets, attached side by side at the tip of petiole, e.g., *Balanites, Hardwickia*;
- **Unifoliolate** (a single leaflet separated from the petiole by a constriction) e.g., *Citrus*.
- The leaf of a citrus appears to be a simple leaf with an undivided lamina and winged petiole. However, it has a joint or constriction between the lamina and the petiole of the leaf. The close relatives of *Citrus* possess trifoliolate leaves (*Aegle marmelos*,).

Even in Citrus many abnormal leaves bear two small leaflets just on the sides of the normal blade This clearly shows that the leaf of Citrus is, in reality, a palmate compound leaf where the two lateral leaflets have been suppressed and only the central leaflet (the normal blade) is functional. Such a palmate compound leaf, with one functional leaflet, is called unifoliolate compound leaf.

## Leaf Base

- **Connate**- Two sessile opposite leaves meeting each other across the stem and fusing together, e.g., *Lomicera flava*.
- **Amplexicaul**- Clasping or surrounding the stem, as base of leaf, e.g., *Sonchus*.
- **Auriculate**- Leaf with expanded bases surrounding stem, e.g., *Calotropis*.
- **Decurrent**- Having leaf base prolonged down stem as a winged expansion or rib, e.g., Laggerapterodonta.
- **Perfoliate**- A leaf with basal lobes so united as to appear as if stem ran through it, e.g., Aloe perfoliata.

Bifoliate of Balanites

Trifoliate of Oxalis

Trifoliolate of Aegle

Quadrifoliate of Paris

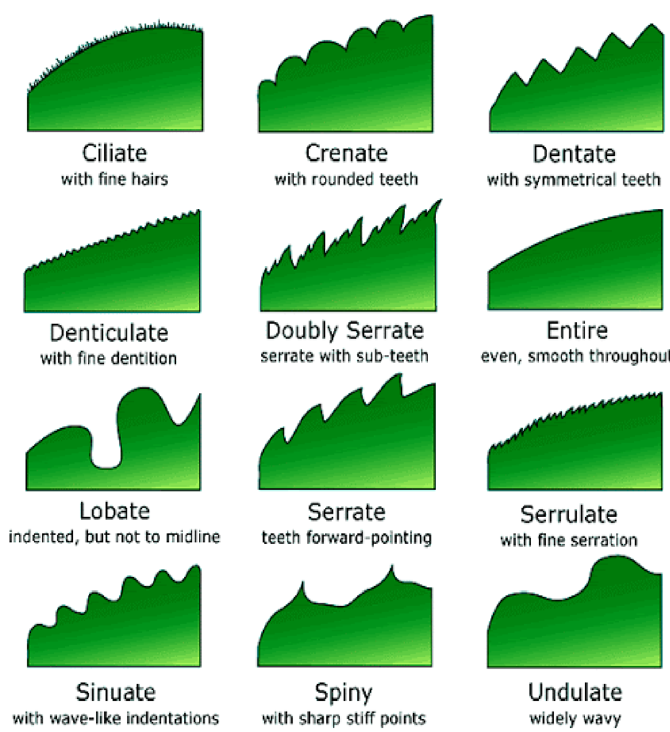
Quadrifoliolate of Marsilia

Multifoliolate of Bombax

## Important Terminologies

### Margin of Lamina

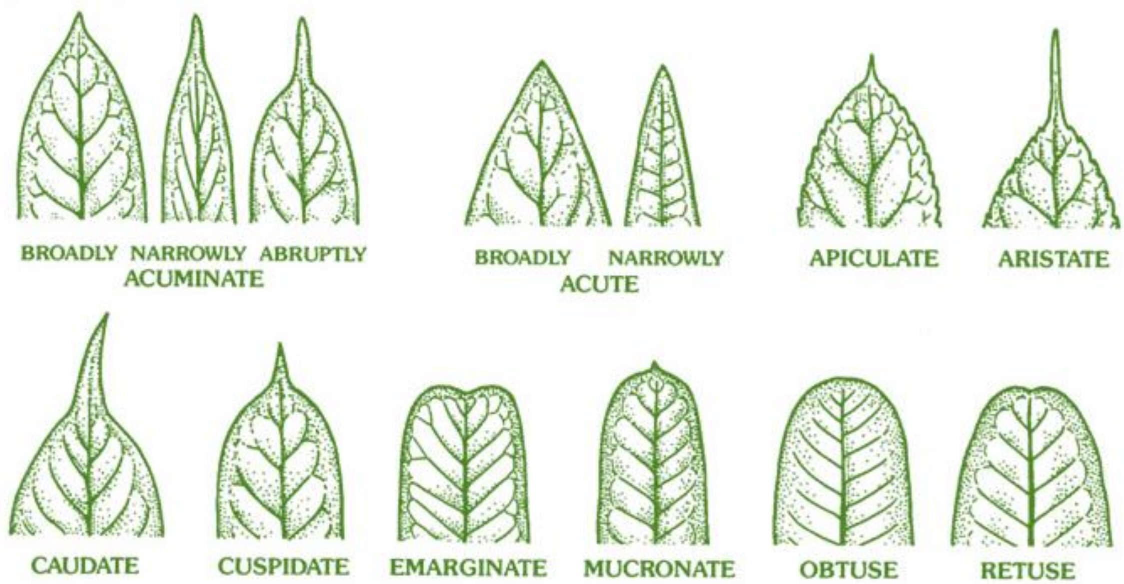
**Entire**- With continuous margin, e.g., Psidium.
**Dentate**- With large saw-like teeth on the margin.
**Serrate-dentate**- With serrate edges themselves toothed.
**Undulate**- Wavy, e.g., Polyalthia.
**Convolute**- Rolled together.
**Crenate**- With scalloped margin, e.g., Bryophyllum.
**Lacerate**- Having margin or apex deeply cut into irregular lobes, e.g., many members of Ranunculaceae.
**Laciniate**- Irregularly incised; fringed.
**Laciniolate**- Minutely incised or fringed.
**Ciliate**- Bearing fine hairs on the margin.
**Crispate**- Curled or extremely undulate margin.
**Spinous**- Bearing many spines, e.g., Argemone.




**Pectinate**- Comb-like. **Lobed**- Leaf margin divided into many lobes, e.g., Ranunculus.

### Leaf Apex

- **Acute**- Ending in a sharp point forming an acute angle, e.g., mango.
- **Acuminate**- Drawn out into long point; tapering; pointed, e.g., Ficus religiosa.
- **Obtuse**- With blunt or rounded end, e.g., Banyan.
- **Emarginate**- Having a notch at apex, e.g., Bauhinia.
- **Truncate**- Terminating abruptly, as if tapering end were cut off, e.g., Caryotaurens.




- **Mucronate**- Abruptly terminated by a sharp spine, e.g., apex of leaflet of Cassia obtusifolia.
- **Cuspidate**- Terminating in a point.
- **Aristate**- Provided with awns, or with a well developed bristle.
- **Retuse**- Obtuse with a broad shallow notch in middle, e.g., Oxalis.
- **Cirrhose**- Leaf with prolongation of midrib forming a tendril, e.g., Gloriosa.
- **Apiculate**- Forming abruptly to a small tip, e.g., Dalbergia.

## Leaf Surface

- **Hairy**- Leaf surface covered with tine hairs.
- **Glabrous**- With a smooth even surface, without hairs, e.g., China rose.
- **Glaucous**- Shiny green, e.g., Citrus.
- **Spiny**- Covered with spines, e.g., Argemone.


Hairy


Glabrous


Glaucous


Spiny

**Venation**- System or disposition of veins.

- **Reticulate (net veined)** - Like net work, e.g., most of dicots.
- **Parallel**- Parallel veined, e.g., most of monocots.
- **Unicostale**- Having only one principal vein.
- **Multicostate**- Having many principal veins.

## Texture

- **Coriaceous**- Leathery, e.g., Calotropis.
- **Fleshy**- Soft and thick, e.g., Spergula.
- **Succulent**- Full of juice or sap, e.g., Aloe.

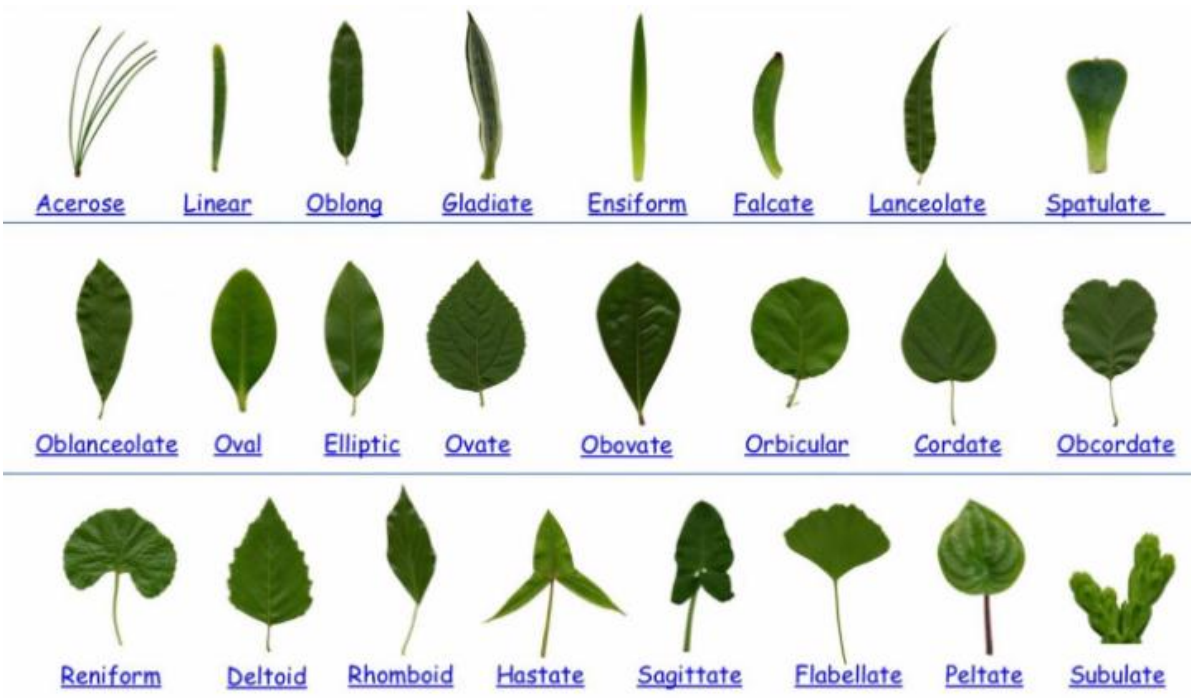
## Colour

- **Green**- Usually the leaves are green in colour.
- **Pigmented**- In certain leaves the pigments are developed, e.g., *Aerva*.

**Note: In** a compound leaf the leaflet should be described in the manner as a simple leaf.

## Shape of the Leaf

- **Linear**- Long and narrow leaf, e.g., many grasses.
- **Lanceolate**- Lance-shaped leaf, e.g., bamboo, Nerium, etc.
- **Round or orbicular**- Leaf with a circular leaf blade, e.g., lotus, garden nasturtium, etc.
- **Elliptical**- An ellipse-shaped leaf, e.g., guava, jack, etc.
- **Ovate**- Leaf with an egg-shaped leaf blade, i.e., slightly broader at the base than at the apex, e.g. banyan, China rose, etc.
- **Spathulate**- Spathula-shaped leaf, i.e., broad and round at the top and narrower towards the base, e.g.. Calendula and Drosera.
- **Oblique**- Leaf with two unequal halves, e.g., Begonia.
- **Oblong**- Leaf with wide and long leaf blade. Here the two margins run more or less straight up, e.g., banana.
- **Reniform**- Kidney-shaped leaf, e.g., Indian pennywort.
- **Cordate**- Leaf with heart-shaped leaf blade, e.g.,betel (inversely heart-shaped leaf called as obcordate, e.g., wood-sorrel).
- **Sagittate**- Leaf with an arrow-shaped leaf blade, e.g., arrowhead and some aroids.
- **Hastate**- Sagittate leaf with its two lobes directed outside, e.g., water bindweed and Typhonium.
- **Lyrate**- Lyre-shaped leaf, i.e., with a large terminal lobe and some smaller lateral lobes, e.g., radish, mustard, etc.
- **Acicular**- Long narrow and cylindrical leaf, i.e., needle shaped, e.g., pine.
- **Cuneate**- Wedge shaped leaf, e.g., water lettuce.




## Other Leaf Types

Multilayered epidermis is found in a few leaves like *Ficus*, *Begonia* and *Nerium*. In xerophytic leaves, spongy parenchyma is reduced. Palisade parenchyma may occur on both upper and lower sides with spongy parenchyma sand witched between the two, e.g., *Nerium*. In *Nerium* or Oleander, the lower surface bears deep depressions called crypts (Stomatal crypts). The crypts possess a number of cutinized hair and stomata. In other xerophytic plants, stomata occur individually and are sunken below the surface due to their being overtopped by accessory or subsidiary cells.

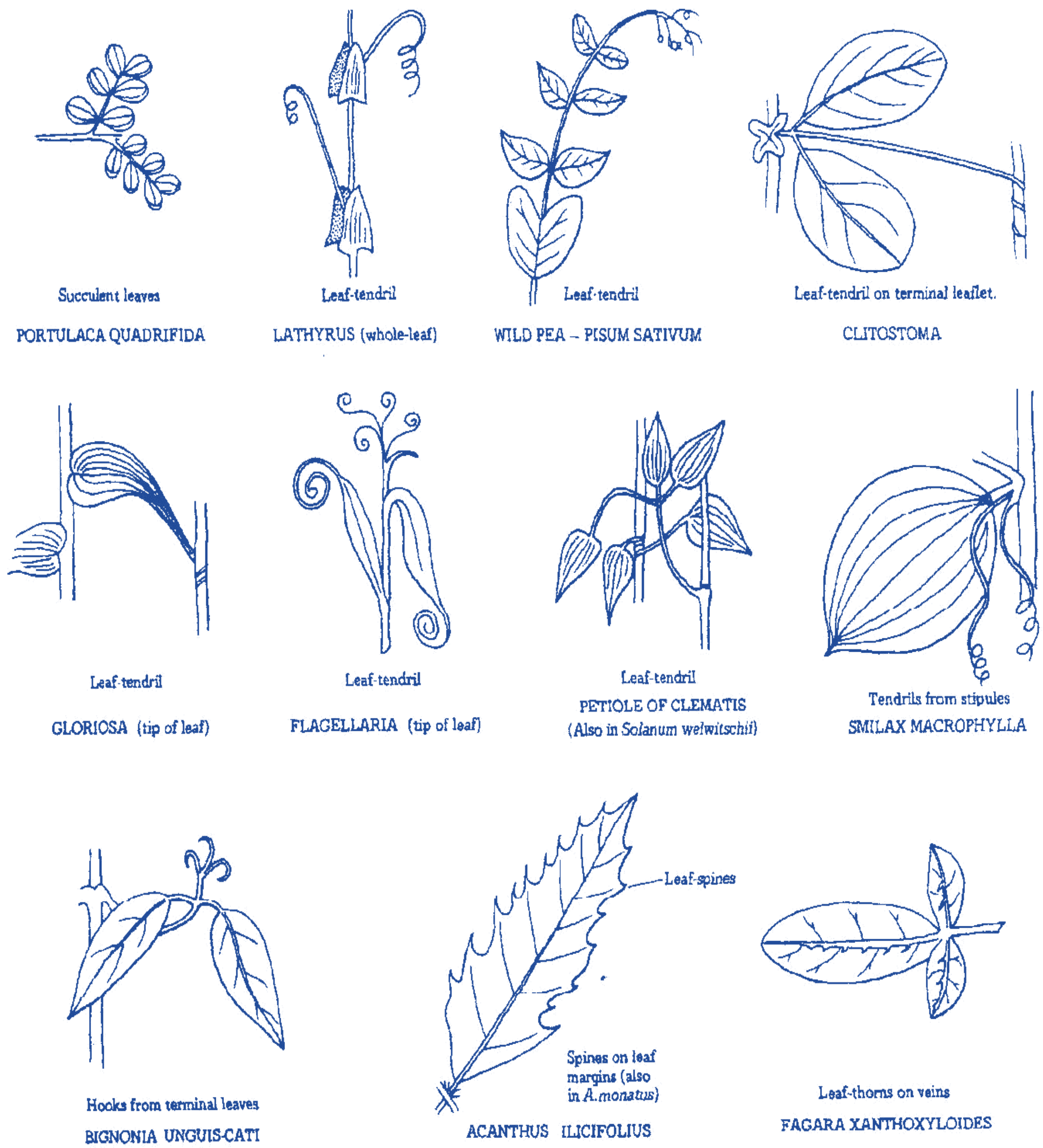
Floating leaves possess stomata on the upper surface (epistomatic) only, e.g., Nymphea. Submerged hydrophytic leaves do not have stomata (e.g., *Hydrilla*, *Potamogeton*). The leaves are covered by mucilage. Internally, they have thin undifferentiated mesophyll. Mechanical tissue is absent. Aerenchyma is present. Xylem is reduced. It may be replaced by a cavity.

## Modification of Leaf

Some of the important types of modification of leaves are listed below.-

- **Whole Leaf Tendrils :** In Wild Pea (*Lathyrus aphaca*,) the whole leaf is modified into a tendril for climbing. The stipules become foliaceous to perform e function of photosynthesis. An axillary bud is found in the axil of the tendril.
- **Leaflet Tendrils :** A few upper leaflets of the pinnate compound leaves of Pea (*Pisum sativum*, and Sweet Pea (*Lathyrus odoratus*) are transformed into tendrils while the rest are normal.
- **Petiolar Tendrils :** The petioles of Garden Nasturtium (*Tropaeolum majus*, and *Nepenthes* (Fig. 5.61 D) are elongated, sensitive and capable of coiling around the support like the tendrils.

- **Rachis and Petiolule Tendrils :** The petiole, rachis and the stalks of the leaflets (Petiolule) in *Clematis* are sensitive to contact and can coil around the support to help the plant in climbing.
- **Rachis Tip Tendrils :** In Lentil (*Lens culinaris*, vern. Masur) the tip of the rachis is transformed into a tendril.
- **Leaf Tip Tendrils :**The leaf apices of *Gloriosa superba* (vern. Kulhan or Kalihan; Glory Lily are greatly elongated to function like the tendrils.
- **Stipular Tendrils :** They are found in Smilax at the free ends of adnate stipules.




## 2. Leaf Spines

The leaf parts become changed into spines in order to protect the plant from grazing animals and excessive transpiration. Prickles occur at various positions (margins, apex, surface) on the leaves for the same purpose, e.g., *Aloe*, *Solanum surattense* (= *S. xanthocarpum*), *Carthamus oxycantha*. In Barberry, the leaves of the main stem are modified into branched 3-5 rayed spines. Dwarf branches arise in their axils. The spines present on the areoles of *Opuntia* also represent the leaves. Leaf spines also occur in other cacti and the climbing varieties of Asparagus. Spines of *Zizyphus* and *Acacia* are modified stipules.

### 3. Leaflet Hooks

In *Doxantha (Bignonia) unguiscati* the terminal leaflets of the compound leaves become transformed into three stiff claw-like and curved hooks. They resemble the nails of a cat and hence the names of the plant, the hooks cling to the bark of the supporting tree very firmly and allow the plant to climb up.

### 4. Phyllodes (Phyllodia)

In several species of Acacia found in the deserts of Australia (e.g., *A. longifolia*, *A. glaucescens*, *A. recurva*, *A. auriculiformis)*, the bipinnate lamina is absent. Instead petiole and part of the rachis become flattened into sickle-shaped structure for performing the function of food synthesis. Such a flattened petiole which carries out the functions of the lamina is called phyllode. Phyllodes are vertically placed and (ii) Has fewer stomata. In *Parkinsonia aculeata*, the rachis ends in a spine. Rachis branches (= secondary raches) are elongated, flattened and green to function as phyllodes. They bear small leaflets which fall off very early.

### 5. Leaf Bladders

They occur in the aquatic carnivorous plants of Utricularia (Bladderwort). Some of the leaf segments are modified to form small bladders (1-3 mm in diameter). A bladder has sensitive hair, branched trigger bristles, a trap valve, internal and external glands for trapping and digesting small animals (e.g., Water Fleas).

### 6. Leaf Pitchers

The leaf or lamina is modified to form a large pitcher in Dischidia, Nepenthes and Sarracenia. In epiphytic Dischidia the whole leaf is changed into an open pitcher for storing rain water. The same is absorbed throughout the year by adventitious roots (= nest roots).

In Nepenthes and *Sarracenia* the pitchers are meant for catching and digesting insects. The lamina is modified into pitcher. The leaf apex gives rise to a coloured lid for attracting the insects. In Nepenthes the leaf base is foliaceous while the leaf stalk is tendrillar. The rim of the pitcher has nectariferous glands. The interior of the pitcher is slippery. The base is filled up with a digestive fluid.

### 7. Succulent Leaves

The leaves are fleshy or swollen. They store water, mucilage or food materials. Succulent leaves occur in plants of saline and xerophytic habitats, e.g., *Aloe*, *Agave*, *Bryophyllum*, *Portulaca*. In bulbs the fleshy scales are actually the leaf bases, e.g., Onion.

### 8. Scale Leaves

They are whitish or brownish, small, dry and membranous leaves which do not take part in photosynthesis. Photosynthesis is performed by green stems, e.g., *Casuarina, Ruscus*.

### 9. Coloured Leaves

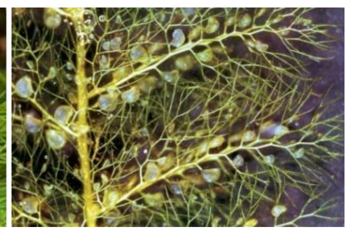
In Poinsettia (= Euphorbia pulcherrima, vern. Lai Patti), the leaves borne near the cyathia are brightly coloured to attract insects for pollination.

### 10. Floral Organs

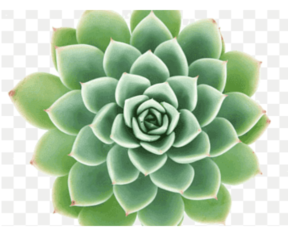
Floral organs are specialized leaves— sepals, petals, stamens and carpels. Sepals are protective and green, petals are coloured and attractive, stamens are pollen bearing structures or microsporophylls while carpels are ovule-bearing megasporophylls.


Phyllodes (Parkinsonia)


Cladodes (Asperagus)


Leaf Bladders (Utricularia)


Leaf Pitchers (Nepanthes)


Succulent Leaves (Cactus)


Scaly Leaves (Thuja)


Coloured Leaves (Maple)


Floral Structures (Fern)

## Functions of Leaves

### i. Primary or Main Functions

- The most important single function of the leaves is synthesis of organic food in the process of photosynthesis. The raw materials are carbon dioxide and water. Sunlight is required for providing energy. The leaves have chlorophyll for trapping sun energy.
- Leaves possess minute pores called stomata. Gaseous exchange takes place through stomata.
- Leaves are the main seat of loss of water called transpiration. Transpiration produces a tension in the water column of the plant and provides the necessary force for the ascent of sap.
- Leaves protect the axillary and terminal buds from mechanical injury and desiccation.

- Vascular strands represented by veins conduct water and minerals from stem to leaves in their xylem and transport organic materials from leaf blade to stem in their phloem.

## ii. Secondary or Accessory Functions

- Storage of water in the cells of some succulent plants, e.g., *Aloe*. In *Dischidia* the leaf is modified to form pitcher for collecting rain water.
- Storage of food as in the leaf base of Onion.
- Protection from browsing animals by producing spines, e.g., *Barberry*, *Opuntia*, *Argemone mexicana*, etc.
- Protection against transpiration by changing into phyllodes (expanded petioles) and forming spines.
- To help in climbing. For this, different parts of a leaf can be converted into tendrils (leaf tendril, leaflet tendril, petiole tendril, rachis tendril, leaf tip tendril, etc.), hooks (e.g., leaflet hooks of *Doxantha unguiscati*) and spines (e.g., *Asparagus*).
- Leaves are modified to store air either in lamina or petiole for gaseous exchange and floating in the aquatic plants, e.g., *Nelumbo*, *Eichhornia*, *Trapa*, etc.
- In Salvinia one leaf of each node is changed into roots that act as balancers for floating.
- Leaf or leaf segment is modified into a trap mechanism for catching and digesting small animals in insectivorous or carnivorous plants (e.g., *Utricularia*, *Dionaea*, *Nepenthes*).
- The leaves of some plants (e.g., *Ardisia*, *Psychotria*) bear areas which contain nitrogen fixing organisms. They thus add to the total nitrogen content of the plant.
- Leaves are changed into hygroscopic appendages in *Tamarix*.
- They are modified into sepals, petals, stamens and carpels to take part in sexual reproduction.
- In Poinsettia (= *Euphorbia pulcherrima*) the young leaves are brightly coloured to attract insects for pollination.
- Leaves of *Bryophyllum*, *Begonia*, etc. help in vegetative multiplication. In Begonia, adventitious buds develop in the region of injury. They occur in marginal notches in intact leaf of *Bryophyllum*.
- As bud scales stipules provide protection to buds, e.g., Ficus.

- Stipules are foliaceous in *Lathyrus aphaca* to take part in photosynthesis.