Unit II: Plant Morphology and Taxonomy of Angiosperm

Chapter 3

Vegetative Morphology

Learning Objectives

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 and functions of leaf*

Chapter Outline

The study of various external features of the organism is known as **Morphology. Plant Morphology** is also known as **external morphology that** 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 like 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 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. Example: *Phyllanthus amarus, Cleome viscosa.* 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: *Allium cepa*

II. Shrubs

A shrub is a perennial, woody plant with several main stems arising from the ground level. Example: *Hibiscus rosa sinensis* (shoe flower)

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 two major categories: I. Terrestrial and II.Aquatic.

I. Terrestrial

Plants growing on land are called **terrestrial plants.**

II. Aquatic

Plants that are living in water are called **aquatic plants** or hydrophytes.

3.3 Life Span

Based on life span plants are classified into 3 types. They are annuals, biennials and perennials

I. Annuals

A plant that completes its life cycle in one growing season. Example: Maize, Water melon, Groundnut, Rice.

II. Biennials

A plant that lives for two seasons, growing vegetatively during the first season and flowering and fruiting during the second season. Example: Carrot, Radish, Cabbage.

III. Perennials

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 perennials.** 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 perennials**. Example: *Bambusa*, *Agave, Musa.*

3.4 Parts of a flowering plant

Flowering plants are called **"Angiosperms"** or **Magnoliophytes**. They are sporophytes 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.

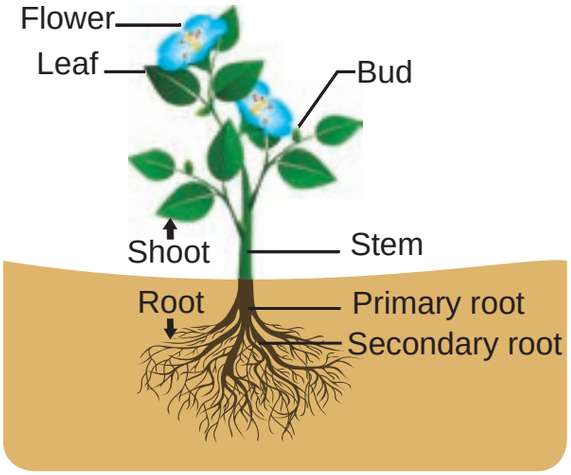


Figure: 3.1: Parts of a flowering plant

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 structure made of parenchymatous cells called **root cap.**

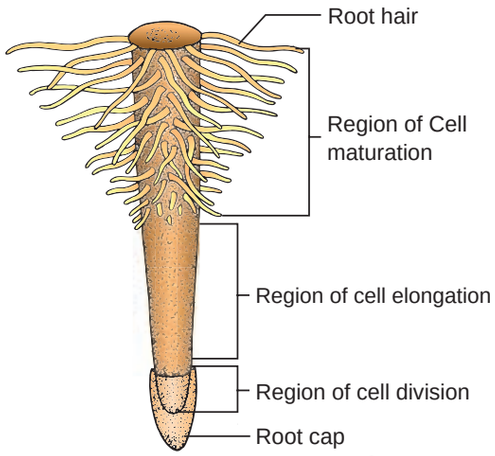
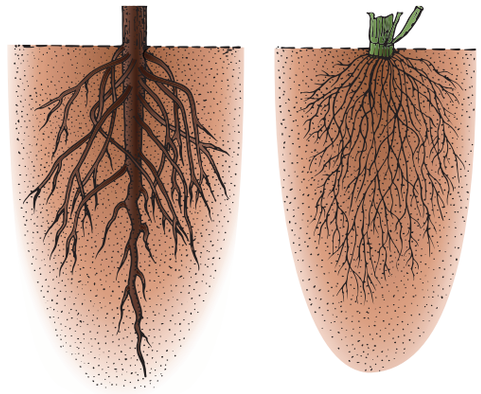


Figure 3.2: Regions of root

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

3.5.1 Types of root system



Tap root system Fibrous root system

Figure 3.3: Types of root system

I. Tap root system

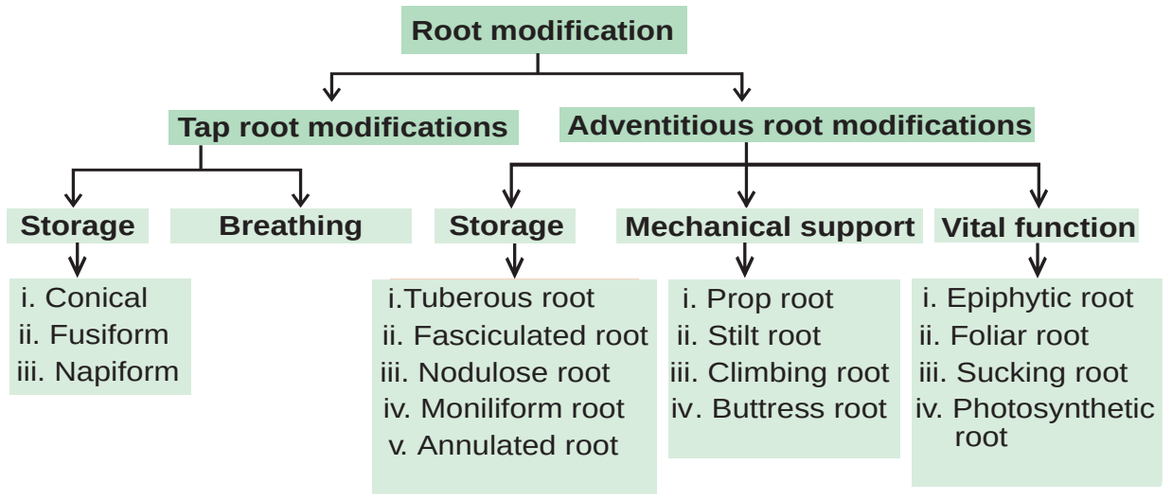
Primary root is the direct prolongation of the radicle. When the primary root persists and continues to grow as in dicotyledons, it forms the main root of the plant and is called the **Tap root.** Tap root produces lateral roots that further branches into finer roots. Lateral roots along with the branches 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, Piper nigrum*. In most of the monocots the primary root of the seedling is short lived and lateral

Table 3.1: Root zones

Feature	1. Meristematic Zone (Region of cell division)	2. Zone of Elongation	3. Zone of Maturation
Position	It lies just above the root cap	It lies just above the meristematic zone	It lies above the zone of elongation.
Types of cells	Meristematic cells, actively divide and continuously increase in number	Elongated cells	Mature differentiated cells
Functions	This is the main growing tip of the root	The cells increase the length and cause enlargement of the root.	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



roots arise from various regions of the plant body. These are bunch of thread-like roots nearly equal in size which are collectively called **fibrous** root system generally found in grasses. Example: *Oryza sativa, Eleusine coracana*.

3.5.2 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, structure of roots are modified.

3.5.3 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 at the apex and suddenly tapers like a tail at the base. Example: *Beta vulgaris*

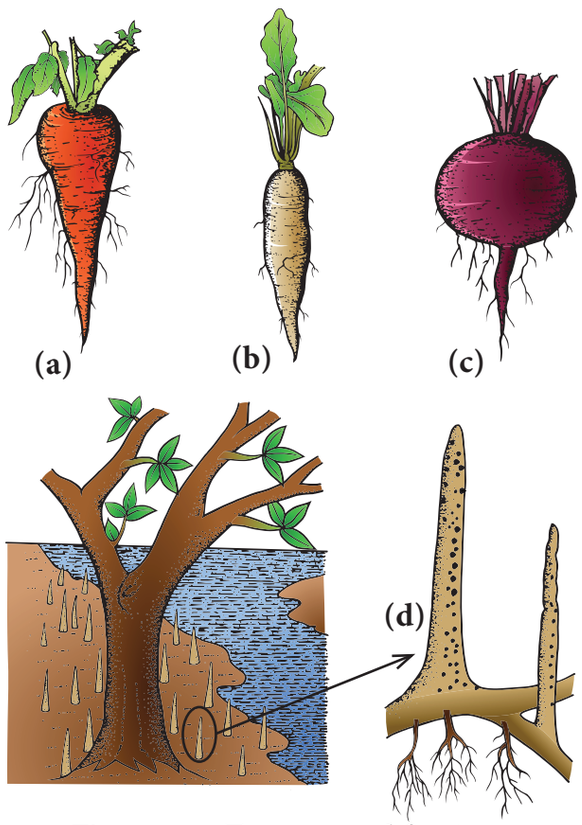


Figure 3.4: Tap root modifications
(a) *Daucus carota* **(b)** *Raphanus sativus*
(c) *Beta vulgaris* **(d)** *Avicennia* - pneumatophores

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 number of breathing pores on 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.*

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.*

5. Annulated root

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

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

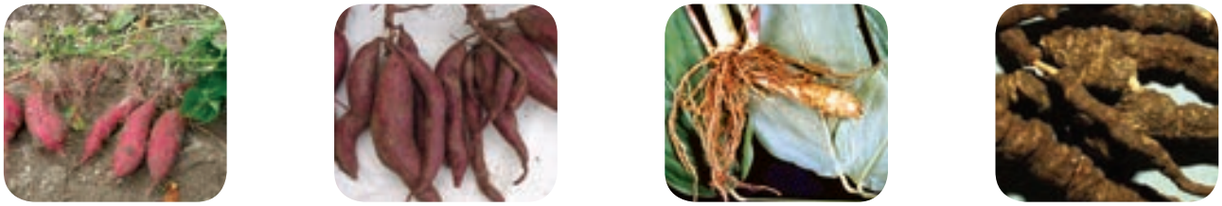
These are thick roots growing obliquely from the basal nodes of the main stem. These provide mechanical support. Example: *Saccharum officinarum, Zea mays, Pandanus and Rhizophora*.

3. Climbing (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: *Piper betel.*

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: *Bombax ceiba* (Red silk cotton tree), *Ceiba pentandra* (white silk cotton tree), *Delonix regia, Bombax.*



Ipomoea batatas *Dahlia* *Maranta* *Psychotria*

Figure 3.5: Adventitious Root Modification for Storage

Ficus benghalensis *Saccharum officinarum* *Epipremnum pinnatum* *Bombax*

Figure 3.6: Adventitious root modifications for mechanical support

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*.

2. Foliar root

Roots are produced from the veins or lamina of the leaf for the formation of new plant. Example: *Bryophyllum, Begonia*.

3. Sucking or Haustorial roots

These roots are found in parasitic plants. Parasites develop adventitious roots from stem which penetrate into the tissue of 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 aerial, green, photosynthetic and has nodes and internodes.
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. It provides support and bears leaves, flowers and fruits.
2. It transports water and mineral nutrients to other parts from the root.
3. It transports food prepared by leaves to other parts of the plant body.

Secondary functions

1. **Food storage**- Example: *Solanum tuberosum, Colocasia* and *Zingiber officinale*
2. **Perennation / reproduction** – Example: *Zingiber officinale, Curcuma longa*
3. **Water storage** – Example: *Opuntia*
4. **Bouyancy** – Example: *Neptunia*

Vanda *Bryophyllum* *Cuscuta* *Tinospora*

Figure 3.7: Adventitious Root Modification for Vital Functions

5. **Photosynthesis** – Example: *Opuntia, Ruscus, Euphorbia.*
6. **Protection** – Example: *Citrus, Bougainvillea, Acacia.*
7. **Support** - Example: *Passiflora, Vitis, Cissus quadrangularis.*

3.6.1 Buds

Buds are the growing points surrounded by protective scale leaves. The bud primordium matures into bud. They have compressed axis in which the internodes are not elongated and the young leaves are closed and crowded. When these buds develop, the internodes elongate and the leaves spread out. Buds have architecture identical to the original shoot and develop into lateral branches or may terminate by developing into a flower or inflorescence. Based on origin, buds are classified into (a) Terminal or Apical bud (b) Lateral or Axillary or Axil bud. Based on function buds are classified into (a) Vegetative bud (b) Floral or Reproductive bud.

1. **Terminal bud or apical bud:** These buds are present at the apex of the main stem and at the tips of the branches.
2. **Lateral bud or Axillary bud:** These buds occur in the axil of the leaves and develop into a branch or flower.
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 buds. 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. *Example Agave* and *Allium proliferum*.

3.6.2 Types of Stem

Majority of angiosperm possess upright, vertically growing erect stem. They may be many types they are (i) Excurrent, (ii) Decurrent, (iii) Caudex and (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: *Monoon longifolium(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.*

iii. Caudex

It is an unbranched, stout, cylindrical stem, marked with scars of fallen leaves. Example: *Cocos nucifera.*

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 produce roots at each node. Example: *Cynodon dactylon, 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: *Indigofera prostrata.*

ii. **Decumbent:** A stem that grows flat but becomes erect during reproductive stage. Example: *Tridax.*

iii. **Diffuse:** A trailing stem with spreading branches. Example: *Boerhavia diffusa.*

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 (arising from nodes) as in species of *Piper betel, Piper nigrum, Pothos.*

ii. Stem climbers (Twiners)

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

Stem climbers may coil around the support either 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 (figure: 3.17). 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.*

vi. Tendril climbers

Tendrils are thread-like coiling structures which help the plants in climbing. Tendrils may be modifications of Stem – as in *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.

4. 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, Muehlenbeckia* (flattened phylloclade) *Casuarina, Euphorbia tirucalli, Euphorbia antiquorum* (cylindrical phylloclade).

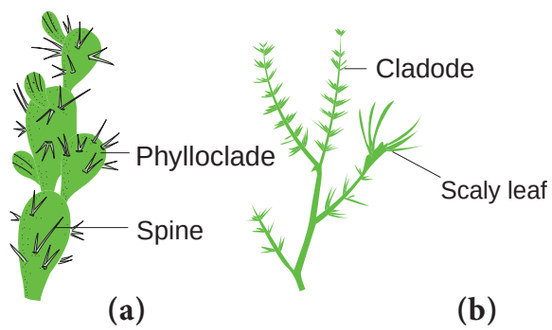
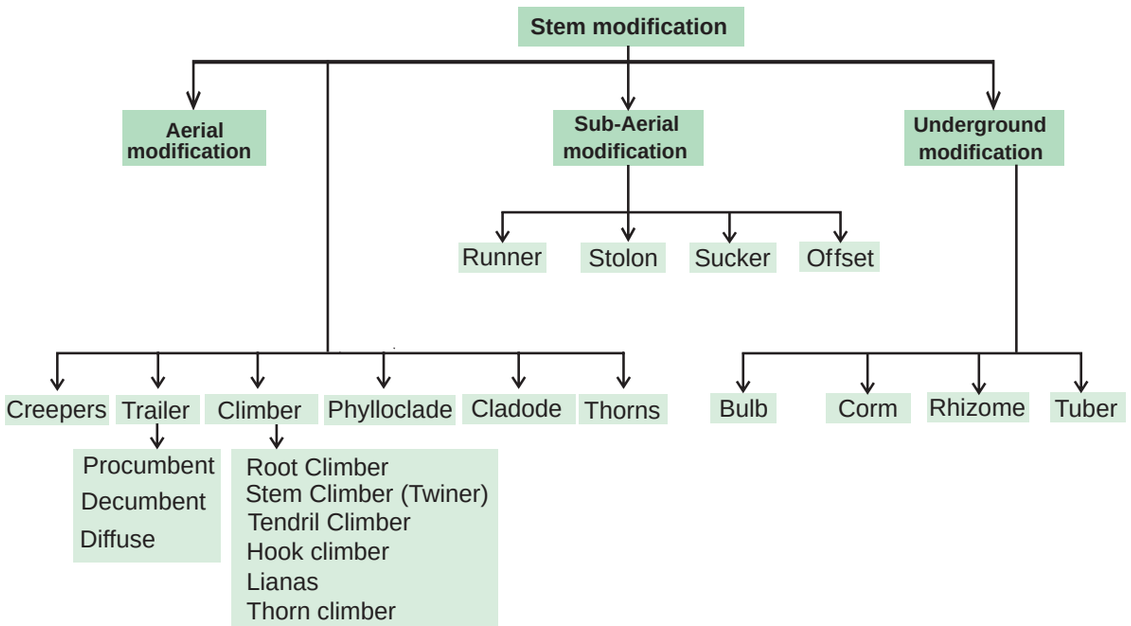


Figure 3.8: (a) Phylloclade-*Opuntia* (b) Cladode-*Asparagus*

5. Cladode

Cladode is a flattened or cylindrical stem similar to Phylloclade but with one or two



internodes only. Their stem nature is evident by the fact that they bear buds, scales and flowers. Example: *Asparagus* (cylindrical cladode), *Ruscus* (flattened cladode).

6. Thorns

Thorn is a woody and sharp pointed modified stem. Either the axillary bud or the terminal bud gets modified into thorns. In *Citrus* and *Atalantia* axillary bud is modified into thorns.

II. Sub aerial stem modifications

Sub aerial stem found in plants with weak stem in which branches lie horizontally on the ground. These are meant for vegetative propagation. They may be sub aerial or partially sub terranean.

1. Runner

This is a slender, prostrate branch creeping on the ground and rooting at the nodes. Example: *Oxalis* (Wood sorrel), lawn grass (*Cynodon dactylon*).

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).

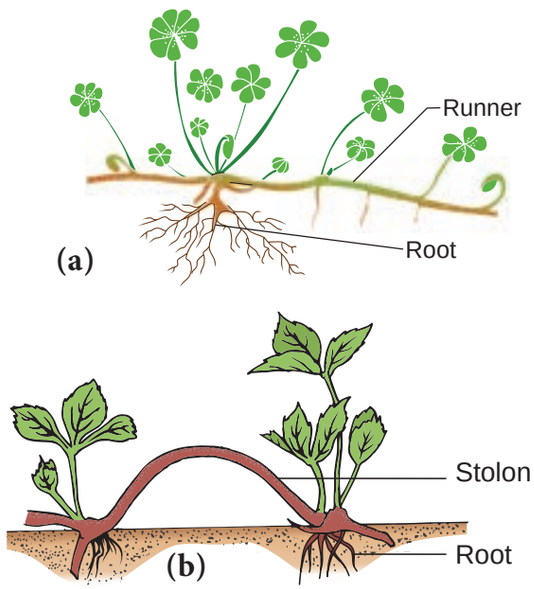


Figure 3.9: (a) Runner-*Oxalis* **(b)** Stolon-*Fragaria*

3. Sucker

Sucker develops from an underground stem and grows obliquely upwards and gives rise to a separate plantlet or new plant. Example: *Chrysanthemum, 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 root at nodes. Example: *Eichhornia* (water hyacinth), *Pistia* (water lettuce).

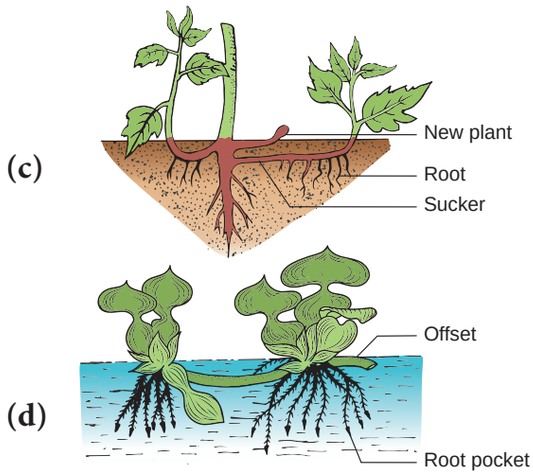


Figure 3.9: (c) Sucker-*Chrysanthemum* **(d)** Offset-*Eichhornia*

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. They can be classified into two types (a) Simple Tunicated bulb Example: *Allium cepa* (b) Compound Tunicated bulb. Example: *Allium sativum*.

2. Corm

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

Figure 3.10: Underground Stem Modification

3. Rhizome

This is an underground stem growing horizontally with several lateral growing tips. Rhizome posses conspicuous nodes and internodes covered by scale leaves. Example: *Zingiber officinale, Canna, Curcuma longa, Musa.*

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*.
2. **Determinate:** The terminal bud caese 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. 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.
3. It is exogenous in origin.
4. It has limited growth.
5. It does not posses apical bud.
6. It has three main parts namely, leaf base, petiole and lamina.
7. Lamina of the leaf is traversed by vascular strands, called **veins.**

II. Functions of the leaf

Primary functions

1. Photosynthesis
2. Transpiration
3. Gaseous exchange
4. Protection of buds
5. Conduction of water and dissolved solutes.

Secondary functions

1. Storage – Example: *Aloe, Agave*.
2. Protection – Example: *Opuntia, Argemone mexicana*.
3. Support – Example: *Gloriosa, Nepenthes*.
4. Reproduction - Example: *Bryophyllum, Begonia, Zamia*.

3.7.1 Parts of the leaf

Three main parts of a typical leaf are:

i. Leaf base (Hypopodium)
ii. Petiole (Mesopodium)
iii. Lamina (Epipodium)

I. Leaf base (hypopodium)

The part of the leaf attached to the node of the stem is called **leaf base.** Usually it protects the growing buds at its axil.

Pulvinus: In legumes leaf base become broad and swollen which is known as **pulvinus.** Example: *Clitoria, Lablab, Cassia, Butea*.

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.

II. Petiole (stipe or mesopodium)

It is the bridge between lamina 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 are said to be **petiolate.** Example: *Ficus, Hibiscus.* Leaves that do not possess petiole is said to be **sessile**. Example*: Calotropis.*

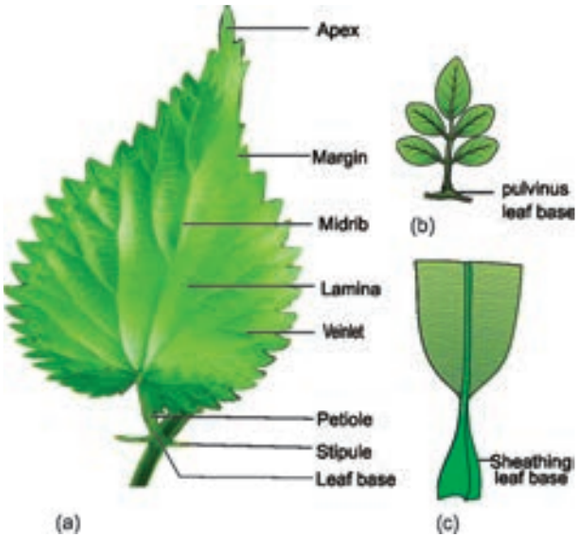


Figure 3.11: (a) Parts of the leaf **(b)** Pulvinus leaf base **(c)** Sheathing leaf base

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 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 **exstipulate or estipulate**. The stipules are commonly found in dicotyledons. In some grasses (Monocots) an additional out growth 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.

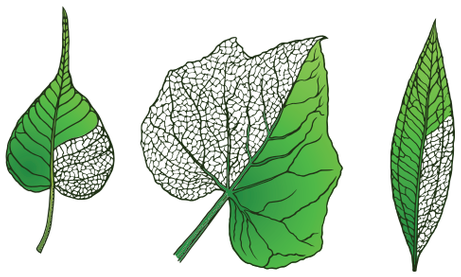
3.7.2 Venation

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.*
2. **Palmately reticulate 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



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

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

   i. **Divergent type:** When all principal veins originate from the base and diverge from one another towards the margin of the leaf as in *Carica papaya*.
   ii. **Convergent:** When the veins converge to the apex of the leaf, as in Indian plum (*Zizyphus*), bay leaf (*Cinnamomum*).

II. Parallel venation

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

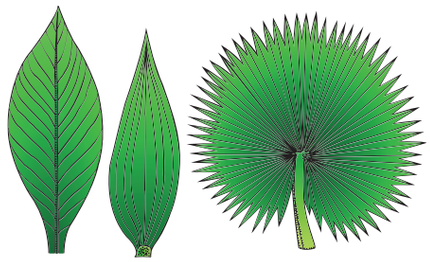
1. Pinnately Parallel Venation (Unicostate)

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

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 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 of 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), *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*, *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*.

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 shorter petioles. Example: *Acalypha.*

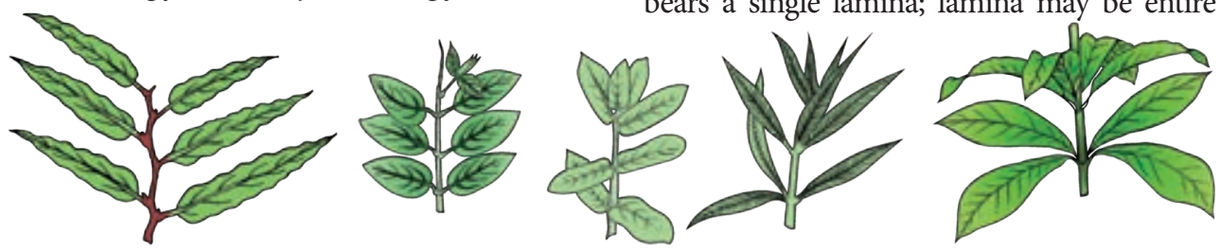
3.7.5 Leaf type

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



Alternate *Polyalthia* | Opposite Superposed *Guava* | Opposite Decussate *Calotropis* | Ternate *Nerium* | Whorled *Allamanda*

Figure 3.14: Phyllotaxy

(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 Tamarindus, *Cassia*.

i. **Unipinnate:** The rachis is simple and unbranched which bears leaflets directly on its sides in alternate or opposite manner. Example: *Rose*, *Neem*. Unipinnate leaves are of two types.
   a. when the leaflets are even in number, the leaf is said to be **paripinnate**. Example: *Tamarindus*.
   b. when the leaflets are odd in number, the leaf is said to be **imparipinnate.** Example: *Azadirachta* (Neem).

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*.

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*.

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

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.*

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

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*

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

Figure 3.16: Types of palmately compound leaves

(a) Unifoliolate - *Citrus* (b) Bifoliolate – *Zornia* **(c)** Trifoliolate – *Aegle marmelos*
(d) Quadrifoliolate – *Paris quadrifolia* (e) Multifoliolate – *Bombax*

ii. **Bifoliolate:** When there are two leaflets articulated to the petiole it is said to be bifoliolate. Example: *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*).

iv. **Quadrifoliolate:** There are four leaflets articulated to the petiole it is said to be quadrifoliolate. Example: *Paris quadrifolia, Marsilia*

v. **Multifoliolate or digitate:** Five or more leaflets are joined and spread like fingers from the palm, as in *Cleome pentaphylla, Bombax ceiba*

3.7.6 Modification of Leaf

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

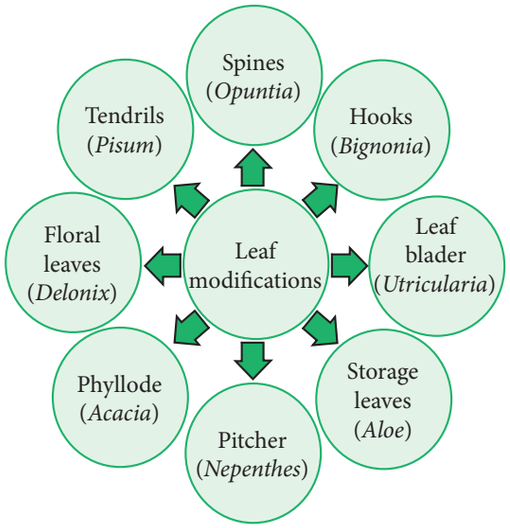
I. Leaf tendrils

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:

Entire leaf—*Lathyrus,* stipules—*Smilax,* terminal leaflet—*Naravelia,* Leaf tip— *Gloriosa,* Apical leaflet—*Pisum,* petiole— *Clematis.*

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: *Zyzypus Argemone mexicana* (Prickly poppy), *Solanum trilobatum*. In xerophytes such as *Opuntia* (Prickly pear) and *Euphorbia* leaves and stipules are modified into spines.

Prickles are small, sharp structure 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.*

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*.

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.*


Leaf hooks-*Bignonia*


Leaf spines- *Opuntia*


Phyllode-*Acacia*


Pitcher-*Nepenthes*

Figure 3.17: Leaf Modification

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 tendrillar structure. The apical part of the leaf is 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 Leaf duration

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

Caducuous (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.

Summary

Flowering plants consist of two major organ systems: Underground root system and aerial shoot 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 radicle which further branches into secondary roots. Adventitious roots arise from different parts of the plant other than radicle. Stem helps to display the leaves to get maximum sunlight and positioning flowers and fruits to attract pollination and dispersal agents. Apart from the normal functions the stems are modified to perform various functions such as food storage, perennation and protection. Leaves are exogenous in origin and function as food synthesizing and gaseous exchange sites. Some leaves also perform additional functions for which they are modified in their morphology.

Leaves possess vascular tissues in the form of veins which render support to the lamina and help in transport of water, nutrients and food in and out of leaves. Phyllotaxy is the arrangement or distribution of leaves on the stem or its branches in such a way that they receive maximum sunlight to perform photosynthesis.

Activity

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

Evaluation

1. Which of the following is polycarpic plant?
   a. *Mangifera*
   b. *Bambusa*
   c. *Musa*
   d. *Agave*

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2. 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
3. *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
4. Which of the following is the correct statement?
   a. In *Pisum sativum* leaflets modified into tendrils
   b. In *Atalantia* terminal bud is modified into thorns
   c. In *Nepenthes* midrib is modified into lid
   d. In *Smilax* inflorescence axis is modified into tendrils
5. Select the mismatch pair
   a. *Musa* - Unicostate
   b. *Lablab* - Trifoliolate
   c. *Acalypha* - Leaf mosaic
   d. *Allamanda* - Ternate phyllotaxy
6. Draw and label the parts of regions of root.
7. Write the similarities and differences between
   1. *Avicennia* and *Trapa*
   2. Radical buds and foliar buds
   3. Phylloclade and cladode
8. How root climbers differ from stem climbers?
9. Compare sympodial branching with monopodial branching.
10. Differentiate pinnate unicostate with palmate multicostate venation