UNIT 2

Structural Organisation in Plants and Animals

MORPHOLOGY AND ANATOMY OF FLOWERING PLANTS

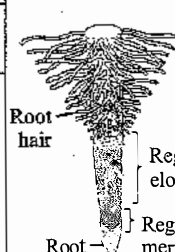
- An organism's structure can be studied completely under two branches of biology- morphology and anatomy.
- **Morphology** deals with the study of form, size, colour, structure and relative position of various parts of the organisms. It indicates the structural adaptations of organisms to their environment.
- On the other hand, **Anatomy** (*Ana* – as under and *tommein*- to cut) deals with the ontogeny, structure and distribution of various types of tissues. It is the branch which deals with the study of gross internal structure of plant organs as observed after section cutting.
- Histology (Greek *histos* - web, *logos* - science) is the study of tissues, their composition, structure and organisation as observed with the help of microscope. For plants, the terms, anatomy and histology are synonymous and interchangeable.

PLANT MORPHOLOGY

- The angiosperms are most diverse and wide-spread of all plant groups. Depending on their habitat they can be classified as **hydrophytes, mesophytes** and **xerophytes.** According to the various habitats they show modifications in their morphology. Plant morphology includes study of root, stem, leaves, flowers, fruits and seeds and their modifications.

ROOT

- Root is an important vegetative part of the plant mainly responsible for nutrition and support. Root develops from **radicle** of seed. It is the descending, non-green, underground, positively geotropic and negatively phototropic part. Roots are absent in some angiosperms, *e.g.*, *Utricularia*, *Ceratophyllum*, *Cuscuta*, *Wolffia*, *Balanophora*, etc.
- A typical root can be divided into 4 regions as discussed in the following table.

Feature	Root cap	Meristematic zone	Zone of elongation	Maturation zone	Structure
Position	Sub apical, just below the root apex	Just above root cap	Just above the meristematic zone	Proximal part of root	 **Fig.:** Regions of the root tip
Component cells	Dead cells	Meristematic cells	Enlarging cells	Mature, differentiated cells	
Function	Protects the young growing cells of the apical region; Secretes mucilage help in easy penetration of roots into soil. Root caps are absent in hydrophytes, epiphytes, parasites (haustoria) and mycorrhizae.	Main growing region of the root. Meristematic initial cells produce two types of cells - one formed towards apex develops into calyptrogen and the second formed towards base develops into histogen.	Increases length of the root.	Area of origin of lateral roots, secondary growth, xylem and phloem differentiation and root hairs formation. Root hair region is called piliferous zone which helps in absorption of water.	

- Roots in flowering plants are of two types; tap roots and adventitious roots.

Types of roots

Tap roots
- Develops from radicle.
- Gives rise to secondary and tertiary roots forming tap root system.
- Generally found in dicotyledonous plants.

Adventitious roots
- Develops from any part of the plant instead of radicle.
- They are usually shallow surface feeders like fibrous roots of grasses.
- Found in monocotyledonous plants.

Root modifications

- Roots undergo morphological modifications in order to perform various functions such as food storage, photosynthesis etc. These modifications are discussed in the following flow chart.

Modifications of roots

Adventitious roots

Fleshy storage roots

- These roots store reserve food and swell up in various shapes. They maybe:
  - Fasciculated : *Asparagus, Dahlia*
  - Tuberous : *Ipomoea batata*
  - Nodulose : *Curcuma amada, Maranta*
  - Moniliform : *Portulaca Momordica*
  - Palmate : *Orchis*

Supportive roots

- They provide mechanical support to the plant and may be of following types:
  - Prop roots : *Ficus bengalensis, F. elastica*
  - Stilt roots : *S. officinarum, Z. mays*
  - Climbing roots : *Pothos, Piper betle,* etc.

Roots with special function

- They may perform special functions like photosynthesis, symbiosis etc. Depending upon their function they are classified as follows.
  - Assimilatory roots : *Tinospora, Trapa*
  - Epiphytic roots : Orchids
  - Parasitic roots : *Cuscuta*
  - Root thorns : *Pothos armatus*
  - Contractile roots : *Crocus, Allium cepa*
  - Mycorrhizal roots : *Pinus*

Tap roots

Fleshy storage roots

- These tap roots store food and are of various shapes such as:
  - Fusiform : *Raphanus sativus*
  - Conical : *Daucus carota*
  - Tuberous : *Mirabilis jalapa*
  - Napiform: *Brassica rapa, Beta vulgaris, Chenopodium album.*

Respiratory roots (Pneumatophores)

- In halophytes, negatively geotropic roots called pneumatophores are present to facilitate gaseous exchange.
- Examples: *Rhizophora, Avicennia, Sonneratia.*

Root buttress

- These are horizontal roots arising from base of trunk and tap root for better support, *e.g.,* Rubber tree.

Nodulated roots

- In leguminous plants roots produce nodules to provide space for symbiont
- Examples: *Pisum, Arachis, Cicer.*

STEM

- Stem is the aerial part of the plant which develops from plumule. It is the ascending portion of the plants which is positively phototropic and negatively geotropic. It bears nodes, internodes and buds. It holds the plants upright and performs the function of storage. It transports the absorbed water and minerals from the roots to different parts of the plant. Sugar synthesised in leaves are transported to the roots by stem.
- They are of various types discussed as follows:

Stem

Underground

- They are found below the soil surface *e.g.,* ginger
- Underground stems are not roots because of the
  - Absence of root cap
  - Root hairs
  - Presence of terminal buds.
  - Presence of distinct nodes and internodes, scale leaves, axillary buds.

Aerial

These stems grow vertically above the ground *e.g.,* mango. Sometimes, a part or whole stem may be prostrate, or / running parallel to ground then it is termed subaerial; *e.g., Oxalis.*

Upright stout stems

- **Excurrent :** Both main axis and lateral branches grow continuously and tree acquires cone like shape, *e.g., Pinus.*
- **Deliquescent :** Lateral branches grow rapidly and tree acquires rounded shape, *e.g., Mangifera.*
- **Caudex :** Unbranched, strong and cylindrical stem, e.g., *Cocos nucifera.*
- **Culm :** Stem with solid nodes and hollow internodes, *e.g., Bambusa.*

Feeble or weak stems

- **Creepers :** Stem creeps on earth and the roots arise at the nodes, *e.g., Oxalis,* grasses.
- **Trailers :** Stem creeps on ground, roots are absent at nodes, *e.g., Tridex, Boerhaavia.*
- **Climbers** are plants with weak and flexible stems which possess clinging structures for clasping support. They may be of following types.
  - **Root climbers :** *e.g., Pothos, Piper.*
  - **Tendril climbers :** *e.g., Lathyrus, Pisum.*
  - **Lianas :** *e.g., Bauhinia, Gnetum.*
- **Twiners :** Stem tip undergoes regular circular movements around support, *i.e.,* coils around, the phenomenon is known as circumnutation *e.g., Tinospora, Cuscuta.*

Stem modifications

- Stems too, show morphological modifications to perform functions, required for survival in a particular habitat or environment etc.

Modifications of stem

- **Underground stems**
  - **Tuber :** Accumulates food in it and swells up, *e.g.*, potato.
  - **Rhizome :** Grows horizontal to soil surface & bears nodes, internodes, buds and scaly leaves, *e.g.*, ginger, turmeric.
  - **Corm :** Grows vertically to soil surface, *e.g.*, arvi, saffron, etc.
  - **Bulb :** Highly reduced disc shaped stem. Leaf bases are fleshy and edible, *e.g.*, onion, garlic.
- **Sub-aerial**
  - **Runner :** Elongated, prostrate, aerial stem with long internodes and roots at nodes, *e.g.*, *Oxalis.*
  - **Offset :** Short horizontal branch giving a group of leaves on the upper portion and group of roots below *e.g.*, *Eichhornia, Pistia.*
  - **Sucker :** Formed from the node of underground stem. Grows horizontally under the soil and comes up obiquely in the form of leafy shoot, *e.g.*, *Mentha, Chrysanthemum.*
  - **Stolon :** Vertical branches formed from the nodes of horizontally growing underground stem come out of the soil surface, *e.g.*, *Fragaria, Jasminum.*
- **Aerial**
  - **Tendrils :** Axillary buds are modified into coiled, wiry, thin structures, *e.g.*, *Passiflora, Vitis*, groundnut
  - **Cladode :** Phylloclade with only one internode, *e.g.*, *Asparagus, Ruscus.*
  - **Phylloclade :** Stem modifies into green fleshy leaf like structures with nodes and internodes. Leaves modify into spines, *e.g.*, *Opuntia, Ruscus.*
  - **Thorns :** Axillary buds modify into hard spiny structures which possess vascular supply, *e.g.*, *Aegel marmelos, Citrus, Duranta.*
  - **Bulbils :** Organs of vegetative reproduction which are the modified vegetative buds, *e.g.*, *Agave, Oxalis.*

LEAF

- Leaf is a green, flattened outgrowth of the plant arising from the node of the stem and is specialized to perform photosynthesis. An axillary bud is often present in the axil of the leaf. A leaf is known as the **kitchen of the plant** or **food factory of the plant** because it performs photosynthesis.
- Abundant stomata present on the leaves make them the major seats of **transpiration.** Leaves of some plants help in **vegetative propagation** and protection by modifying themselves into different forms. A typical leaf consists of three parts, leaf base, leaf stalk or petiole and leaf blade or lamina.
- **Leaf base** (hypopodium) is the lower most part of the leaf and is joined to the node of the stem. Different types of leaf bases are pulvinus, sheathing and decurrent.
  - In pulvinus leaves, leaf base in swollen and leaf is easy to pluck due to weak attachment with stem, *e.g.*, mango, pea, gram, banyan, etc.
  - Sheathing leaf base forms a sheath around stem portion above the node. It may be amplexicaul (completely sheathing) or semi-amplexicaul.
  - Decurrent leaf base is wing like that covers the upper part of the node.
- In some plants leaf base consists of small appendages on both sides, these are called **stipules.** The leaves having stipules are termed as **stipulate** while the leaves without stipules are called **exstipulate**. Mainly stipules perform the function of **protection of leaves.**
- **Petiole** (Mesopodium) is a cylindrical or subcylindrical smooth; or grooved stalk of the leaf which connects

the lamina with the stem. Leaf having petiole is called **petiolate** and when it is absent, it is called **sessile**.

- **Lamina** (epipodium) or leaf blade is green, flattened part of leaf performing the important functions of **photosynthesis, transpiration** and **respiration.** In the middle of lamina, a thick **midrib** is present extending from petiole to the apex. The midrib produces thinner lateral veins, which in turn, give rise to still thinner veins or veinlets and as a result a net like structure is visible in the lamina.

Venation

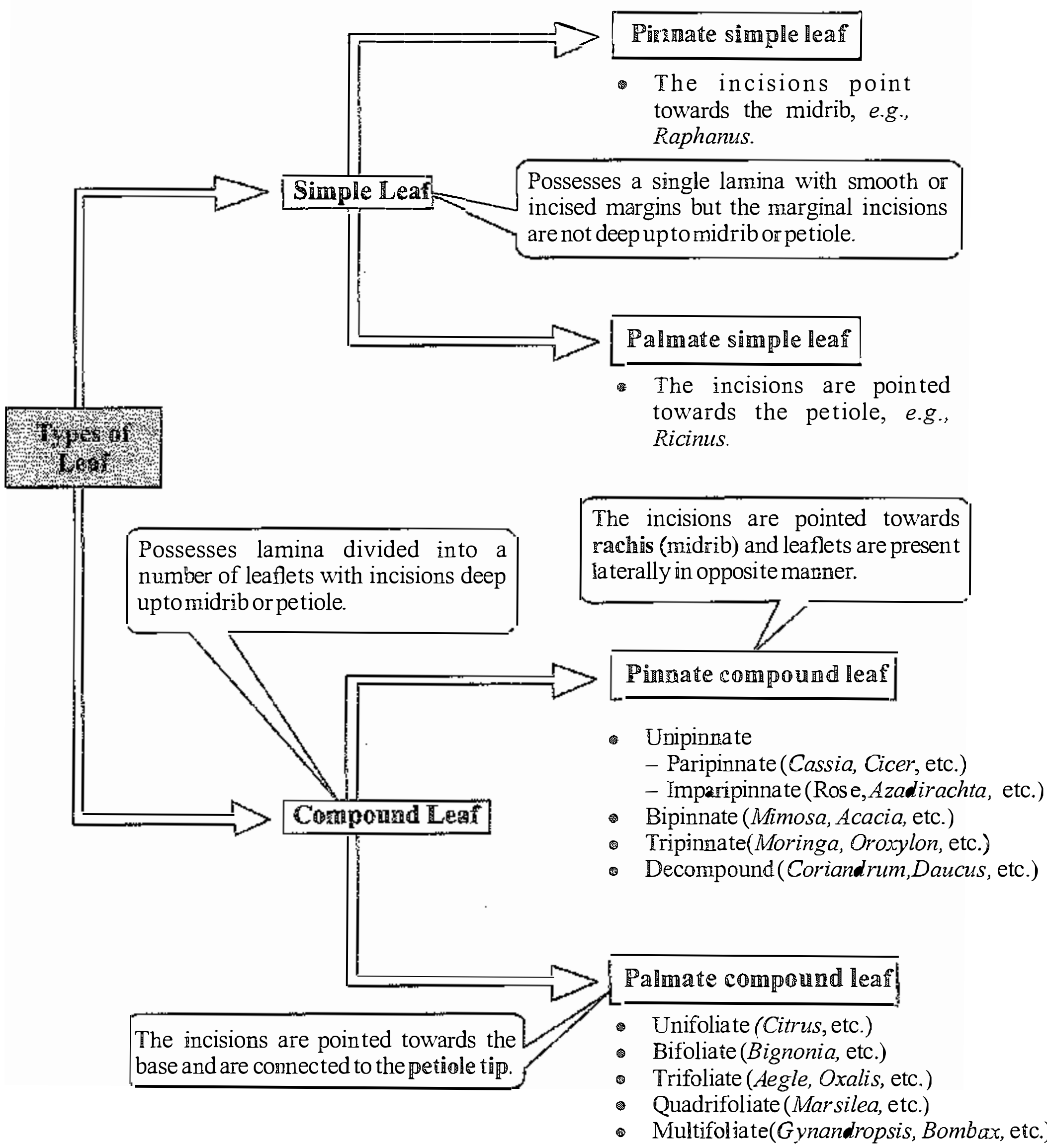
- The arrangement of veins and veinlets on the lamina of a leaf is called **venation. In parallel** venation the veins run parallel to each other. Generally found in monocotyledons and rarely in some dicotyledonous leaves. *E.g., Eryngium, Calophyllum*, etc. In **reticulate** venation the main vein forms a number of branches and gives rise to a net like structure in the leaf. It is generally found in dicots and rarely in monocots. *E.g., Smilax, Alocasia, Dioscorea*, etc.

Phyllotaxy

- Phyllotaxy means the arrangement of leaves on the true stem and its branches. The arrangement of leaves are of three types: alternate, opposite and whorled arrangement.
  - In **alternative (spiral) arrangement** only one leaf is borne on a node and the leaves of the adjacent nodes roughly lie towards the opposite side, *e.g.*, shoe flower, mango, mustard, tobacco, etc.
  - In **opposite arrangement,** a node give rise to two leaves, arranged opposite to each other
  - In **whorled** type of arrangement more than two leaves are formed from each node, which are arranged in a whorl, *e.g., Alstonia, Nerium, Vangueria*, etc.

Types of leaves

- Depending upon the incision of lamina, leaves are of two types, *i.e.*, simple and compound. These two types are further subdivided into two types each *(refer the given flow chart).*



Leaf modifications

- Leaves show various modifications to perform functions other than photosynthesis such as climbing up a support, protection etc. These modifications are discussed in the following flowchart.

Modifications of Leaves

- **Tendrils** - They are meant for climbing up the support. Various leaf parts that get modified into tendrils are:
  - Stipules in *Smilax*,
  - Petiole in *Clematis*,
  - Leaftip in *Gloriosa*,
  - Apical leaflets in *Pisum*,
  - Terminal leaflets in *Narvelia*,
  - Whole leaf in *Lathyrus*.
- **Spines** - They give protection, various leaf parts modified into spines are
  - Stipules in *Acacia*, *Zizyphus*
  - Leaf margins in *Argemone*,
  - Leaf apex in *Phoenix*, *Yucca*
  - Whole leaf in *Berberis*.
- **Hooks** - They help the plants in climbing, *e.g.*, *Bignonia*, *Asparagus*.
- **Scale or protective leaves** - They protect the vegetative buds by covering them, *e.g.*, *Ficus*, *Artocarpus*.
- **Leafroots** - A leaf transforms into roots for balancing on water, *e.g.*, *Salvinia*.
- **Tentacles** - Leaves form tentacles mainly for catching prey in insectivorous plants, *e.g.*, *Drosera*.
- **Phyllode** - Petioles modify into a leafy structure, *e.g.*, *Acacia*, *Parkinsonia*.
- **Pitchers** - Leaf lamina modifies to form a large pitcher, *e.g.*, *Nepenthes* (insectivorous), *Dischidia* (non-insectivorous).
- **Leaf bladders** - Leaf modifies into bladders which trap insects and then close by a valve present on the tip of bladder, *e.g.*, *Utricularia*.

INFLORESCENCE

- Inflorescence is the arrangement of flowers on the floral axis (peduncle) which may be positioned either
  - on the tip of stem branches, *i.e.*, terminal *e.g.*, *Crotolaria*.
  - in leaf axils, *i.e.*, axillary, *e.g.*, *Petunia*.
  - in between the floral axis, *i.e.*, intercalary, *e.g.*, *Callistemon*.
- Depending upon the growth pattern of peduncle an inflorescence may be cymose, racemose or mixed.
- In **racemose type,** main axis of inflorescence has an indefinite (indeterminate) growth and it gives rise to (lateral or axillary) flowers in an acropetal order, *i.e.*, the youngest flower is at the apex while the oldest is at the base of peduncle.
- **In cymose inflorescence** the growth of the main axis is limited and the rachis or peduncle apices are terminated by flower (no further elongation of the axis).
- **Mixed inflorescence** has combination of cymose and racemose characters, *e.g.*, cymose umbel, thyrsus (main branching is racemose and lateral branching is cymose). Special type of inflorescences are basically cymose but ultimately it is modified to form a special appearance.
- Various subtypes of these four *viz.* cymose, racemose, mixed and special inflorescence are discussed in the flowchart.

Inflorescence

- **Racemose (Indefinite)**
  - Raceme *e.g.*, Cruciferae
  - Panicle *e.g.*, *Delonix*
  - Spike *e.g.*, Lily
  - Catkin *e.g.*, *Casuarina*
  - Spikelet *e.g.*, Wheat
  - Spadix *e.g.*, *Alocasia*
  - Corymb *e.g.*, *Iberis*
  - Umbel *e.g.*, *Coriandrum*
  - Capitate *e.g.*, *Acacia*
  - Head or capitulum *e.g.*, Sunflower
- **Cymose (Definite)**
  - Solitary *e.g.*, *Gossypium*
  - Simple *e.g.*, *Bougainvillea*
  - Monochasial *e.g.*, Lily
    - Scopioid *e.g.*, Brinjal
    - Helicoid *e.g.*, *Hamelia*
  - Dichasial *e.g.*, *Clerodendron*
  - Polychasial *e.g.*, *Calotropis*
  - Cymose head *e.g.*, *Anthocephalus*
- **Special**
  - Cythium *e.g.*, *Euphorbia*
  - Coenanthium *e.g.*, *Dorstemia*
  - Hypanthodium *e.g.*, *Ficus*
  - Verticillaster *e.g.*, *Ocimum*
- **Mixed** → *E.g.*, *Thyrsus*

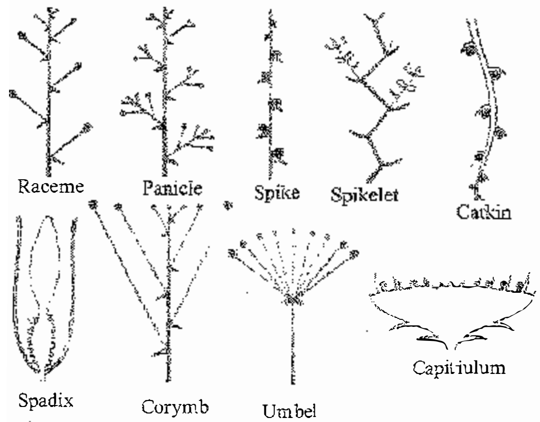


Fig.: Types of racemose inflorescence (diagrammatic representation)

FLOWER

- Flower is a modified condensed shoot of limited growth which bears floral leaves that carry on sexual reproduction and give rise to seeds and fruits. Peduncle is the stalk of a solitary flower or inflorescence. In an inflorescence stalk of a single flower is known as pedicel. The tip of the pedicel is called **thalamus** or **torus** or **receptacle.** Thalamus is formed by the **condensation of internodes of the floral axis.**
- **Actinomorphic flowers** can be cut into two equal parts in any plane, *e.g., Solanum.* **Zygomorphic flowers** can be cut into two equal parts in only one plane, *e.g., Pisum.* **Asymmetric flowers** cannot be cut into two equal parts in any plane, *e.g., Canna.*
- There are two lower whorls of **accessory or non essential organs** (calyx and corolla) and two upper whorls of reproductive or **essential organs** (androecium and gynoecium). Flowers possessing both androecium and gynoecium are termed **bisexual. Unisexual flowers** possess either only androecium or gynoecium.
- A flower possessing superior ovary is known as **hypogynous** while a flower possessing inferior ovary is **epigynous. A perigynous flower** possesses **half-inferior** and **half-superior ovary.** In **pentamerous** flower each whorl especially calyx and corolla possess 5 units. In **trimerous** and **tetramerous** flower each whorl possess 3 and 4 units, respectively.

Calyx

- The outermost or the first accessory whorl of flower consisting of sepals is called **calyx.** It may be polysepalous (calyx with free sepals) and gamosepalous (calyx with fused sepals). They protect floral organs during 'bud' stage.

Corolla

- The second whorl of a flower consisting of petals is called **corolla.** Corolla are brightly coloured and attract insects for pollination and protect the inner essential whorls from injury. Corolla with free petals is a **polypetalous** corolla. Corolla with fused petals is a **gamopetalous** corolla. Shape of polypetalous corolla are **cruciform, caryophyllaceous, rosaceous** and **papilionaceous.**
- In monochlamydeous flower when single accessory whorl is present (with no distinction between sepal and petal), the whorl is described as **perianth.** Unit of perianth or individual member of perianth is known as **tepal.**
- The mode of arrangement of sepals or petals or even tepals in a flower bud is called **aestivation.** When their margins are not overlapping it is **valvate aestivation.** When of the total number, one is completely out, one is completely in and the rest are in and out, it is **imbricate aestivation. In descending imbricate** aestivation the standard petal is large and overlaps the two wing petals which in turn overlap the two keel petals. It is technically known as **vexillary aestivation.** When of the total number, two are completely out, two are completely in and the rest is in and out, it is **quincuncial aestivation.** In **contorted** or **twisted aestivation** all sepals or petals are in and out.

Fig.: Different types of aestivations : (A) Valvate, (B) Twisted, (C) Imbricate, (D) Quincuncial, (E) Vexillary

Androecium

- The third whorl of the flower or the first essential whorl of the flower, composed of stamens is called **androecium.** A sterile stamen is called **staminode.** A typical stamen consists of a stalk called **filament,** a **connective** and an **anther.** While the connective links the two **anther lobes,** the anther produces the **pollen.** The stamens of an androecium may be free or exhibit **cohesion** or **adhesion.**
- When stamens are partially or completely fused among themselves, such a condition is known as **adelphy.** Stamens may be **monadelphous,** *e.g., Hibiscus, Abutilon, Crotolaria,* etc, **diadelphous,** *e.g., Pisum* (pea), *Indigofera, Tephrosia, Clitoria,* etc, **polyadelphous,** *e.g., Bombax,* **syngenesious,** *e.g., Tridax, Helianthus* (sunflower) or **synandrous,** *e.g. Cucurbita, Coccinia.*
- When stamens are adhered to either sepals or petals the conditions are known as **episepalous** and **epipetalous,** respectively. Episepalous, *e.g., Quisqualis indica,* epipetalous, *e.g., Solanum, Leucas, Vinca,* etc.
- When two stamens are long and two are short as in labiatae, acanthaceae, etc. the condition is said to be **didynamous.** In **tetradynamous** condition four stamens are long and two are short, *e.g.,* cruciferae.

Gynoecium

- A typical gynoecium (pistil) may consist of one or more units known as carpels. A carpel is differentiated into a basal ovule(s) containing part called **ovary,** a middle elongated or short **style** and the pollen receiving terminal structure called **stigma.** A gynoecium with free carpels is known as **apocarpous,** while one with fused carpels is known as **syncarpous.**
- The swollen part of the ovary where the ovules are attached is called **placenta.** Arrangement of placentae in ovary is known as placentation which may be **marginal,** basal, axile, free central or parietal. **In marginal** placentation

placentae are present along the ventral suture, found in monocarpellary ovary, *e.g.*, family fabaceae. In **basal** type the placenta is located on the floor of the locule of the ovary, *e.g.*, *Tridax, Helianthus* (sunflower), etc.

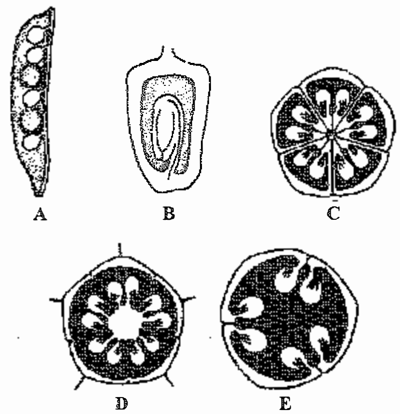


Fig.: Types of placentation : (A) Marginal, (B) Basal, (C) Axile, (D) Free-central, (E) Parietal

- In **axile** placentation placentae are located along the axis of the ovary, but partitioned by radial septae, *e.g.*, *Hibiscus, Tribulus, Allium cepa* (onion), etc. In **free-central** type, lacentae are located along the axis of the ovary as in axile placentation, but are not partitioned by radial septae, *e.g.*, *Dianthus*. In **pariental** type, two or more placentae are longitudinally located on the inner side of ovary wall, *e.g.*, *Cucurbita, Cucumis, Raphanus* (radish), *Brassica* (mustard), etc.

FRUIT

- A fruit can be defined as **matured ovary or ovaries,** with or without seeds together with any accessory structure closely associated with them. True fruits develop only from the ovary and other floral parts do not take part in its development. Fruits formed by some other parts of flower are known as false fruits or pseudocarpic fruits. *E.g.*, apple in which fruit consists of swollen thalamus enclosing mature ovary. **Parthenocarpic** fruits or seedless fruits, are fruits which are formed **without fertilization** *e.g.*, banana. Mature wall of the ovary after ripening is called **pericarp.** It has three layers.

Pericarp
- **Outermost layer** – Epicarp (skin of fruit)
- **Middle layer** – Mesocarp (may be thin and membranous in orange, hard and stony in plums, fleshy and juicy in mango, etc.
- **Innermost layer** – Endocarp (thin and membranous)

Classification of different kinds of fruit

- Fruits are classified into various types according to the structure of pericarp, mode of dehiscence and the ovary from which they have developed. These types of fruits are discussed in brief in the following flow chart.

Fruits
- **Simple fruits** – Develop from mono or multicarpellary syncarpous ovary.
  - **Dry fruits**
    - **Dehiscent** – Dehisce at maturity, multiseeded.
      - Pod, *e.g.*, Gram, Pea
      - Follicle, *e.g.*, *Delphinium*
      - Siliqua, *e.g*, Mustard, Radish
      - Silicula, *e.g.*, *Iberis, Capsella*
      - Capsule, *e.g.*, Cotton, Opium, *Datura*
    - **Indehiscent** – Do not dehisce, single seeded.
      - Cypsella *e.g.* Members of Compositae
      - Caryopsis *e.g*, Members of Gramineae
      - Achene, *e.g.*, *Clematis*
      - Samara, *e.g.*, *Dioscorea, Hiptage*
      - Nut, *e.g.*, Litchi, *Quercus*
    - **Schizocarpic** – At maturity split into smaller units called merocarps.
      - Lomentum, *e.g.*, Tamarind
      - Cremocarp, *e.g*, Coriander
      - Double samara, *e.g.*, *Acer*
      - Regma, *e.g.*, *Ricinus, Euphorbia*
      - Carcerulus, *e.g.*, *Ocimum*
  - **Fleshy fruits**
    - Drupe, *e.g.*, Mango, Plum
    - Berry, *e.g.*, Tomato, Guava
    - Pepo, *e.g.*, Cucurbits
    - Pome, *e.g*, Apple, Pear
    - Hesperidium *e.g*, Orange, Lemon
    - Balausta, *e.g.*, Pomegranate
    - Amphisarca, *e.g.*, Wood apple
- **Aggregate fruits** – Develop from the multi-carpellary apocarpous ovary.
  - Etaerio of achenes, *e.g.*, Rose, Strawberry
  - Etaerio of follicles, *e.g.*, *Michelia*
  - Etaerio of drupes, *e.g.*, Raspberry
  - Etaerio of berries, *e.g.*, Custard apple, *Polyalthia*
- **Composite fruits** – Develop from the complete inflorescence.
  - Sorosis, *e.g.*, Pineapple, Screwpine, Jack fruit, Mulberry
  - Syconus, *e.g.*, Banyan, Fig, Peepal, Gular

SEED

- Morphologically, seed (ripened ovule) is the integumented, mature, megasporangium which is developed from a fertilized ovule and is with an embryo (future plant, enclosed by seed coat). In **bitegmic** ovules (with two distinct layers) outer, thick hard, leathery seed coat is called **testa** (if one seed coat is present, then it is also called testa) and the inner thin, papery layer is called **tegmen.**

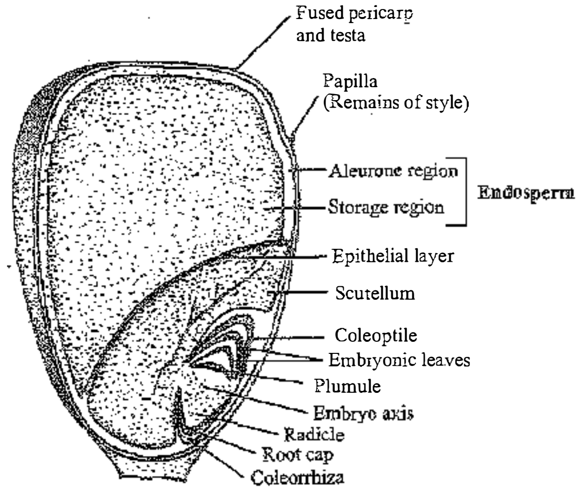


Fig.: Structure of maize seed in L.S. or V.S. of grain) monocotyledonous

- With the help of a stalk called **funicle,** a seed is attached to the fruit wall (pericarp) and the point of attachment is called **hilum. Raphe** is the part of funicle that is fused with the seed coats or integuments. **Chalaza** is that region from which the seed coats originate. Micropyle is a small opening or pore, present just below the hilum. **Kernel** is obtained by removing the seed coat and it mainly consists of the embryo. Kernel may also contain endosperm (reserve food; present in **endospermic** or albuminous seeds like cereals, castor, coconut, etc.) – a special type of nutritive tissue. In exalbuminous or **non-endospermic seeds** like gram, pea, mustard, etc., endosperm is fully consumed by the embryo.
- There is one cotyledon, in monocotyledonous angiosperms and two cotyledons, in dicotyledonous angiosperms. Over narrower end of seed a brownish pad is found which is called **caruncle.** Below seed coat a very thin membrane is found over kernel called **perisperm** (the persistent nucellus). Below perisperm there is a large, white, swollen and oily mass found called **endosperm.** The outer covering of endosperm separates the embryo by a proteinous layer called aleurone layer. Cotyledon is shield-shaped and called **scutellum** in monocotyledonous seed. 2-4 protective layers are found over plumule which are called **coleoptile.** Such protective layers over radicle are called **coleorrhiza.**

Table : Differences between endospermic and non-endospermic seeds

	Endospermic seeds	Non-endospermic seeds
1.	Possess endosperms.	Endosperms is fully consumed by embryo, thus do not possess endosperms.
2.	Called as albuminous seeds.	Called as ex-albuminous seeds
3.	Example- (i) Dicot seeds; castor, papaya, cotton. (ii) Monocot seeds ; maize, rice, wheat	Example- (i) Dicot seeds; gram, bean, pea, cucumber, tamarind. (ii) Monocot seeds; *Pothos, Vallisneria, Alisma,*

DISPERSAL OF FRUITS AND SEEDS

- For better growth of plants, it is needed that seeds reach places distant from the parent plant. Dispersal is important as it prevents overcrowding at a place thus decreases competition between seedlings for nutrients, etc. Besides, it results in wide distribution of various plant species thus invasion of new habitats. Various methods of seed and fruit dispersal are summarized in the given table.

Mode of dispersal and adaptations	Examples of plants
Wind (anemochory)	
Wings (i) Winged seeds (ii) Winged fruits (pericarp forms wings)	 *Tecoma, Cinchona, Moringa, Oroxylon, Lagerstroemia* *Hiptage, Shorea, Acer, Dioscorea, Dodonaea*
Parachute (i) Pappus (modified calyx) (ii) Coma (tufts of hair) (iii) Persistent hairy style (iv) Balloon like appendages	 *Sonchus, Taraxacum* *Calotropis, Alstonia* *Clematis, Narvelia* *Physalis* (calyx) *Colutea* (ovary)
Censer (seeds scattered from pores) **mechanism**	*Papaver, Argemone, Aristolochia.*
Dust seeds/light seeds (very small and dry)	Grasses, orchids
Propellar fruits (fruits flattened and twisted)	*Ailanthus*
Tumble weeds (plants get uprooted and tumble alongwith wind to disperse seeds)	*Carthamus, Salsola, Argemone*
Water (hydrochory)	
Spongy outer coat Spongy seed coat Spongy thalamus Air cavity in seeds	Coconut *Nymphaea*, lotus *Mucuna* (in seeds) *Entada*

Animals (zoochory)	
Hooked fruits and seeds (hooks, barbs, spines, bristles, stiff hairs etc.)	*Xanthium* (curved hooks), *Pupalia* (stellate hooked bristles), *Aristida* (stiff hairs), *Martynia* (Tiger's nail), *Tribulus* (rigid spines)
Sticky fruits and seeds (sticky glands)	*Boerhaavia*, *Plumbago*, *Rafflesia* (by elephants)
Fleshy fruits	*Solanum nigrum*, *Citrullus*
Edible fruits	Guava, brinjal, tomato, etc.
Mimicry	*Biserula* and *Scorpiurus* (resemble caterpillar)
Explosion of fruits (autochory)	
Jaculator mechanism	*Andrographis*, *Barleria*, *Ruellia*
5 valved or 2 valved (valve burst open)	*Impatiens*, *Ruellia tuberosa*, *Ecballium*, *Entada*, *Bauhinia* (camel's foot climber)

SEMI-TECHNICAL DESCRIPTION OF A FLOWERING PLANT

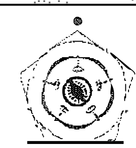
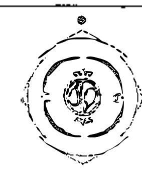
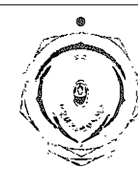
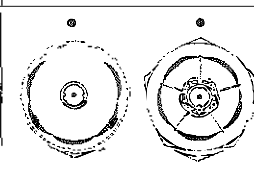
- For ease of study, identification and classification it is necessary to describe a flower in semitechnical language. Description of a flowering plant in semitechnical language is done using various morphological features. The symbolic representation of the flower just like a chemical formula is called **floral formula** (FF). Symbols used to write floral formula are shown below.

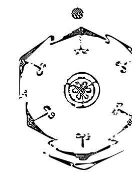
Br. – Bracteate
Ebr. – Ebracteate
⊕ – Actinomorphic or regular flower
% or + or ⦶ – Zygomorphic or irregular flower
⚥ – Bisexual flower
♀ – Female flower
♂ – Male flower
K – Calyx
C – Corolla
P – Perianth
A – Androecium
G – Gynoecium
$\underline{G}$ – Superior ovary
$\overline{G}$ – Inferior ovary
1, 2, 3, 4, ... – Number of sepals, petals, stamens or carpels.
( ) – Fused or united, *e.g.*, $C_{(5)}$, *i.e.*, five petals of corolla fused
$\widehat{C\ A}$ – Epipetalous condition, *i.e.*, stamens attached to petals.

E.g., floral formula of *Solanum nigrum* (solanaceae) is ⊕ ⚥ $K_{(5)}\widehat{C_{(5)}A_{(5)}}\underline{G}_2$

- Some important angiospermic families are discussed in brief in the following table.

Table: Some important angiospermic families

Family	Features	Floral formula	Floral diagram
Solanaceae	• 5 stamens, epipetalous and polyandrous. • Superior ovary, carpels obliquely placed. • Placentation axile with swollen placenta.	Ebr. ⊕ ⚥ $K_{(5)}\widehat{C_{(5)}A_{(5)}}\underline{G}_{(2)}$	
Cruciferae	• Tetradynamous condition of androecium, green nectaries occur at the base of the stamen. • Bicarpellary, syncarpous gynoecium with parietal placentation. • Presence of false septum or replum in ovary.	Ebr. ⊕ ⚥ $K_{2+2}\,C_4\,A_{2+4}\,\underline{G}_{(2)}$	
Fabaceae	• Diadelphous androecium. • Gynoecium monocarpellary, ovary unilocular with marginal placentation.	Br. % ⚥ $K_5\,C_{1+2+(2)}\,A_{1+(9)}\,\underline{G}_1$	
Compositae	• Sepals modified to pappus • 5 epipetalous stamens with syngenesious condition. • Ovary inferior with basal placentation.	**Ray florets:** (a) Ligulate and female : Br. % ♀ $K_{5\ (pappus)}\,C_{(5)}\,A_0\,\overline{G}_{(2)}$ (b) Ligulate and neuter : Br. % $K_{5\ (pappus)}\,C_{(5)}\,A_0\,G_0$ **Disc florets:** Br. ⊕ ⚥ $K_{5\ (pappus)}\,\widehat{C_{(5)}A_{(5)}}\overline{G}_{(2)}$	

Gramineae	• Anthers generally divaricate and versatile. • Gynoecium monocarpellary with unilocular and uniovuled ovary. • Basal placentation.	Br. Brl.% ⚥ $P_{2(\text{lodicules})}\ A_{3\ \text{or}\ 3+3}\ \underline{G}_1$	
Liliaceae	• Androecium 6 in two whorls. • Gynoecium tricarpellary, syncarpous with axile placentation.	Br. ⊕ ⚥ $\overline{P_{3+3\ \text{or}\ (3+3)}\ A_{3+3}}\ \underline{G}_{(3)}$	

PLANT ANATOMY

- Plant anatomy is the branch which deals with the study of **gross internal structure** of plant organs as observed after section cutting.
- Study of this branch started in 1671, when **Marcello Malpighi** and **N. Grew** independently studied the anatomy of vegetable plants. N. Grew is known as 'Father of Plant Anatomy'.
- A group of cells having a common origin and co-operating with one another to perform a similar function (or a set of similar functions) is described as a **tissue**. All the plant organs *viz*., roots, stem, leaves, flowers and fruits are made up of different kinds of tissues to perform different functions. Based on the capacity to divide, the plant tissues have been classified into two fundamental types, **meristematic** and **permanent**.

Meristematic tissues

- The regions of indefinitely dividing capacity or regions of theoretically unlimited growth are called **meristems** or **meristematic tissues**.
- On the basis of origin, meristems are of two types, **primary** and **secondary**. **Primary meristems** are those that originate from the embryonic meristems or promeristems. They cause the meristematic nature throughout the life of the plant. They are located at the tips of stems, roots and appendages. The **secondary meristems** originate as new meristems from the permanent tissues which have already undergone differentiation. They do not have their own promeristem.
- Depending upon their position, meristems are of three types : **apical, intercalary** and **lateral. Apical meristems** are present at the tips of stem, root and their branches. They cause growth in length. **Intercalary meristems** are meristematic regions which are derived from the apical meristems. These help in elongation of the organs and also allow the fallen stems of cereals to become erect. These are commonly found at the bases of leaves, above the nodes (*e.g*., grasses) or below the nodes (*e.g*., mint). Both apical meristems and intercalary meristems are primary meristems because they appear early in life of a plant and contribute to the formation of the primary plant body.
- **Lateral meristem** occurs on the sides and takes part in increasing girth of the plant. They are cylindrical meristems and give rise to secondary tissues that constitute secondary growth. The common examples are fascicular vascular cambium, interfascicular cambium and cork cambium or phellogen.

Permanent tissues

- Permanent tissues are those tissues which have **lost the power of cell division.** Cells of permanent tissues are matured, assumed a definite shape, size and function. The permanent tissues which develop from primary apical meristem are called **primary permanent tissues.** The permanent tissues which develop secondary meristem are called **secondary permanent tissues. On the basis of constituent cells** permanent tissues are classified into three types : **simple tissues, complex tissues** and **special tissues** (*e.g*., secretory tissues).

Simple permanent tissues

- A simple permanent tissue is made up of similar permanent cells that carry out the same function or similar set of functions. Simple permanent tissues are of three types – **parenchyma, collenchyma** and **sclerenchyma.**
- **Parenchyma** is phylogenetically and ontogenetically the primitive tissue. The tissue mainly consists of thin-walled living cells which have intercellular spaces between them and their cell wall is made of cellulose or calcium pectate. Each cell possesses a prominent nucleus and vacuolate cytoplasm.
- **Collenchyma** is a simple permanent tissue of refractile, **nonlignified** living cells which possess **pectocellulose** thickenings in specific areas of their walls. Internally each cell possesses a large central vacuole and a peripheral cytoplasm. Chloroplasts are often present. Depending upon the thickening, collenchyma is of three types – angular, lamellate and lacunate collenchyma.
- **Sclerenchyma** consists of thick-walled dead cells and possesses hard and extremely thick secondary walls due to uniform deposition of lignin. Sclerenchyma is of two types, sclerenchyma fibres and sclereids. The **sclerenchyma fibres** are highly elongated narrow and spindle-shaped, thick-walled cells with pointed or oblique end walls. The fibres occur in all those parts where mechanical strength is required, *viz*., leaves, petioles, cortex and around vascular bundles.

Table : Differences between different types of simple tissues

	Parenchyma	Collenchyma	Sclerenchyma
1.	Cells are living.	Cells are living.	Cells are dead.
2.	The cell wall is thin and does not have secondary depositions.	Pectin deposits are present outside the primary wall.	The secondary cell wall is made of lignin.
3.	Pits are absent from the wall.	Pits are absent from the wall.	Simple pits are present in the wall.
4.	Intercellular spaces are present.	Intercellular spaces are absent.	Intercellular spaces are absent.
5.	Functions– synthesis of food and its storage, packing and also acts as meristematic tissue.	Functions – being a mechanical tissue, provides rigidity with flexibility, also carries vital processes like photosynthesis, if required.	Functions – being a major mechanical tissue, provides rigidity with hardness.

Complex permanent tissues

- The permanent tissues which contain more than one type of cells and work as a unit are called complex tissues. The common complex permanent tissues are conducting tissues, **phloem** and **xylem.**

Phloem or leptome

- **Phloem** is a complex tissue which transports organic food inside the body of the plant. Phloem is also called **bast** and consists of four types of cells, *viz.*, **sieve tubes, companion cells, phloem parenchyma** and **fibres.** Haberlandt (1914) used the term leptome for the conducting part of phloem. The first formed primary phloem consists of narrow sieve tubes and is referred to as protophloem and the later formed phloem has bigger sieve tubes and is referred to as **metaphloem.**
- **Sieve tubes** are elongated tubular conducting channels formed of several cells called sieve tube members or sieve tube cells. Sieve tube members are placed end to end and have many **small pores** or **sieve pits** lined by a layer of **callose.** Due to the presence of sieve pits the end walls are commonly called **sieve plates.** On the other hand, a **sieve cell** is a special kind of cell which possesses sieve areas in its lateral walls and there is no specialized sieve plate in it. The sieve cells are usually found in pteridophytes and gymnosperms. The sieve tubes are found in angiosperms.
- Companion cells are narrow, elongated and thin walled living cells on the sides of the sieve tubes and are closely associated with them through **compound plasmodesmata.** The companion cells are absent in pteridophytes and gymnosperms. They are present in angiosperms (both in monocots and dicots). Sieve tube member and its adjacent companion cells are derived from the same mother cell. Thus death of one results in death of the other as well. Phloem parenchyma are ordinary living elongated parenchyma cells having abundant plasmodesmata and store food, resins, latex, mucilage, etc. The cells help in slow conduction of food, especially to the sides.
- **Phloem fibres** are also called **bast fibres** and mostly occur in secondary phloem. The fibres have both **cellulose** and **lignified** thickenings.

Xylem or hadrome

- **Xylem** is a complex tissue which performs the function of transport of water or sap inside the plant and also provides mechanical strength. The term xylem (Greek, xylos = wood) was introduced by **Nageli** (1858). Xylem is also known as wood. It consists of four types of cells, *viz.*, tracheids, vessels (both tracheary elements), xylem or wood parenchyma and xylem or wood fibres. Conduction of sap is carried out by tracheids. The conducting elements of the xylem have been called **hadrome** by Haberlandt (1914). **Tracheids** are **dead, lignified** and elongated cells with tapering ends. Tracheids are commonly found in pteridophytes, gymnosperms and xylem of dicotyledons. Tracheids possess annular, scalariform, spiral, reticulate and border pitted thickenings on their walls.
- **Vessels** are present in angiosperms and are much elongated tubes (2 metres in *Quercus*) and (3 – 6 metres in *Eucalyptus*), which are closed at either end and are formed by the union of several short, wide and thickened cells called **vessel elements.** Vessels are **absent** in pteridophytes and gymnosperms. Vessels help in conduction of water and dissolved salts from roots to the different parts of the shoot and provide mechanical support.
- Parenchyma associated with xylem is called **xylem parenchyma** or **wood parenchyma.** It is made up of small thin or thick walled parenchymatous cells having simple pits. It helps in lateral conduction of water or sap and stores food (starch, fat) and sometimes tannins. **Xylem fibres** are sclerenchyma (dead cells) fibres associated with xylem. Xylem fibres add to the mechanical strength of the plant body
- First formed xylem is **protoxylem** and later formed xylem is **metaxylem.** Depending upon the position of protoxylem in relation to metaxylem, xylem can be of four types – **exarch, mesarch, centrarch** and **endarch.** In exarch type, protoxylem lies towards the outside of metaxylem. It is inner in the endarch, in middle of metaxylem in the mesarch xylem and at centre of metaxylem in centrarch xylem.

Special tissues

- Cells concerned with secretion or excretion of materials together constitute secretory tissue or special tissue. They secrete substances like enzymes, nectar, mucilage, oil, etc. They occur in different parts of the plant body.
- Secretory tissues are of two types: glandular tissues, laticiferous tissues. **Glandular tissues** consist of glands. A gland is specialised group of cells, capable of secreting some substances. These glands may be external or internal *e.g*, digestive glands are external glands present in insectivorous plants like, *Drosera, Nepenthes,* etc. while **hydathodes** are internal glands.
- **Laticiferous tissues** or laticifers are common in tropical plants. They secrete latex which is an emulsion of proteins, sugars, alkaloids, enzymes, rubber and other substances

in the matrix of watery fluid. Most commonly latex is milky white in colour. Laticifers are of two types, latex cells and latex vessels.

TISSUE SYSTEM

- A group of tissues performing some common function irrespective of their position in the plant body is called tissue system. **Sachs** classified the tissue systems into three types namely **epidermal tissue system, ground tissue system** and **vascular tissue system.** Epidermal tissue system is derived from **protoderm,** ground tissue system from **ground meristem** and vascular tissue system from **procambium.**

Epidermal tissue system

- Epidermal tissue system consists of **epidermis** and **epidermal outgrowths.** Epidermis is the superficial layer covering the entire surface of the primary plant body. All the epidermal cells are living (parenchymatous) and contain vacuolated protoplasms (a large central vacuole and a peripheral thin cytoplasm). The epidermis is covered with a cutin layer called **cuticle** on its outer surface. It is **absent in young roots.** Root epidermis is called **rhizodermis** or **epiblema** or **piliferous layer.** The epidermis of aerial parts usually bears a number of minute pores called **stomata.**
- The specialised green epidermal cells present around the stomata are called **guard cells.** Guard cells in **dicots** are **kidney** (bean) shaped and in **monocots** (grasses) are **dumb– bell** shaped. Outer wall of guard cells is thin but inner wall is thick and inelastic. Moreover, the cellulose micelles in guard cell walls are oriented radially rather than laterally to help in opening and closing of stomata. The guard cells are surrounded by two or more epidermal cells called **subsidiary cells.** When subsidiary cells lie above the guard cells, the stomata are called sunken. **Stomatal aperture, guard cell** and **subsidiary cells** together constitute a complex called **stomatal apparatus.**
- **Epidermal outgrowths** are of two kinds - trichomes and emergences. The unicellular or multicellular outgrowths formed from epidermis only are called **trichomes.** Trichomes may be of various types as hairs, scales, etc. **Hair** are elongated outgrowths of epidermis present in almost all the plant parts. Hairs are of two types – unicellular hair, multicellular hair. The multicellular outgrowths formed from both epidermis and outer most cortical cells are called **emergences.** Prickles in *Rosa* are emergences. They are sharp and stiff outgrowths. Prickles do not have vascular supply. They protect the plant from excessive transpiration and grazing animals.

Ground tissue system

- Ground tissue system, also known as fundamental tissues, contain various types of tissues excluding epidermis and vascular tissues. Ground tissue system is derived partly from **periblem** and partly from **plerome.** Ground tissue system is of two types - **extrastellar** ground tissue system and **intrastellar** ground tissue system. Extrastellar ground tissue system is also called **cortex.** Intrastellar ground tissue system includes **pericycle, pith** and **medullary rays.**

Vascular tissue system

- Central column of axis (root and stem) is called **stele** which is made up of a number of vascular bundles, which constitute vascular tissue system.
- Each **vascular bundle** comprises of **xylem, phloem** and **cambium** (if present).

Vascular bundle according to occurrence
- **Open** – Cambium present
- **Closed** – Cambium absent

Vascular bundles according to relative position of xylem and phloem
- **Radial** – Xylem and phloem on different radii
- **Conjoint** – Xylem and phloem on same radii
  - **Collateral** – Phloem on outer side and xylem inner side
  - **Bicollateral** – Xylem is sandwiched between outer and inner phloem
- **Concentric** – One surrounds the other
  - **Amphicribal or hadrocentric** – Phloem surrounds xylem
  - **Amphivasal or leptocentric** – Xylem surrounds phloem

ANATOMY OF DICOT ROOT

- Dicot root consists of a single layer of **epiblema** or piliferous cells which bears unicellular root hairs. Some cells of the epiblema give rise to thin-walled tubular outgrowths called root hairs, also called **trichoblasts. Cortex** lies below the epiblema and is made up of many layers of thin walled parenchyma cells which enclose intercellular spaces for diffusion of gases. The cells of the cortex store food and conduct water from the epilblema to the inner tissues. Cuticle or stomata is absent in root.
- **Endodermis** is made up of single layer of barrel shaped cells without intercellular spaces. The cells are rich in starch grains. **Casparian strips,** bands of thickenings are present along the tangential and radial walls of endodermis. Due to the presence of casparian strips, the endodermal cells do not allow wall to wall movement of substances between cortex and pericycle. Substances must enter the cytoplasm of endodermal cells. As a result, endodermis functions as a **biological check post.**
- Endodermis is followed by one (sunflower) or more (mulberry) layers of **pericycles.** Inner to pericycle lies radially arranged **vascular bundles** (2 - 6). Xylem and phloem are equal in number and lie on different radii. In between the two adjacent xylem bundles is found a phloem bundle which is oval in outline. Phloem and xylem bundles are separated from each other by one or more layers of small thin walled cells called conjunctive parenchyma or tissue. Xylem is exarch. Later on the conjunctive tissue becomes meristematic to form vascular cambium. Generally pith is absent in root or if present is very small.

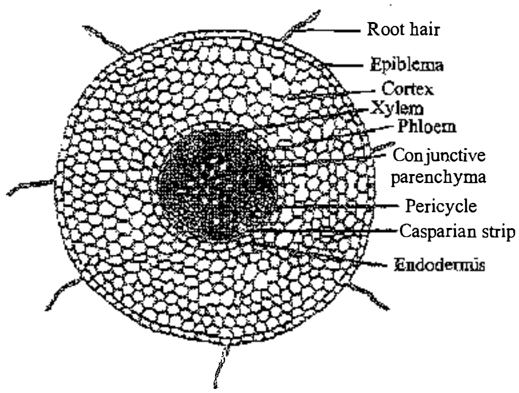


Fig.: T.S. of root of sunflower (dicot)

ANATOMY OF MONOCOT ROOT

- Monocot root is similar to dicot roots in having epiblema, cortex, endodermis and vascular tissues. In older roots the outer one (*e.g., Smilax*) or more (*e.g.*, maize) layers of the cortex become thick walled and suberised and constitute the **exodermis.** It is protective and to some extent absorptive in function.
- The number of radial vascular bundles are more than that in dicot roots. Xylem is exarch and polyarch. The conjunctive tissue present in between xylem and phloem, store food and provide mechanical strength but do not form cambium. The centre of the monocot root is occupied by, a large well-developed pith.

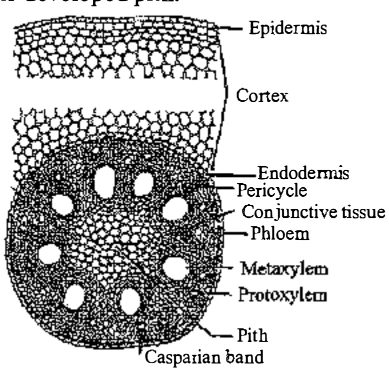


Fig.: A portion of root of *Zea mays* (maize) in transverse section

ANATOMY OF DICOT STEM

- Epidermis of dicot stem is made up of compactly arranged, elongated parenchymatous cells, having distinct cuticle, stomata and trichomes (*e.g.*, sunflower). Inner to epidermis is present 3-4 layers of collenchymatous hypodermis. Collenchyma cells are green and enclose small intercellular spaces. Inner to hypodermis is cortex. In the young green stem, the outer cortical cells possess chloroplasts (chlorenchyma) and manufacture food. However, major function of the cortex is storage of food.
- Endodermis lies at the innermost boundary of cortex and is called starch sheath. Casparian strips are absent in stem. Inner to endodermis is present a few layers of heterogenous pericycle (parenchyma and sclerenchyma). A large number of vascular bundles are arranged in a ring. The 'ring' arrangement of vascular bundles is a characteristic of dicot stem. Bundle sheath is usually absent. Vascular bundles are conjoint, collateral and open. Cambium helps in secondary growth. Xylem is endarch and fascicular cambium is present. Medullary rays are present in between vascular bundles. The central portion is occupied by pith.

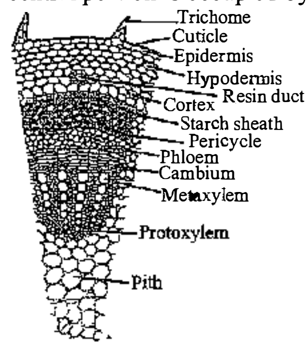


Fig.: T.S. of dicot stem (sunflower)

ANATOMY OF MONOCOT STEM

- Monocot stem is characterised by single layered epidermis, 2 - 3 layered hypodermis and undifferentiated ground tissue system. The outer walls of epidermal cells possess deposition of silica and cutin. Hypodermis is made up of thick walled lignified, non-green sclerenchyma fibres & acts as heat screen and provides rigidity and mechanical strength to the stem. Ground tissue does not show distinction into cortex, endodermis, pericycle, pith and pith rays.
- Vascular strand is **atactostele** (numerous and scattered). Vascular bundles are conjoint, collateral, closed and endarch. A sclerenchymatous **bundle sheath** is generally present on the outside of each vascular bundle. Phloem parenchyma is absent. **Secondary growth is usually absent.** A cavity containing water is found in vascular bundle by the dissolution or separation of some protoxylem vessels and parenchyma cells lying nearby.

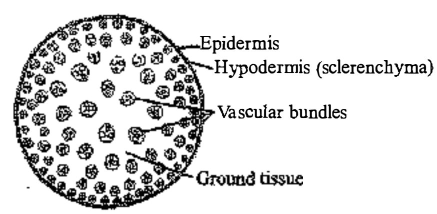


Fig.: Transverse section of stem of *Zea mays* (maize)

ANATOMY OF DICOT LEAF

- Dicot leaf shows differences between upper (dorsal) and lower (ventral) surfaces, in the number of stomata and texture etc. Such leaves are called **dorsiventral leaves.**
- Dicot leaf is characterized by upper and lower epidermis, cuticle, mesophyll cells and vascular bundles. The outer walls of epidermal cells are coated with cuticle. Usually the stomata are present more in lower epidermis as compared to upper epidermis. Mesophyll is present in between upper and lower epidermis. Mesophyll is differentiated into **palisade parenchyma** and **spongy parenchyma.** The palisade parenchyma lies below the upper epidermis which consists of 1–3 layers of vertically elongated, parallel and closely placed columnar or cylindrical cells. The cells are rich in discoid chloroplasts. They are, therefore, the **main site of photosynthesis.**

- The spongy parenchyma or spongy mesophyll lies between the lower epidermis and the palisade parenchyma. They enclose large cavities or intercellular spaces which are connected with the atmosphere through the stomata. Thus a large substomatal cavity lies below each stoma. Vascular bundles (VBs) are scattered in spongy parenchyma and the vascular bundle in midrib region is largest. VBs are conjoint, collateral and closed. Each vascular bundle is surrounded by a bundle sheath of parenchymatous cells. Xylem is present towards the upper epidermis and phloem towards the lower epidermis.

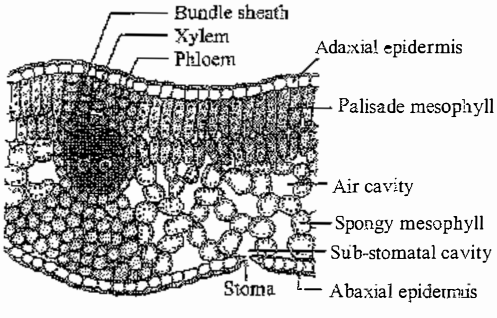


Fig.: T.S. of dicot leaf

ANATOMY OF MONOCOT LEAF

- Monocot leaves show similar appearance on both the surface. Such leaves are called **isobilateral leaves.**
- Monocot leaf is somewhat similar to dicot leaf in having epidermis and cuticle. Stomata are present on both the surfaces of epidermis. The leaf is therefore, **amphistomatic.** Bulliform cells or motor cells are present. Mesophyll is undifferentiated into palisade and spongy parenchyma. Instead it is similar to spongy tissue. The mesophyll cells are chlorenchymatous and contain a number of chloroplasts. Therefore, mesophyll constitutes the photosynthetic tissue of the leaf.
- Each vascular bundle is surrounded by a bundle sheath of compactly arranged chlorenchyma cells. Larger vascular bundles bear bundle sheath extensions, which are sclerenchymatous and provide mechanical strength to the leaf. Vascular bundles are conjoint, collateral, closed with phloem towards lower side and xylem towards upper side. The wide midrib does not contain any mesophyll. Above and below larger vascular bundles are present patches of sclerenchymatous cells.

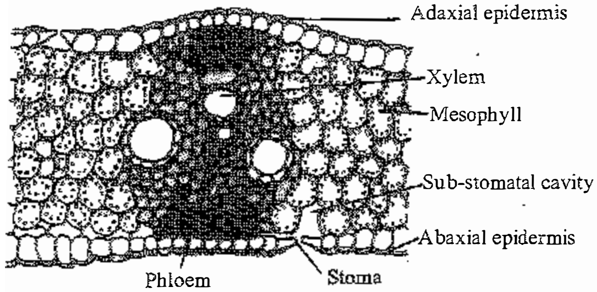


Fig.: T.S. of monocot leaf

SECONDARY GROWTH

- The formation of secondary tissue which leads to increase in girth is called secondary growth. Secondary tissues are formed by two types of lateral meristems - **vascular cambium** (formed from conjunctive parenchyma and pericycle) and **cork cambium** or **phellogen** (formed from pericycle).
- Cork cambium or phellogen produces phellem (cork cells) on the outer side and phelloderm on the inner side. Phellem, phellogen and phelloderm together constitute the periderm.
- The fascicular cambium and the interfascicular cambium together constitutes the vascular cambium. Vascular cambium produces secondary vascular tissues. The cambial ring cuts of secondary xylem towards the centre and secondary phloem towards the periphery. Secondary xylem consists of vessels, xylem parenchyma and few fibres and secondary phloem consists of sieve tubes, companion cells, phloem parenchyma and fibres. Amount of secondary xylem is more than secondary phloem. Due to secondary growth, stem increases in girth. Cambial cells are of two types – fusiform initials and ray initials. Fusiform initials give rise to medullary rays **vessels** and **tracheids.** Ray initials give rise to rays in secondary tissue.
- The wood formed in a single year is called **annual ring.** Spring wood is the secondary xylem formed during spring when the cambial activity is more. Wood elements are larger in size and have wider lumen. Autumn wood (or late wood) is the wood element formed during winter when cambial activity is less. Wood formed is lesser in amount and have narrow lumen. The age of tree can be determined by counting **annual rings,** the process is known as **dendrochronology.**
- In perennial woody trees, the central portion is dark, hard and tough due to deposition of resins, tannins, gums and formation of tyloses. This region consists of dead elements and do not conduct water but provides mechanical support. This central region is called **heartwood** (duramen). The outer or peripheral portion is soft and lighter in colour consisting of living cells. It is called **sap wood** (alburnum) and helps in conduction of water and minerals.
- **Wood of gymnosperm** is called **nonporous** or **soft wood** (absence of vessels and fibres) and that of **dicots** is called **porous** or **hard wood. Tyloses** are balloon like structures, produced due to ingrowth of xylem parenchyma into the lumen of xylem vessels through pits. Bark is all the tissues outside vascular cambium. There are certain loosely arranged areas in the periderm formed due to rapid activity of phellogen, called lenticels. **Lenticels** help in gaseous exchange and transpiration.

CONCEPT MAP

Plant Tissues

- **Meristematic tissues**
  - Capable of active cell division
  - Thinwalledandliving
  - Variable shape
  - Compactly arranged
  - Found in root and shoot apices
  - **Division on the basis of**
    - **Origin and development**
      - Primary meristem
        - Protoderm (Epidermis)
        - Procambium (Pericycle, phloem, xylem, cambium)
        - Ground meristem (Hypodermis, cortex, endodermis, pith)
      - Secondary meristem
    - **Position or location**
      - Apical
      - Intercalary
      - Lateral
    - **Plane of division**
      - **Mass meristem** (Young, in all planes)
      - **Plate meristem** (Anticlinal division in two plane)
      - **Rib meristem** (Perpendicular / anticlinal division in one plane, occasional periclinal division)
- **Permanent tissues**
  - Growth is ceased temporarily
  - Have definite shape, size and form
  - **Divisions on the basis of constitution**
    - **Simple tissues** – One type of cells, homogenous
      - **Parenchyma**
        - Thin walled, isodiametric, compactly arranged
        - Provide protection, storage area, growth and perform photosynthesis
        - Three types – **aerenchyma, chlorenchyma, prosenchyma**
      - **Collenchyma**
        - Absent in secondary tissues
        - Occupies hypodermal position
        - Polygonal and living cells
        - Provide mechanical strength
      - **Sclerenchyma**
        - Cells dead and empty
        - Lignified, divided into
          - **Fibres**
          - **Sclereids**
            - **Macrosclereids** (columnar, rod shaped)
            - **Osteosclereids** (bone shaped)
            - **Astrosclereids** (star shaped)
            - **Brachysclereids** (isodiametric, also called stone cells)
            - **Trichosclereids** (hair like)
            - **Filiform** (fibre like)
    - **Complex tissues** – More than one type of cells, heterogenous
      - **Xylem**
        - Water conducting part. It consists of
          - **Tracheids** (Dead elongated cells with tapering ends)
          - **Vessels** (Made of row of dead cells)
          - **Xylem fibres** (Lignified and sclerenchymatous)
          - **Xylem parenchyma** (Living and cellulosic)
      - **Phloem**
        - Solute conducting part.
        - It consists of
          - **Sieve tubes** (Tube like elongated cells with large lumen)
          - **Companion cells** (Found only in angiosperms)
          - **Phloem parenchyma** (Living parenchymatous cells, absent in monocot & herbaceous dicot)
          - **Phloem fibres** (Thick walled sclerenchymatous cells, mechanical in function)
    - **Secretory tissues** – Produce secretory substances
      - **Glandular tissue** (*e.g.*, digestive glands in insectivorous plants)
      - **Laticifers** (secrete latex)