EXERCISES

1. What are the difficulties that you would face in classification of animals, if common fundamental features are not taken into account?
2. If you are given a specimen, what are the steps that you would follow to classify it?
3. How useful is the study of the nature of body cavity and coelom in the classification of animals?
4. Distinguish between intracellular and extracellular digestion?
5. What is the difference between direct and indirect development?
6. What are the peculiar features that you find in parasitic platyhelminthes?
7. What are the reasons that you can think of for the arthropods to constitute the largest group of the animal kingdom?
8. Water vascular system is the characteristic of which group of the following:

   (a) Porifera (b) Ctenophora (c) Echinodermata (d) Chordata
9. "All vertebrates are chordates but all chordates are not vertebrates". Justify the statement.
10. How important is the presence of air bladder in Pisces?
11. What are the modifications that are observed in birds that help them fly?
12. Could the number of eggs or young ones produced by an oviparous and viviparous mother be equal? Why?
13. Segmentation in the body is first observed in which of the following:

    (a) Platyhelminthes (b) Aschelminthes (c) Annelida (d) Arthropoda
14. Match the following:

(a) Operculum	(i) Ctenophora
(b) Parapodia	(ii) Mollusca
(c) Scales	(iii) Porifera
(d) Comb plates	(iv) Reptilia
(e) Radula	(v) Annelida
(f) Hairs	(vi) Cyclostomata and Chondrichthyes
(g) Choanocytes	(vii) Mammalia
(h) Gill slits	(viii) Osteichthyes

15. Prepare a list of some animals that are found parasitic on human beings.

UNIT 2

STRUCTURAL ORGANISATION IN PLANTS AND ANIMALS

The description of the diverse forms of life on earth was made only by observation – through naked eyes or later through magnifying lenses and microscopes. This description is mainly of gross structural features, both external and internal. In addition, observable and perceivable living phenomena were also recorded as part of this description. Before experimental biology or more specifically, physiology, was established as a part of biology, naturalists described only biology. Hence, biology remained as a natural history for a long time. The description, by itself, was amazing in terms of detail. While the initial reaction of a student could be boredom, one should keep in mind that the detailed description, was utilised in the later day reductionist biology where living processes drew more attention from scientists than the description of life forms and their structure. Hence, this description became meaningful and helpful in framing research questions in physiology or evolutionary biology. In the following chapters of this unit, the structural organisation of plants and animals, including the structural basis of physiologial or behavioural phenomena, is described. For convenience, this description of morphological and anatomical features is presented separately for plants and animals.

Katherine Esau
(1898 – 1997)

KATHERINE ESAU was born in Ukraine in 1898. She studied agriculture in Russia and Germany and received her doctorate in 1931 in United States. She reported in her early publications that the curly top virus spreads through a plant via the food-conducting or phloem tissue. Dr Esau's *Plant Anatomy* published in 1954 took a dynamic, developmental approach designed to enhance one's understanding of plant structure and an enormous impact worldwide, literally bringing about a revival of the discipline. The *Anatomy of Seed Plants* by Katherine Esau was published in 1960. It was referred to as Webster's of plant biology – it is encyclopediac. In 1957 she was elected to the National Academy of Sciences, becoming the sixth woman to receive that honour. In addition to this prestigious award, she received the National Medal of Science from President George Bush in 1989.

When Katherine Esau died in the year 1997, Peter Raven, director of Anatomy and Morphology, Missouri Botanical Garden, remembered that she 'absolutely dominated' the field of plant biology even at the age of 99.

CHAPTER 5

MORPHOLOGY OF FLOWERING PLANTS

The wide range in the structure of higher plants will never fail to fascinate us. Even though the angiosperms show such a large diversity in external structure or **morphology**, they are all characterised by presence of roots, stems, leaves, flowers and fruits.

In chapters 2 and 3, we talked about classification of plants based on morphological and other characteristics. For any successful attempt at classification and at understanding any higher plant (or for that matter any living organism) we need to know standard technical terms and standard definitions. We also need to know about the possible variations in different parts, found as adaptations of the plants to their environment, e.g., adaptions to various habitats, for protection, climbing, storage, etc.

If you pull out any weed you will see that all of them have roots, stems and leaves. They may be bearing flowers and fruits. The underground part of the flowering plant is the root system while the portion above the ground forms the shoot system (Figure 5.1).

5.1 THE ROOT

In majority of the dicotyledonous plants, the direct elongation of the radicle leads to the formation of **primary root** which grows inside the soil. It bears lateral roots of several orders that are referred to as **secondary, tertiary,** etc. **roots.** The primary roots and its branches constitute the

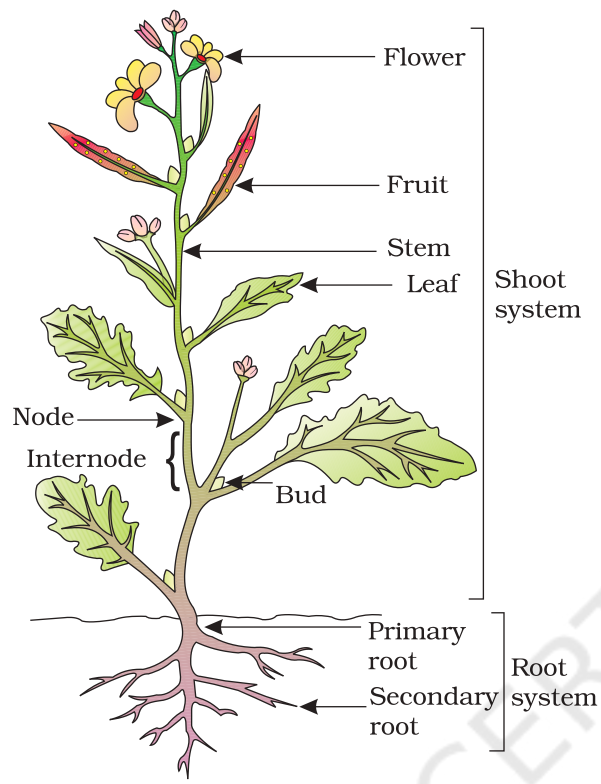


Figure 5.1 Parts of a flowering plant

tap root system, as seen in the mustard plant (Figure 5.2a). In monocotyledonous plants, the primary root is short lived and is replaced by a large number of roots. These roots originate from the base of the stem and constitute the **fibrous root system**, as seen in the wheat plant (Figure 5.2b). In some plants, like grass, *Monstera* and the banyan tree, roots arise from parts of the plant other than the radicle and are called **adventitious roots** (Figure 5.2c). The main functions of the root system are absorption of water and minerals from the soil, providing a proper anchorage to the plant parts, storing reserve food material and synthesis of plant growth regulators.

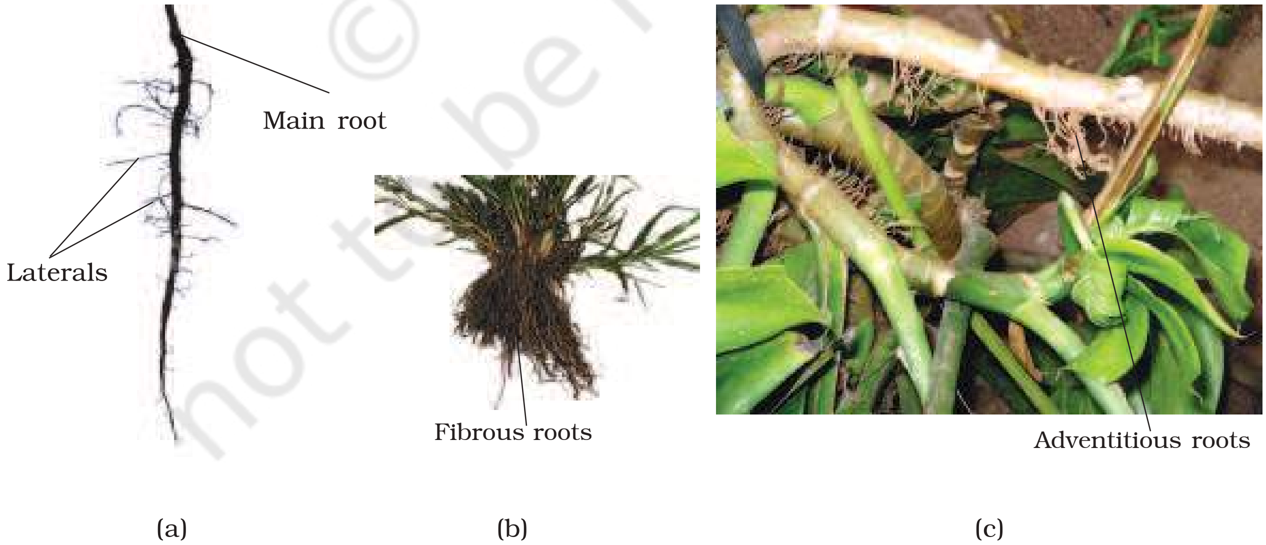


Figure 5.2 Different types of roots : (a) Tap (b) Fibrous (c) Adventitious

5.1.1 Regions of the Root

The root is covered at the apex by a thimble-like structure called the **root cap** (Figure 5.3). It protects the tender apex of the root as it makes its way through the soil. A few millimetres above the root cap is the **region of meristematic activity**. The cells of this region are very small, thin-walled and with dense protoplasm. They divide repeatedly. The cells proximal to this region undergo rapid elongation and enlargement and are responsible for the growth of the root in length. This region is called the **region of elongation**. The cells of the elongation zone gradually differentiate and mature. Hence, this zone, proximal to region of elongation, is called the **region of maturation**. From this region some of the epidermal cells form very fine and delicate, thread-like structures called **root hairs**. These root hairs absorb water and minerals from the soil.

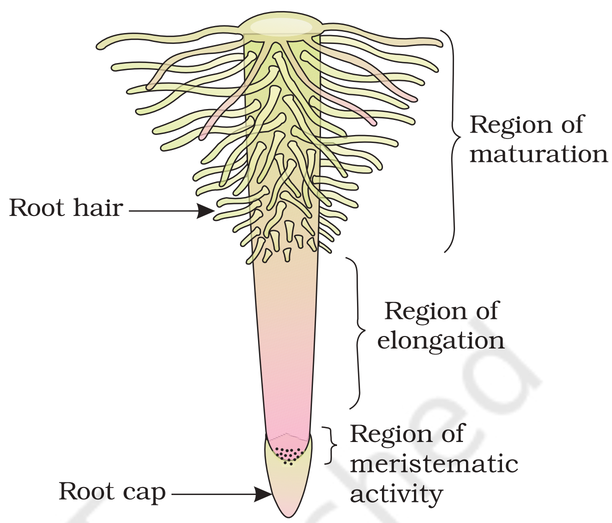


Figure 5.3 The regions of the root-tip

5.1.2 Modifications of Root

Roots in some plants change their shape and structure and become modified to perform functions other than absorption and conduction of water and minerals. They are modified for support, storage of food and respiration (Figure 5.4 and 5.5). Tap roots of carrot, turnip and adventitious roots of sweet potato, get swollen and store food. Can you give some more such examples? Have you ever wondered what those hanging structures that support a banyan tree are? These are called **prop** roots. Similarly, the stems of maize and sugarcane have supporting roots coming out of the lower nodes of the stem. These are called **stilt** roots. In some plants such as *Rhizophora* growing in swampy areas, many roots come out of the ground and grow vertically upwards. Such roots, called **pneumatophores**, help to get oxygen for respiration.

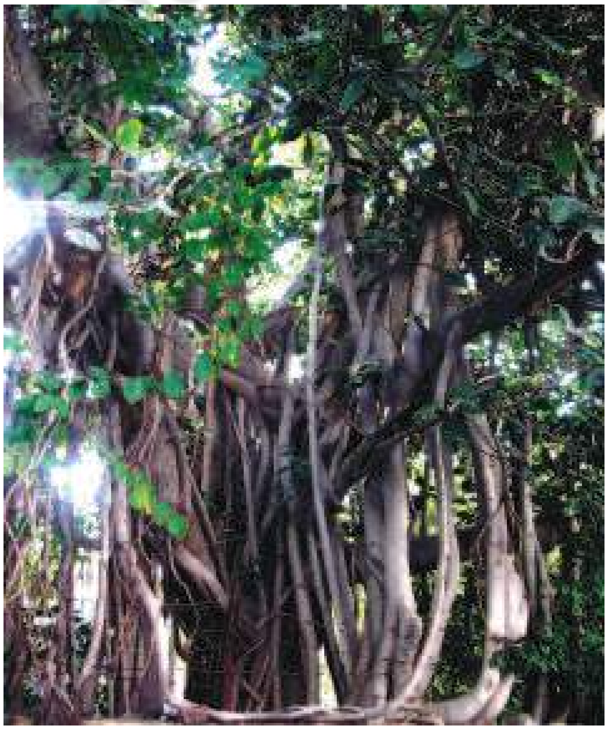


Figure 5.4 Modification of root for support: Banyan tree

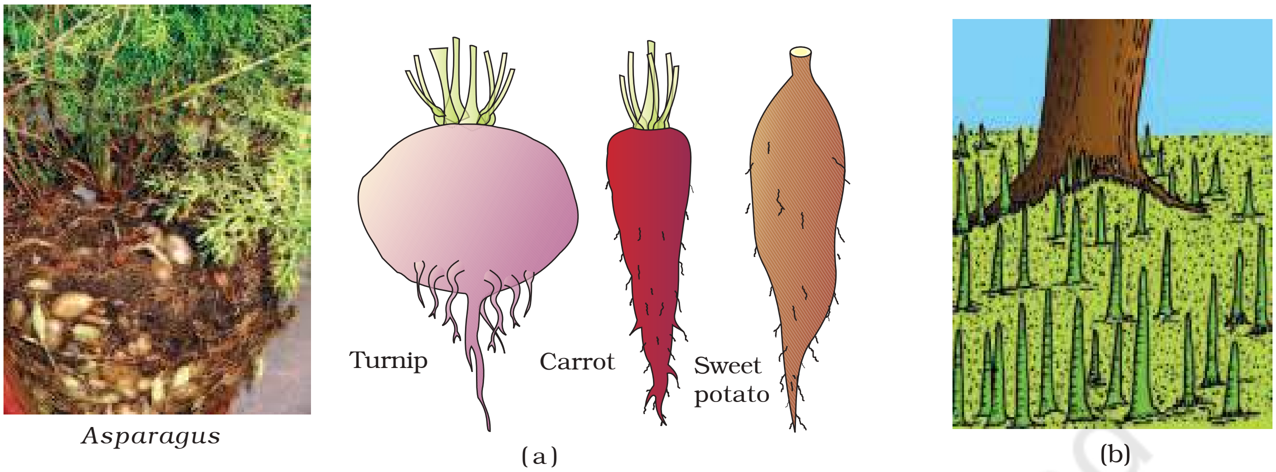


Figure 5.5 Modification of root for : (a) storage (b) respiration: pneumatophore in *Rhizophora*

5.2 THE STEM

What are the features that distinguish a stem from a root? The stem is the ascending part of the axis bearing branches, leaves, flowers and fruits. It develops from the plumule of the embryo of a germinating seed. The stem bears **nodes** and **internodes**. The region of the stem where leaves are born are called nodes while internodes are the portions between two nodes. The stem bears buds, which may be terminal or axillary. Stem is generally green when young and later often become woody and dark brown.

The main function of the stem is spreading out branches bearing leaves, flowers and fruits. It conducts water, minerals and photosynthates. Some stems perform the function of storage of food, support, protection and of vegetative propagation.

5.2.1 Modifications of Stem

The stem may not always be typically like what they are expected to be. They are modified to perform different functions (Figure 5.6). Underground stems of potato, ginger, turmeric, *zaminkand, Colocasia* are modified to store food in them. They also act as organs of perennation to tide over conditions unfavourable for growth. Stem **tendrils** which develop from axillary buds, are slender and spirally coiled and help plants to climb such as in gourds (cucumber, pumpkins, watermelon) and grapevines. Axillary buds of stems may also get modified into woody, straight and pointed **thorns**. Thorns are found in many plants such as *Citrus*, *Bougainvillea*. They protect plants from browsing animals. Some plants of arid regions modify their stems into flattened (*Opuntia*), or fleshy cylindrical *(Euphorbia)* structures. They contain chlorophyll and carry

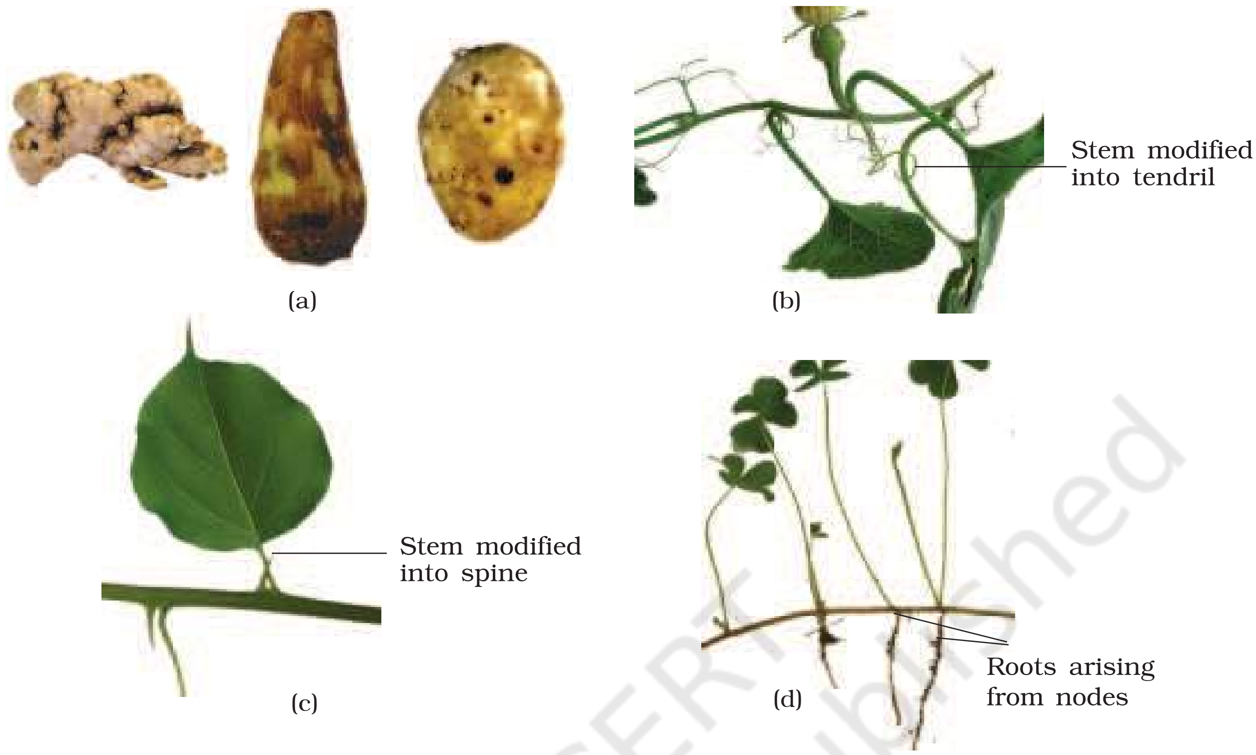


Figure 5.6 Modifications of stem for : (a) storage (b) support (c) protection (d) spread and vegetative propagation

out photosynthesis. Underground stems of some plants such as grass and strawberry, etc., spread to new niches and when older parts die new plants are formed. In plants like mint and jasmine a slender lateral branch arises from the base of the main axis and after growing aerially for some time arch downwards to touch the ground. A lateral branch with short internodes and each node bearing a rosette of leaves and a tuft of roots is found in aquatic plants like *Pistia* and *Eichhornia*. In banana, pineapple and *Chrysanthemum*, the lateral branches originate from the basal and underground portion of the main stem, grow horizontally beneath the soil and then come out obliquely upward giving rise to leafy shoots.

5.3 THE LEAF

The leaf is a lateral, generally flattened structure borne on the stem. It develops at the node and bears a bud in its axil. The **axillary bud** later develops into a branch. Leaves originate from shoot apical meristems and are arranged in an acropetal order. They are the most important vegetative organs for photosynthesis.

A typical leaf consists of three main parts: leaf base, petiole and lamina (Figure 5.7 a). The leaf is attached to the stem by the **leaf base** and may

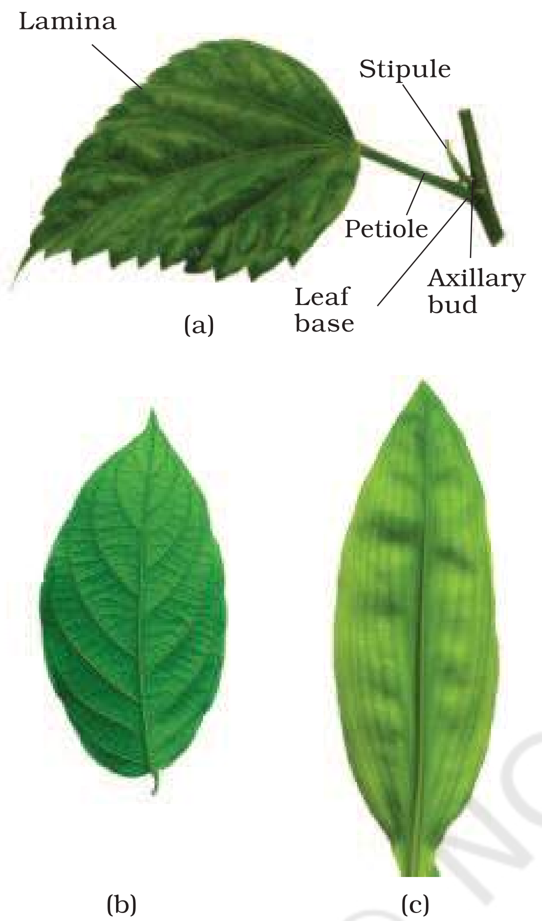


Figure 5.7 Structure of a leaf :
(a) Parts of a leaf
(b) Reticulate venation
(c) Parallel venation

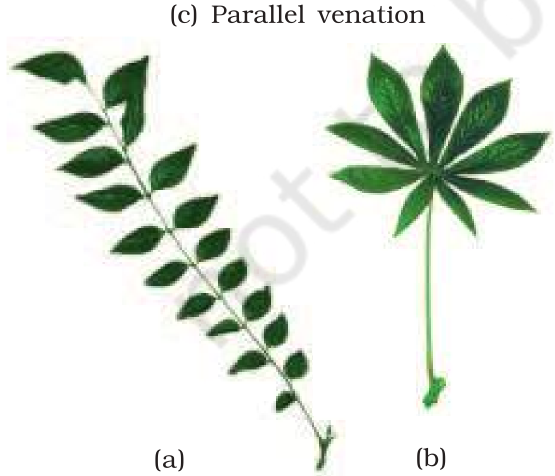


Figure 5.8 Compound leaves :
(a) pinnately compound leaf
(b) palmately compound leaf

bear two lateral small leaf like structures called stipules. In monocotyledons, the leaf base expands into a sheath covering the stem partially or wholly. In some leguminous plants the leafbase may become swollen, which is called the **pulvinus**. The **petiole** help hold the blade to light. Long thin flexible petioles allow leaf blades to flutter in wind, thereby cooling the leaf and bringing fresh air to leaf surface. The **lamina** or the **leaf blade** is the green expanded part of the leaf with veins and veinlets. There is, usually, a middle prominent vein, which is known as the midrib. Veins provide rigidity to the leaf blade and act as channels of transport for water, minerals and food materials. The shape, margin, apex, surface and extent of incision of lamina varies in different leaves.

5.3.1 Venation

The arrangement of veins and the veinlets in the lamina of leaf is termed as **venation**. When the veinlets form a network, the venation is termed as **reticulate** (Figure 5.7 b). When the veins run parallel to each other within a lamina, the venation is termed as **parallel** (Figure 5.7 c). Leaves of dicotyledonous plants generally possess reticulate venation, while parallel venation is the characteristic of most monocotyledons.

5.3.2 Types of Leaves

A leaf is said to be **simple**, when its lamina is entire or when incised, the incisions do not touch the midrib. When the incisions of the lamina reach up to the midrib breaking it into a number of leaflets, the leaf is called **compound**. A bud is present in the axil of petiole in both simple and compound leaves, but not in the axil of leaflets of the compound leaf.

The compound leaves may be of two types (Figure 5.8). In a **pinnately compound leaf** a number of leaflets are present on a common axis, the **rachis**, which represents the midrib of the leaf as in neem.

In **palmately compound leaves,** the leaflets are attached at a common point, i.e., at the tip of petiole, as in silk cotton.

5.3.3 Phyllotaxy

Phyllotaxy is the pattern of arrangement of leaves on the stem or branch. This is usually of three types – alternate, opposite and whorled (Figure 5.9). In **alternate** type of phyllotaxy, a single leaf arises at each node in alternate manner, as in china rose, mustard and sun flower plants. In **opposite** type, a pair of leaves arise at each node and lie opposite to each other as in *Calotropis* and guava plants. If more than two leaves arise at a node and form a whorl, it is called **whorled,** as in *Alstonia.*

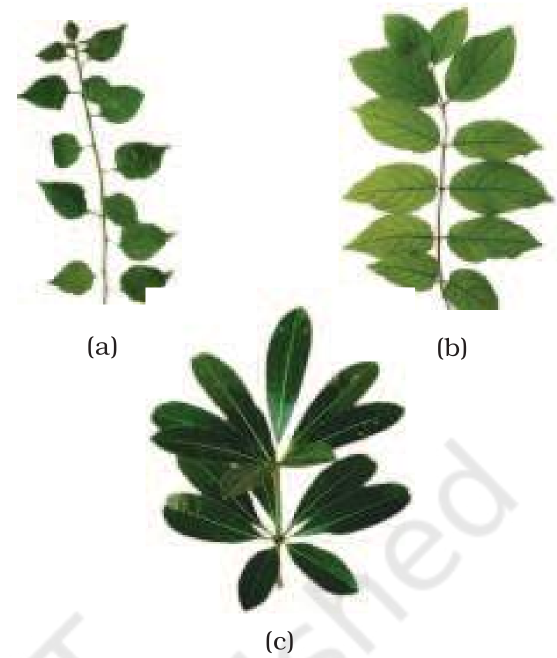


Figure 5.9 Different types of phyllotaxy : (a) Alternate (b) Opposite (c) Whorled

5.3.4 Modifications of Leaves

Leaves are often modified to perform functions other than photosynthesis. They are converted into **tendrils** for climbing as in peas or into **spines** for defence as in cacti (Figure 5.10 a, b). The fleshy leaves of onion and garlic store food (Figure 5.10c). In some plants such as Australian acacia, the leaves are small and short-lived. The petioles in these plants expand, become green and synthesise food. Leaves of certain insectivorous plants such as pitcher plant, venus-fly trap are also modified leaves.

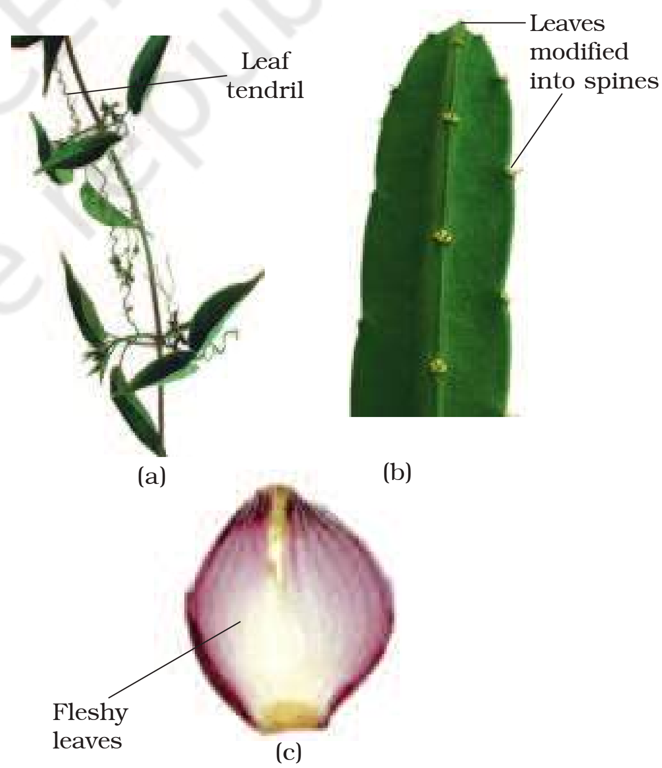


Figure 5.10 Modifications of leaf for : (a) support: tendril (b) protection: spines (c) storage: fleshy leaves

5.4 THE INFLORESCENCE

A flower is a modified shoot wherein the shoot apical meristem changes to floral meristem. Internodes do not elongate and the axis gets condensed. The apex produces different kinds of floral appendages laterally at successive nodes instead of leaves. When a shoot tip transforms into a flower, it is always solitary. The arrangement of flowers on the

Figure 5.11 Racemose inflorescence

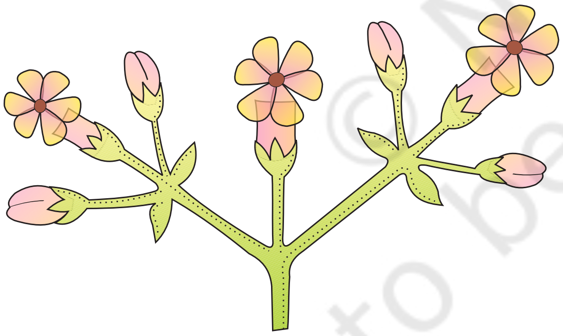


Figure 5.12 Cymose inflorescence

floral axis is termed as **inflorescence**. Depending on whether the apex gets converted into a flower or continues to grow, two major types of inflorescences are defined – racemose and cymose. In **racemose** type of inflorescences the main axis continues to grow, the flowers are borne laterally in an acropetal succession (Figure 5.11).

In **cymose** type of inflorescence the main axis terminates in a flower, hence is limited in growth.The flowers are borne in a basipetal order (Figure 5.12).

5.5 The Flower

The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. A typical flower has four different kinds of whorls arranged successively on the swollen end of the stalk or pedicel, called **thalamus or receptacle**. These are calyx, corolla, androecium and gynoecium. Calyx and corolla are accessory organs, while androecium and gynoecium are reproductive organs. In some flowers like lily, the calyx and corolla are not distinct and are termed as perianth. When a flower has both androecium and gynoecium, it is **bisexual**. A flower having either only stamens or only carpels is **unisexual.**

In symmetry, the flower may be **actinomorphic** (radial symmetry) or **zygomorphic** (bilateral symmetry). When a flower can be divided into two equal radial halves in any radial plane passing through the centre, it is said to be **actinomorphic,** e.g., mustard, *datura*, chilli. When it can be divided into two similar halves only in one particular vertical plane, it is **zygomorphic,** e.g., pea, gulmohur, bean, *Cassia*. A flower is **asymmetric** (irregular) if it cannot be divided into two similar halves by any vertical plane passing through the centre, as in canna.

A flower may be **trimerous, tetramerous** or **pentamerous** when the floral appendages are in multiple of 3, 4 or 5, respectively. Flowers with bracts-reduced leaf found at the base of the pedicel-are called **bracteate** and those without bracts, **ebracteate**.

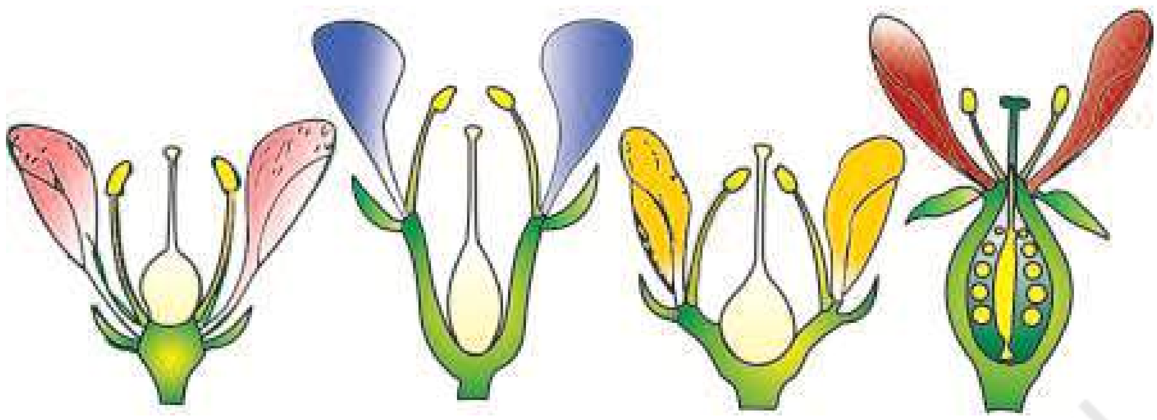


Figure 5.13 Position of floral parts on thalamus : (a) Hypogynous (b) and (c) Perigynous (d) Epigynous

Based on the position of calyx, corolla and androecium in respect of the ovary on thalamus, the flowers are described as hypogynous, perigynous and epigynous (Figure 5.13). In the **hypogynous** flower the gynoecium occupies the highest position while the other parts are situated below it. The ovary in such flowers is said to be **superior,** e.g., mustard, china rose and brinjal. If gynoecium is situated in the centre and other parts of the flower are located on the rim of the thalamus almost at the same level, it is called **perigynous.** The ovary here is said to be **half inferior,** e.g., plum, rose, peach. In **epigynous flowers,** the margin of thalamus grows upward enclosing the ovary completely and getting fused with it, the other parts of flower arise above the ovary. Hence, the ovary is said to be **inferior** as in flowers of guava and cucumber, and the ray florets of sunflower.

5.5.1 Parts of a Flower

Each flower normally has four floral whorls, viz., calyx, corolla, androecium and gynoecium (Figure 5.14).

5.5.1.1 Calyx

The calyx is the outermost whorl of the flower and the members are called sepals. Generally, sepals are green, leaf like and protect the flower in the bud stage. The calyx may be **gamosepalous** (sepals united) or **polysepalous** (sepals free).

5.5.1.2 Corolla

Corolla is composed of petals. Petals are usually brightly coloured to attract insects for pollination. Like calyx, corolla may be also united

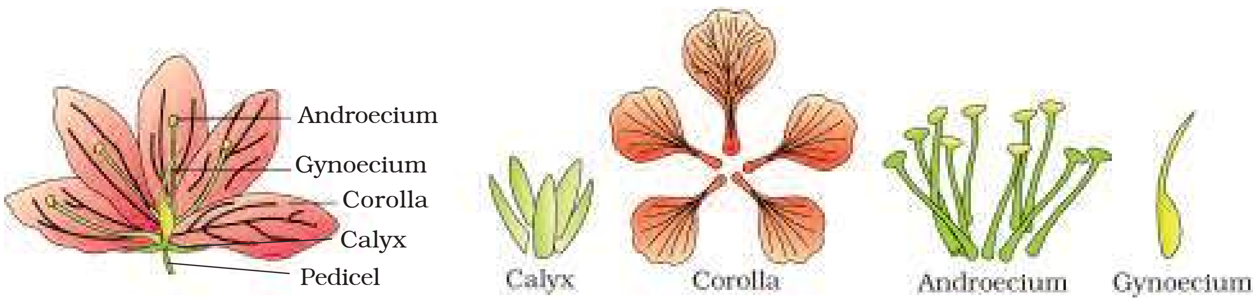


Figure 5.14 Parts of a flower

gamopetalous (petals united) or **polypetalous** (petals free). The shape and colour of corolla vary greatly in plants. Corolla may be tubular, bell-shaped, funnel-shaped or wheel-shaped.

Aestivation: The mode of arrangement of sepals or petals in floral bud with respect to the other members of the same whorl is known as aestivation. The main types of aestivation are valvate, twisted, imbricate and vexillary (Figure 5.15). When sepals or petals in a whorl just touch one another at the margin, without overlapping, as in *Calotropis*, it is said to be **valvate.** If one margin of the appendage overlaps that of the next one and so on as in china rose, lady's finger and cotton, it is called **twisted**. If the margins of sepals or petals overlap one another but not in any particular direction as in *Cassia* and gulmohur, the aestivation is called **imbricate**. In pea and bean flowers, there are five petals, the largest (standard) overlaps the two lateral petals (wings) which in turn overlap the two smallest anterior petals (keel); this type of aestivation is known as **vexillary** or papilionaceous.

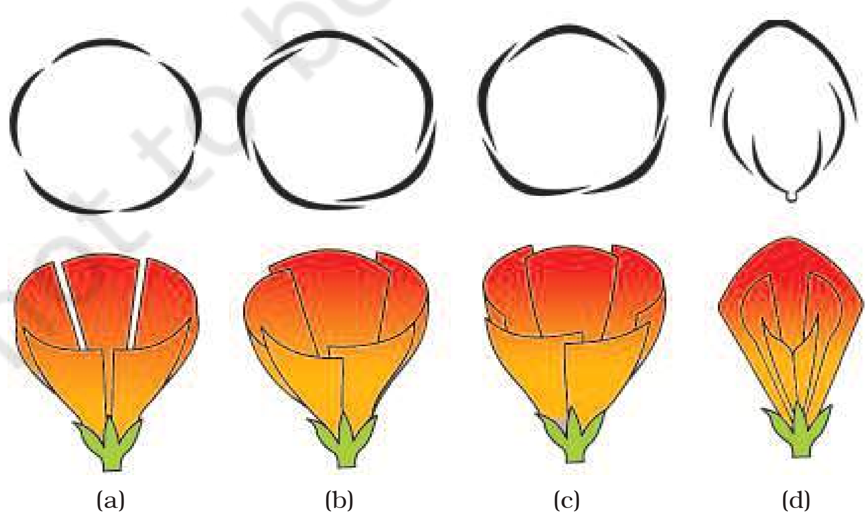


Figure 5.15 Types of aestivation in corolla : (a) Valvate (b) Twisted (c) Imbricate (d) Vexillary

5.5.1.3 Androecium

Androecium is composed of stamens. Each stamen which represents the male reproductive organ consists of a stalk or a filament and an anther. Each anther is usually bilobed and each lobe has two chambers, the pollen-sacs. The pollen grains are produced in pollen-sacs. A sterile stamen is called **staminode**.

Stamens of flower may be united with other members such as petals or among themselves. When stamens are attached to the petals, they are **epipetalous** as in brinjal, or **epiphyllous** when attached to the perianth as in the flowers of lily. The stamens in a flower may either remain free (polyandrous) or may be united in varying degrees. The stamens may be united into one bunch or one bundle **(monoadelphous)** as in china rose, or two bundles **(diadelphous)** as in pea, or into more than two bundles **(polyadelphous)** as in citrus. There may be a variation in the length of filaments within a flower, as in *Salvia* and mustard.

5.5.1.4 Gynoecium

Gynoecium is the female reproductive part of the flower and is made up of one or more carpels. A carpel consists of three parts namely stigma, style and ovary. **Ovary** is the enlarged basal part, on which lies the elongated tube, the style. The style connects the ovary to the stigma. The **stigma** is usually at the tip of the **style** and is the receptive surface for pollen grains. Each ovary bears one or more ovules attached to a flattened, cushion-like **placenta**. When more than one carpel is present, they may be free (as in lotus and rose) and are called **apocarpous**. They are termed **syncarpous** when carpels are fused, as in mustard and tomato. After fertilisation, the ovules develop into seeds and the ovary matures into a fruit.

Placentation: The arrangement of ovules within the ovary is known as placentation. The placentation are of different types namely, marginal, axile, parietal, basal, central and free central (Figure 5.16). In **marginal** placentation the placenta forms a ridge along the ventral suture of the ovary and the ovules are borne on this ridge forming two rows, as in pea. When the placenta is axial and the ovules are attached to it in a multilocular ovary, the placentaion is said to be **axile**, as in china rose, tomato and lemon. In **parietal** placentation, the ovules develop on the inner wall of the ovary or on peripheral part. Ovary is one-chambered but it becomes two-chambered due to the formation of the false septum, e.g., mustard and *Argemone*. When the ovules are borne on central axis and septa are absent, as in *Dianthus* and *Primrose* the placentation is

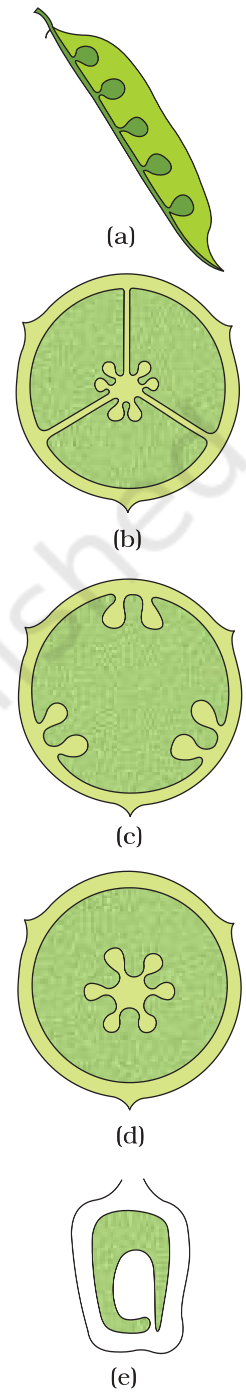


Figure 5.16 Types of placentation : (a) Marginal (b) Axile (c) Parietal (d) Free central (e) Basal

called **free central.** In **basal** placentation, the placenta develops at the base of ovary and a single ovule is attached to it, as in sunflower, marigold.

5.6 The Fruit

The fruit is a characteristic feature of the flowering plants. It is a mature or ripened ovary, developed after fertilisation. If a fruit is formed without fertilisation of the ovary, it is called a **parthenocarpic** fruit.

Generally, the fruit consists of a wall or **pericarp** and seeds. The pericarp may be dry or fleshy. When pericarp is thick and fleshy, it is differentiated into the outer **epicarp,** the middle **mesocarp** and the inner **endocarp**.

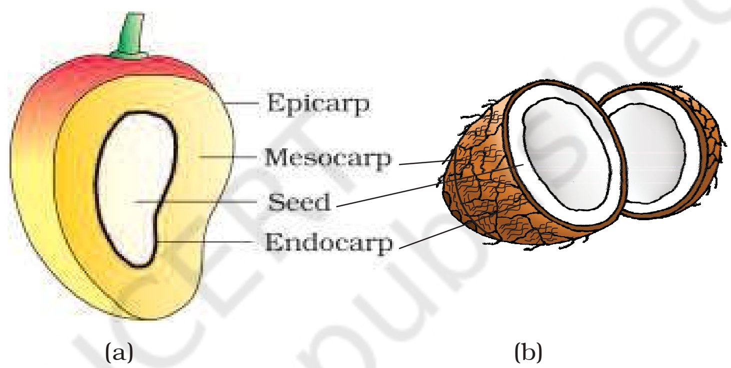


Figure 5.17 Parts of a fruit : (a) Mango (b) Coconut

In mango and coconut, the fruit is known as a drupe (Figure 5.17). They develop from monocarpellary superior ovaries and are one seeded. In mango the pericarp is well differentiated into an outer thin epicarp, a middle fleshy edible mesocarp and an inner stony hard endocarp. In coconut which is also a drupe, the mesocarp is fibrous.

5.7 The Seed

The ovules after fertilisation, develop into seeds. A seed is made up of a seed coat and an embryo. The embryo is made up of a radicle, an embryonal axis and one (as in wheat, maize) or two cotyledons (as in gram and pea).

5.7.1 Structure of a Dicotyledonous Seed

The outermost covering of a seed is the seed coat. The seed coat has two layers, the outer **testa** and the inner **tegmen**. The **hilum** is a scar on the seed coat through which the developing seeds were attached to the fruit. Above the hilum is a small pore called the **micropyle**. Within the seed coat is the embryo, consisting of an embryonal axis and two cotyledons. The cotyledons are often fleshy and full of reserve food materials. At the two ends of the embryonal axis are present the radicle and the plumule (Figure 5.18). In some seeds such as castor the **endosperm** formed as a result of double fertilisation, is a food storing tissue. In plants such as bean, gram and pea, the endosperm is not present in mature seeds and such seeds are called non-endospermous.

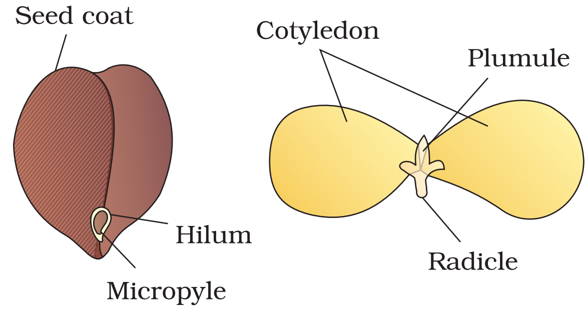


Figure 5.18 Structure of dicotyledonous seed

5.7.2 Structure of Monocotyledonous Seed

Generally, monocotyledonous seeds are endospermic but some as in orchids are non-endospermic. In the seeds of cereals such as maize the seed coat is membranous and generally fused with the fruit wall. The endosperm is bulky and stores food. The outer covering of endosperm separates the embryo by a proteinous layer called **aleurone layer**. The embryo is small and situated in a groove at one end of the endosperm. It consists of one large and shield shaped cotyledon known as **scutellum** and a short axis with a **plumule** and a **radicle**. The plumule and radicle are enclosed in sheaths which are called **coleoptile** and **coleorhiza** respectively (Figure 5.19).

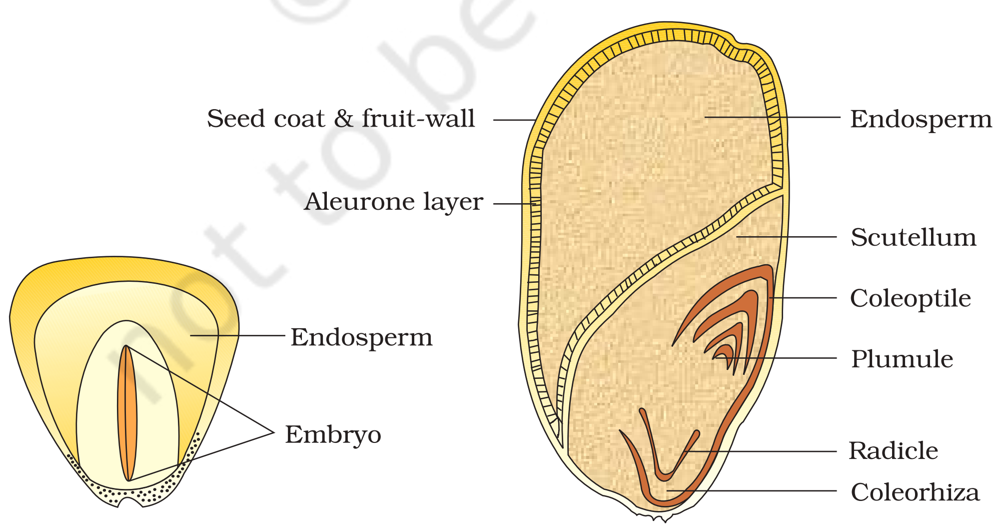
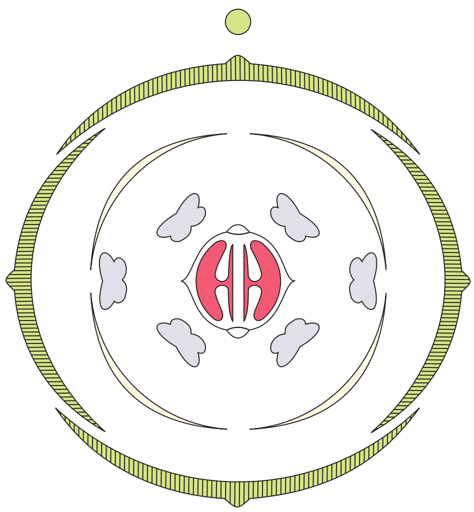


Figure 5.19 Structure of a monocotyledonous seed



$\oplus$ ⚥ $K_{2+2}\,C_4\,A_{2+4}\,\underline{G}_{(2)}$

Figure 5.20 Floral diagram with floral formula

5.8 Semi-Technical Description of a Typical Flowering Plant

Various morphological features are used to describe a flowering plant. The description has to be brief, in a simple and scientific language and presented in a proper sequence. The plant is described beginning with its habit, vegetative characters – roots, stem and leaves and then floral characters inflorescence and flower parts. After describing various parts of plant, a floral diagram and a floral formula are presented. The floral formula is represented by some symbols. In the floral formula, **Br** stands for bracteate **K** stands for calyx , **C** for corolla, **P** for perianth, **A** for androecium and **G** for Gynoecium, $\underline{\mathbf{G}}$ for superior ovary and $\overline{\mathbf{G}}$ for inferior ovary, ♂ for male, ♀ for female, ⚥ for bisexual plants, $\oplus$ for actinomorphic and % for zygomorphic nature of flower. Fusion is indicated by enclosing the figure within bracket and adhesion by a line drawn above the symbols of the floral parts. A floral diagram provides information about the number of parts of a flower, their arrangement and the relation they have with one another (Figure 5.20). The position of the mother axis with respect to the flower is represented by a dot on the top of the floral diagram. Calyx, corolla, androecium and gynoecium are drawn in successive whorls, calyx being the outermost and the gynoecium being in the centre. Floral formula also shows cohesion and adhesion within parts of whorls and between whorls. The floral diagram and floral formula in Figure 5.20 represents the mustard plant (Family: Brassicaceae).

5.9 Description of Some Important Families

5.9.1 Fabaceae

This family was earlier called Papilionoideae, a subfamily of family Leguminosae. It is distributed all over the world (Figure 5.21).

Vegetative Characters

Trees, shrubs, herbs; root with root nodules
Stem: erect or climber
Leaves: alternate, pinnately compound or simple; leaf base, pulvinate; stipulate; venation reticulate.

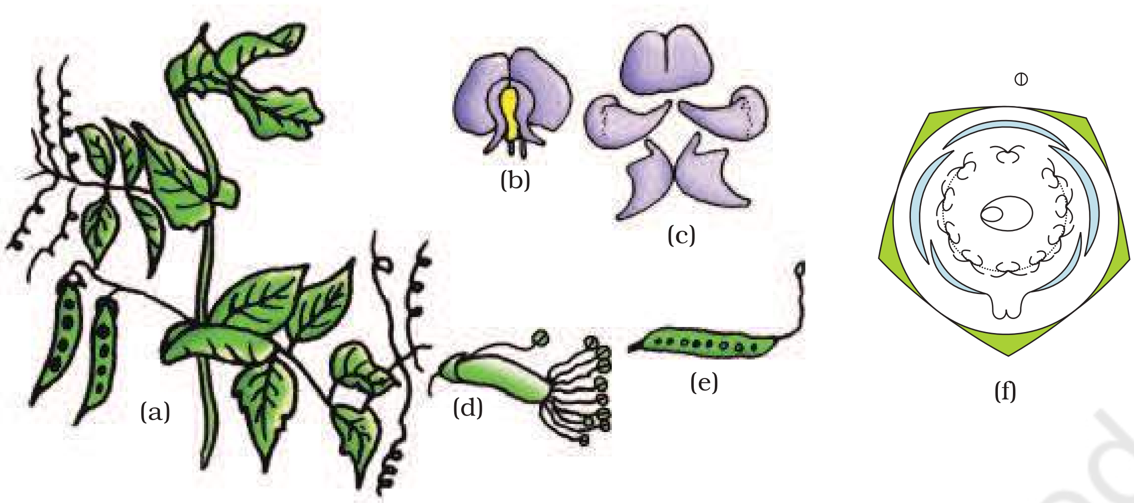


Figure 5.21 *Pisum sativum* (pea) plant : (a) Flowering twig (b) Flower (c) Petals (d) Reproductive parts (e) L.S.carpel (f) Floral diagram

Floral characters

Inflorescence: racemose
Flower: bisexual, zygomorphic
Calyx: sepals five, gamosepalous; valvate/imbricate aestivation
Corolla: petals five, polypetalous, papilionaceous, consisting of a posterior standard, two lateral wings, two anterior ones forming a keel (enclosing stamens and pistil), vexillary aestivation
Androecium: ten, diadelphous, anther dithecous
Gynoecium: ovary superior, mono carpellary, unilocular with many ovules, style single
Fruit: legume; seed: one to many, non-endospermic
Floral Formula: % ⚥ $K_{(5)}$ $C_{1+2+(2)}$ $A_{(9)+1}$ $\underline{G}_1$

Economic importance

Many plants belonging to the family are sources of pulses (gram, *arhar, sem, moong*, soyabean; edible oil (soyabean, groundnut); dye (Indigofera); fibres (sunhemp); fodder *(Sesbania, Trifolium)*, ornamentals (lupin, sweet pea); medicine (*muliathi*).

5.9.2 Solanaceae

It is a large family, commonly called as the 'potato family'. It is widely distributed in tropics, subtropics and even temperate zones (Figure 5.22).

Vegetative Characters

Plants mostly herbs, shrubs and rarely small trees
Stem: herbaceous rarely woody, aerial; erect, cylindrical, branched, solid

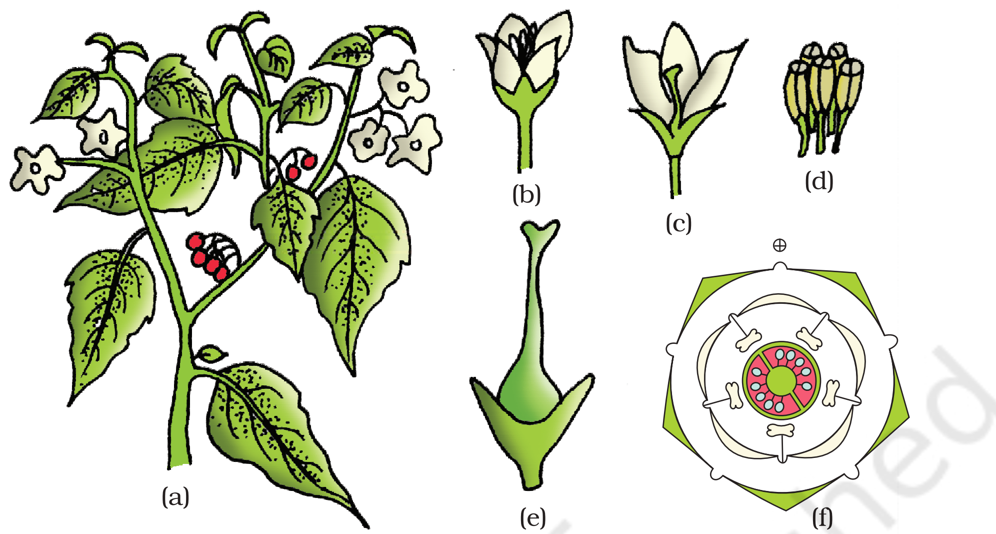


Figure 5.22 *Solanum nigrum* (makoi) plant : (a) Flowering twig (b) Flower (c) L.S. of flower (d) Stamens (e) Carpel (f) Floral diagram

or hollow, hairy or glabrous, underground stem in potato (*Solanum tuberosum*)

Leaves: alternate, simple, rarely pinnately compound, exstipulate; venation reticulate

Floral Characters

Inflorescence : Solitary, axillary or cymose as in *Solanum*
Flower: bisexual, actinomorphic
Calyx: sepals five, united, persistent, valvate aestivation
Corolla: petals five, united; valvate aestivation
Androecium: stamens five, epipetalous
Gynoecium: bicarpellary, syncarpous; ovary superior, bilocular, placenta swollen with many ovules
Fruits: berry or capsule
Seeds: many, endospermous

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

Economic Importance

Many plants belonging to this family are source of food (tomato, brinjal, potato), spice (chilli); medicine (belladonna, *ashwagandha*); fumigatory (tobacco); ornamentals (petunia).

5.9.3 Liliaceae

Commonly called the 'Lily family' is a characteristic representative of monocotyledonous plants. It is distributed world wide (Figure 5.23).

Vegetative characters: Perennial herbs with underground bulbs/corms/rhizomes

Leaves mostly basal, alternate, linear, exstipulate with parallel venation

Floral characters

Inflorescence: solitary / cymose; often umbellate clusters

Flower: bisexual; actinomorphic
Perianth tepal six (3+3), often united into tube; valvate aestivation
Androecium: stamen six, 3+3, epitepalous
Gynoecium: tricarpellary, syncarpous, ovary superior, trilocular with many ovules; axile placentation
Fruit: capsule, rarely berry
Seed: endospermous
Floral Formula: Br $\oplus$ ⚥ $\overbrace{P_{(3+3)}A_{3+3}}$ $\underline{G}_{(3)}$
Economic Importance

Many plants belonging to this family are good ornamentals (tulip, *Gloriosa*), source of medicine (*Aloe*), vegetables (*Asparagus*), and colchicine (*Colchicum autumnale*).

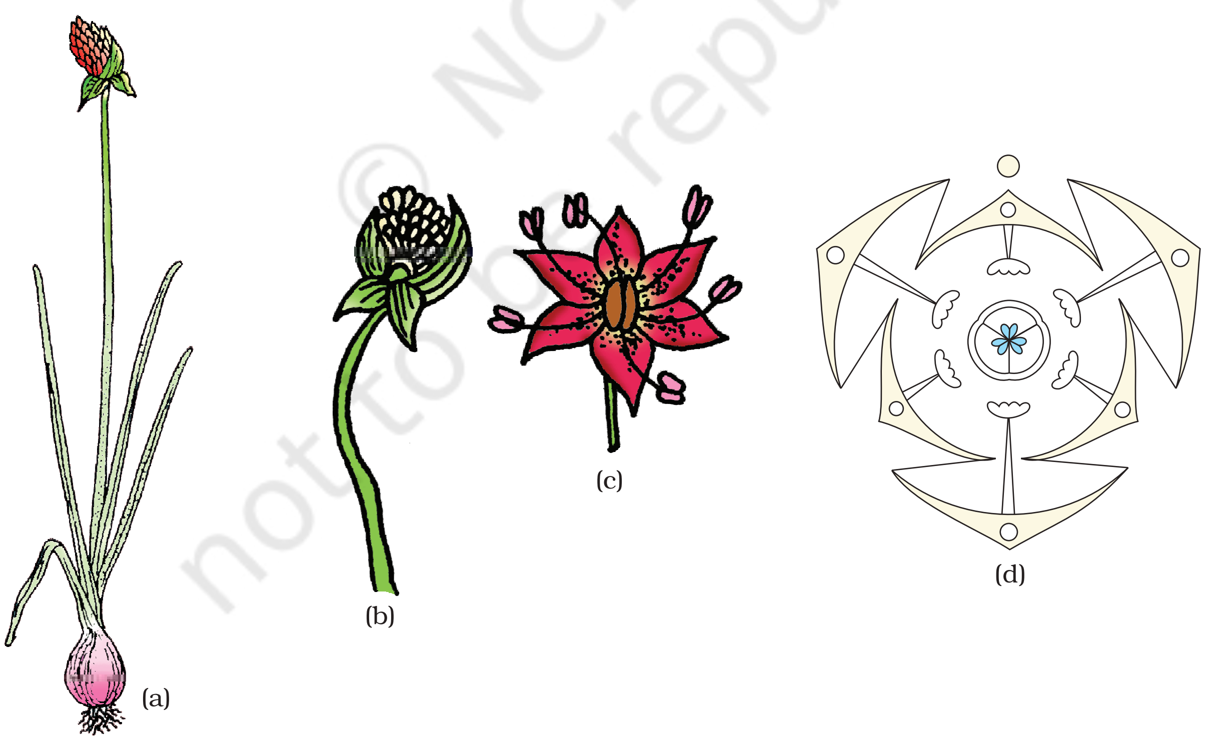


Figure 5.23 *Allium cepa* (onion) plant : (a) Plant (b) Inflorescence (c) Flower (d) Floral diagram

SUMMARY

Flowering plants exhibit enormous variation in shape, size, structure, mode of nutrition, life span, habit and habitat. They have well developed root and shoot systems. Root system is either tap root or fibrous. Generally, dicotyledonous plants have tap roots while monocotyledonous plants have fibrous roots. The roots in some plants get modified for storage of food, mechanical support and respiration. The shoot system is differentiated into stem, leaves, flowers and fruits. The morphological features of stems like the presence of nodes and internodes, multicellular hair and positively phototropic nature help to differentiate the stems from roots. Stems also get modified to perform diverse functions such as storage of food, vegetative propagation and protection under different conditions. Leaf is a lateral outgrowth of stem developed exogeneously at the node. These are green in colour to perform the function of photosynthesis. Leaves exhibit marked variations in their shape, size, margin, apex and extent of incisions of leaf blade (lamina). Like other parts of plants, the leaves also get modified into other structures such as tendrils, spines for climbing and protection respectively.

The flower is a modified shoot, meant for sexual reproduction. The flowers are arranged in different types of inflorescences. They exhibit enormous variation in structure, symmetry, position of ovary in relation to other parts, arrangement of petals, sepals, ovules etc. After fertilisation, the ovary is converted into fruits and ovules into seeds. Seeds either may be monocotyledonous or dicotyledonous. They vary in shape, size and period of viability. The floral characteristics form the basis of classification and identification of flowering plants. This can be illustrated through semi-technical descriptions of families. Hence, a flowering plant is described in a definite sequence by using scientific terms. The floral features are represented in the summarised form as floral diagrams and floral formula.

EXERCISES

1. What is meant by modification of root? What type of modification of root is found in the:

   (a) Banyan tree (b) Turnip (c) Mangrove trees

2. Justify the following statements on the basis of external features:

   (i) Underground parts of a plant are not always roots.
   (ii) Flower is a modified shoot.

3. How is a pinnately compound leaf different from a palmately compound leaf?

4. Explain with suitable examples the different types of phyllotaxy.

5. Define the following terms:
   (a) aestivation (b) placentation (c) actinomorphic
   (d) zygomorphic (e) superior ovary (f) perigynous flower
   (g) epipetalous stamen
6. Differentiate between
   (a) Racemose and cymose inflorescence
   (b) Fibrous root and adventitious root
   (c) Apocarpous and syncarpous ovary
7. Draw the labelled diagram of the following:
   (i) gram seed (ii) V.S. of maize seed
8. Describe modifications of stem with suitable examples.
9. Take one flower each of the families Fabaceae and Solanaceae and write its semi-technical description. Also draw their floral diagram after studying them.
10. Describe the various types of placentations found in flowering plants.
11. What is a flower? Describe the parts of a typical angiosperm flower.
12. How do the various leaf modifications help plants?
13. Define the term inflorescence. Explain the basis for the different types inflorescence in flowering plants.
14. Write the floral formula of a actinomorphic, bisexual, hypogynous flower with five united sepals, five free petals, five free stamens and two united carples with superior ovary and axile placentation.
15. Describe the arrangement of floral members in relation to their insertion on thalamus.

CHAPTER 6

ANATOMY OF FLOWERING PLANTS

You can very easily see the structural similarities and variations in the external morphology of the larger living organism, both plants and animals. Similarly, if we were to study the internal structure, one also finds several similarities as well as differences. This chapter introduces you to the internal structure and functional organisation of higher plants. Study of internal structure of plants is called anatomy. Plants have cells as the basic unit, cells are organised into tissues and in turn the tissues are organised into organs. Different organs in a plant show differences in their internal structure. Within angiosperms, the monocots and dicots are also seen to be anatomically different. Internal structures also show adaptations to diverse environments.

6.1 THE TISSUES

A tissue is a group of cells having a common origin and usually performing a common function. A plant is made up of different kinds of tissues. Tissues are classified into two main groups, namely, meristematic and permanent tissues based on whether the cells being formed are capable of dividing or not.

6.1.1 Meristematic Tissues

Growth in plants is largely restricted to specialised regions of active cell division called **meristems** (*Gk. meristos*: divided). Plants have different kinds of meristems. The meristems which occur at the tips of roots and shoots and produce primary tissues are called **apical meristems** (Figure 6.1).

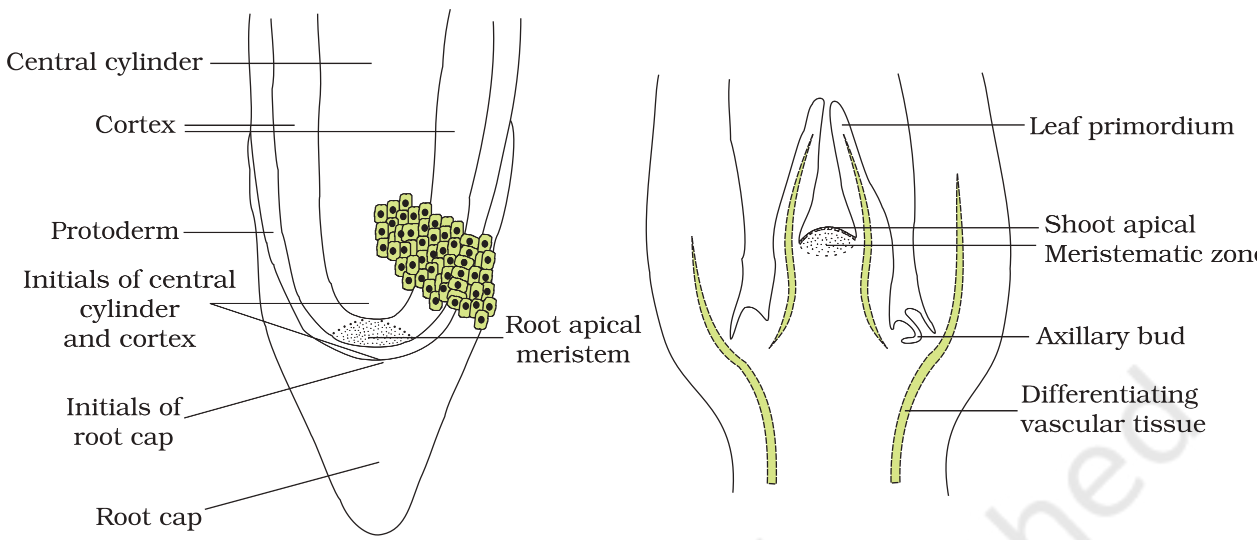


Figure 6.1 Apical meristem: (a) Root (b) Shoot

Root apical meristem occupies the tip of a root while the shoot apical meristem occupies the distant most region of the stem axis. During the formation of leaves and elongation of stem, some cells 'left behind' from shoot apical meristem, constitute the **axillary bud**. Such buds are present in the axils of leaves and are capable of forming a branch or a flower. The meristem which occurs between mature tissues is known as **intercalary meristem**. They occur in grasses and regenerate parts removed by the grazing herbivores. 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.

The meristem that occurs in the mature regions of roots and shoots of many plants, particularly those that produce woody axis and appear later than primary meristem is called the **secondary** or **lateral meristem.** They are cylindrical meristems. Fascicular vascular cambium, interfascicular cambium and cork-cambium are examples of lateral meristems. These are responsible for producing the secondary tissues.

Following divisions of cells in both primary and as well as secondary meristems, the newly formed cells become structurally and functionally specialised and lose the ability to divide. Such cells are termed **permanent** or **mature cells** and constitute the permanent tissues. During the formation of the primary plant body, specific regions of the apical meristem produce dermal tissues, ground tissues and vascular tissues.

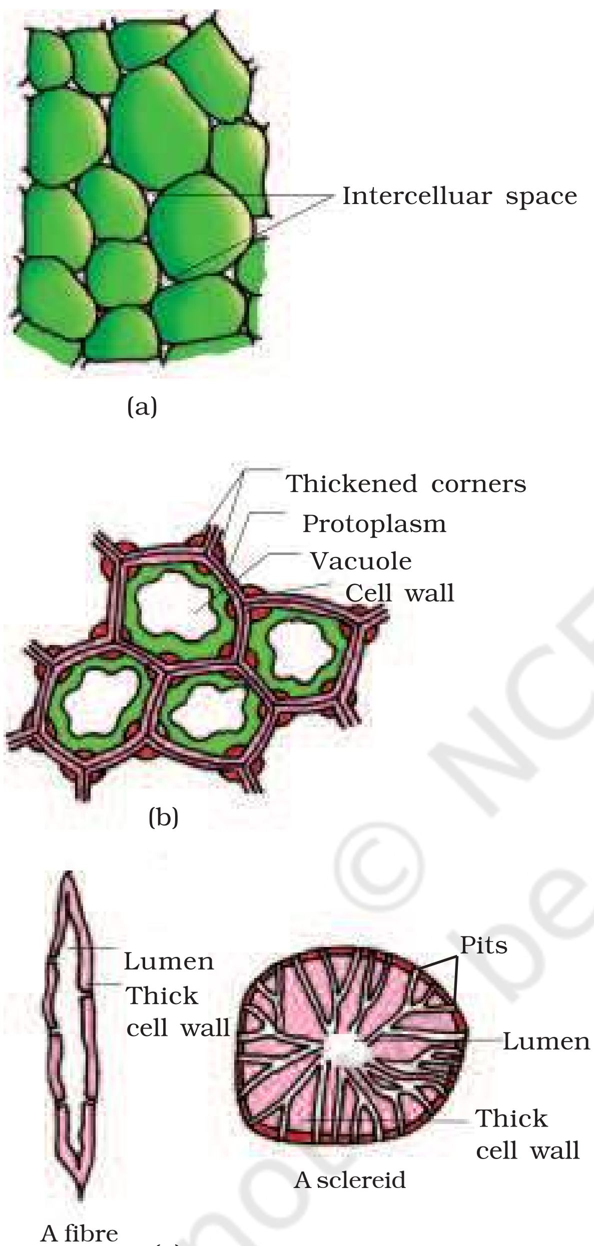


Figure 6.2 Simple tissues :
(a) Parenchyma
(b) Collenchyma
(c) Sclerenchyma

6.1.2 Permanent Tissues

The cells of the permanent tissues do not generally divide further. Permanent tissues having all cells similar in structure and function are called **simple tissues**. Permanent tissues having many different types of cells are called **complex tissues**.

6.1.2.1 Simple Tissues

A simple tissue is made of only one type of cells. The various simple tissues in plants are parenchyma, collenchyma and sclerenchyma (Figure 6.2). **Parenchyma** forms the major component within organs. The cells of the parenchyma are generally isodiametric. They may be spherical, oval, round, polygonal or elongated in shape. Their walls are thin and made up of cellulose. They may either be closely packed or have small intercellular spaces. The parenchyma performs various functions like photosynthesis, storage, secretion.

The **collenchyma** occurs in layers below the epidermis in dicotyledonous plants. It is found either as a homogeneous layer or in patches. It consists of cells which are much thickened at the corners due to a deposition of cellulose, hemicellulose and pectin. Collenchymatous cells may be oval, spherical or polygonal and often contain chloroplasts. These cells assimilate food when they contain chloroplasts. Intercellular spaces are absent. They provide mechanical support to the growing parts of the plant such as young stem and petiole of a leaf.

Sclerenchyma consists of long, narrow cells with thick and lignified cell walls having a few or numerous pits. They are usually dead and without protoplasts. On the basis of variation in form, structure, origin and development, sclerenchyma may be either fibres or sclereids. The **fibres** are thick-walled, elongated and pointed cells, generally occuring in groups, in various parts of the plant. The **sclereids** are spherical, oval or cylindrical, highly thickened dead cells with very narrow cavities (lumen). These are commonly found in the fruit walls of nuts; pulp of fruits like guava, pear and sapota; seed coats of legumes and leaves of tea. Sclerenchyma provides mechanical support to organs.

6.1.2.2 Complex Tissues

The complex tissues are made of more than one type of cells and these work together as a unit. Xylem and phloem constitute the complex tissues in plants (Figure 6.3).

Xylem functions as a conducting tissue for water and minerals from roots to the stem and leaves. It also provides mechanical strength to the plant parts. It is composed of four different kinds of elements, namely, tracheids, vessels, xylem fibres and xylem parenchyma. Gymnosperms lack vessels in their xylem. **Tracheids** are elongated or tube like cells with thick and lignified walls and tapering ends. These are dead and are without protoplasm. The inner layers of the cell walls have thickenings which vary in form. In flowering plants, tracheids and vessels are the main water transporting elements. **Vessel** is a long cylindrical tube-like structure made up of many cells called vessel members, each with lignified walls and a large central cavity. The vessel cells are also devoid of protoplasm. Vessel members are interconnected through perforations in their common walls. The presence of vessels is a characteristic feature of angiosperms. **Xylem fibres** have highly thickened walls and obliterated central lumens. These may either be septate or aseptate. **Xylem parenchyma** cells are living and thin-walled, and their cell walls are made up of cellulose. They store food materials in the form of starch or fat, and other substances like tannins. The radial conduction of water takes place by the ray parenchymatous cells.

Primary xylem is of two types – protoxylem and metaxylem. The first formed primary xylem elements are called **protoxylem** and the later formed primary xylem is called **metaxylem.** In stems, the protoxylem lies towards the centre (pith) and the metaxylem lies towards the periphery of the organ. This type of primary xylem is called **endarch**. In roots, the protoxylem lies towards periphery and metaxylem lies towards the centre. Such arrangement of primary xylem is called **exarch.**

Phloem transports food materials, usually from leaves to other parts of the plant. Phloem in angiosperms is composed of sieve tube elements, companion cells, phloem parenchyma

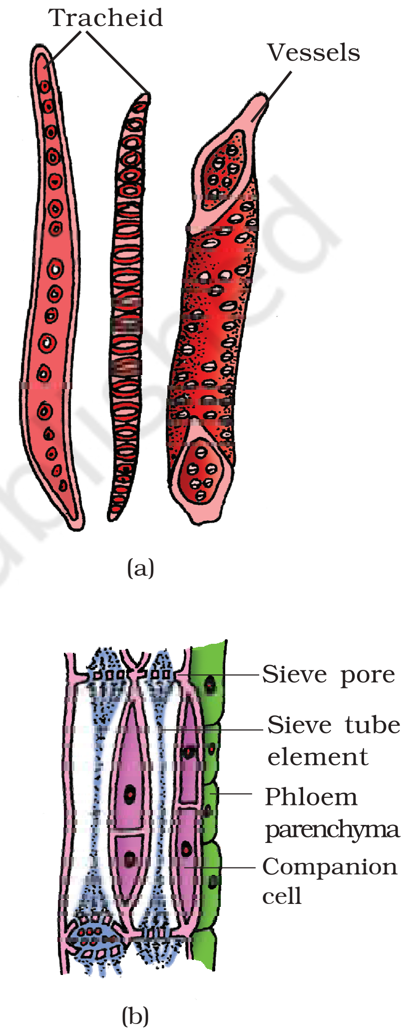


Figure 6.3 (a) Xylem
(b) Phloem

and phloem fibres. Gymnosperms have albuminous cells and sieve cells. They lack sieve tubes and companion cells. **Sieve tube elements** are also long, tube-like structures, arranged longitudinally and are associated with the companion cells. Their end walls are perforated in a sieve-like manner to form the sieve plates. A mature sieve element possesses a peripheral cytoplasm and a large vacuole but lacks a nucleus. The functions of sieve tubes are controlled by the nucleus of companion cells. The **companion cells** are specialised parenchymatous cells, which are closely associated with sieve tube elements. The sieve tube elements and companion cells are connected by pit fields present between their common longitudinal walls. The companion cells help in maintaining the pressure gradient in the sieve tubes. **Phloem parenchyma** is made up of elongated, tapering cylindrical cells which have dense cytoplasm and nucleus. The cell wall is composed of cellulose and has pits through which plasmodesmatal connections exist between the cells. The phloem parenchyma stores food material and other substances like resins, latex and mucilage. Phloem parenchyma is absent in most of the monocotyledons. **Phloem fibres** (bast fibres) are made up of sclerenchymatous cells. These are generally absent in the primary phloem but are found in the secondary phloem. These are much elongated, unbranched and have pointed, needle like apices. The cell wall of phloem fibres is quite thick. At maturity, these fibres lose their protoplasm and become dead. Phloem fibres of jute, flax and hemp are used commercially. 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**.

6.2 THE TISSUE SYSTEM

We were discussing types of tissues based on the types of cells present. Let us now consider how tissues vary depending on their location in the plant body. Their structure and function would also be dependent on location. On the basis of their structure and location, there are three types of tissue systems. These are the epidermal tissue system, the ground or fundamental tissue system and the vascular or conducting tissue system.

6.2.1 Epidermal Tissue System

The epidermal tissue system forms the outer-most covering of the whole plant body and comprises epidermal cells, stomata and the epidermal appendages – the trichomes and hairs. The **epidermis** is the outermost layer of the primary plant body. It is made up of elongated, compactly arranged cells, which form a continuous layer. Epidermis is usually single-layered. Epidermal cells are parenchymatous with a small amount of cytoplasm lining the cell wall and a large vacuole. The outside of the epidermis is often covered with a waxy thick layer called the **cuticle** which prevents the loss of water. Cuticle is absent in roots. **Stomata** are structures present in the epidermis of leaves. Stomata regulate the process of transpiration and gaseous exchange. Each stoma is composed of two bean-shaped cells known as **guard cells** which enclose stomatal pore. In grasses, the guard cells are dumb-bell shaped. The outer walls of guard cells (away from the stomatal pore) are thin and the inner walls (towards the stomatal pore) are highly thickened. The guard cells possess chloroplasts and regulate the opening and closing of stomata. Sometimes, a few epidermal cells, in the vicinity of the guard cells become specialised in their shape and size and are known as **subsidiary cells**. The stomatal aperture, guard cells and the surrounding subsidiary cells are together called **stomatal apparatus** (Figure 6.4).

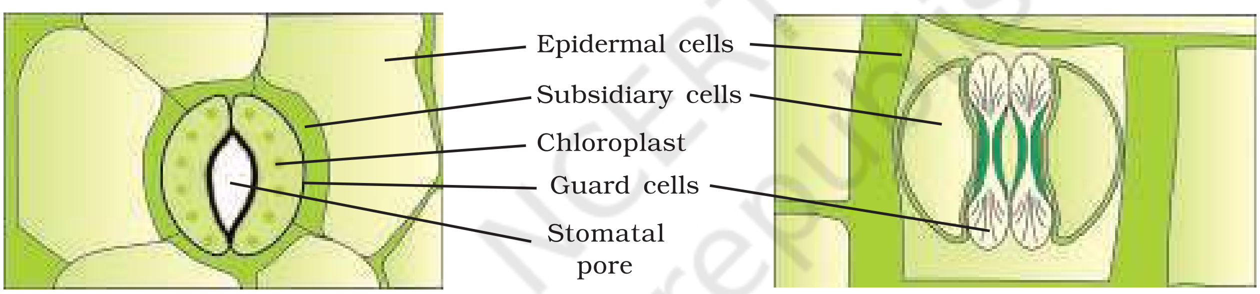


Figure 6.4 Diagrammatic representation: (a) stomata with bean-shaped guard cells (b) stomata with dumb-bell shaped guard cell

The cells of epidermis bear a number of hairs. The **root hairs** are unicellular elongations of the epidermal cells and help absorb water and minerals from the soil. On the stem the epidermal hairs are called **trichomes**. The trichomes in the shoot system are usually multicellular. They may be branched or unbranched and soft or stiff. They may even be secretory. The trichomes help in preventing water loss due to transpiration.

6.2.2 The Ground Tissue System

All tissues except epidermis and vascular bundles constitute the **ground tissue**. It consists of simple tissues such as parenchyma, collenchyma and sclerenchyma. Parenchymatous cells are usually present in cortex, pericycle, pith and medullary rays, in the primary stems and roots. In leaves, the ground tissue consists of thin-walled chloroplast containing cells and is called **mesophyll**.

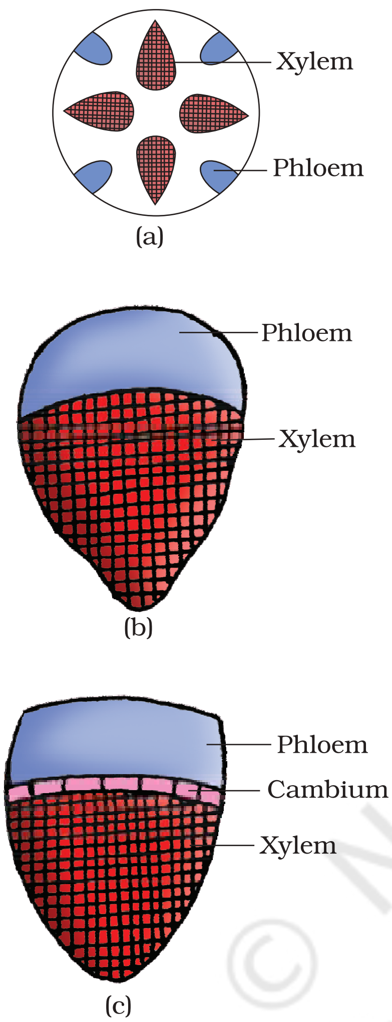


Figure 6.5 Various types of vascular bundles : (a) radial (b) conjoint closed (c) conjoint open

6.2.3 The Vascular Tissue System

The vascular system consists of complex tissues, the phloem and the xylem.The xylem and phloem together constitute vascular bundles (Figure 6.5). In dicotyledonous stems, **cambium** is present between phloem and xylem. Such vascular bundles because of the presence of cambium possess the ability to form secondary xylem and phloem tissues, and hence are called **open vascular bundles**. In the monocotyledons, the vascular bundles have no cambium present in them. Hence, since they do not form secondary tissues they are referred to as **closed**. When xylem and phloem within a vascular bundle are arranged in an alternate manner on different radii, the arrangement is called **radial** such as in roots. In **conjoint** type of vascular bundles, the xylem and phloem are situated at the same radius of vascular bundles. Such vascular bundles are common in stems and leaves. The conjoint vascular bundles usually have the phloem located only on the outer side of xylem.

6.3 Anatomy of Dicotyledonous and Monocotyledonous Plants

For a better understanding of tissue organisation of roots, stems and leaves, it is convenient to study the transverse sections of the mature zones of these organs.

6.3.1 Dicotyledonous Root

Look at Figure 6.6 (a), it shows the transverse section of the sunflower root. The internal tissue organisation is as follows:

The outermost layer is **epidermis.** Many of the epidermal cells protrude in the form of unicellular root hairs. The **cortex** consists of several layers of thin-walled parenchyma cells with intercellular spaces. The innermost layer of the cortex is called **endodermis.** It comprises a single layer of barrel-shaped cells without any intercellular spaces. The tangential as well as radial walls of the endodermal cells have a deposition of water-impermeable, waxy material-suberin-in the form of **casparian strips**. Next to endodermis lies a few layers of thick-walled parenchyomatous cells referred to as **pericycle**. Initiation of lateral roots and vascular cambium during the secondary growth takes place in these cells. The pith is small or inconspicuous. The parenchymatous cells which lie between the xylem and the phloem are called **conjuctive tissue**. There are usually two to four xylem and phloem patches. Later, a cambium ring develops between the xylem and phloem. All tissues on the innerside of the endodermis such as pericycle, vascular bundles and pith constitute the **stele**.

6.3.2 Monocotyledonous Root

The anatomy of the monocot root is similar to the dicot root in many respects (Figure 6.6 b). It has epidermis, cortex, endodermis, pericycle, vascular bundles and pith. As compared to the dicot root which have fewer xylem bundles, there are usually more than six (polyarch) xylem bundles in the monocot root. Pith is large and well developed. Monocotyledonous roots do not undergo any secondary growth.

6.3.3 Dicotyledonous Stem

The transverse section of a typical young dicotyledonous stem shows that the **epidermis** is the outermost protective layer of the stem

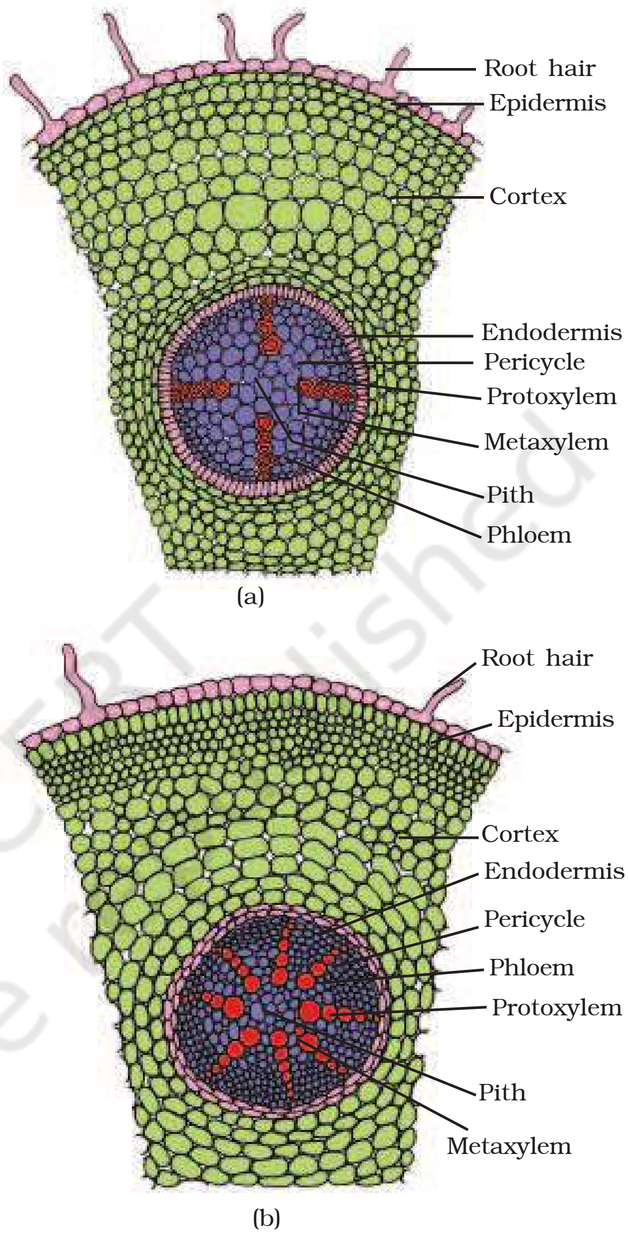


Figure 6.6 T.S. : (a) Dicot root (Primary) (b) Monocot root

(Figure 6.7 a). Covered with a thin layer of cuticle, it may bear trichomes and a few stomata. The cells arranged in multiple layers between epidermis and pericycle constitute the cortex. It consists of three sub-zones. The outer **hypodermis**, consists of a few layers of collenchymatous cells just below the epidermis, which provide mechanical strength to the young stem. **Cortical layers** below hypodermis consist of rounded thin walled parenchymatous cells with conspicuous intercellular spaces. The innermost layer of the cortex is called the **endodermis.** The cells of the endodermis are rich in starch grains and the layer is also referred to as the **starch sheath. Pericycle** is

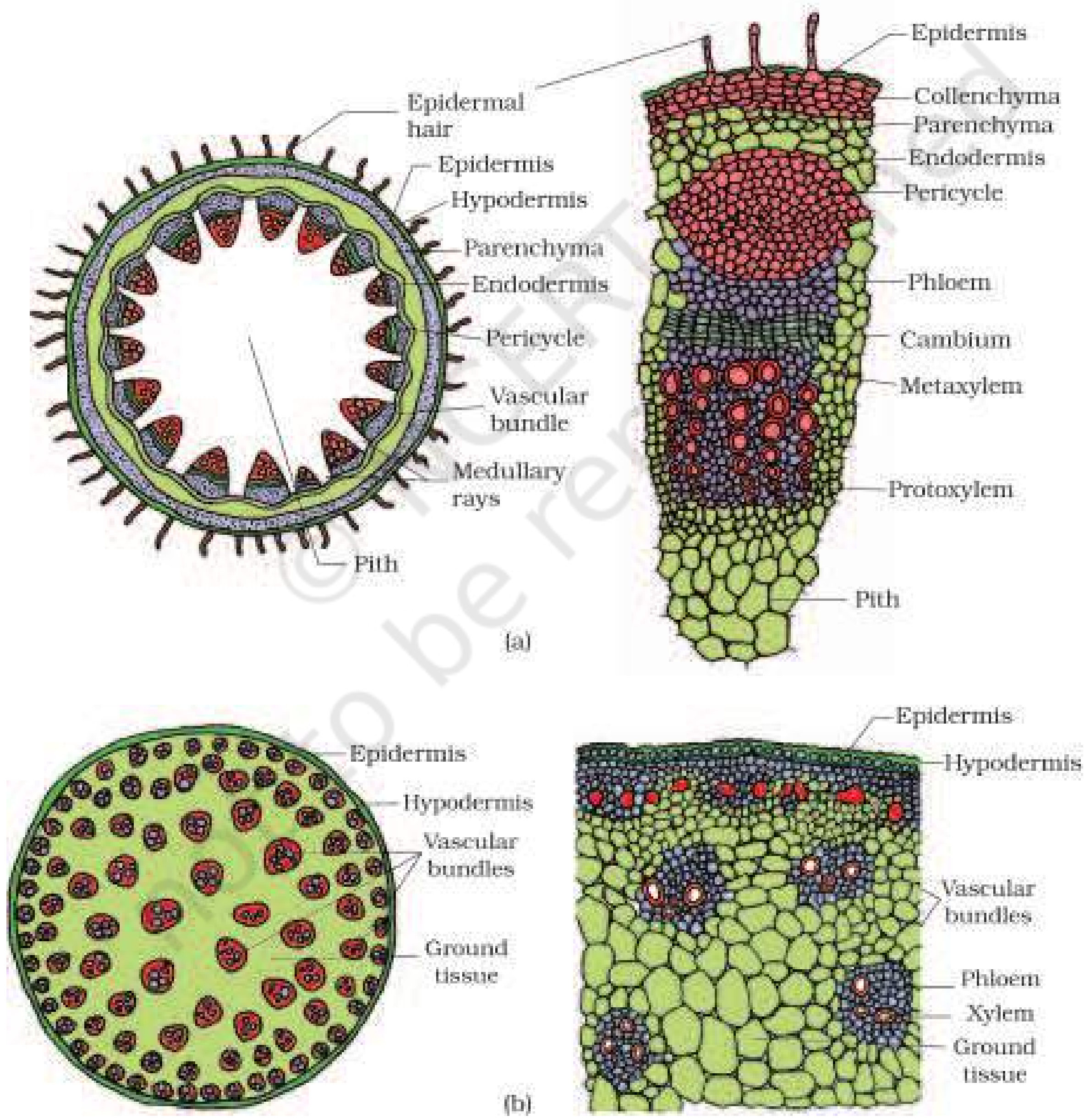


Figure 6.7 T.S. of stem : (a) Dicot (b) Monocot

present on the inner side of the endodermis and above the phloem in the form of semi-lunar patches of sclerenchyma. In between the vascular bundles there are a few layers of radially placed parenchymatous cells, which constitute medullary rays. A large number of **vascular bundles** are arranged in a ring ; the 'ring' arrangement of vascular bundles is a characteristic of dicot stem. Each vascular bundle is conjoint, open, and with endarch protoxylem. A large number of rounded, parenchymatous cells with large intercellular spaces which occupy the central portion of the stem constitute the **pith**.

6.3.4 Monocotyledonous Stem

The monocot stem has a sclerenchymatous hypodermis, a large number of scattered vascular bundles, each surrounded by a sclerenchymatous bundle sheath, and a large, conspicuous parenchymatous ground tissue (Figure 6.7b). Vascular bundles are conjoint and closed. Peripheral vascular bundles are generally smaller than the centrally located ones. The phloem parenchyma is absent, and water-containing cavities are present within the vascular bundles.

6.3.5 Dorsiventral (Dicotyledonous) Leaf

The vertical section of a dorsiventral leaf through the lamina shows three main parts, namely, epidermis, mesophyll and vascular system. The **epidermis** which covers both the upper surface (adaxial epidermis) and lower surface (abaxial epidermis) of the leaf has a conspicuous cuticle. The abaxial epidermis generally bears more stomata than the adaxial epidermis. The latter may even lack stomata. The tissue between the upper and the lower epidermis is called the **mesophyll**. Mesophyll, which possesses chloroplasts and carry out photosynthesis, is made up of parenchyma. It has two types of cells – the **palisade parenchyma** and the **spongy parenchyma**. The adaxially placed palisade parenchyma is made up of elongated cells, which are arranged vertically and parallel to each other. The oval or round and loosely arranged spongy parenchyma is situated below the palisade cells and extends to the lower epidermis. There are numerous large spaces and air cavities between these cells. **Vascular system** includes vascular bundles, which can be seen in the veins and the midrib. The size of the vascular bundles are dependent on the size of the veins. The veins vary in thickness in the reticulate venation of the dicot leaves. The vascular bundles are surrounded by a layer of thick walled **bundle sheath cells**. Look at Figure 6.8 (a) and find the position of xylem in the vascular bundle.

6.3.6 Isobilateral (Monocotyledonous) Leaf

The anatomy of isobilateral leaf is similar to that of the dorsiventral leaf in many ways. It shows the following characteristic differences. In an

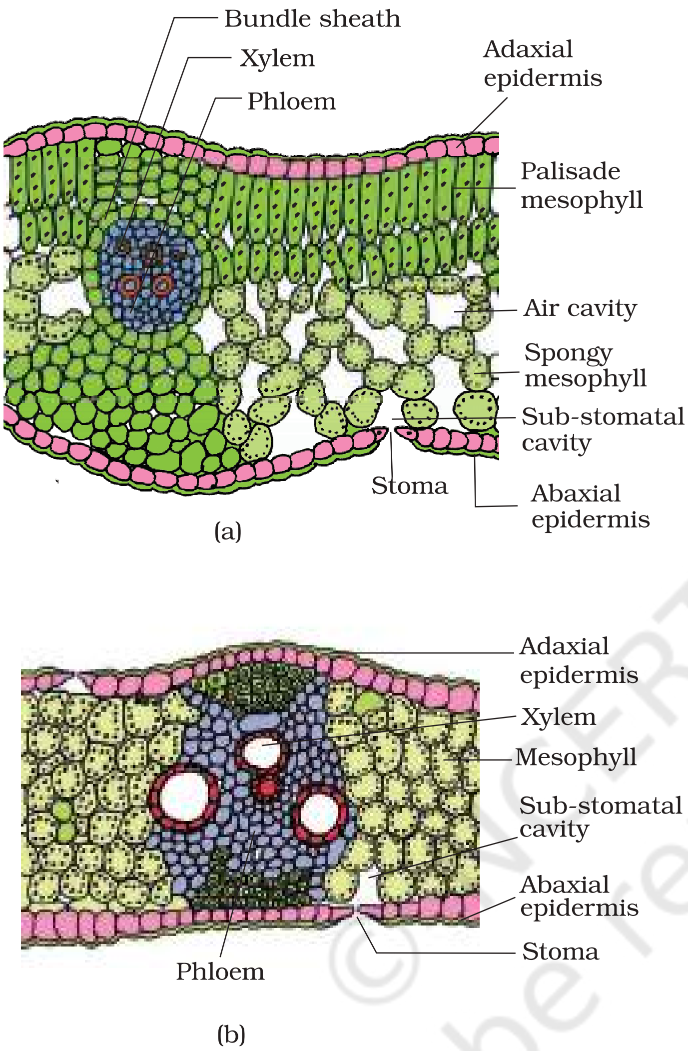


Figure 6.8 T.S. of leaf : (a) Dicot (b) Monocot

isobilateral leaf, the stomata are present on both the surfaces of the epidermis; and the mesophyll is not differentiated into palisade and spongy parenchyma (Figure 6.8 b).

In grasses, certain adaxial epidermal cells along the veins modify themselves into large, empty, colourless cells. These are called **bulliform cells.** When the bulliform cells in the leaves have absorbed water and are turgid, the leaf surface is exposed. When they are flaccid due to water stress, they make the leaves curl inwards to minimise water loss.

The parallel venation in monocot leaves is reflected in the near similar sizes of vascular bundles (except in main veins) as seen in vertical sections of the leaves.

6.4 SECONDARY GROWTH

The growth of the roots and stems in length with the help of apical meristem is called the primary growth. Apart from primary growth most dicotyledonous plants exhibit an increase in girth. This increase is called the **secondary growth**. The tissues involved in secondary growth are the two **lateral meristems: vascular cambium** and **cork cambium**.

6.4.1 Vascular Cambium

The meristematic layer that is responsible for cutting off vascular tissues – xylem and pholem – is called vascular cambium. In the young stem it is present in patches as a single layer between the xylem and phloem. Later it forms a complete ring.

6.4.1.1 Formation of cambial ring

In dicot stems, the cells of cambium present between primary xylem and primary phloem is the **intrafascicular cambium**.

The cells of medullary rays, adjoining these intrafascicular cambium become meristematic and form the **interfascicular cambium**. Thus, a continuous ring of cambium is formed.

6.4.1.2 Activity of the cambial ring

The cambial ring becomes active and begins to cut off new cells, both towards the inner and the outer sides. The cells cut off towards pith, mature into **secondary xylem** and the cells cut off towards periphery mature into **secondary phloem**. The cambium is generally more active on the inner side than on the outer. As a result, the amount of secondary xylem produced is more than secondary phloem and soon forms a compact mass. The primary and secondary phloems get gradually crushed due to the continued formation and accumulation of secondary xylem. The primary xylem however remains more or less intact, in or around the centre. At some places, the cambium forms a narrow band of parenchyma, which passes through the secondary xylem and the secondary phloem in the radial directions. These are the **secondary medullary rays** (Figure 6.9).

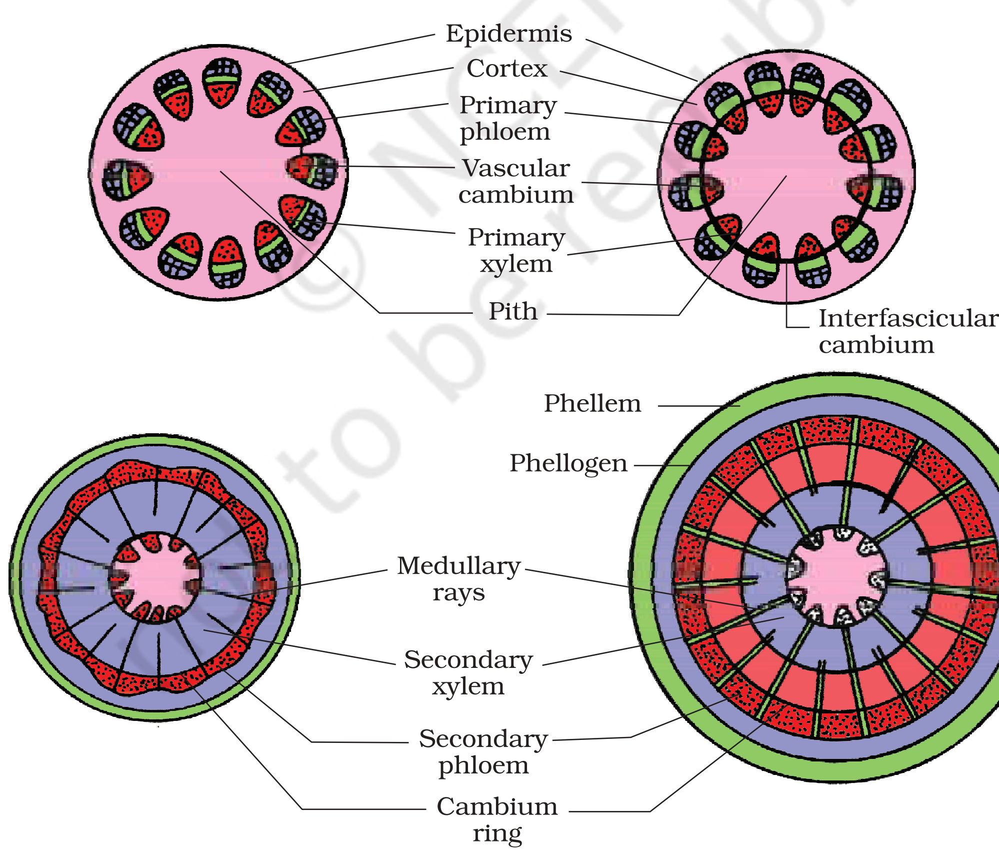


Figure 6.9 Secondary growth in a dicot stem (diagrammatic) – stages in transverse views

6.4.1.3 Spring wood and autumn wood

The activity of cambium is under the control of many physiological and environmental factors. In temperate regions, the climatic conditions are not uniform through the year. In the spring season, cambium is very active and produces a large number of xylary elements having vessels with wider cavities. The wood formed during this season is called **spring wood** or **early wood**. In winter, the cambium is less active and forms fewer xylary elements that have narrow vessels, and this wood is called **autumn wood** or **late wood**.

The spring wood is lighter in colour and has a lower density whereas the autumn wood is darker and has a higher density. The two kinds of woods that appear as alternate concentric rings, constitute an **annual ring.** Annual rings seen in a cut stem give an estimate of the age of the tree.

6.4.1.4 Heartwood and sapwood

In old trees, the greater part of secondary xylem is dark brown due to deposition of organic compounds like tannins, resins, oils, gums, aromatic substances and essential oils in the central or innermost layers of the stem. These substances make it hard, durable and resistant to the attacks of micro-organisms and insects. This region comprises dead elements with highly lignified walls and is called **heartwood.** The heartwood does not conduct water but it gives mechanical support to the stem. The peripheral region of the secondary xylem, is lighter in colour and is known as the **sapwood.** It is involved in the conduction of water and minerals from root to leaf.

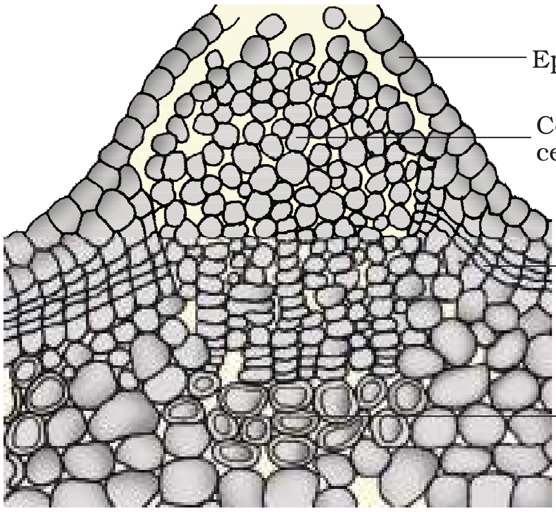
6.4.2 Cork Cambium

As the stem continues to increase in girth due to the activity of vascular cambium, the outer cortical and epidermis layers get broken and need to be replaced to provide new protective cell layers. Hence, sooner or later, another meristematic tissue called **cork cambium** or **phellogen** develops, usually in the cortex region. Phellogen is a couple of layers thick. It is made of narrow, thin-walled and nearly rectangular cells. Phellogen cuts off cells on both sides. The outer cells differentiate into **cork** or **phellem** while the inner cells differentiate into **secondary cortex** or **phelloderm.** The cork is impervious to water due to suberin deposition in the cell wall. The cells of secondary cortex are parenchymatous. Phellogen, phellem, and phelloderm are collectively known as **periderm**. Due to activity of the cork cambium, pressure builds up on the remaining layers peripheral to phellogen and ultimately these layers die and slough off. **Bark** is a non-technical term that refers to all tissues exterior to the vascular cambium, therefore including secondary phloem. Bark refers to a number of tissue types, viz., periderm and secondary phloem. Bark that is formed early in the season is called **early** or **soft** bark. Towards the end of the season, **late** or **hard** bark is formed. *Name the various kinds of cell layers which constitute the bark.*

At certain regions, the phellogen cuts off closely arranged parenchymatous cells on the outer side instead of cork cells. These parenchymatous cells soon rupture the epidermis, forming a lens-shaped openings called lenticels. **Lenticels** permit the exchange of gases between the outer atmosphere and the internal tissue of the stem. These occur in most woody trees (Figure 6.10).

6.4.3 Secondary Growth in Roots

In the dicot root, the vascular cambium is completely secondary in origin. It originates from the tissue located just below the phloem bundles, a portion of pericycle tissue, above the protoxylem forming a complete and continuous wavy ring, which later becomes circular (Figure 6.11). Further events are similar to those already described above for a dicotyledon stem.



(a)

(b)

Figure 6.10 (a) Lenticel and (b) Bark