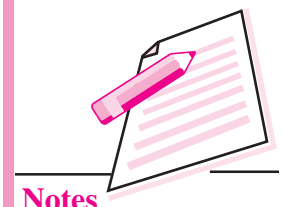


Notes

6

ROOT SYSTEM

The root system is the **descending** (growing downwards) portion of the plant axis. When a seed germinates, **radicle** is the first organ to come out of it. It elongates to form **primary** or the **tap root**. It gives off lateral branches (**secondary** and **tertiary** roots) and thus forms the root system. Its branches penetrate through large and deep areas in the soil and anchor the plant very firmly. It also plays another vital role of absorbing water and mineral salts from the soil and transporting them upwards. How is the root suited in structure to carry out such functions? You shall learn in this lesson.

OBJECTIVES

After studying this lesson, you will be able to :

- *define and identify root;*
- *distinguish between different types of root systems;*
- *describe and illustrate different regions of a root apex;*
- *describe various modifications and functions of roots;*
- *describe and distinguish between primary structure of dicot and monocot root;*
- *illustrate and explain the mode of secondary growth in a dicot root;*
- *describe the deep-seated (endogenous) origin of lateral roots.*

6.1. CHARACTERISTICS OF ROOTS

The main features of roots by which you can recognize them are :

- Non-green due to absence of chlorophyll;
- Not divided into nodes and internodes;
- Absence of leaves and buds;
- Positively geotropic **(grow towards gravity)**;
- Positively hydrotropic **(grow towards water)**;
- Negatively phototropic **(grow away from light)**.

6.2. TYPES OF ROOT SYSTEMS

Root systems are mainly of two types:

(i) **Tap root system —** It is the root system that develops from the radicle and continues as the primary root (tap root) which gives off lateral roots. These provide very strong anchorage as they are able to reach very deep into the soil. It is the main root system of dicots e.g. gram, chinarose, neem (Fig. 6.1a).

(ii) **Fibrous root system** — In this root system, the primary root is short-lived. A cluster of slender, fiber-like roots arises from the base of the radicle and plumule which constitute the fibrous root system. They do not branch profusely, are shallow and spread horizontally, hence cannot provide strong anchorage. Fibrous root system is the main root system of monocots, e.g. maize, grasses, wheat (Fig. 6.1b).

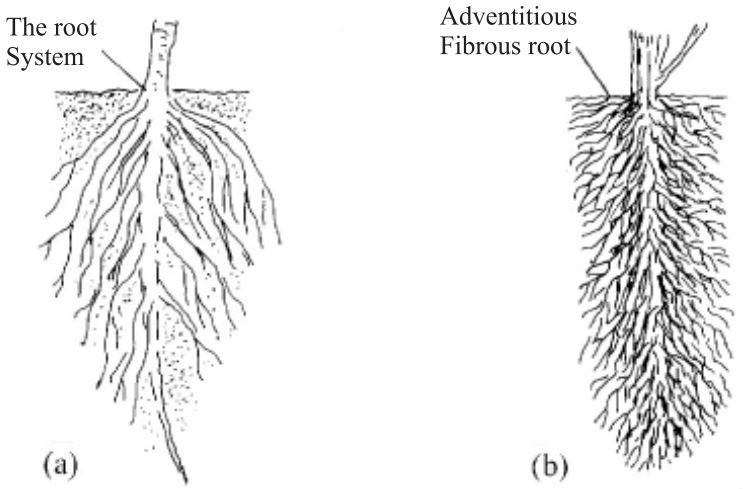


Fig. 6.1 Types of root systems (a) Tap root system (b) Fibrous root system

6.3 TYPES OF ROOTS

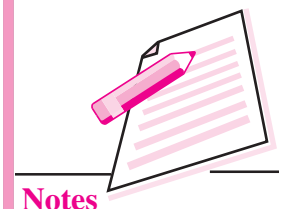
(i) **Tap root** – It is the **primary** and the main root that develops from the radicle, bears numerous branches and remains underground. It is usually found in dicots e.g. sunflower, mustard, carrot, mango (Fig. 6.1a).

(ii) **Adventitious root** – These are roots that develop from any part of the plant except the radicle. They may be aerial or underground (Fig. 6.1b). They may grow from node (money plant, bamboo), stem cutting (rose), tree branch (banyan) or stem base (fibrous roots in monocots).

INTEXT QUESTIONS 6.1

1. Name the plant organ which grows towards gravity and water but away from light?

.....



2. From which part of the germinating seed does the root develop?

.....

3. Which root system gives better anchorage and why?

.....

4. Give two examples each of plants having fibrous and tap root system?

.....

5. Mention three characters by which you can say that carrot which you eat is a root.

.....

6.4 REGIONS OF ROOT

The apical region of roots of any root system shows the same zones or regions as can be seen in Fig.6.2a. A longitudinal section of root apex (Fig.6.2b) shows the following structures:

1. **Root cap region** — It is a thimble-like structure produced by meristematic (rapidly dividing) zone and protects the tender apex (apical meristem) from harsh soil particles. As the root grows further down in soil, root cap wears out but it is constantly renewed . In aquatic plants (*Pistia* and water hyacinth) root cap is like a loose thimble, called **root *pocket***.

2. **Region of meristematic cells** — is a small region of actively dividing cells called the apical meristem. It consists of :

   (i) Dermatogen (outermost layer whose cells mature into epiblema and root cap);

   (ii) Periblem (inner to dermatogen whose cells mature into cortex) and

   (iii) Plerome (central region whose cells mature into stele). In monocots, cap is formed by independent group of cells known as *Calyptrogen*.

3. **Region of elongation** — This is situated next to the meristematic region, wherein, the cells elongate and enlarge to make the root grow in length.

4. **Region of maturation** — This is next to the region of elongation, wherein the cells mature and differentiate into various tissues constituting (i) **Root hair** or **piliferous region** having unicellular hairs which absorb water and mineral salts from the soil and (ii) **Permanent region** which lies behind the root hair zone and is without hairs. It produces lateral roots, anchors the plant in soil and conducts water and minerals upwards.

In the maize root tip, Clowes (1958) discovered a central cup-like reservoir of inactive cells, lying between the root cap and the active meristematic region, called the **Quiescent Centre**. These cells become active whenever the previously active meristematic cells are damaged.

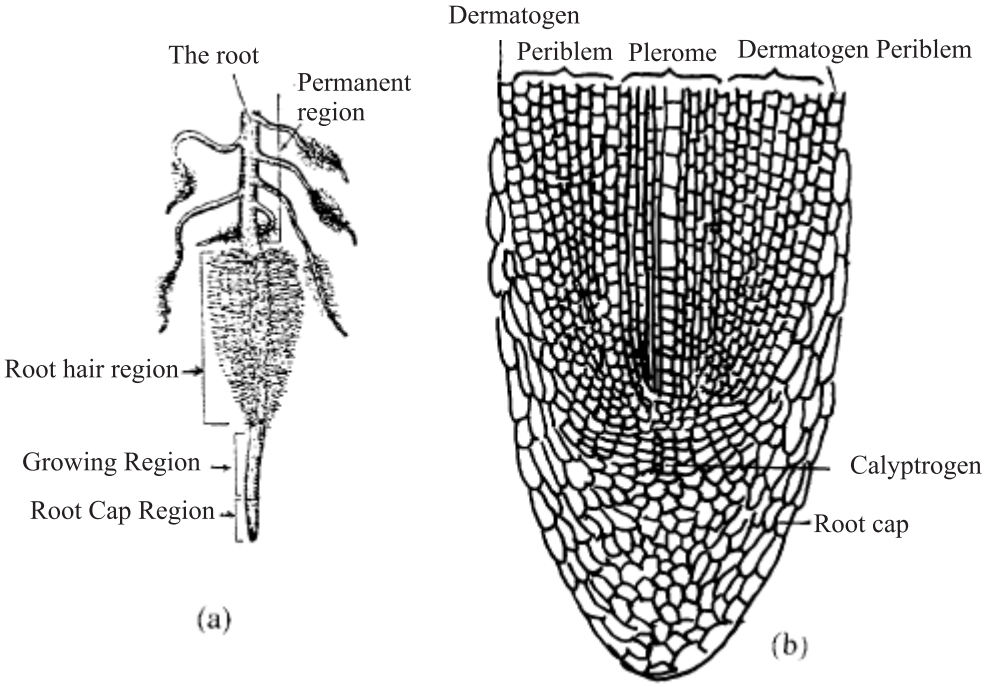


Fig. 6.2 (a) Apical part of a root showing four different regions; (b) LS through root apex

INTEXT QUESTIONS 6.2

1. Name the structure which protects the root apical meristem.

   .....

2. Give in a sequence, the various regions of root from its tip towards its base.

   .....

3. Into which tissues do dermatogen and plerome differentiate?

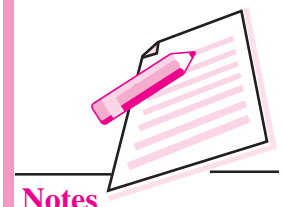
   .....

4. Which region of root absorbs water and mineral salts?

   .....

6.5 MODIFICATIONS OF ROOTS

Tap roots and adventitious roots can get modified into a variety of forms to perform various functions as can be seen from the following chart and Tables 6.1 and 6.2.



Modifications of roots

Tap root modification	Adventitious root modification
(i) Conical root	(i) Tuberous root
(ii) Fusiform root	(ii) Fasciculated root
(iii) Napiform root	(iii) Nodulose roots
(iv) Tuberous root	(iv) Moniliform roots
	(v) Annulated roots
	(vi) Assimilatory roots
	(vii) Epiphytic roots
	(viii) Pneumatophores/Respiratory roots
	(ix) Sucking roots or haustoria
	(x) Prop roots
	(xi) Stilt roots
	(xii) Climbing roots
	(xiii) Clinging roots
	(xiv) Floating roots

A. Tap root modifications

Tap roots become fleshy for storage of food (Table 6.1)

Table 6.1 – Tap root modifications for food storage

Type	Characters	Example
1. Conical (Fig. 6.3a)	Base is broad and tapers gradually towards apex	Carrot
2. Fusiform (Fig. 6.3b)	Swollen in middle, tapering towards both ends	Radish
3. Napiform (Fig. 6.3c)	Spherical at base tapering sharply towards the tip	Turnip
4. Tuberous (Fig. 6.3d)	Thick and fleshy with no definite shape	4 O'clock plant

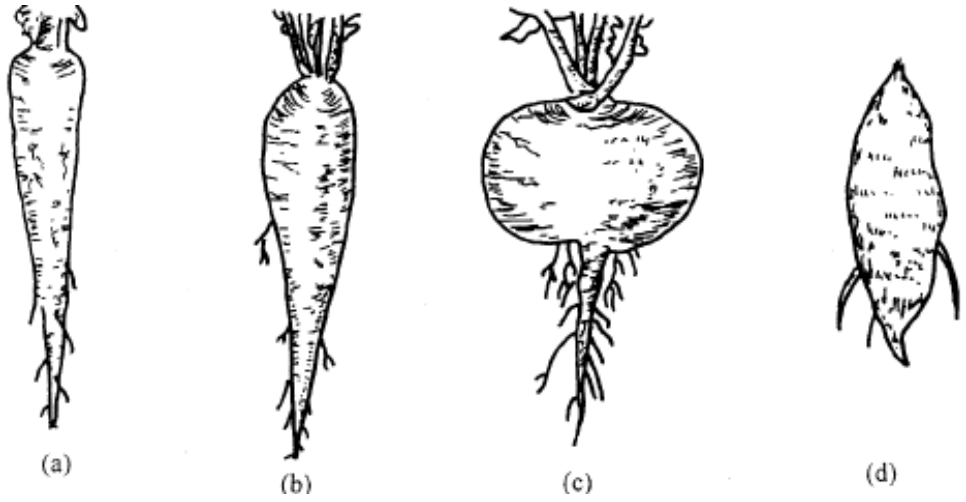


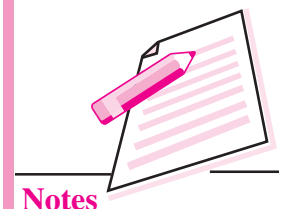
Fig.6.3 Modifications of tap root (a) Conical (carrot); (b) Fusiform (radish); (c) Napiform (turnip); (d) Tuberous (4 o'clock plant)

B. Adventitious root modifications

Adventitious roots get modified for various functions (Table 6.2)

Table 6.2 – Adventitious root modifications

Type	Characters	Example
(i) Modifications for food storage		
1. Tuberous (Fig 6.4a)	Swollen roots developing from nodes of prostrate stem	Sweet Potato
2. Fasciculated (Fig. 6.4b)	Swollen roots developing in a cluster from the stem	*Dahlia*
3. Nodulose (Fig. 6.4c)	Only apices of roots become swollen like single beads	Mango-ginger
4. Moniliform (Fig.6.4d)	Roots alternately swollen and constricted presenting a beaded or moniliform appearance	Grasses, Sedges
5. Annulated (Fig.6.4e)	Looks as if formed by a number of discs placed one above the other	Ipecac
(ii) Modification for photosynthesis		
Assimilatory roots (Fig6.4f)	Roots which when exposed to sun develop chlorophyll, turn green and manufacture food	*Tinospora* (aerial root), orchid



(iii) Modification for absorbing atmospheric moisture

Epiphytic roots (Fig.6.4f)	Aerial roots of epiphytes are greenish and covered with spongy tissue (Velamen) with which they absorb atmospheric moisture	orchids (*Vanda*)

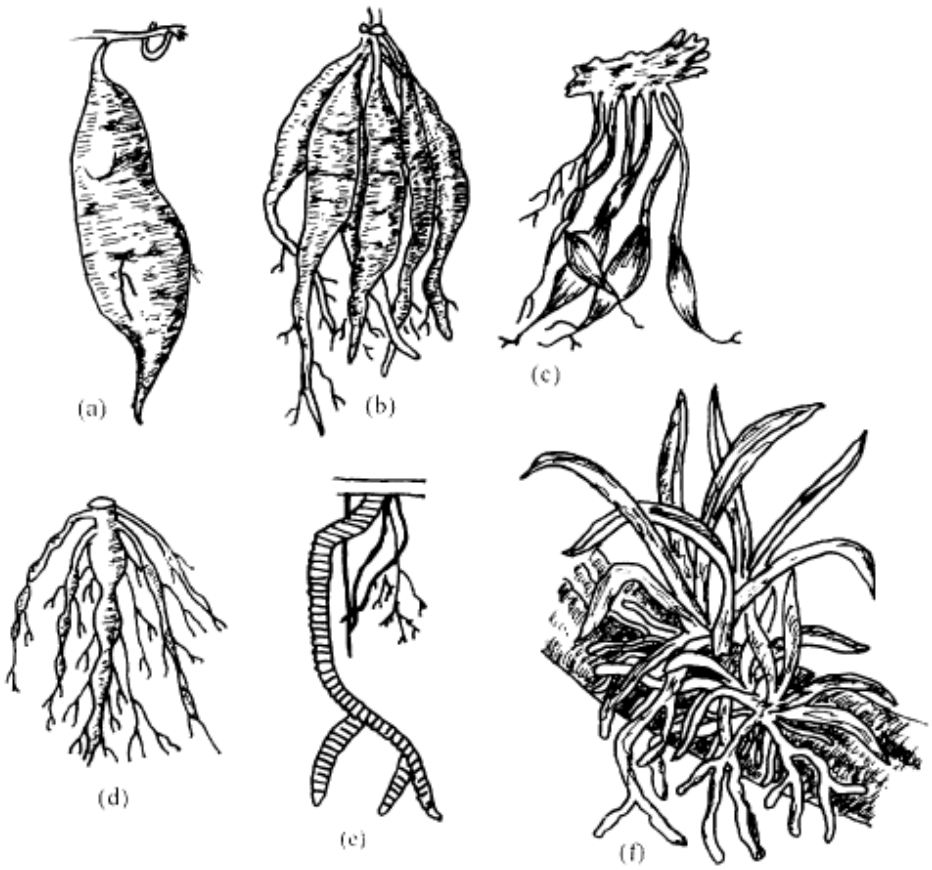


Fig. 6.4 Adventitious root modifications (a) Tuberous root (sweet potato); (b) Fasciculated roots (*Dahlia*); (c) Nodulose roots (mango ginger); (d) Moniliform roots (grass); (e) Annulated roots (*Ipecac*); (f) Assimilatory and epiphytic roots (orchid)

(iv) Modification for better gaseous exchange

Pneumatophores or respiratory roots (Fig.6.5a)	Some roots grow vertically up (negatively geotropic) into air. Exposed root tips possess minute pores through which roots respire, appear like conical spikes coming out of water	Mangroves (marshy plants) *Rhizophora*

(v) Modification for sucking nutrition from host

Sucking roots or haustoria (Fig.6.5 bi,bii)	Parasitic plants give out sucking roots or haustoria which penetrate living host plant and suck food from phloem.	*Cuscuta*

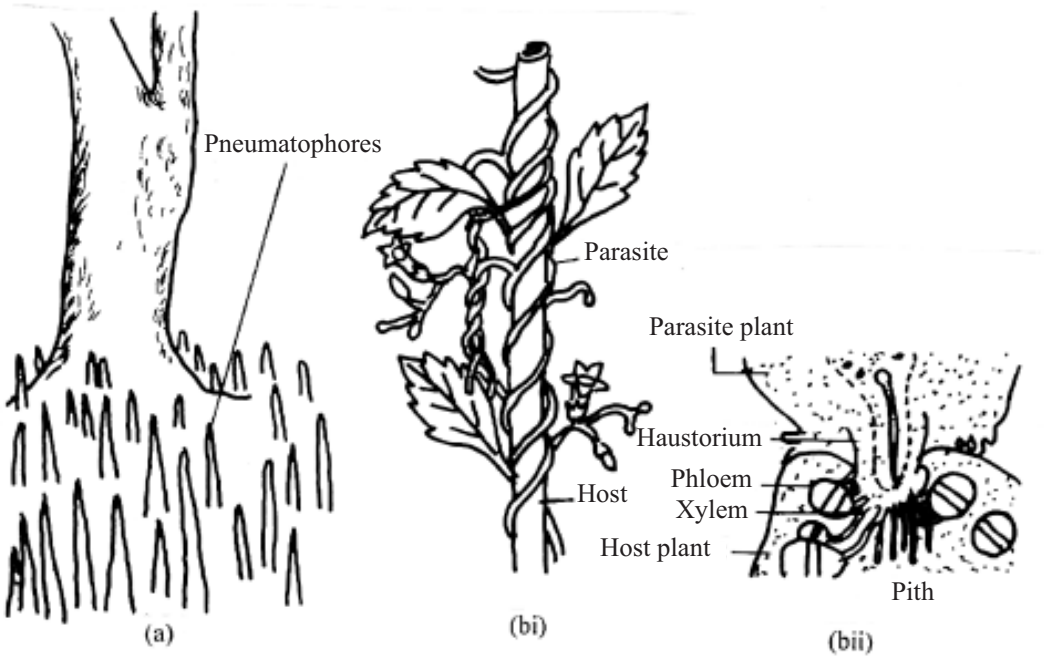


Fig. 6.5 Adventitious root modifications (a) Pneumatophores of a mangrove plant; (bi) *Cuscuta* (parasite) on host; (bii) Section showing sucking root or haustorium penetrating the host plant

(vi) Modification for strong support

1. Prop roots (Fig.6.6a)	Roots develop from tree branches, hang downwards and ultimately penetrate the ground, thus provide support to heavy branches	Banyan
2. Stilt roots (Fig.6.6b)	Extra roots developing from nodes near the base of stem, grow obliquely downwards and penetrate the soil giving strong anchorage	Sugarcane, Screwpine
3. Climbing roots (Fig.6.6c)	Weak climbers twine around and clasp the support with the help of climbing roots arising from their nodes	money plant betel
4. Clinging roots (Fig.6.4f)	Special clinging roots arise, enter the crevices of support and fix the epiphyte	epiphytes orchids

(vii) Modification for buoyancy and respiration

Floating roots (Fig.6.6d)	Spongy, floating roots filled with air, arise from nodes of some aquatic plants, and help in floating and respiration	*Jussiaea*

The great Banyan tree in Sibpur, Kolkata is more than 200 years old, forming a crown of over 404 meters in circumference and has about 1600 prop roots.

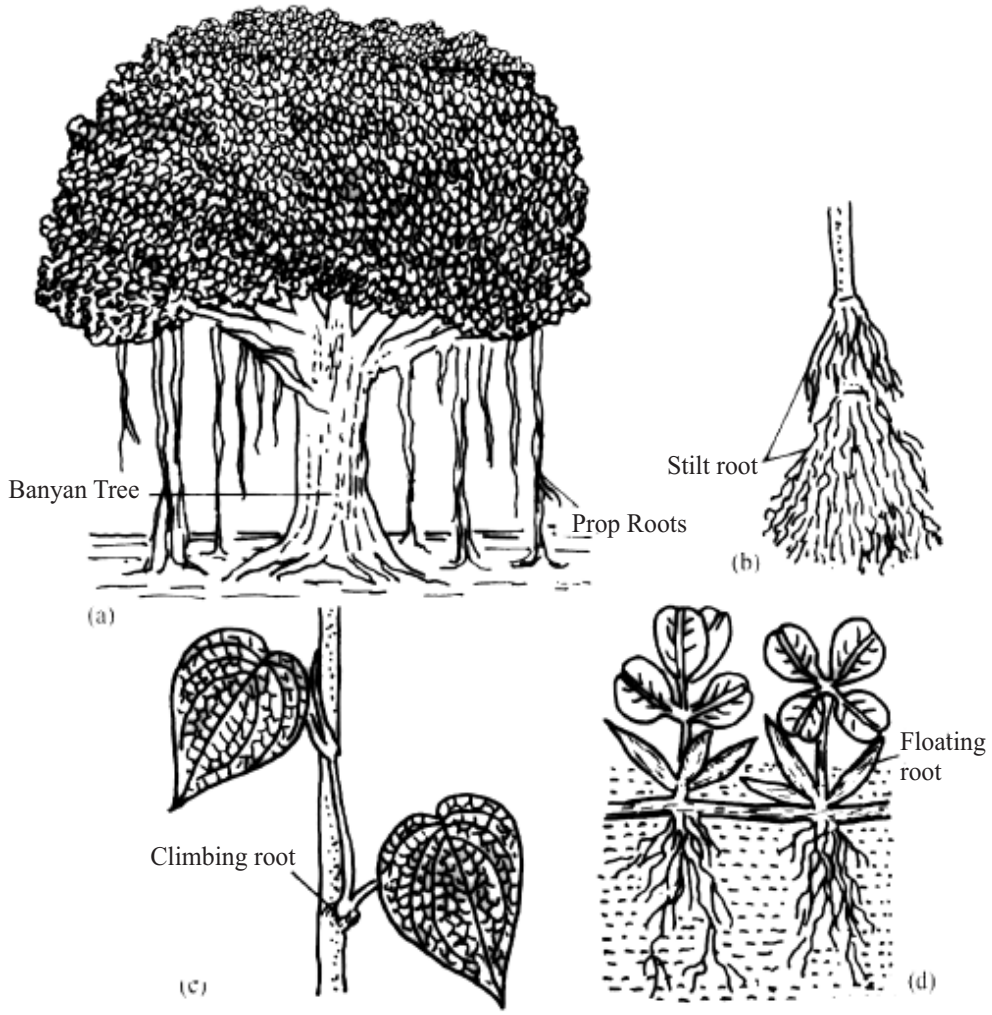


Fig.6.6 Adventitious root modifications – (a) Prop roots in banyan; (b) Stilt roots of sugarcane; (c) Climbing roots of betel; (d) Floating roots of *Jussiaea.*

6.6 FUNCTIONS OF ROOTS

(i) Anchorage – Roots anchor the plant firmly to the soil (mechanical function).

(ii) Absorption – Roots absorb water and mineral salts and conduct them upwards (physiological function).

(iii) Special functions – By undergoing modifications in their structure, roots perform special physiological functions like food storage, assimilation, absorption of atmospheric moisture, sucking food from host, better gaseous exchange and mechanical functions like floating (buoyancy), stronger anchorage and climbing.

INTEXT QUESTIONS 6.3

1. Are carrot, radish and turnip roots? Justify. Why have they become fleshy?

   .....

2. Name the type of root modification found in plants growing in marshy areas. What is their function?

   .....

3. What is the tissue in aerial roots of epiphytes known as which helps in absorption of moisture from the atmosphere?

   .....

4. What are the two main functions of roots?

   .....

5. Match the items of column A with those in column B

A	B
(a) Prop roots	(i) Storage
(b) Haustorium	(ii) *Jussiaea*
(c) Sweet potato	(iii) Banyan
(d) Floating roots	(iv) *Cuscuta*

You would enjoy doing the following activity.

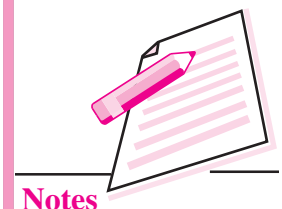
ACTIVITY 6.1

AIM : To study the characteristics of roots, type of root and modification of root in given plants.

Material required: Carrot, radish, turnip, sweet potato, sugarcane, money plant, uprooted grass, mustard/coriander plant.

Method: Observe the roots carefully and tabulate your answers to the following questions–

1. Is the root green?
2. Does it have nodes and internodes?
3. Are leaves present on the roots?
4. Are any buds present on the roots?
5. Is it a tap or adventitious root?
6. Name the type of modification, if present.



6.7 PRIMARY STRUCTURE OF ROOTS

A. DICOT ROOT (e.g. gram)

A thin transverse section of dicot root (Fig. 6.7) shows the following structures —

(i) Epiblema : Single, outermost layer of thin-walled cells. Some cells are prolonged to form unicellular root hairs. It protects and absorbs water.

(ii) Cortex : Large zone, many layered, cells thin-walled parenchymatous with intercellular spaces, stores food and water.

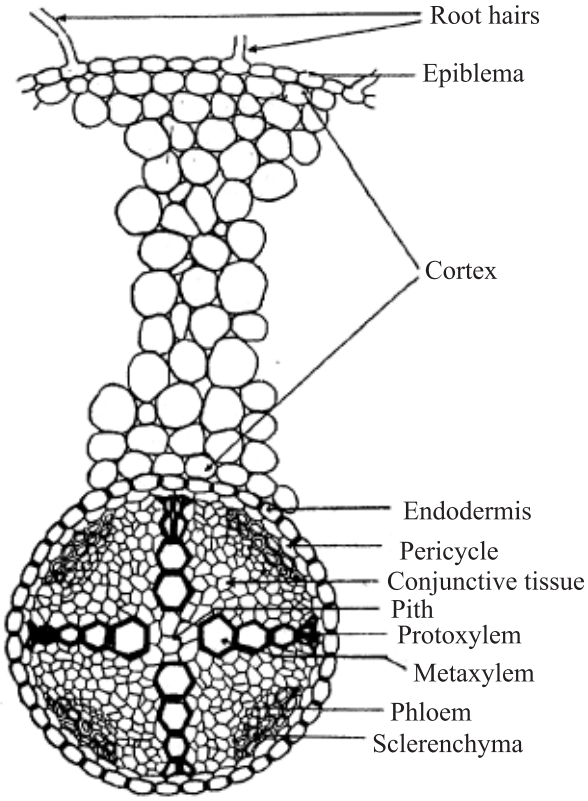


Fig. 6.7 A portion of dicot root in transverse section

(iii) Endodermis : Innermost layer of cortex, cells barrel-shaped, closely packed, that show band like thickenings on their radial walls called *casparian strips.* Some cells (opposite the protoxylem) which lack these strips are called *passage cells.* They help in the movement of water and dissolved salts from cortex directly into xylem.

Stele : All tissues inner to endodermis comprise stele.

(iv) Pericycle : Inner to endodermis lies a single layer of pericycle. It is the seat of origin of lateral roots and vascular cambium and cork cambium during secondary growth.

(v) Vascular bundle : It consists of xylem and phloem patches lying on alternate radii i.e., it is *radial*. Xylem is *exarch* where *protoxylem* (first formed , having narrow vessels and tracheids) lies towards the periphery and metaxylem

(differentiates later, has wider vessels and tracheids) lies towards the center. Depending upon the number of xylem patches a root may be *diarch* (di-2 patches) to hexarch (hexa- 6 patches).

(vi) Pith : Sometimes the metaxylem of all xylem patches meet in the centre, and in that case pith is absent or is small and parenchymatous.

(vii) Conjunctive parenchyma: Parenchyma which separates xylem and phloem lying on different radii.

B. MONOCOT ROOT (e.g. maize root)

A thin transverse section of monocot root (Fig. 6.8) shows the following structures

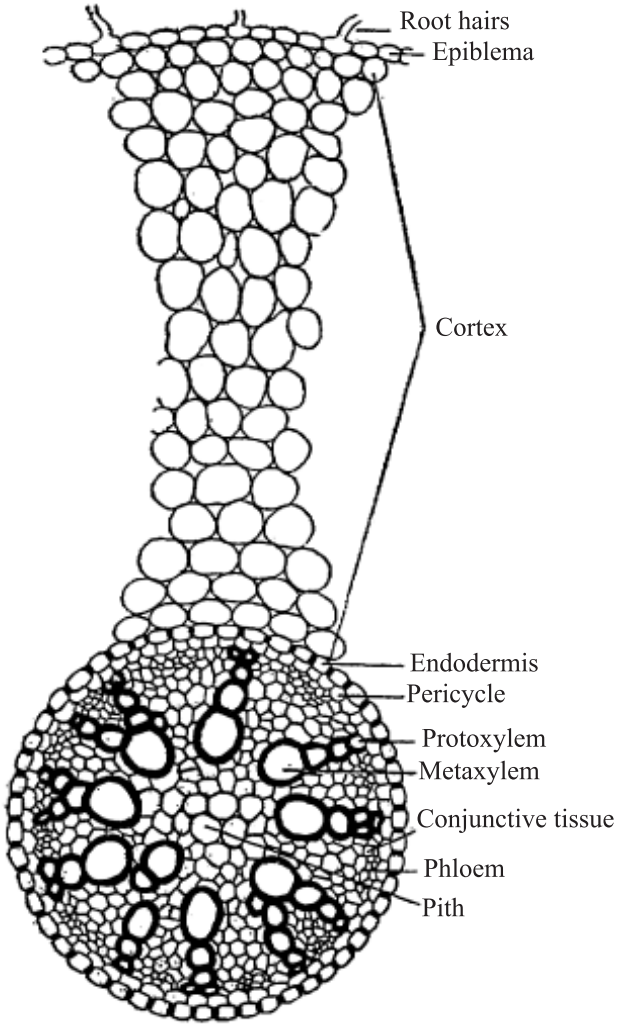
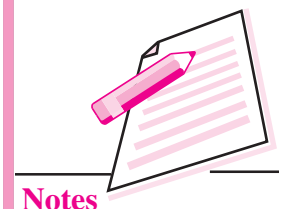


Fig. 6.8 A portion of monocot root in transverse section.

(i) Epiblema : Outermost, single layer of thin-walled, closely packed cells. Some cells are prolonged into unicellular root hairs.

(ii) Cortex : Large zone, multilayered, composed of parenchymatous cells with intercellular spaces, stores water and food material.



(iii) Endodermis : Innermost layer of cortex with characteristic *casparian strips* and *passage cells.*

Stele : All the tissues inner to endodermis constitute stele

(iv) Pericycle : Single layered, having polygonal thin walled cells. The lateral roots originate from this layer.

(v) Vascular bundle : It consists of many patches of xylem and phloem arranged radially. The xylem is exarch and polyarch (poly-many).

(vi) Pith : Is situated in the center, large, well developed, parenchymatous or sclerenchyamatous , stores food.

(vii) Conjunctive Parenchyma : Is located in between the strands of xylem and phloem.

The anatomical differences between Dicot and Monocot roots can be studied from Table 6.3

Table 6.3 Differences between a Dicot and Monocot root

Characters	Dicot root	Monocot root
1.Number of vascular bundles	2-6 (*di-hexarch*)	Many (*polyarch*)
2. Pericycle	Seat of origin of lateral roots, vascular and cork cambium	Seat of origin of lateral roots only
3. Cambium	Present	Absent
4. Secondary growth	Present	Absent
5. Pith	Very small or absent	Large

6.8 ORIGIN OF LATERAL ROOTS

- The origin of lateral roots is endogenous i.e. from a deeper layers.
- The seat of its origin is pericycle where cells opposite the protoxylem divide and form a hump in the endodermis (Fig. 6.9 a-b).
- The hump penetrates into the cortex (Fig. 6.9 c-d), and emerges as a lateral branch.

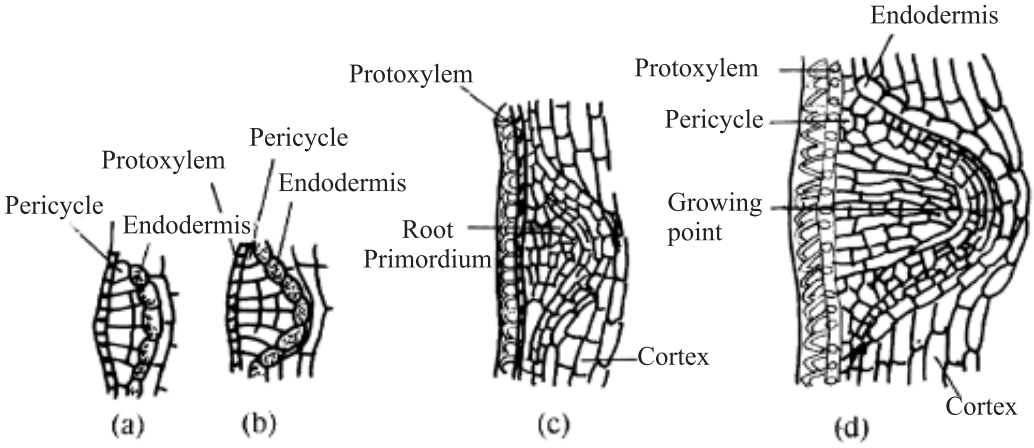


Fig. 6.9 a-d Formation of lateral root (Endogenous origin)- Stages as seen in longitudinal sections of root.

- Later, the hump differentiates into 3 regions of the root apex i.e. *dermatogen, periblem* and *plerome*.
- Finally the lateral root comes out.
- The number of lateral roots corresponds to the number of xylem bundles.

INTEXT QUESTIONS 6.4

1. Name the condition where protoxylem lies towards the periphery and metaxylem towards centre.

   .....

2. Why is it difficult to pluck lateral roots from carrot?

   .....

3. What is the seat of origin of lateral roots and cambium?

   .....

4. Name the endodermal cells which do not possess casparian strips and help in the movement of water?

   .....

5. Give two major differences between a dicot and monocot root.

   .....

6. If the number of xylem bundles is 4 (tetrarch), how many lateral roots will be formed in that area?

   .....

6.9 SECONDARY GROWTH IN DICOT ROOTS

The roots grow in length with the help of apical meristem. It is called **primary growth**. Apart from primary growth, roots grow in width i.e., they increase in girth. This increase is called **secondary growth**. It is found only in dicot roots.

The tissues involved in secondary growth are *lateral meristems* i.e., *vascular cambium* and *cork cambium*.

It is important to remember that the vascular cambium and cork cambium are secondary in origin and arise from the pericycle.

Secondary growth is as follows-

- Pericycle cells outside the protoxylem divide to form a strip of cambium (Fig 6.10b).
- Another strip of vascular cambium appears in the conjunctive tissue on the inner side of phloem bundle (Fig. 6.10 a, b).

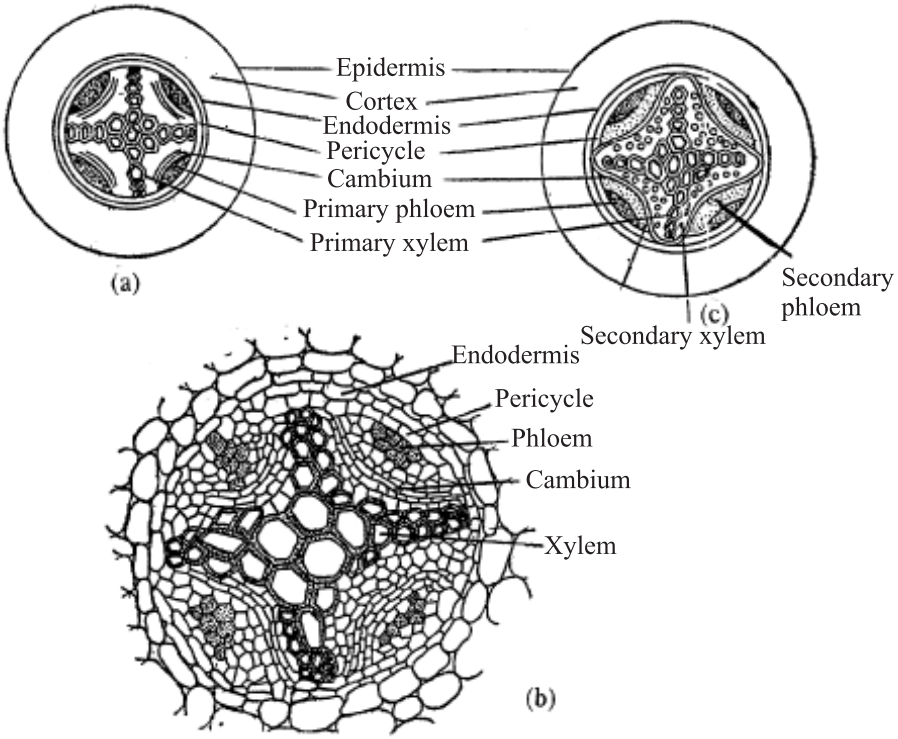


Fig. 6.10 T. S. Dicot Root – (a) and (c) (diagrammatic) – Early stages in secondary growth (b) Stele enlarged (cellular)

- These two vascular cambium strips join laterally to form a ring which may initially be wavy (Fig. 6.10c) but later becomes circular due to over production of secondary xylem tissue inner to primary phloem (Fig. 6.11a).
- Cambium cells consist of brick shaped cells which divide and add cells on its either side i.e. towards periphery and towards center. Those added towards the periphery differentiate into *secondary phloem* and the ones formed towards the center differentiate into *secondary xylem*.

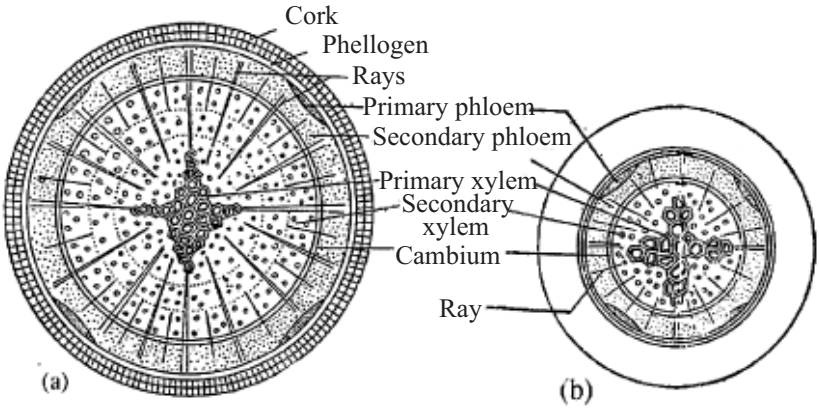


Fig. 6.11 T. S. Dicot root (Diagrammatic) a,b. Later stages in secondary growth.

- Secondary tissue formed outer to the protoxylem bundle differentiates into prominent *primary medullary ray* thus, protoxylem does not get crushed (Fig. 6.11a).

- Later, cork cambium (**Phellogen**) also differentiates in the pericycle (Fig. 6.11b).
- The cork cambium divides and gives rise to cork (**Phellem**) towards outside and secondary cortex (**Phelloderm**) towards inside.
- All the three layers i.e. *Phellogen*, *Phellem* and *Phelloderm* together form the **Periderm** of the root and have protective function.
- Finally all the primary tissues outside the developing cork (i.e. endodermis, cortex and epiblema) are sloughed off.

INTEXT QUESTIONS 6.5

1. Name the lateral meristems found in old dicot roots? What is their function?

   .....

2. From which layer does the vascular cambium originate?

   .....

3. What is the conjunctive tissue?

   .....

4. Define periderm. What role does it play in a root?

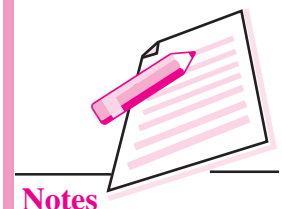
   .....

5. Do primary roots of dicot plant possess cambium?

   .....

WHAT YOU HAVE LEARNT

- The radicle elongates to form the primary or tap root.
- Roots are non-green due to the absence of chlorophyll, lack nodes and internodes, leaves and buds.
- These grow towards gravity (positively geotropic) and water (positively hydrotropic) but grow away from light (negatively phototropic).
- Root systems are of two types – Tap root system (in dicots) and Fibrous root system (in monocots).
- Tap root develops from the radicle while adventitious roots develop from any part of the plant except the radicle.
- Apical region of root has 4 regions namely root cap region, region of meristematic cells, region of elongation and region of maturation.
- Main functions of root are anchorage and absorption of water and ninerals.
- In some plants, roots undergo modifications in their structure to perform special physiological functions (food storage, assimilation, respiration, absorption of



atmospheric moisture and sucking nutrients from host plants) and mechanical functions (stronger anchorage, climbing, buoyancy).

- Internal structure of root shows unicellular hairs, single-layered epiblema, large multilayered cortex, prominent one-layered endodermis with casparian strips and some passage cells. The stele consists of single layered pericycle, radial vascular bundles, exarch xylem and pith.
- Dicot root differs from monocot root in having lesser number of vascular bundles (2-6), very small pith and presence of cambium (secondarily formed).
- Origin of lateral roots is endogenous.
- Number of lateral roots corresponds to the number of xylem bundles.
- Lateral roots , vascular cambium and cork cambium originate from pericycle in dicot roots.
- Due to the presence of cambium dicot roots undergo secondary growth.
- Because of apical meristem roots undergo primary growth and increase in length.
- The dicot roots grow in girth by undergoing secondary growth due to the involvement of lateral meristems (vascular cambium and cork cambium).
- Vascular cambium originates as a strip in pericycle cells lying outside the protoxylem and in conjunctive tissue inner to each phloem bundle.
- Initially the cambium is wavy but later becomes circular.
- The vascular cambium gives rise to secondary phloem towards periphery and secondary xylem towards centre.
- Primary medullary rays differentiate outer to protoxylem.
- Cork cambium (phellogen) also differentiates in the pericycle and gives rise to cork (phellem) towards periphery and secondary cortex (phelloderm) towards inside.
- Phellem, Phellogen and Phelloderm together form the periderm which is protective in function.

TERMINAL EXERCISES

1. Describe any four adventitious root modifications.
2. Give one point of difference between:
   (i) Tap root and adventitious root
   (ii) Prop and stilt roots
   (iii) Protoxylem and metaxylem
   (iv) Phelloderm and periderm
   (v) Vascular cambium and cork cambium

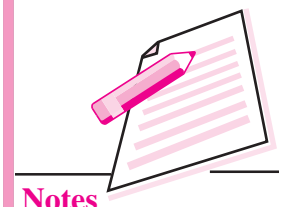
3. Describe the various types of edible roots which you have studied.
4. What are pneumatophores? Where are they found and what is their function?
5. Describe secondary growth in dicot roots.
6. Why is it difficult to break the lateral roots from the main root?
7. What is periderm ? How is it formed?
8. Give four characteristics by which you can identify a root.
9. What is the function of region of maturation?
10. Give one example each of plants having pneumatophores, climbing roots, floating roots and haustoria.
11. A cross section of plant organ when seen under the microscope shows—radial vascular bundles, exarch xylem, single layered pericycle and unicellular hair. What organ is it?
12. Name the meristematic tissues which help the dicot roots to grow in length and girth.
13. Name the modification of root which supports tree branches.
14. If a transverse section of root shows polyarch condition of vascular bundles, large pith and no cambium, which type of root will it be?
15. Differentiate between stele of dicot and monocot root.

ANSWERS TO INTEXT QUESTIONS

6.1 1. Root
2. Radicle
3. Tap root system gives better anchorage because it is very deep seated, and branches profusely which ramify through large areas in soil.
4. Fibrous root system in maize, sugarcane and tap root system in sunflower, mango.
5. Absence of nodes and internodes, buds and leaves.

6.2 1. Root cap
2. Root cap region, region of meristematic cells, region of elongation, region of maturation.
3. Dermatogen differentiates into epiblema and cap, whereas plerome differentiates into stele.
4. Root hair or piliferous region /Region of maturation.

6.3 1. Yes, they are roots since they do not have nodes and internodes, buds or leaves; they become fleshy for storage of food.



2. Pneumatophore, respiration
3. Velamen
4. Anchorage and absorption of water and mineral salts
5. (a) – (iii); (b) – (iv); (c) – (i); (d) – (ii)

6.4

1. Exarch
2. Because these arise from the inner layer i.e.pericycle/ endogenous origin
3. Pericycle
4. Passage cells
5. In dicot root 2-6 vascular bundles and cambium is present but in monocot root many vascular bundles are present while cambium is absent.
6. Four

6.5

1. Vascular cambium and cork cambium; Vascular cambium forms secondary vascular tissue while cork cambium forms cork and secondary cortex.
2. Pericycle and conjunctive tissue.
3. Conjunctive tissue is the parenchyma tissue lying between xylem and phloem patches that are arranged radially in roots.
4. Periderm is a tissue which is formed during secondary growth and consists of phellem, phellogen and phelloderm; protection.
5. No, cambium is absent in the primary dicot root.