13 LIFE HISTORY OF PINUS

Pinus is the most important genus of the family *Pinaceae* and is represented by ninety to one hundred species in the world. They usually grow on the slopes of hills and form dense and extensive forests of evergreen trees in the North Temperate regions of world and sometimes extend up to the sub-arctic regions and in the tropical hills. The species of pine are of great economic value and are the main sources of resins of various types and of various types of woods that are employed as timber. Seeds of some species are a source of food. In India the genus is represented by four naturally growing species. Their distribution and general vegetative characters are given below :

1. *Pinus roxburghii* Sarg. (= *P. longifolia Roxb.*) : It is also known as Chir pine and grows in the outer Himalayas from Indus to Bhutan at 1,500 to 7,500 feet above sea level. It is abundant on the hill slopes in both Western and Eastern Himalayas. It is a tall tree with stem displaying the excurrent habit and reaches a height of 50—60 metres and varies in diameter from 1.5 to 3 metres. The stem has two types of branches and the green leaves as the needles are confined only to the dwarf shoots that bear three needles. The scale leaves occur on the main stem, long shoots and also the dwarf shoots are brown in colour. The seeds are edible and possess wings that are as long as the seed. The megasporophylls have a distinct hooked beak at the tip of umbo. It is also cultivated in the plains as an ornamental.

2. *Pinus wallichiana* A.B. Jacks (= *P. excelsa*) : It is also known as the blue pine or kail. It forms pure or mixed forests on hill slopes at elevations varying between 6,000 to 11,000 feet above sea level. It sometimes grows with *P. roxburghii* at 5,000 feet. It extends from Garhwal through Jaunsar, the Simla Hills, Ram Pur Bushair to Kulu, Chamba and Kashmir. In the Eastern Himalayas it grows in NEFA. It is a beautiful tree with a diameter of 8—10 feet and a height of 100—150 feet. The stem has an excurrent habit with thin, greyish brown and fissured bark in old trees and smooth in young trees and branches. The stem bears whorled branches. The dwarf shoots bear groups of 5 needles on each dwarf shoot. The needles are slightly bent. The scales are lanceolate in younger portions and triangular in older portions. The winter buds are long and cylindrical. The dwarf shoots are about a millimeter in length and arise in the axil of a scale leaf. Each dwarf shoot is covered with spirally arranged 10—12 cataphylls. The first formed or outer cataphylls that are also called prophylls are two in number and occur opposite to each other. They are smaller than the inner ones and possess a distinct midrib. The male cones arise in axils of lower scale leaves on a long shoot and are longer in size than those of *P. roxburghii*. The needles in this case are minutely toothed and ridged. Stomata are arranged between the ridges in distinct longitudinal rows.

3. *P. gerardiana* Wall. ex. Lamb. is the chilgoza pine whose seeds are sold in the market as chilgoza or Neoza. It grows in N.W. Himalayas at 5,000—12,000 feet above sea level and also in Kashmir. Dense forests of this species occur in Afghanistan above 10,000 feet. The dwarf shoots bear three needles.

4. *P. insularis* Endl. (= *P. Khasya* Royle) is also known as khasi pine and grows only in the Khasia and Chittagong hills in Eastern Himalayas. The tree is totally absent in the Western

Himalayas. It also extends into Burma. The trees range in height from 75 feet to 100 feet and are evergreen with excurrent habit.

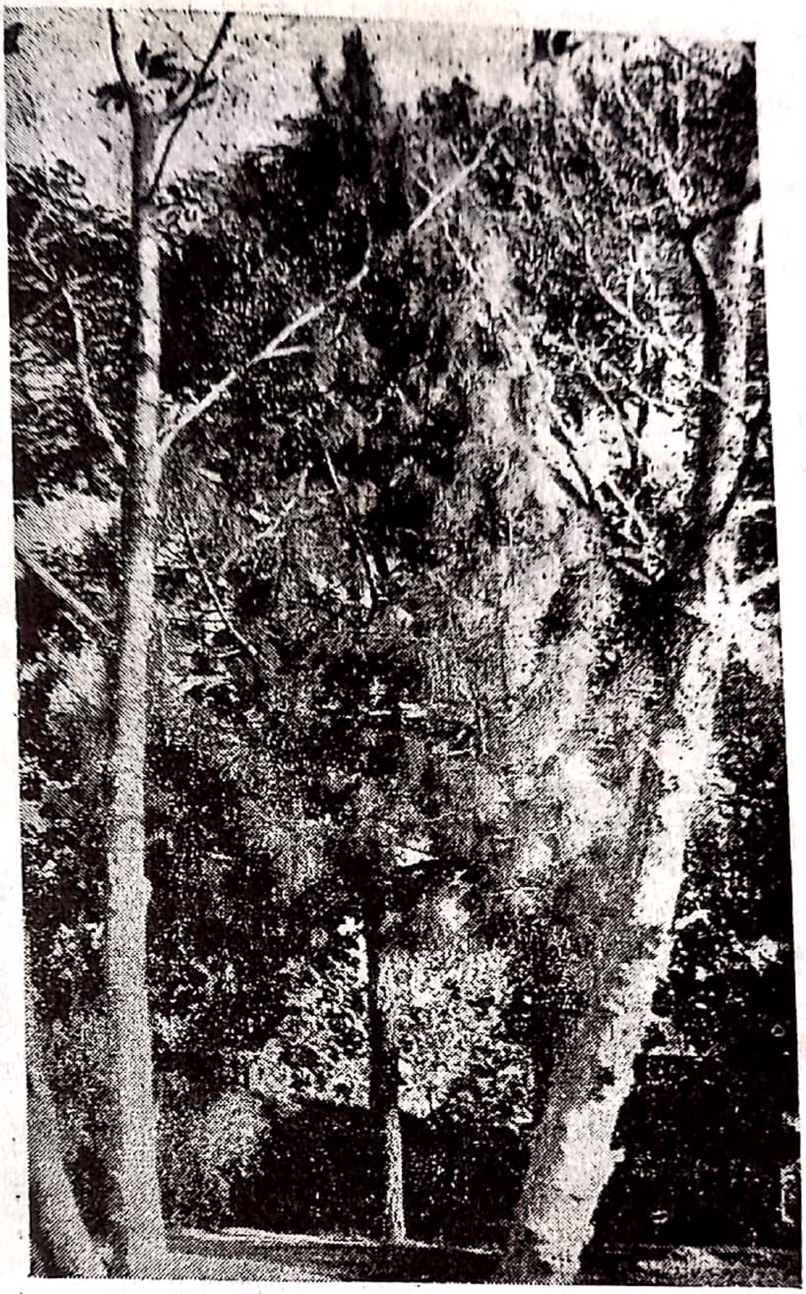

Plate XII : A tree of *Pinus roxburghii* growing in Botanical garden of Govt. College, Chandigarh.

5. *Pinus merkusii* Jungh. can be distinguished from other Indian species in possessing two needles per dwarf shoot. It grows in Burma but extends into India in the Eastern parts of Himalayas.

6. *P. armandi* Franchet has five needles per dwarf shoot. The needles are sharply bent. It is a Chinese species that extends into NEFA region of Assam.

The other common species of *Pinus* that grow elsewhere include : *P. palustris* (Virginia to Florida) ; *P. caribaea* (Carolina, Florida and Lousiana) ; *P. banksiana* (Canada) ; *P. contorta* (N. America) ; *P. ponderosa* (Texas) ; *P. monticola* (British Columbia) ; *P. strobus* (N. America) ; *P. sylvestris, P. nigra* and *P. pinaster* (Northern Europe) ; *P. halepensis* (Mediterranean) ; *P. cembra* (North Russia) ; *P. pumila* and *P. koralensis* (Manchuria) ; and North American *P. monophylla, P. cembroides* and *P. edulis, P. albicaulis, P. lambertiana, P.*

sabiniana, P. coulteri, P. torreyana and *P. Jeffreyi* are other common species that have economic uses.

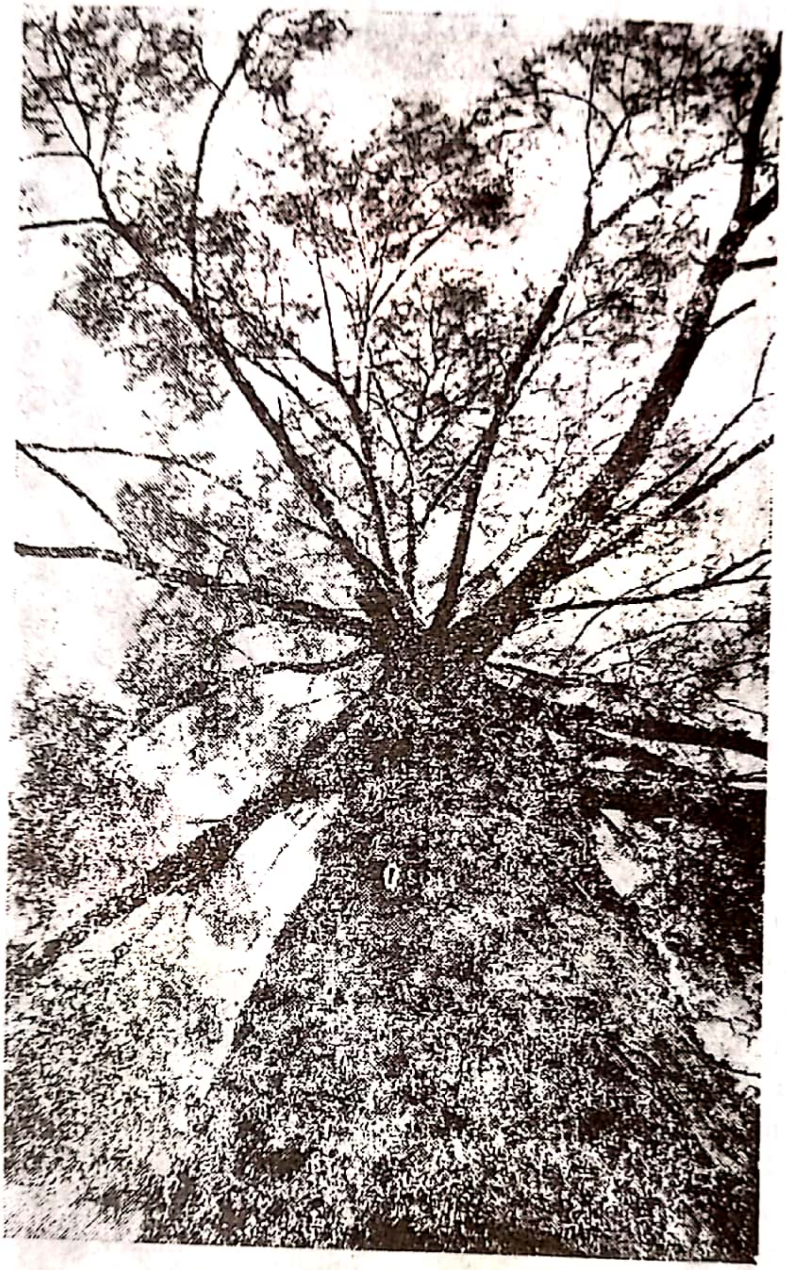

Plate XIII : An old tree of *Pinus wallichiana* from Simla.

A general account of the genus is presented below. The main events in the life history pertain mainly to those of *P. roxburghii* and *P. wallichiana* that have now been thoroughly worked out by Sethi (1929), Konar (1960) and Konar and Ramchandani (1958). The account given here has been adopted from these works and those of famous authors like Chamberlain (1935), Haupt (1941), Holloway (1937), Florin (1954) and others.

EXTERNAL FEATURES

The Pine trees very in height from 70 feet to 200 feet and reach a diameter of about 12 feet or even more. *Pinus aristata* from California (Billings, 1957) is about 4,000 years old. It grows on the slopes where rain-water is easily drained off. As in the pteridophytes the pinus tree is the sporophyte. It is differentiated into roots, stem and leaves. Typically the stem displays the excurrent habit. It is tall, stately and straight and is covered with rugged scaly bark. The main stem is branched. The branches are of two types :

Long branches and the short dwarf ones

Long branches. These are the ordinary or normal branches. They continue indefinitely in active growth by means of an apical bud. They are often called shoots of unlimited growth. They are covered with brown bud scales. These branches arise as buds in the axils of scale leaves at the end of each year's extension growth. The following year these buds develop as an apparent whorl of normal branches. They occur at regular intervals on the main trunk and are horizontal. They become gradually shorter towards the apex. Hence the pine tree presents a graceful tapering or pyramidal appearance. The older parts of the long shoots are covered with scars left by the fallen dwarf shoots and the subtending scales while the younger parts bear brown scale leaves with dwarf shoots in their axils. At regular intervals it also bears compact rings of bud scales or scars. The portion between these successive rings represents each year's growth.

Short branches. In addition to the main branches or long shoots which arise directly from the trunk there are very numerous branches of limited growth borne on the ordinary branches in the axils of scale leaves (Fig. 13.1). They are often called the dwarf shoots or shoots of limited growth. The dwarf shoot consists of a short axis terminating in a cluster of three green needles (Fig. 12.1, A). It has an ephemeral terminal bud that stops growing and becomes inactive. It is covered with scales. The dwarf shoot is up to 1/2" in length and is covered with 10—12 scale leaves or *Cataphylls* in *P. wallichiana*. The two outermost cataphylls are called *prophylls* and are opposite to each other as compared to the other spirally arrnaged ones. The prophylls are smaller than the cataphylls. The innermost cataphylls are the largest.

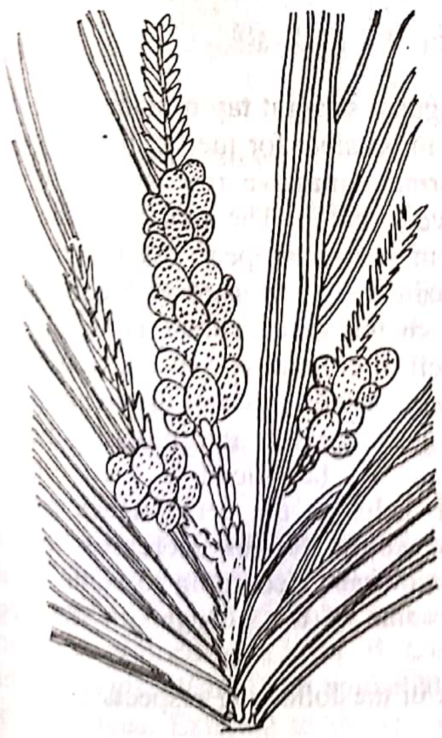

Fig. 13.1. A long shoot bearing dwarf shoots or spurs and three clusters of male cones. Each dwarf shoot bears three needles.

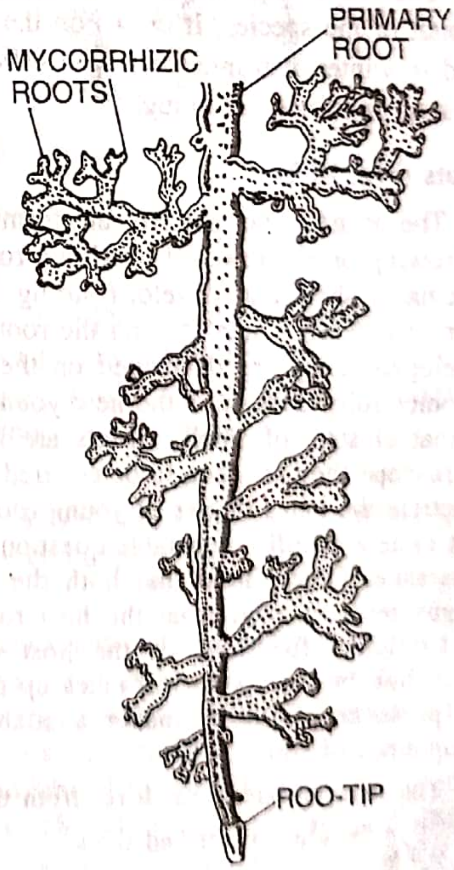

Fig. 13.2. The primary or tap root of *Pinus raxburghii* bearing mycorrhizic roots.

Leaves

The leaves are also of two kinds. The first kind of leaves are the **foliage leaves.** They are of somewhat unusual type being long, narrow (acicular), tough and green and are frequently known as "**Pinus** or **pine needles.**" Their surface is smooth. They are not borne on ordinary branches but appear only on dwarf shoots in clusters of two (*P. merkusii*), three (*P. roxburghii*) or five (*P. wallichiana*) according to the species. In *P. monophylla* only one leaf is produced on the dwarf shoot. The dwarf shoots bearing foliage leaves are known as "Spurs". The spur of *P. roxburghii* with three needles is called **trifoliar** spur. Those of *P. monophylla* are **monofoliar**, of *P. merkusii* are **bifoliar** and of *P. wallichiana* are **penta foliar.** A thin, dry membranous sheath surrounds the base of each cluster of needles. The needles are persistent. They fall only when the spur is shed as a whole. Hence the pine tree is evergreen. The green leaves in *P. wallichiana* are minutely toothed and ridged. The ridges are epidermal projections between which the stomata are arranged in distinct longitudinal rows. The needles are straight on young shoots but spread outwards or drop down in older shoots.

Secondly, there are the **scale leaves**. They are brown membraneous and are protective in function. The scale leaves are the only ones borne on the long branches. They are found on dwarf shoots as well. They fall off as the branches mature. Male cones also arise in the axils of scale leaves on long shoots. The scale leaves near the basal portions of branches are triangular and more or less lanceolate in the younger parts and around the bud. Sometimes they are matted with resin. The scale leaves on the dwarf shoots are called the cataphylls and possess a distinct midrib.

The reduced size and sclerotic character of leaves have been associated with xerophyte habitat of the species. It grows on the slopes where rain water is easily drained off. Extreme cold in winter also interferes with efficient root absorption by lowering temperature and thus causing physiological draught.

Roots (Fig. 13.2)

The primary root persists and forms a typical elongated straight tap root. In case the plant is growing on shallow soil overlying rocks which it is impossible for the tap root to penetrate, it remains short and develops strong lateral roots forming massive root system spread out over an extensive area. Tip on the root has a protective root cap. The root hairs are not well developed. They are developed on the young roots but soon disappear. As the root system becomes fully developed the new young branches remain short and undergo frequent forking so that clusters of small rootlets are formed. These are the **mycorrhizal roots**. Under the microscope they are seen to be covered with a close weft of colourless hyphae. Some of these penetrate the outer tissues of young roots. The exact relationship between the hyphae and the root system is still a debatable question. Some physiologists consider the fungus to be merely a parasite. Others hold that both the partners are mutually beneficial to each other. The fungus receives food from the host roots. In return it helps in the performance of certain physiological functions of the host root. The presence of fungus increases the water absorption by roots and thus takes up the function of root hair. According to some botanists the presence of fungus makes available to the host some of the nitrogen in the organic compounds of soil.

The mycorrhizic roots differ from the normal roots in the following respects :

1. They are short and thick.
2. They lack root hair.
3. They lack root caps.
4. They are more extensively branched or occasionally unbranched.
5. They are covered with fungal hyphae.

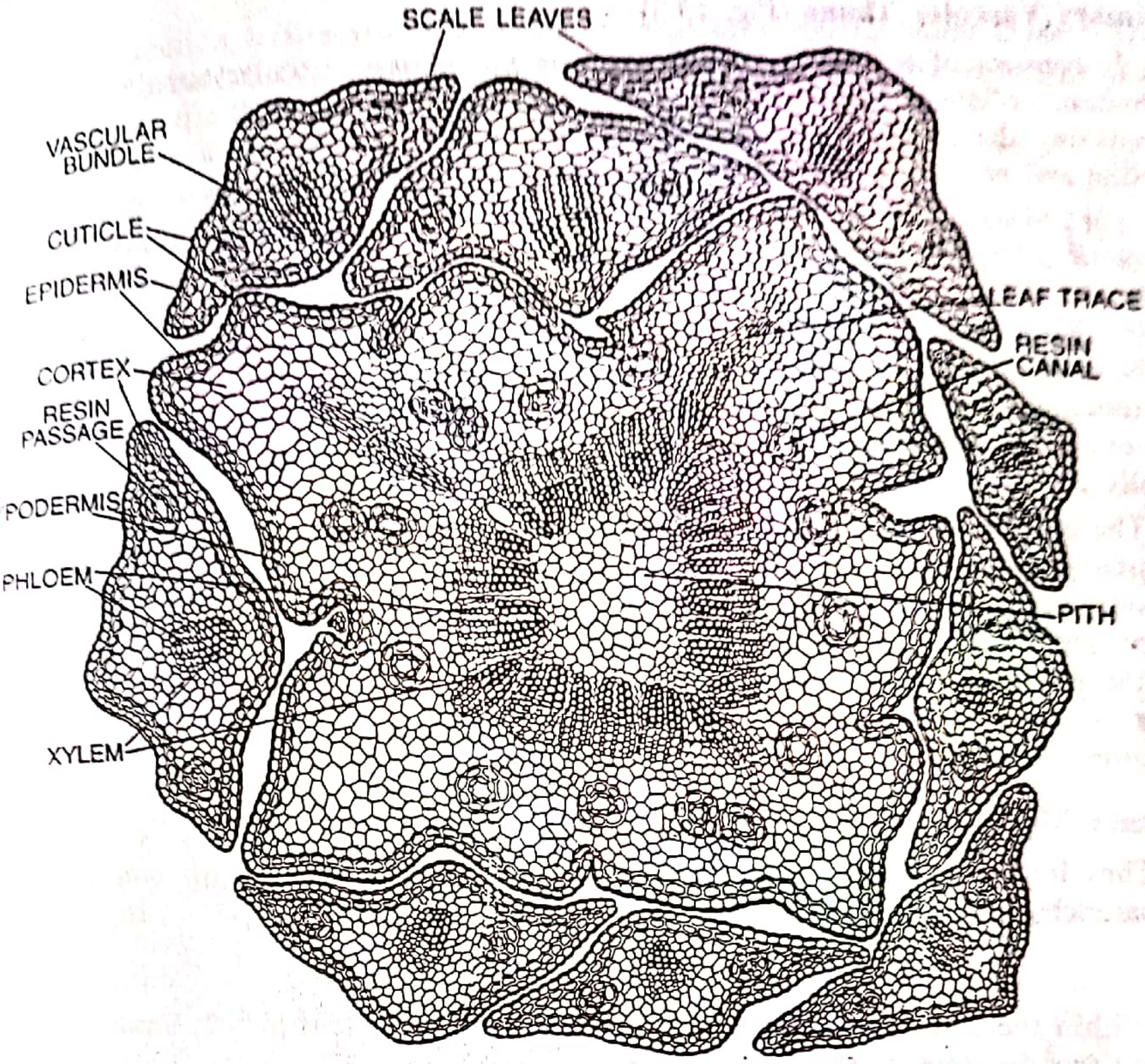

Fig. 13.3. T.S. young stem of *Pinus roxburghii.*

ANATOMY

Primary Structure of Stem

Anatomically the stem shows a considerable advance over the cycadales. Like the stem of dicotyledons it has a concentric arrangement of primary permanent tissues (Fig. 13.3). It is composed of a small pith, a thick vascular cylinder made up of a ring of separate collateral and open vascular bundles, a thin cortex and an epidermis.

Epidermis

It covers the outer surface of stem and is single layered and irregular in outline. The epidermis cells are highly thickened with walls strongly cutinized.

Cortex

The cortical cells beneath the epidermis are strongly thickened to form the hypodermis. The inner cortex consists of thin-walled parenchymatous cells. It is traversed by large resin ducts or canals (Fig. 13.3) which run both radially and longitudinally through the stem. Each duct or canal is lined by a layer of thin-walled parenchymatous glandular secretary cells constituting the **epithelium.** The epithelial cells usually possess abundant cytoplasm and a conspicuous nucleus. External to the epithelial layer is the **sclerotic sheath** consisting of thick-walled cells. The epithelial cells secrete resin into the canal. This resin flows out when an injury breaks the tissues open. Little is known of the functions of this resin to the plant itself except that on exposure to air the liquid resin forms a solid covering on the wound until fresh bark is formed. It serves as a valuable protection against the invasion of wounded tissues by Fungi or Bacteria. Resin is the chief source of natural **turpentine.** The latter is a valuable antiseptic reagent. Neither endodermis nor pericycle is recognizable.

Primary Vascular Tissue (Fig. 13.3)

It consists of a ring of five to six separate primary vascular bundles. The bundles are common, collateral and open. They lie close together so that the primary medullary rays connecting the pith with the cortex are narrow. Each bundle has a primary phloem on the outside and primary xylem on the inner side with primary cambium in between the two.

The primary xylem contains neither true vessels (tracheae) nor wood fibres which are characteristics of Angiosperms. It consists of tracheids that are arranged in uniform radial rows and xylem parenchyma only. Each tracheid is a closed cell with bordered pits on its walls. The protoxylem elements have a loose spiral thickening with a few small bordered pits on their radial walls. Annular thickenings are rare (Bierhorst, 1970). The metaxylem elements are reticulate and pitted. The reticulum is close. The bordered pits on their walls are larger and more numerous but uniseriately arranged. The xylem is traversed by **wood rays**, each usually consisting of a single layer of parenchyma cells. They run radially through the xylem.

The phloem contains sieve tubes. Phloem parenchyma cells are also formed. There are no companion cells. The sieve tubes are elongated more or less pointed cells with sieve plates on the side walls. Albuminous cells also occur and have the same relation to sieve cells on the companion cells (Esau, 1935). The **primary cambium** which is located between the xylem and the phloem of each bundle consists of a single layer of **meristematic cells**. It provides for a continuous increase in diameter. The cambium divides repeatedly in a tangential direction.

Primary Medullary Rays

They lie between the primary vascular bundles and connect the pith with the cortex. They are parenchymatous and narrow.

Pith

Within the ring of vascular bundles is the parenchymatous pith. It forms the core of the upright woody stem of *Pinus*.

The *Pinus* stem and branches (long shoots) grow apically by means of an apical meristem that shows no clear distinction between the **tunica** and **corpus** but there is an initial group of apical cells that divide anticlinally and periclinally to give rise to lateral derivatives and **central mother cell zone** below. In the centre of this zone there is a gradual differentiation of cells with meristematic properties that give rise to the **peripheral zone** from which arise in part leaf primordia, cortex, procambium, and epidermis. The central mother cell also gives rise basally to the rib meristem which produces the pith. As the stem tissues differentiate, from the base of the apex, provascular strands arise from the peripheral zone and vascular tissues differentiate as collateral bundles in a eustele with endarch primary xylem.

Secondary Structure (Fig. 13.4)

The secondary tissues are formed in the same way as in the dicotyledons. The primary cambium of the stele extends tangentially. The edges of the bundle cambia come closer and eventually make contact. In this way a complete or closer ring of cambium is formed. The cambial cells divide repeatedly in a tangential direction. Two cells are formed at each division. Of these, one remains **camblal**. The other, which is called the **tissue mother cell**, may divide once or twice. The cells thus formed become differentiated into xylem or phloem according to their position on the inside or outside of the cambial cell. Such growth is known as **secondary growth**. The new xylem cells which are added to the outside of the primary xylem constitute the **secondary xylem** and the new phloem cells which are added to the inside of the primary phloem form **secondary phloem**. The cambial cell in the meantime increases in size and again divides. As a consequence a continuous ring of **secondary xylem** on the inner side and one of secondary phloem on the outer side are formed. The cambium remains as a permanent meristem between them. Each year the cambium forms a band of secondary xylem and secondary phloem. The bands of secondary xylem are quite distinct from each other. In a cross section it appears as a series of concentric layers. Each layer or band represents a year's growth and is commonly called as an **annual ring**. The annual rings are

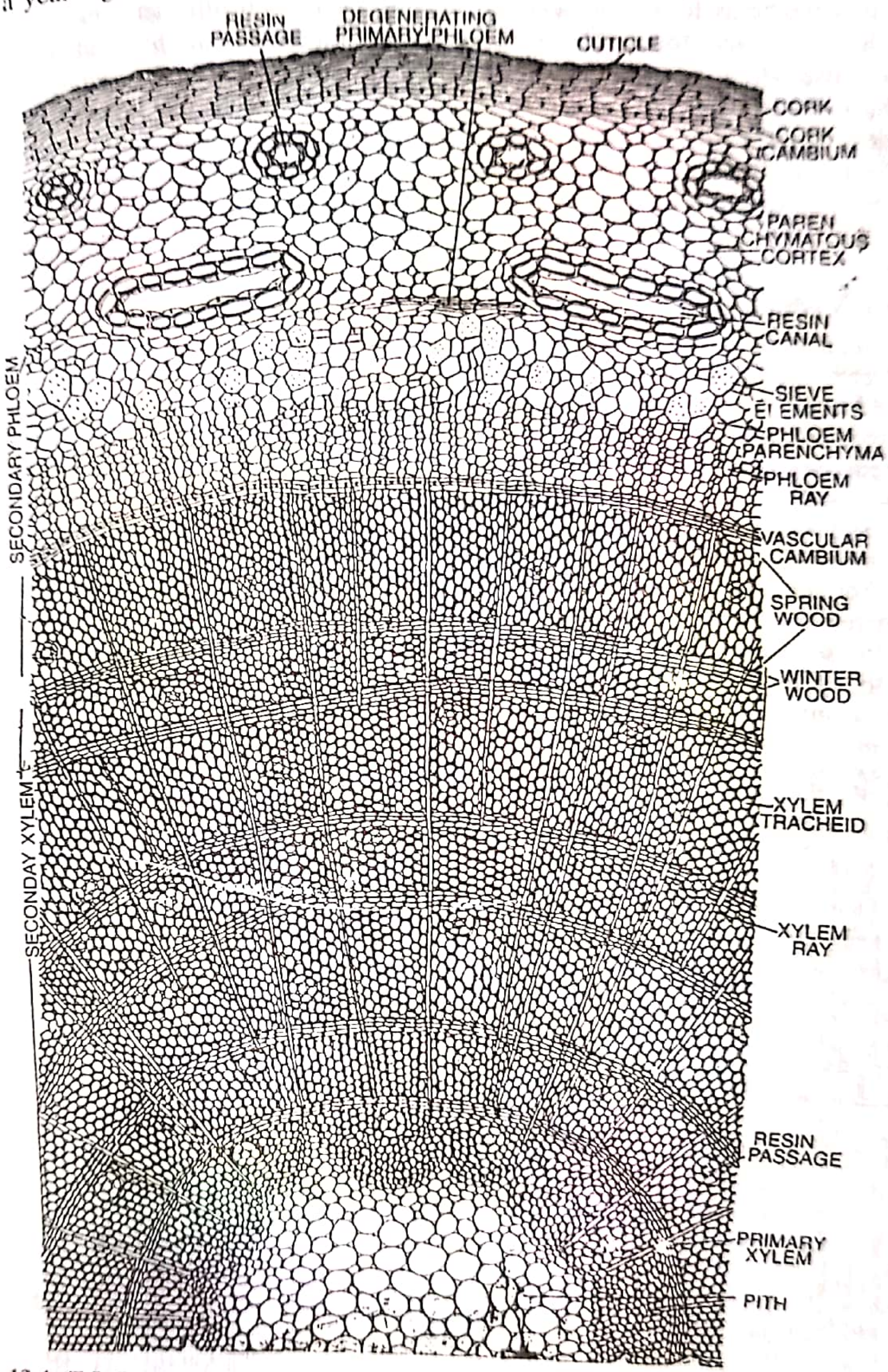

Fig. 13.4. T.S. Portion of old stem of *Pinus roxburghii* showing details of secondary structure.

caused by the difference in size of tracheids formed in the spring as compared with those formed in the summer. The autumn wood has thick-walled tracheids with narrow lumina as compared to the spring wood. Counting the number of these rings gives an indication of the age of the tree or branch. Resin ducts are present both in the primary and secondary wood. The tracheids of autumn wood have small bordered pits whereas those of spring wood have larger pits. The former are squarish in transaction whereas the latter appear polygonal. The spring wood tracheids have comparatively thinner walls with little amount of lignifications. The pits have a distinct **torus**. The tracheids have bordered pits on their radial and tangential walls and uniseriate in arrangement. Resin canals are also present in the secondary wood (Fig. 13.4). The secondary phloem consists of radial rows of sieve cells that taper at both their ends and possess sieve plates on their radial walls. There are no companion cells but phloem parenchyma and albuminous cells are present. The sieve tubes deposit callus in the sieve plates after the year's growth. The tracheids also become non-functional by the growth of **tylosoids** into their lumina or cavities. These are outgrowths of wall material. **Bars of sanio** are present around the bordered pits.

Secondary Medullary Rays

They replace the primary medullary rays and are formed by the cambial cells (Fig. 13.5). They traverse the secondary xylem and phloem zones at certain places. They vary in size from 2—12 cells in height and are only one cell broad. (Figs. 13.5 and 13.6). New medullary rays are formed each year, alternating with those previously laid down. Structurally the secondary medullary rays are much more complex than those of the dicotyledons. The rays in the secondary wood consist of thick-walled rectangular parenchymatous cells contaiing cytoplasm, a nucleus and starch grains. They possess simple pits. At the upper and lower ends of these rays are elongated, **horizontally** situated one or two rows of short tracheidal cells. They are elongated horizontally and are called the **marginal ray tracheids**. The marginal ray tracheids have bordered pits on their lateral and end walls and thus allow radial diffusion of watery fluids. In the secondary phloem and cambium regions the ray tracheids are absent. Their place is taken up by large thin-walled cells which are elongated vertically. They are commonly called the **albuminous cells**. They contain protein. In a radial longitudinal section of the wood the medullary ray is cut longitudinally. It is seen crossing the tracheids in a horizontal direction. The bordered pits are seen in surface view on the radial walls of the tracheids. A longitudinal tangential section of the wood cuts across the medullary ray. The bordered pits are seen in section on the radial walls of the tracheids which are cut through in this case.

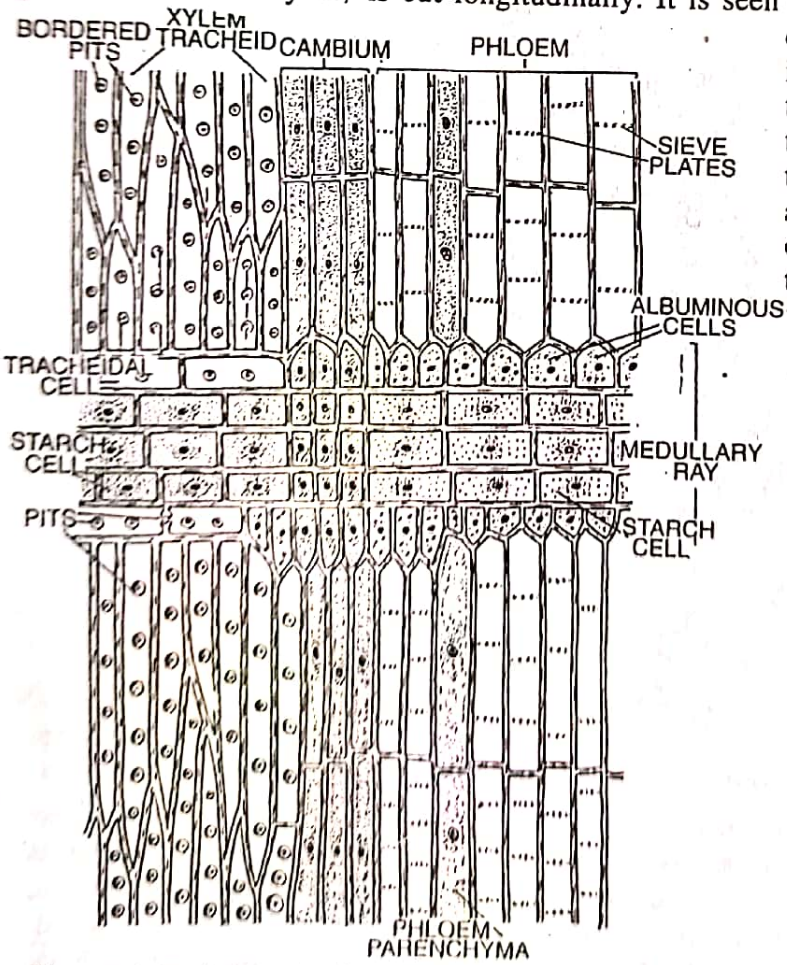

Fig. 13.5. Radial longitudinal section of secondary wood and phloem of *Pinus roxburghii* showing the structure of secondary medullary ray.

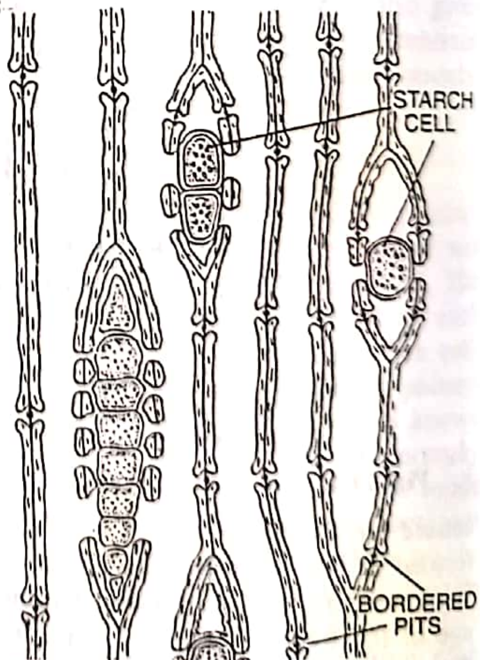

Fig. 13.6. Tangential longitudinal section of secondary wood showing the medullary rays of *P. roxburghii*.

Periderm or Cork (Fig. 13.4)

The formation of the secondary vascular tissues stretches the outermost tissues of the stem which eventually rupture and are peeled off as thin strips of scaly bark. Before this takes place a special protective tissue the **periderm** or **cork** is formed. It is formed by a layer of cortical cells near the outside. These cells become meristematic and constitute the **cork cambium** or **phellogen**. It is secondary meristem. The cells of the cork cambium divide by two parallel walls. The inner cells form the additional cortex whereas the outer constitute the **periderm** or **cork**. The latter tissue serves to protect the delicate tissues lying within it when the epidermis is peeled off. It is impervious to water and thus helps to prevent excessive evaporation. It may be mentioned here that cambial activity, xylem and phloem differentiation and formation of cork cambium are all hormone controlled.

The main chemical components of the walls of tracheids in gymnosperms including *Pinus* are : (*i*) cellulose, (*ii*) the non-cellulosic polysaccharides ; and (*iii*) lignin. The cellulose makes up the framework of tracheidal wall. The polymeric strands combine to form micelles which, in combination, form the microfibrils. The microfibrils in turn form a crystalline lattice that is embedded in an amorphous matrix consisting of noncellulosic polysaccharides, later in combination with the lignin. Lignification usually is initiated within the primary wall at the corners, then spreads intercellularly and only later into the secondary wall.

Structure of the Root (Fig. 13.7)

It consists of piliferous layer, cortex and stele. The arrangement of tissues is in general similar to those of the root of dicotyledons.

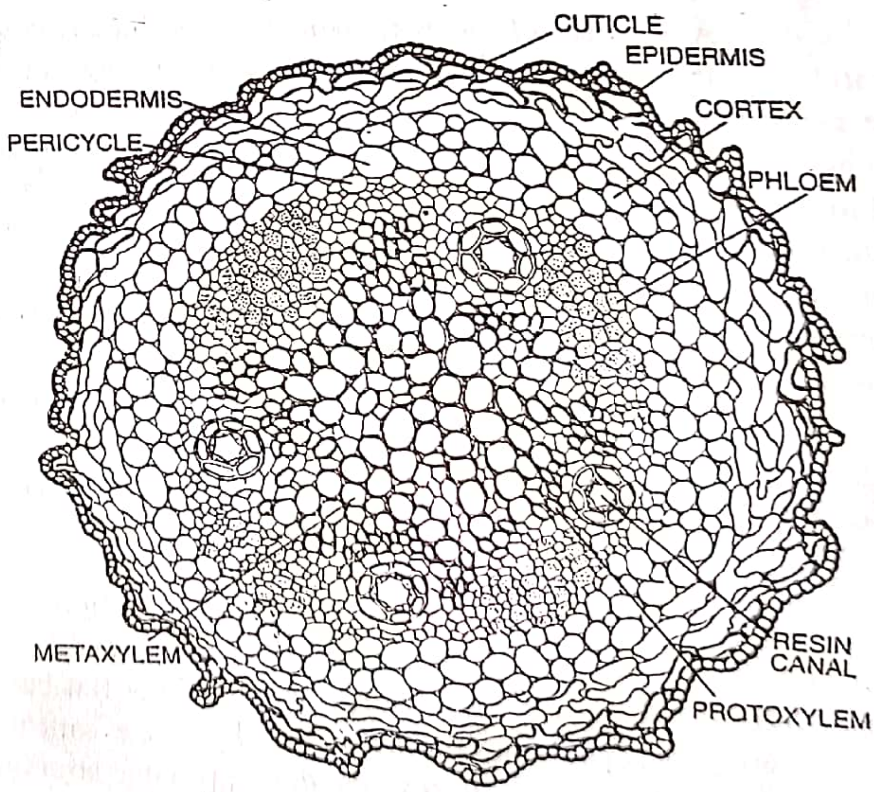

Fig. 13.7. T.S. Primary root of *Pinus roxburghii*.

Piliferous Layer

It is the outermost layer. The cells of this layer fit tightly against their neighbours.

Cortex

Within the piliferous layer is the cortex. It is a wide zone of parenchymatous cells and thus forms most of the bulk of the root. It is bounded on the inside by the endodermis.

Endodermis

It is single layered. The cells are of brownish orange colour. They are suberized and usually impregnated with tannin.

Pericycle

It delimits the stele and is many layered. The pericycle cells contain starch and are usually impregnated with tannin.

Stele

It is **diarch** occasionally **triarch** or tetrarch. The higher number is up to six. An equal number of phloem bundles alternate with the xylem bundles. The protoxylem groups lie at the ends of metaxylem which occupies the centre of the root. As the development of the metaxylem is centripetal, in young roots the central cells may be found unlignified constituting the **pith**. Each protoxylem group is forked so that the xylem bundle appears Y-shaped. A resin passage lies between the arrows of the Y.

A cross section through the mycorrhizal root shows that the hyphae run mainly between the cortical cells. They lie thickly in the intercellular spaces. No fungus is present within the endodermis. Most of the hyphae forming a complete layer over the surface of the root are cut transversely. They present the appearance of an outer pseudo-parechymatous tissue.

Secondary Growth (Fig. 13.8)

It takes place by the development of cambial *strips* (two in diarch roots, three in triarch and four in tetrarch) in the the parenchymatous cells separating the phloem and the metaxylem. These cambial arcs later become continuous by the pericycle cells external to protoxylem resuming meristematic activity. Secondary xylem is formed towards the centre and secondary phloem towards the outside. Ultimately the cambium assumes a circular outline and in mature root shows a radial arrangement of vascular elements as in the stem. The annual rings are also distinct in the root but are narrower as compared to the stem. The tracheids are longer and thick-walled as compared to the stem. They possess bordered pits like those of the stem.

The phellogen or the **Cork Cambium** arises deep down in the pericycle. It forms periderm or cork towards the outside. As a result a thick layer of cork is formed separating the stele from the cortex. The latter eventually dies and disappears as **bark**.

Anatomy of the Leaf (Figs. 13.9, 13.10)

The leaf shows a complex and unusual structure very much different from that of the leaves of the cryptogams as well as the typical leaf of the Angiosperms. Its anatomy suggests that it is adapted to endure severe environmental conditions. It is not flat but is about as thick as broad. In a cross section it is shaped like the tri-sector of a circle with the curved surface facing outwards and the vertex inwards. It reveals the following structure from without inwards.

Epidermis

Forming the outer boundary of the leaf is a single layered epidermis. The epidermal cells are thick-walled and heavily cutinized so that the epidermis is covered on the outside by a thick cuticle. The deeply sunken stomata are present on all sides of the leaf. They are developed in longitudinal rows. Their **guard cells** are situated well below the level of the epidermis so that there is a sunken **pit** leading to the stomatal aperture.

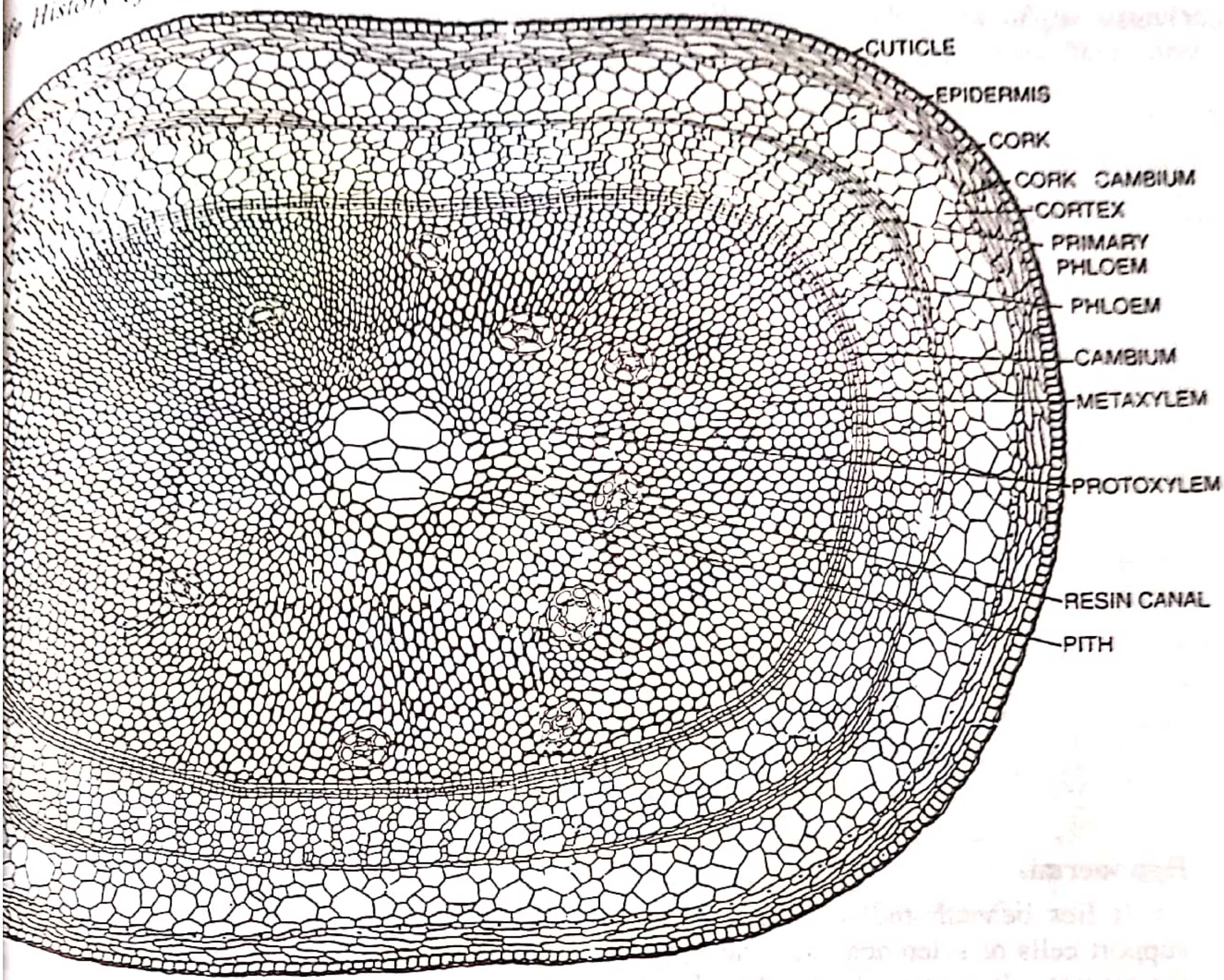

Fig. 13.8. T.S. old root of *Pinus roxburghii* showing secondary structures.

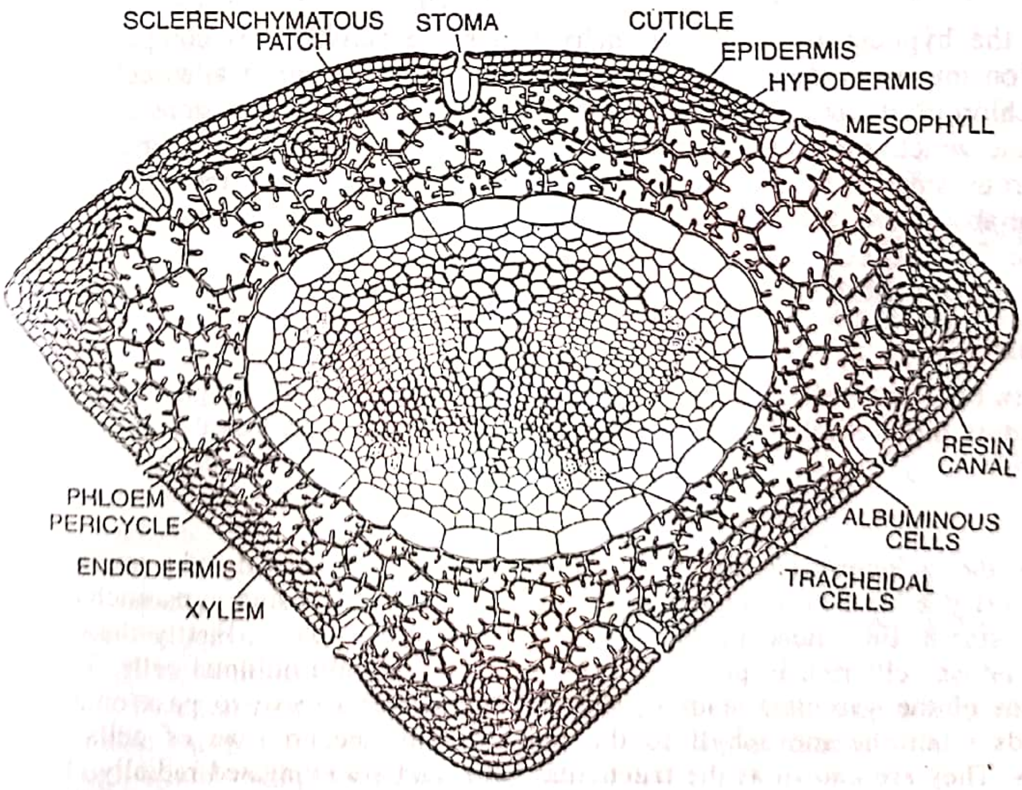

Fig. 13.9. T.S. needle of *P. roxburghii* showing detailed internal structure.

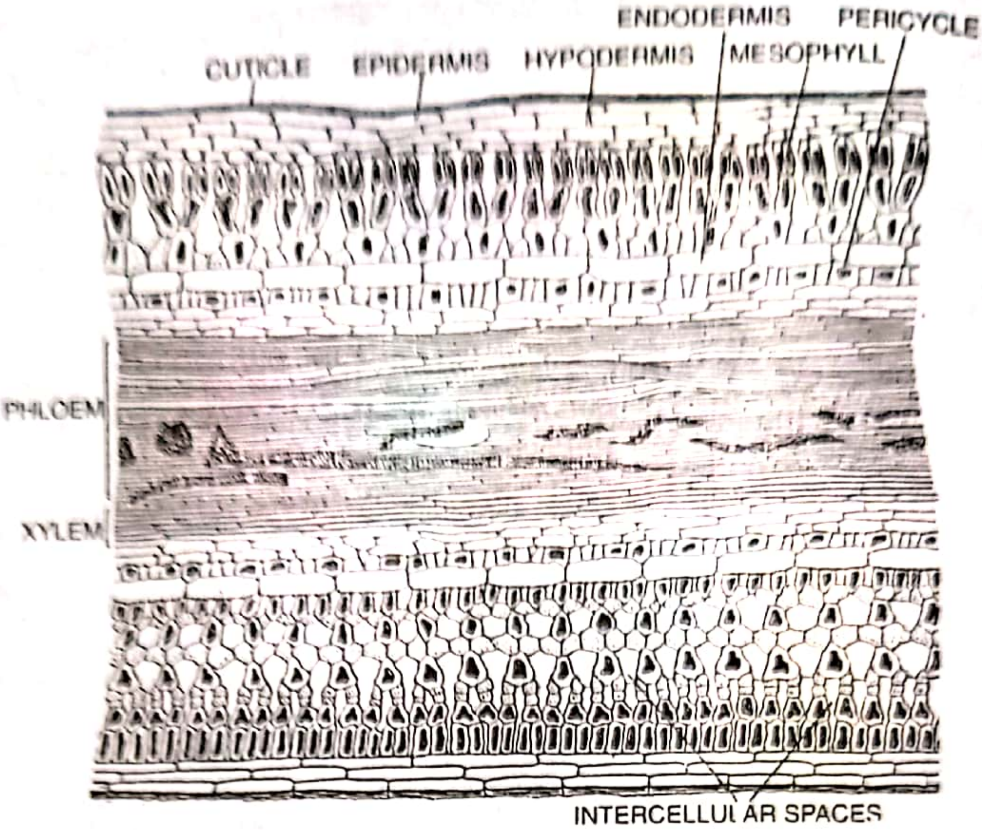

Fig. 13.10. L.S. Needle of *P. roxburghii*.

Hypodermis

It lies beneath the epidermis and is composed of one or more layers of thick-walled support cells or sclerenchyma. The hypodermis is frequently interrupted by air spaces beneath the stomata. It is strongly developed at the angles.

Mesophyll

Within the hypodermis is the parenchymatous **mesophyll.** It is compact and shows no differentiation into palisade and spongy tissues. It consists of thin-walled cells which contain numerous chloroplasts and abundant starch. The mesophyll thus functions as the chlorophyll bearing tissue which manufactures food for the plants. Its cells are peculiar in that their walls have numerous small infoldings which project into the cavities of the cells. These serve to increase the absorptive, aerating and excreting surface of the protoplasm in each cell and thus compensate for reduced leafy surface. The mesophyll contains a number of **resin ducts** immediately under the hypodermis. They are similar in structure to those of the stem.

Endodermis

The central tissue of the leaf is enclosed by a conspicuous single layered endodermis which delimits the mesophyll. The endodermal cells are large and oval and possess casparian strips.

Pericycle

Within the endodermis is the many-layered pericycle. It consists of a number of types of cells. Majority of the cells constituting the pericycle are ordinary parenchymatous cells, containing starch. Embedded in them are two other types of cells. Firstly there are the other parenchymatous cells rich in proteins. They are called the **albuminous cells**. They abut upon the phloem of the vascular bundles. The albuminous cells serve to pass on the elaborated compounds from the mesophyll to the phloem. The second type of cells resemble the tracheides. They are known as the **tracheidal cells**, and are elongated radially. The tracheidal cells are contiguous to the xylem of the bundle and thus serve to carry watery fluids from the xylem to the mesopyll. These special kinds of cells collectively constitute the **transfusion** tissue. Probably the transfusion tissue makes up for the poor development of the vascular tissue. Besides the transfusion tissue, the pericycle includes schlerenchymatous fibres near and between the bundles.

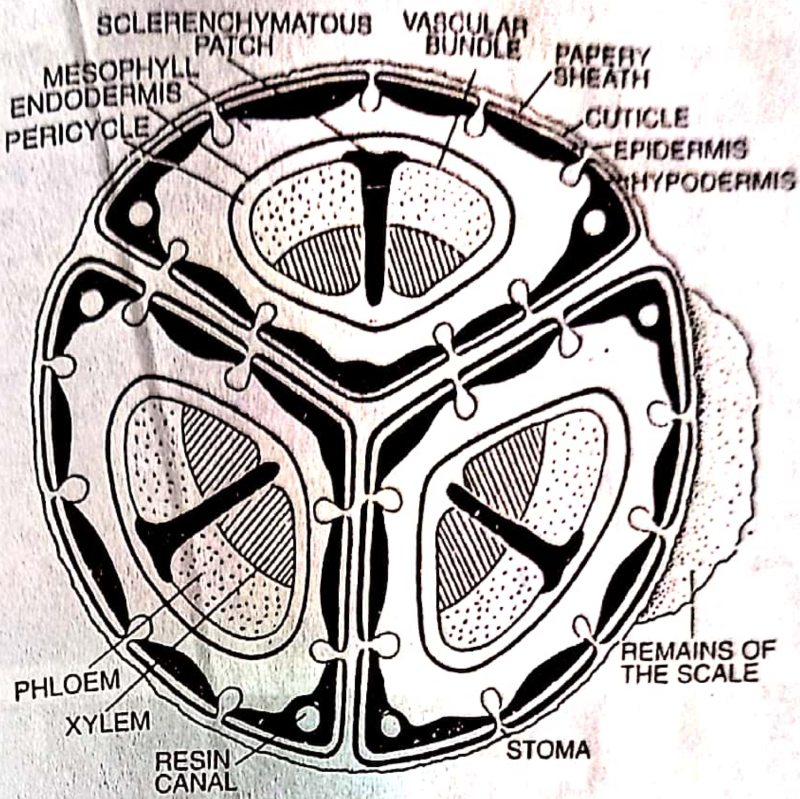

Fig. 13.11 T.S. tip of dwarf shoot showing three needles in transection

Vascular Bundles

Embedded in the pericycle are the two vascular bundles. They are separated by a band of schlerenchymatous fibres. The two bundles run closely parallel from the base to the apex of the leaf and are unbranched. In some species there is only a single bundle. Each bundle contains xylem and phloem. The phloem faces the curved lower or outer side. The xylem lies above the phloem facing inwards, *i.e.*, towards the pointed end. The bundle is thus collateral. Acicular form of the leaves, which reduces transpiring leaf surface, thick-walled and heavily cutinized epidermis, schlerenchymatous hypodermis which renders the leaf tough in texture, sunken stomata and poor development of vascular tissues are all xerophytic characters which suggest that the pine leaf is not apt to lose water rapidly by transpiration. These xerophytic leaves are associated with the evergreen habit of the pine tree because, they by conservation of water supplies, enable the plant to retain its leaves through winter without injury.

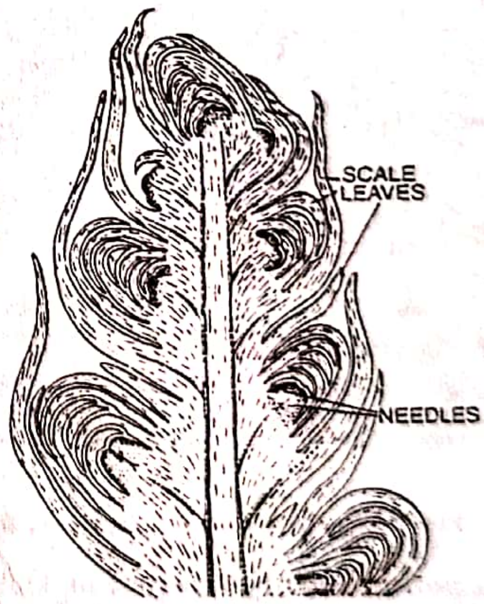

Fig. 13.12. V.S. of tip of long shoot. Note the developing dwarf shoots.