Learning unit 6: Plant structure, growth and development

6.1 Introduction

To complete the learning unit, you will need to refer to pages 816–841 chapter 35 in Campbell et al. (2015)

There is more than 300 000 species of flowering plants that live in and adapted to the many environments on earth as they represent remarkable variety. Most plants show much greater diversity in their individual forms because the growth of most plants, much more than in animals, is affected by local environmental conditions. Take an example of adult lions, they have four legs and are of roughly the same size, but oak trees vary in the number and arrangement of their branches. This is because plants respond to challenges and opportunities in their respective local environment by altering their growth. The highly adaptive development of plants is critical in facilitating their acquisition of resources from their respective growing environments.

In this learning unit, we focus on the on the structure, growth, and development of flowering plants, which are vascular plants characterised by flowers, double fertilisation, endosperm, and seeds enclosed within fruits. We then explore on the key differences between the two main groups of flowering plants, eudicots and monocots.

6.2 Learning outcomes

By the end of this learning unit you should be able to

- identify and discuss the structures of the three basic organs of a plant body, namely the roots, stems and leaves
- describe the characteristics of the three tissue systems that these organs are composed of, namely dermal, vascular and ground tissues
- describe the characteristics of the three cell types that these tissue systems are composed of, namely parenchyma, collenchyma and sclerenchyma cells
- describe the structure and function of apical meristems
- name the meristems responsible for primary growth
- name the meristems responsible for secondary growth
- discuss secondary growth of stems and roots
- describe the production of the periderm

6.3 Plants body have a hierarchy organisation consisting of organs, tissues, and cells

Recommended reading: pages 817–823 chapter 35 in Campbell et al. (2015)

Plants, like multicellular animals, have organs that are composed of different tissues, and tissues are composed of different cell types. A tissue is a group of cells with a common structure and function. An organ consists of several types of tissues that work together to carry out particular functions. We shall firstly look at the organs since are the most visible parts of plant and easy to locate.

6.4 The three basic organs of a plant

The basic morphology of vascular plants reflects their evolutionary history as terrestrial organisms that inhabit and draw resources from two very different environments that are below the ground and above the ground. In addition, plants obtain water and minerals from the soil and they obtain CO_2 and light above ground.

In order for vascular plants to obtain the resources they need, vascular plants have evolved two systems: a subterranean root system and an aerial shoot system of stems and leaves. Each of this system depends on the other for carrying out its purpose. You may now be aware that if a plant is lacking chloroplasts and living in the dark, roots would starve without the sugar and other organic nutrients imported from the photosynthetic tissues of the shoot system. Reciprocally, the shoot system (and its reproductive tissues, flowers) depends on water and minerals absorbed from the soil by the roots. A root is an organ that anchors a vascular plant in the soil, absorbs minerals and water, and stores food. Most eudicots and gymnosperms have a taproot system, consisting of one large vertical root (the taproot) that produces many small lateral, or branch, roots. In angiosperms, taproots often store food that supports flowering and fruit production later.

Seedless vascular plants and most monocots, including grasses, have fibrous root systems consisting of a mat of thin roots that spread out below the soil surface. A fibrous root system is usually shallower than a taproot system. Grass roots are concentrated in the upper few centimeters of soil. As a result, grasses make excellent ground cover for preventing erosion. Sturdy, horizontal, underground stems called rhizomes anchor large monocots such as palms and bamboo. The root system helps anchor a plant. In both taproot and fibrous root systems, absorption of water and minerals occurs near the root tips, where vast numbers of tiny root hairs enormously increase the surface area. Root hairs are extensions of individual epidermal cells on the root surface.

Absorption of water and minerals is also increased by mutualistic relationships between plant roots and bacteria and fungi. Some plants have modified roots. Some arise from roots while adventitious roots arise aboveground from stems or even from leaves. Some modified roots provide additional support and anchorage. Others store water and nutrients or absorb oxygen or water from the air. A stem is an organ consisting of alternating nodes, the points at which leaves are attached, and internodes, the stem segments between nodes.

At the angle formed by each leaf and the stem is an axillary bud with the potential to form a lateral shoot or branch. Growth of a young shoot is usually concentrated at its apex, where there is a terminal bud with developing leaves and a compact series of nodes and internodes. The presence of a terminal bud is partly responsible for inhibiting the growth of axillary buds, a phenomenon called apical dominance. By concentrating resources on growing taller, apical dominance is an evolutionary adaptation that increases the plant’s exposure to light. In the absence of a terminal bud, the axillary buds break dominance and give rise to a vegetative branch complete with its own terminal bud, leaves, and axillary buds. Modified shoots with diverse functions have evolved in many plants. These shoots, which include stolons, rhizomes, tubers, and bulbs, are often mistaken for roots. Stolons, such as the “runners” of strawberry plants, are horizontal stems that grow on the surface and enable a plant to colonise large areas asexually as plantlets form at nodes along each runner. Rhizomes, like those of ginger, are horizontal stems that grow underground. Tubers, including potatoes, are the swollen ends of rhizomes specialized for food storage. Bulbs, such as onions, are vertical, underground shoots consisting mostly of the swollen bases of leaves that store food.

Leaves are the main photosynthetic organs of most plants, although green stems are also photosynthetic. While leaves vary extensively in form, they generally consist of a flattened blade and a stalk, the petiole, which joins the leaf to a stem node. Grasses and other monocots lack petioles. In these plants, the base of the leaf forms a sheath that envelops the stem. Most monocots have parallel major veins that run the length of the blade, while eudicot leaves have a multi-branched network of major veins.

Plant taxonomists use floral morphology, leaf shape, spatial arrangement of leaves, and the pattern of veins to help identify and classify plants. For example, simple leaves have a single, undivided blade, while compound leaves have several leaflets attached to the petiole. The leaflet of a compound leaf has no axillary bud at its base. In a doubly compound leaf, each leaflet is divided into smaller leaflets. Most leaves are specialized for photosynthesis. Some plants have leaves that have become adapted for other functions. These include tendrils that cling to supports, spines of cacti for defense, leaves modified for water storage, and brightly coloured leaves that attract pollinators.

6.5 Plant tissue systems

Each and every organ of a plant has three tissue systems: dermal, vascular, and ground. Each system is continuous throughout the plant body.

The **dermal tissue** is the outer covering. In non-woody plants, it is a single layer of tightly packed cells, or epidermis, which covers and protects all young parts of the plant. The epidermis has other specialized characteristics consistent with the function of the organ it covers. For example, the root hairs are extensions of epidermal cells near the tips of the roots. The epidermis of leaves and most stems secretes a waxy coating, the cuticle, which helps the aerial parts of the plant retain water. In woody plants, protective tissues called periderm replace the epidermis in older regions of stems and roots.

Vascular tissue, continuous throughout the plant, is involved in the transport of materials between roots and shoots. Xylem conveys water and dissolved minerals upward from roots into the shoots. Phloem transports food made in mature leaves to the roots; to nonphotosynthetic parts of the shoot system; and to sites of growth, such as developing leaves and fruits. The vascular tissue of a root or stem is called the stele. In angiosperms, the vascular tissue of the root forms a solid central vascular cylinder, while stems and leaves have vascular bundles, strands consisting of xylem and phloem.

Ground tissue is tissue that is neither dermal tissue nor vascular tissue. In eudicot stems, ground tissue is divided into pith, internal to vascular tissue, and cortex, external to the vascular tissue. The functions of ground tissue include photosynthesis, storage, and support. For example, the cortex of a eudicot stem typically consists of both fleshy storage cells and thick-walled support cells.

6.6 Cells types

Plant cells are differentiated, with each type of plant cell possessing structural adaptations that make specific functions possible. Cell differentiation may be evident within the protoplast, the cell contents exclusive of the cell wall. Modifications of cell walls also play a role in plant cell differentiation. We will consider the major types of differentiated plant cells:

parenchyma, collenchyma, sclerenchyma, water-conducting cells of the xylem and sugar-conducting cells of the phloem.

Mature **parenchyma cells** have primary walls that are relatively thin and flexible, and most lack secondary walls. The protoplast of a parenchyma cell usually has a large central vacuole. Parenchyma cells are often depicted as “typical” plant cells because they generally are the least specialized, but there are exceptions. For example, the highly specialized sieve-tube members of the phloem are parenchyma cells. Parenchyma cells perform most of the metabolic functions of the plant, synthesizing and storing various organic products. For example, photosynthesis occurs within the chloroplasts of parenchyma cells in the leaf. Some parenchyma cells in the stems and roots have colourless plastids that store starch. The fleshy tissue of most fruit is composed of parenchyma cells. Most parenchyma cells retain the ability to divide and differentiate into other cell types under special conditions, such as the repair and replacement of organs after injury to the plant. In the laboratory, it is possible to regenerate an entire plant from a single parenchyma cell.

Collenchyma cells have thicker primary walls than parenchyma cells, though the walls are unevenly thickened. Grouped into strands or cylinders, collenchyma cells help support young parts of the plant shoot. Young stems and petioles often have strands of collenchyma just below the epidermis, providing support without restraining growth. Mature collenchyma cells are living and flexible and elongate with the stems and leaves they support.

Sclerenchyma cells have thick secondary walls usually strengthened by lignin and function as supporting elements of the plant. They are much more rigid than collenchyma cells. Unlike parenchyma cells, they cannot elongate. Sclerenchyma cells occur in plant regions that have stopped lengthening. Many sclerenchyma cells are dead at functional maturity, but they produce rigid secondary cells walls before the protoplast dies. In parts of the plant that are still elongating, secondary walls are deposited in a spiral or ring pattern, enabling the cell wall to stretch like a spring as the cell grows. Two types of sclerenchyma cells, fibers and sclereids, are specialized entirely for support. Fibers are long, slender, and tapered, and usually occur in groups. Those from hemp fibers are used for making rope, and those from flax are woven into linen. Sclereids are irregular in shape and are shorter than fibers. They have very thick, lignified secondary walls. Sclereids impart hardness to nutshells and seed coats and the gritty texture to pear fruits. The water-conducting elements of xylem, the tracheids and vessel elements, are elongated cells that are dead at functional maturity. The thickened cell walls remain as a non-living conduit through which water can flow. Both tracheids and vessels have secondary walls interrupted by pits, thinner regions where only primary walls are present. Tracheids are long, thin cells with tapered ends. Water moves from cell to cell mainly through pits. Because their secondary walls are hardened with lignin, tracheids function in support as well as transport.

Vessel elements are generally wider, shorter, thinner walled, and less tapered than tracheids. Vessel elements are aligned end to end, forming long micropipes or xylem vessels. The ends are perforated, enabling water to flow freely. In the phloem, sucrose, other organic compounds, and some mineral ions move through tubes formed by chains of cells called sieve-tube members. These are alive at functional maturity, although a sieve-tube member lacks a nucleus, ribosomes, and a distinct vacuole. The end walls, the sieve plates, have pores that facilitate the flow of fluid between cells. Each sieve-tube member has a non-conducting nucleated companion cell, which is connected to the sieve-tube member by numerous plasmodesmata. The nucleus and ribosomes of the companion cell serve both that cell and the adjacent sieve-tube member. In some plants, companion cells in leaves help load sugar into the sieve-tube members, which transport the sugars to other parts of the plant.

6.7 Meristems generate cells for new organs

Recommended reading: pages 824–825 chapter 35 in Campbell et al. (2015)

A major difference between plants and most animals is that plant growth is not limited to an embryonic period. Most plants demonstrate indeterminate growth, growing as long as the plant lives. In contrast, most animals and certain plant organs, such as flowers and leaves, undergo determinate growth, ceasing to grow after they reach a certain size. Indeterminate growth does not mean immortality. Annual plants complete their life cycle—from germination through flowering and seed production to death—in a single year or less. Many wildflowers and important food crops, such as cereals and legumes, are annuals. The life of a biennial plant spans two years. Often, there is an intervening cold period between the vegetative growth season and the flowering season.

Plants such as trees, shrubs, and some grasses that live many years are perennials. Perennials do not usually die from old age, but from an infection or some environmental trauma. A plant is capable of indeterminate growth because it has perpetually embryonic tissues called meristems in its regions of growth. These cells divide to generate additional cells, some of which remain in the meristematic region, while others become specialized and are incorporated into the tissues and organs of the growing plant. Cells that remain as wellsprings of new cells in the meristem are called initials. Those that are displaced from the meristem, derivatives, continue to divide for some time until the cells they produce differentiate within developing tissues. The pattern of plant growth depends on the location of meristems. Apical meristems, located at the tips of roots and in the buds of shoots, supply cells for the plant to grow in length. This elongation, primary growth, enables roots to extend through the soil and shoots to increase their exposure to light and carbon dioxide. In herbaceous plants, primary growth produces almost all of the plant body.

Woody plants also show secondary growth, progressive thickening of roots and shoots where primary growth has ceased. Secondary growth is produced by lateral meristems, cylinders of dividing cells that extend along the length of roots and shoots. The vascular cambium adds layers of vascular tissue called secondary xylem and phloem. The cork cambium replaces the epidermis with thicker, tougher periderm.

In woody plants, primary growth produces young extensions of roots and shoots each growing season, while secondary growth thickens and strengthens the older parts of the plant. At the tip of a winter twig of a deciduous tree is the dormant terminal bud, enclosed by bud scales that protect its apical meristem. In the spring, the bud will shed its scales and begin a new spurt of primary growth. Along each growth segment, nodes are marked by scars left when leaves fell in autumn. Above each leaf scar is either an axillary bud or a branch twig. Farther down the twig are whorls of scars left by the scales that enclosed the terminal bud during the previous winter.

Each spring and summer, as the primary growth extends the shoot; secondary growth thickens the parts of the shoot that formed in previous years.

6.8 Primary growth lengthens roots and shoots

Recommended reading: pages 825–829 chapter 35 in Campbell et al. (2015)

Primary growth produces the primary plant body, the parts of the root and shoots systems produced by apical meristems. An herbaceous plant and the youngest parts of a woody plant represent the primary plant body.

Apical meristems lengthen both roots and shoots. However, there are important differences in the primary growth of these two systems. The root tip is covered by a thimble-like root cap, which protects the meristem as the root pushes through the abrasive soil during primary growth. The cap also secretes a polysaccharide slime that lubricates the soil around the growing root tip.

Growth in length is concentrated just behind the root tip, where three zones of cells at successive stages of primary growth are located. These zones—the zone of cell division, the zone of elongation, and the zone of maturation—grade together. The zone of cell division includes the root apical meristem and its derivatives. New root cells are produced in this region, including the cells of the root cap. The zone of cell division blends into the zone of elongation where cells elongate, sometimes to more than ten times their original length. It is this elongation of cells that is mainly responsible for pushing the root tip, including the meristem, ahead. The meristem sustains growth by continuously adding cells to the youngest end of the zone of elongation. In the zone of maturation, cells become differentiated and become functionally mature.

The primary growth of roots consists of the epidermis, ground tissue, and vascular tissue. Water and minerals absorbed from the soil must enter through the epidermis, a single layer of cells covering the root. Root hairs greatly increase the surface area of epidermal cells. Most roots have a solid core of xylem and phloem. The xylem radiates from the centre in two or more spokes, with phloem developing in the wedges between the spokes.

In monocot roots, the vascular tissue consists of a central core of parenchyma surrounded by alternating patterns of xylem and phloem. The ground tissue of roots consists of parenchyma cells that fill the cortex, the region between the vascular cylinder and the epidermis. Cells within the ground tissue store food and are active in the uptake of minerals that enter the root with the soil solution. The innermost layer of the cortex, the endodermis, is a cylinder one cell thick that forms a selective barrier between the cortex and the vascular cylinder.

An established root may sprout lateral roots from the outermost layer of the vascular cylinder, the pericycle. The vascular tissue of the lateral root maintains its connection to the vascular tissue of the primary root. The apical meristem of a shoot is a dome-shaped mass of dividing cells at the terminal bud. Leaves arise as leaf primordia on the flanks of the apical meristem. Axillary buds develop from islands of meristematic cells left by apical meristems at the bases of the leaf primordia. Within a bud, leaf primordia are crowded close together because internodes are very short.

Most of the elongation of the shoot occurs by growth in length of slightly older internodes below the shoot apex. This growth is due to cell division and cell elongation within the internode. In some plants, including grasses, internodes continue to elongate all along the length of the shoot over a prolonged period. These plants have meristematic regions called intercalary meristems at the base of each leaf. This explains why grass continues to grow after being mowed. Unlike their central position in a root, vascular tissue runs the length of a stem in strands called vascular bundles. Because the vascular system of the stem is near the surface, branches can develop with connections to the vascular tissue without having to originate from deep within the main shoot.

In gymnosperms and most eudicots, the vascular bundles are arranged in a ring, with pith inside and cortex outside the ring. The vascular bundles have xylem facing the pith and phloem facing the cortex. In the stems of most monocots, the vascular bundles are scattered throughout the ground tissue rather than arranged in a ring. In both monocots and eudicots, the stem’s ground tissue is mostly parenchyma.

Many stems are strengthened by collenchyma just beneath the epidermis. Sclerenchyma fibre cells within vascular bundles also help support stems. The leaf epidermis is composed of cells tightly locked together like pieces of a puzzle. The leaf epidermis is the first line of defense against physical damage and pathogenic organisms, and its waxy cuticle is a barrier to water loss from the plant. The epidermal barrier is interrupted only by the stomata, tiny pores flanked by specialized epidermal cells called guard cells.

Each stoma is an opening between a pair of guard cells that regulate the opening and closing of the pore. The stomata regulate CO_2 exchange between the surrounding air and the photosynthetic cells inside the leaf. They are also the major avenues of evaporative water loss from the plant—a process called transpiration. The ground tissue of the leaf, the mesophyll, is sandwiched between the upper and lower epidermis. It consists mainly of parenchyma cells with many chloroplasts and specialized for photosynthesis.

In many eudicots, a layer or more of columnar palisade mesophyll lies over spongy mesophyll. Carbon dioxide and oxygen circulate through the labyrinth of air spaces around the irregularly spaced cells of the spongy mesophyll. The air spaces are particularly large near stomata, where gas exchange with the outside air occurs. The vascular tissue of a leaf is continuous with the xylem and phloem of the stem. Leaf traces, branches of vascular bundles in the stem, pass through petioles and into leaves.

Vascular bundles in the leaves are called veins. Each vein is enclosed in a protective bundle sheath consisting of one or more layers of parenchyma. Within a leaf, veins subdivide repeatedly and branch throughout the mesophyll. The xylem brings water and minerals to the photosynthetic tissues and the phloem carries sugars and other organic products to other parts of the plant. The vascular infrastructure also functions to support and reinforce the shape of the leaf.

6.9 Secondary growth adds girth to stems and roots in woody plants

Recommended reading: pages 829–833 chapter 35 in Campbell et al. (2015)

The stems and roots of most eudicots increase in girth by secondary growth. The secondary plant body consists of the tissues produced during this secondary growth in diameter. Primary and secondary growth occurs simultaneously but in different regions. While elongation of the stem (primary growth) occurs at the apical meristem, increases in diameter (secondary growth) occur farther down the stem. The vascular cambium is a cylinder of meristematic cells that forms secondary vascular tissue. It forms successive layers of secondary xylem to its interior and secondary phloem to its exterior.

The accumulation of this tissue over the years accounts for most of the increase in diameter of a woody plant. The vascular cambium develops from parenchyma cells that retain the capacity to divide. This meristem forms in a layer between the primary xylem and primary phloem of each vascular bundle and in the ground tissue between the bundles.

The meristematic bands unite to form a continuous cylinder of dividing cells. This ring of vascular cambium consists of regions of ray initials and fusiform initials. The tapered, elongated cells of the fusiform initials form secondary xylem to the inside of the vascular cambium and secondary phloem to the outside.

Ray initials produce vascular rays that transfer water and nutrients laterally within the woody stem and also store starch and other reserves. As secondary growth continues over the years, layer upon layer of secondary xylem accumulates, producing the tissue we call wood. Wood consists mainly of tracheids, vessel elements (in angiosperms), and fibers. These cells, dead at functional maturity, have thick, lignified walls that give wood its hardness and strength.

In temperate regions, secondary growth in perennial plants ceases during the winter. The first tracheid and vessel cells formed in the spring (early wood) have larger diameters and thinner walls than cells produced later in the summer (late wood). The structure of the early wood maximizes delivery of water to new, expanding leaves.

The thick-walled cells of later wood provide more physical support. This pattern of growth—cambium dormancy, early wood production, and late wood production—produces annual growth rings. As a tree or woody shrub ages, the older layers of secondary xylem, known as heartwood, no longer transport water and minerals. The outer layers, known as sapwood, continue to transport xylem sap. Only the youngest secondary phloem, closest to the vascular cambium, functions in sugar transport. The older secondary phloem dies and is sloughed off as part of the bark.

The cork cambium acts as a meristem for a tough, thick covering for stems and roots that replaces the epidermis. Early in secondary growth, the epidermis produced by primary growth splits, dries, and falls off the stem or root. It is replaced by two tissues produced by the first cork cambium, which arises in the outer cortex of stems and in the outer layer of the pericycle of roots.

The first tissue, phelloderm, is a thin layer of parenchyma cells that forms to the interior of the cork cambium. Cork cambium also produces cork cells, which accumulate at the cambium's exterior.

Waxy material called suberin deposited in the cell walls of cork cells before they die acts as a barrier against water loss, physical damage, and pathogens. The cork plus the cork cambium form the periderm, a protective layer that replaces the epidermis.

In areas called lenticels, spaces develop between the cork cells of the periderm. These areas within the trunk facilitate gas exchange with the outside air. Unlike the vascular cambium, cells of the cork cambium do not divide. The thickening of a stem or root splits the first cork cambium, which loses its meristematic activity and differentiates into cork cells.

A new cork cambium forms to the inside, resulting in a new layer of periderm. As this process continues, older layers of periderm are sloughed off. This produces the cracked, peeling bark of many tree trunks. Bark refers to all tissues external to the vascular cambium, including secondary phloem, cork cambium, and cork.

6.10 Activity 6.1

Do this activity and add it to your portfolio.

Refer to your textbook and answer the following questions:

b. What is the general function of stems? What are some specialized evolutionary adaptations of stems?
d. What is the advantage of apical dominance to a plant?
f. What are five additional functions that modified leaves can perform?
h. Plants have three types of tissues. Place the name of each tissue type and its function in the table below.

Tissue Type Function	Tissue Type Function

e. Explain the following relationships:

-apical meristems and primary growth

-lateral meristems and secondary growth

-primary growth and secondary growth

f. Explain what events occur in the zone of cell division, zone of elongation, and zone of differentiation.
g. Why must new roots formed by the pericycle originate in the centre of the root?

h. How is the arrangement of vascular bundles different in monocot and dicot stems?

6.11 Feedback on activity 6.1

When answering question a), keep in mind that the stem raises or separates leaves, exposing them to sunlight. Stems also raise reproductive structures, facilitating the dispersal of pollen and fruit.

b) Apical dominance is the tendency for growth to be concentrated at the tip of a plant shoot, because the apical bud partially inhibits axillary bud growth. Removing the apical bud stimulates growth of auxiliary buds, regulating the growth of a plant in case a shoot is eaten, or the plant loses sunlight.

c) The five additional functions that modified leaves can perform are support, protection, storage, reproduction and attract pollination.

d)

Tissue Type Function	Tissue Type Function
Dermal tissue system	Plant’s outer protective covering
Vascular tissue system	Carries out long-distance transport of materials between root and shoot systems
Ground tissue system	Includes various cells specialized for functions such as storage, photosynthesis, and support

e) Below is how you should explain the relationship between the two processes:

Apical meristems and **primary growth**: Apical meristems, located at the tips of roots and shoots and in axillary buds or shoots, provide additional cells that enable growth in length, also called primary growth.

Lateral meristems and **secondary growth**: Growth in thickness, known as secondary growth, is caused by lateral meristems called the vascular cambium and cork cambium.

Primary growth and **secondary growth**: Primary growth allows roots to extend throughout the soil and shoots to increase their exposure to light. Woody plants also grow in circumference in the parts of stems and roots that no longer grow in length; this growth in thickness is called secondary growth.

f) **Zone of cell division**: New roots are produced. **Zone of elongation**: Growth occurs and new root cells elongate. **Zone of differentiation**: Cells complete differentiation and become distinct cell types.

In answering question (g), you should bear in mind that in order for the vascular tissue of the new root and the original root to be continuous, the new root must originate from the centre of the original root (recall that the vascular tissue in the root is in the centre, or stele, of the root).

h) In most eudicot species, the vascular tissue consists of vascular bundles arranged in a ring. In most monocot stems, the vascular bundles are scattered throughout the ground tissue rather than forming a ring.

6.12 Summary

Vascular plants have shoots of stems, leaves, and in angiosperms, flowers. Roots anchor the plant, absorb and conduct water and minerals, and store food. Plants have three tissue systems dermal, vascular and ground. Parenchyma cells are relatively unspecialised and thin-walled cells that retain the ability to divide; they perform most of the metabolic functions of synthesis and storage. Whereas, collenchyma cells have unevenly thickened walls. Their function is to support young, growing parts of plant. Sclerenchyma cells, which consist of sclereids and fibres, have thick, lignified walls that help support mature, non-growing parts of the plant.

The root apical meristem is located near the tip of the root, where it generates cells for the growing root axis and the root cap. The apical meristem of a shoot is located in the bud, where it gives rise to alternating internodes and leaf-bearing nodes. Eudicot stems have vascular bundles in a ring, whereas monocot stems have scattered vascular bundles.

Cell division and cell expansion are the primary determinants of growth. A preprophase band of microtubules determines where a cell plate will form in a dividing cell. Microtubules orientation also affects the direction of cell elongation by controlling the orientation of cellulose microfibrils in the cell wall. Morphogenesis the development of body shape and organisation depends on cells responding to positional information from neighbours. Cell differentiation, arising from differential gene activation, enables cells within the plant to assume different functions despite having identical genomes. The manner in which a plant cell differentiates is determined largely by the cell’s position in the developing plant.