RHS Level 3 Certificate
Principles of Plant Growth, Health and Applied Propagation

1: Plant Taxonomy, Structure and Function

Courses for Royal Horticultural Society Qualifications

2. Understand the structure and function of plant tissues and organs in the life of the plant.

Plant tissues

This outcome moves on from the basic knowledge of plant cells and tissues required for Level 2 to look in detail at secondary thickening and growth in dicots, and at the changes that take place in the plant tissues during this process. Notes on cells and tissues from the RHS Level 2 Certificate are repeated here.

Inflorescences, pollination, fertilisation and fruits

This section builds on level 2 studies of flowers and fruit to look at

- The different types of inflorescence,
- Flower adaptations for pollinators
- The process of fertilisation
- Types of fruit

At level 3, the technical terms for tissues, fruit forms, inflorescences etc are used, and you are expected to show that you understand them in in your answers, so there are a lot of definitions and names to cover in this outcome.

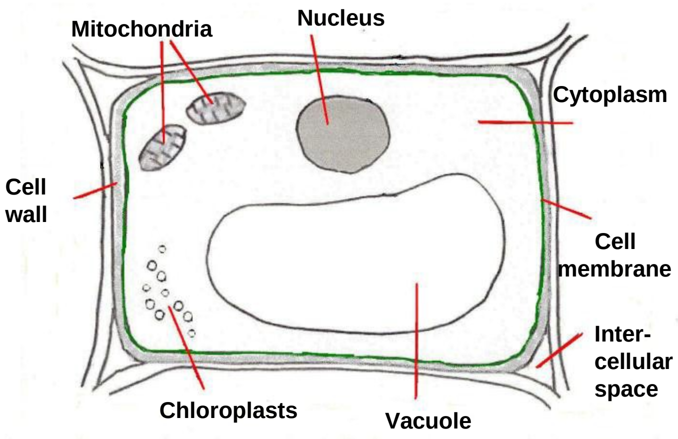
Contents

Tip for pdfs: you can move easily to each of these sections using the 'bookmarks' feature at the side of the pdf, or go to individual pages using the thumbnails.

Outcome 2: Know the structure and function of plant tissues and organs in the life of the plant: recap on level 2 cell notes

Plant Cells

The cell is the basic unit of all plant structures, just as it is for animals. Cells are the basic building blocks of life.



Robert Hooke first described cells in 1665, using an early microscope. With the advent of electron microscopes, much more detail has been discovered.

***Parts of the cell and their functions*:**

- **Cell wall**

This is made of cellulose. Its function is to protect and contain the contents of the cell. It is permeable, allowing gases and liquids through.

The support and rigidity it gives the plant depends on the thickness of the cell wall. For example, a leaf has relatively thin-walled cells, a woody stem has relatively thick cell walls.

As the cell wall thickens, more cellulose is added, and then lignin, which hardens and becomes woody.

Cell wall
Cellulose

Structural support and protection

Permeable to gases and liquids

- **Cell membrane**, sometimes termed the *cytoplasmic membrane*, or *plasma membrane***,** or *plasmalemma* in some books.

This is a membrane inside the cell wall which is semi-permeable: not everything can pass through.

It controls the movement of substances in and out of the cell, i.e. water, foods and minerals.

> ***Cell membrane***
>
> **Semi-permeable**
>
> **Controls movement in and out of cell**

- **Cytoplasm** - this is situated inside the plasma membrane.

It is a colloid, or jelly-like material and contains all the small bodies (***organelles***) which specialise in different functions for the plant.

> ***Cytoplasm***
>
> **Jelly-like cell contents in which organelles are located**

- **Nucleus** - this controls the activity of a cell.

It contains DNA, the plant's coded genetic material.

> ***Nucleus***
> **Cell control centre, DNA**

- **Vacuole** - a large, permanent, fluid-filled cavity.

The fluid may contain salts, sugars, and pigments dissolved in water.

The vacuole may develop to occupy the greater part of a cell. The outward pressure of the vacuole holds the plant cell firm (turgid).

> ***Vacuole***
>
> **Fluid-filled cavity**
> **Holds cell turgid**

- **Chloroplast** - an organelle that contains the green pigment, chlorophyll.

Chlorophyll is vital for photosynthesis, as it has the ability to capture light energy.

Chlorophyll is the pigment which gives plants their green colour. Chloroplasts are found mainly in leaves, sometimes in stems, but generally not in roots.

> ***Chloroplasts***
>
> **Organelles with green pigment**
>
> **Sites of photosynthesis**

- **Mitochondrion** (plural **mitochondria**) - an organelle with folded membranes that is involved in the process of respiration

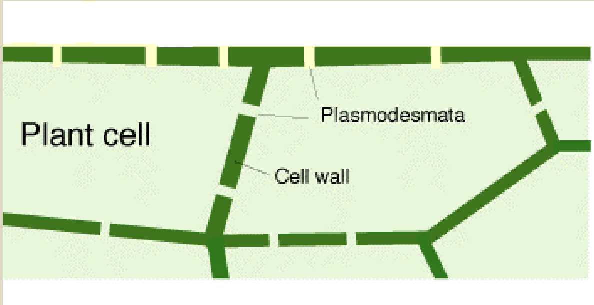
> ***Mitochondria***
>
> **Organelles**
> **Sites of respiration**

- **Intercellular space-** where three cells join, there are significant spaces which allow gases to diffuse around the cells.

Bridges between cells
(this is background information, not in the assessment criteria, but helps with terms you may find in your background reading for this topic.)

- Where adjacent cells touch, they are glued together by a thin layer called the *middle lamella***,** made of pectin.
  Pectin is a polysaccharide and an important part of all plant cell walls, but it may also be familiar to you in the form extracted from citrus fruits to help set jams.)

- There are microscopic tubes called *plasmodesmata (singular is plasmodesma)* which perforate the cell walls and make connections between the contents of adjacent cells, allowing substances to move between cells and making links in the contents where cells are acting together to form tissues. You may also see them called *microtubules* in some textbooks.



Cells and Tissues

Cells are grouped together to form different types of tissue within the plant.

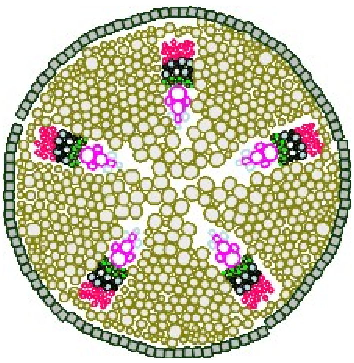
Simple tissue is formed from one type of cell only, **complex tissue** from more than one type of cell.

Tissues –

a collection of similar cells that group together to perform a specialised function.

Protective tissue (*dermal* or *epidermal* tissue)

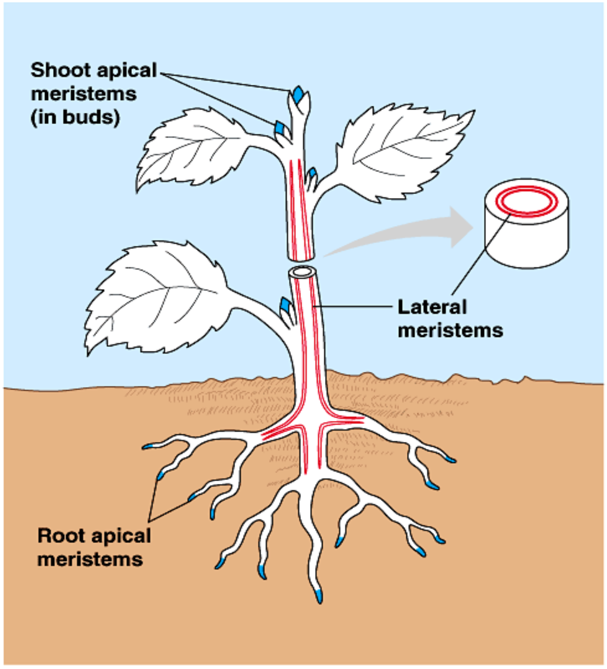
An outer, close-packed layer of cells around **all** parts of the plant – leaves, stems, roots, flowers, etc. This thin layer of tissue protects the plant from water loss or disease, for example the ***epidermis*** of a plant's leaves secretes a coating called the cuticle that helps the plant retain water. It is the equivalent of skin in animals.



In woody stems the bark (*Periderm*) is a protective tissue.

Meristematic tissue

This is called the **cambium**. It is the area of active cell division at the **primary meristems** found at the growing tips of roots and shoots, and in the **lateral meristem** that allows for stem thickening, the **vascular cambium**. [*This is discussed in more detail in outcome 9 on lignification and in the powerpoint on tissues*.]



Cell division at meristems is by mitosis

Primary growth: Apical meristems

Secondary growth: Lateral meristems

Secondary growth takes place in both dicotyledonous plants and gymnosperms (conifers).

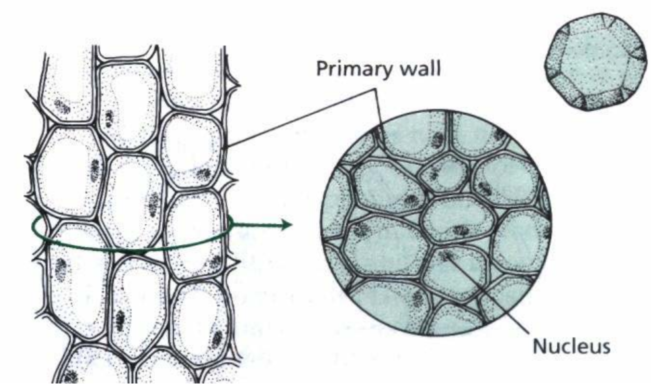
Apart from this there are three main types of simple tissue***:***

Packing or background tissue (*Parenchyma*)

The most common type of tissue, making up the bulk of the plant.

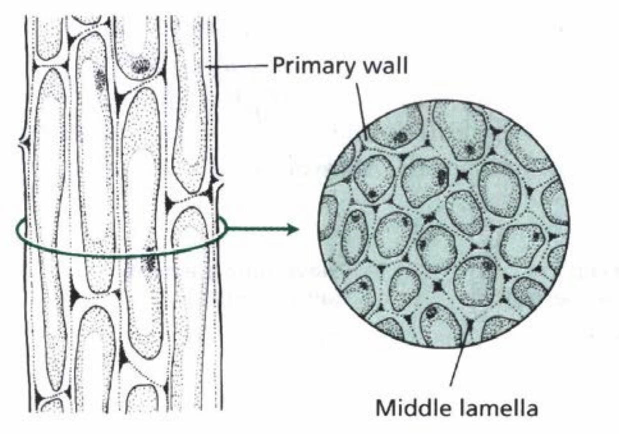
It is used for storage of nutrients; the cells contain organelles which allow the plant to respire (mitochondria) and also some contain choloroplasts for photosynthesis (green tissue only).

It has thin primary cell walls of cellulose and a live nucleus.



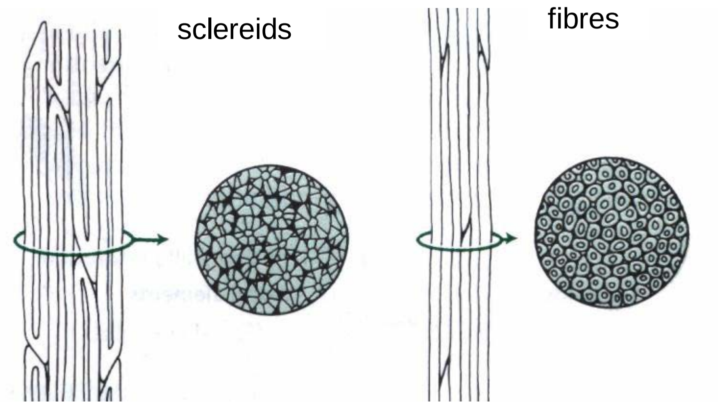
Support tissue (*Collenchyma*)

This tissue is most commonly found in young plants; the cells have thickened walls with extra cellulose to help support the plant but the cell walls are not yet hardened by lignin, and so growth can continue. It is often found at the growing points of the plant (meristems).



Strengthening tissue (*Sclerenchyma***)**

Cells in this tissue are found in stems, roots and leaves. The cellulose cell wall thickens and develops a secondary wall impregnated with lignin which strengthens it, but eventually kills the cell nucleus, leaving a dead cell.



Strengthening tissue is found in two forms:

- Either as elongated cells which form **fibres** - many plants such as flax, hemp, nettle, sisal, etc have been used to produce rope, string or canvas for thousands of years.

- Or as small toughened gritty bodies called **sclereids**. These form part of nut shells, the stones in fruits such as peaches, and sometimes in toughened leaf edges in plants such as *Camellia*. They are also randomly distributed through other tissues in the fruit of pears – they are responsible for the gritty texture.

Simple tissues			
Protective or dermal	epidermal	On the surface of all of the plant	Thin cell walls, live, may be specialised to be water resistant (cuticle); as periderm (bark) dead at maturity
Dividing or meristematic	meristematic	At growing points or meristems	Live cells, thin cell walls, actively dividing
Packing or background or ground	*parenchyma*	Throughout the plant for storage	Live cells, thin cell walls, containing organelles for respiration and in some parts of the plant for photosynthesis
Support	*collenchyma*	Young plant tissue, particularly near growing points	Live cells, cell walls thickened with extra cellulose
Strengthening	*sclerenchyma*	Leaves, stems etc As fibres In nuts, shells or fruit as sclereids	Cells are dead when mature and thickened with a secondary cell wall of lignin. (remember they START OUT live).

Complex tissues

Transport or **vascular tissue**

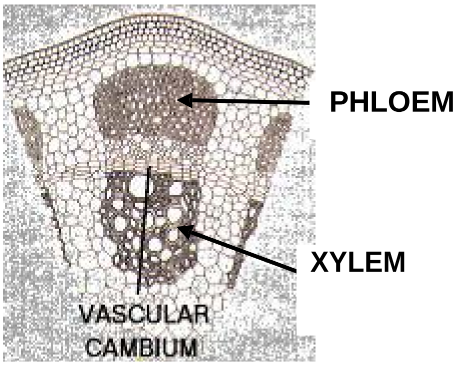
This conducts liquid and food round the plant, like the vascular (blood) supply in a human body. The plant's transport system is vital in connecting leaves, stem and roots.

Both monocots and dicots contain vascular bundles.
The dicot vascular system is made up of three types of tissue:

phloem , **xylem** and **cambium**, the layer of actively dividing, meristematic cells which produces new phloem and xylem cells.

Dicot vascular bundles consist of **phloem xylem** and **cambium**

Together these form **vascular bundles**.

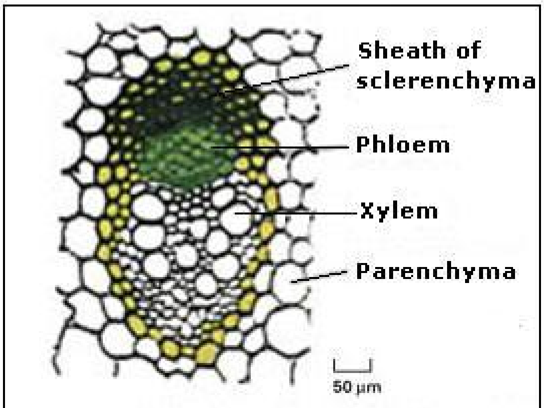


The ***phloem*** is in the upper part: it consists of tightly packed food cells.

The ***xylem*** is the lower part and consists of larger water conducting cells.

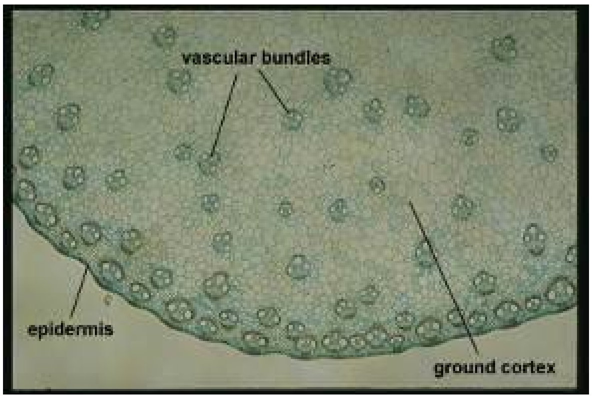
The row of cells between the phloem and xylem is the ***vascular cambium*** responsible for the provision of new cells.

In monocots they are strengthened with *sclerenchyma* in a *bundle cap or sheath* to help give the stem rigidity.

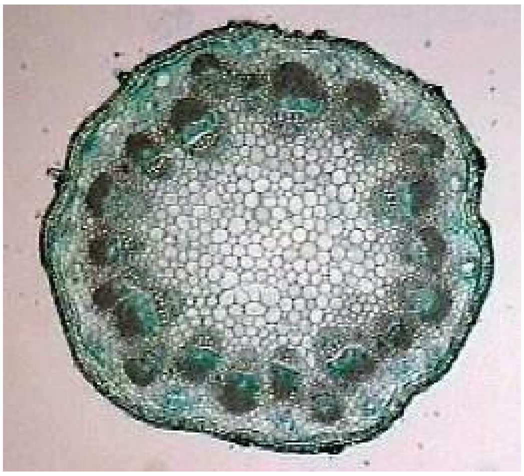


A typical vascular bundle from the young stem of a buttercup

Monocot vascular bundles consist of **phloem** and **xylem** tissue with strengthening fibres.



Monocot vascular bundles are scattered throughout the stem.
Image: http://www.puc.edu/Faculty/Gilbert_Muth/phot0003.jpg

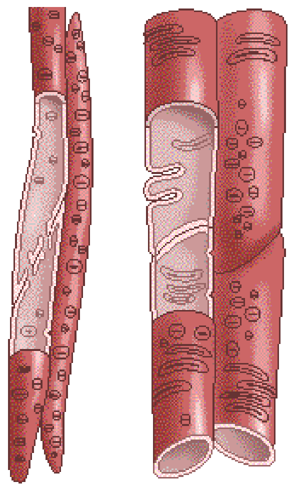


Dicot vascular bundles are arranged in a ring in the stem – the cambium will form new xylem and phloem, so that the bundles will eventually join up in the process of secondary thickening which allows woody growth.
Image: http://www.lima.ohio-state.edu/biology/images/dicotstem.jpg

Both the phloem and xylem consist of more than on type of cell.

Xylem consists of **vessels or vessel elements,** which are short, wide cells with perforated end walls, heavily strengthened withlignin and strung end to end to make continuous "tubes" for conducting water throughout the plant. These are dead cells at maturity with no nucleus.
Vessels are the principal water-conducting cells in the Flowering plants, the angiosperms.

More primitive conducting cells called **tracheids** exist alongside them and are the only water conducting cells found in conifers (gymnosperms) ; tracheids don't have perforated ends, just pits in the sides of the cells, and they overlap with one another so that water is conducted along stems. This is less efficient than the perforated tubes of the vessels. Tracheids are also dead at maturity – the nucleus is killed by the strengthening process.



Left, tracheids; right, vessel elements
http://www.phschool.com/science/biology_place/biocoach/images/plants/Trachves.gif

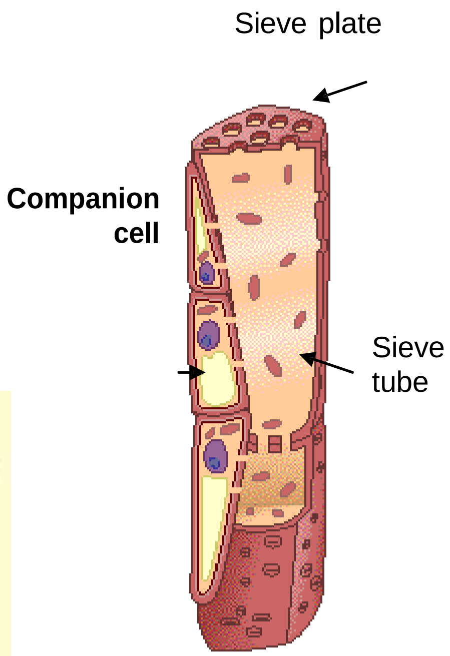
Xylem tissue also includes strengthening and packing tissues.

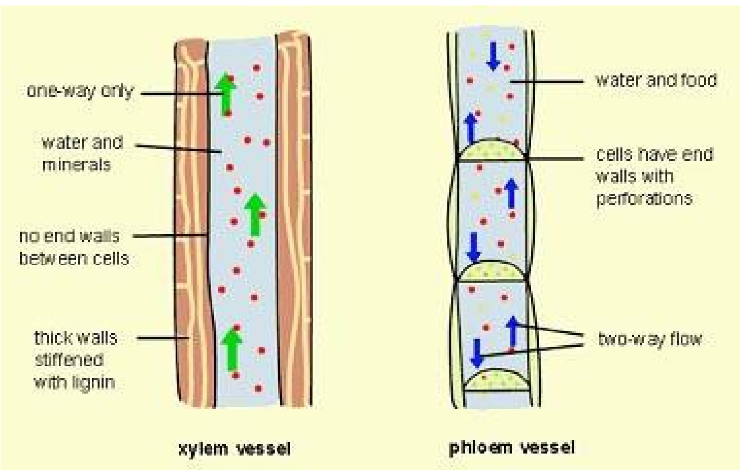
Phloem consists of **companion cells** and **sieve tubes**.

Companion cells are live cells with a nucleus**. Sieve tubes** have no nucleus so are dead cells.

The end walls of the sieve tube cells have pores (sieve plates) through which food is transported from cell to cell in the form of dissolved sugars.

The companion cell is thought to provide the energy to maintain the sieve tube cell.





Xylem and phloem: Transport tissue Image from http://www.tantebazar.com/imgx/vascular_plant_tissue_1.jpg

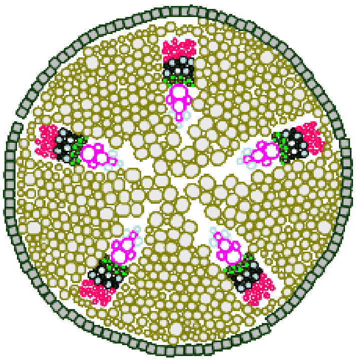
2.1 Identify a range of plant tissues and describe their structure and function.

Tissues
Tissues - a collection of similar cells that group together to perform a specialised function.

Simple tissues:

Protective tissue (*dermal* or *epidermal* tissue)

An outer, close-packed layer of cells around **all** parts of the plant – leaves, stems, roots, flowers, etc. This thin layer of tissue protects the plant from water loss or disease, for example the ***epidermis*** of a plant's leaves secretes a coating called the cuticle that helps the plant retain water. It is the equivalent of skin in animals.

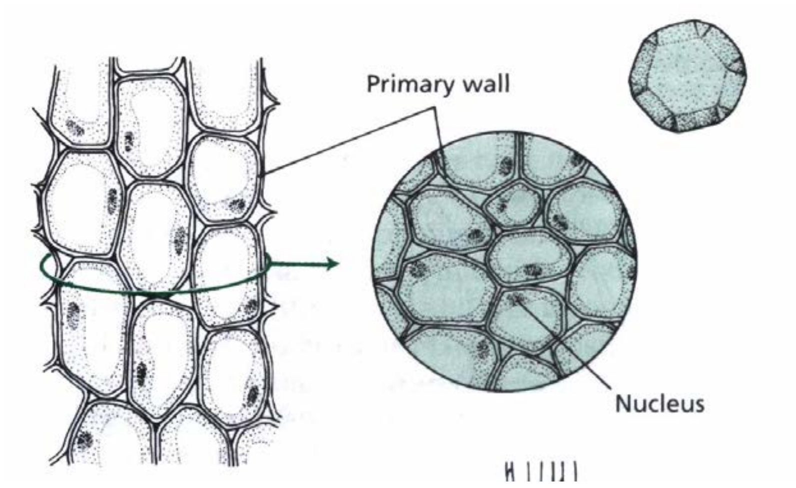


In woody stems the bark (*Periderm*) is a secondary protective tissue – this will be discussed later.

Apart from this there are **three main types of simple tissue:**

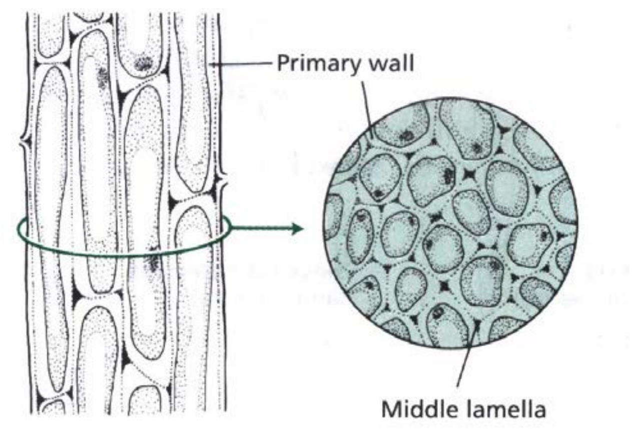
Parenchyma

The most common type of tissue – 'background' tissue.
It is used for storage of nutrients and adapted for more specialist functions such as photosynthesis and respiration.



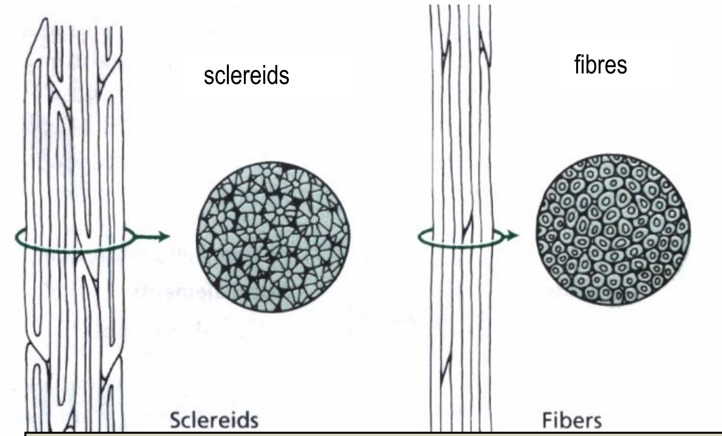
Collenchyma

Support tissue, with thickened cells walls. Often found at the growing points of the plant (meristems).



Sclerenchyma

Cells in this tissue are found in stems, roots and leaves. As the cell wall thickens it produces a substance called lignin which strengthens it, but eventually kills the cell nucleus, leaving a dead cell.



Simple tissues	
Parenchyma	**Live cells, thin walls** **Background tissue**
Collenchyma	**Live cells, thickened walls** **Support tissue**
Sclerenchyma	**Dead cells (when mature)** **Strengthening tissue**

Cell walls and secondary thickening

- When a cell is first formed, the walls are thin and mainly composed of cellulose.
- **This is the primary wall.**
- However with time the cell wall may thicken as more cellulose is produced, and eventually a hardening substance called **lignin** may be introduced.
- This is the basis of **secondary thickening in woody plants.**
- Secondary thickening only happens in **dicots.**

Plant Growth

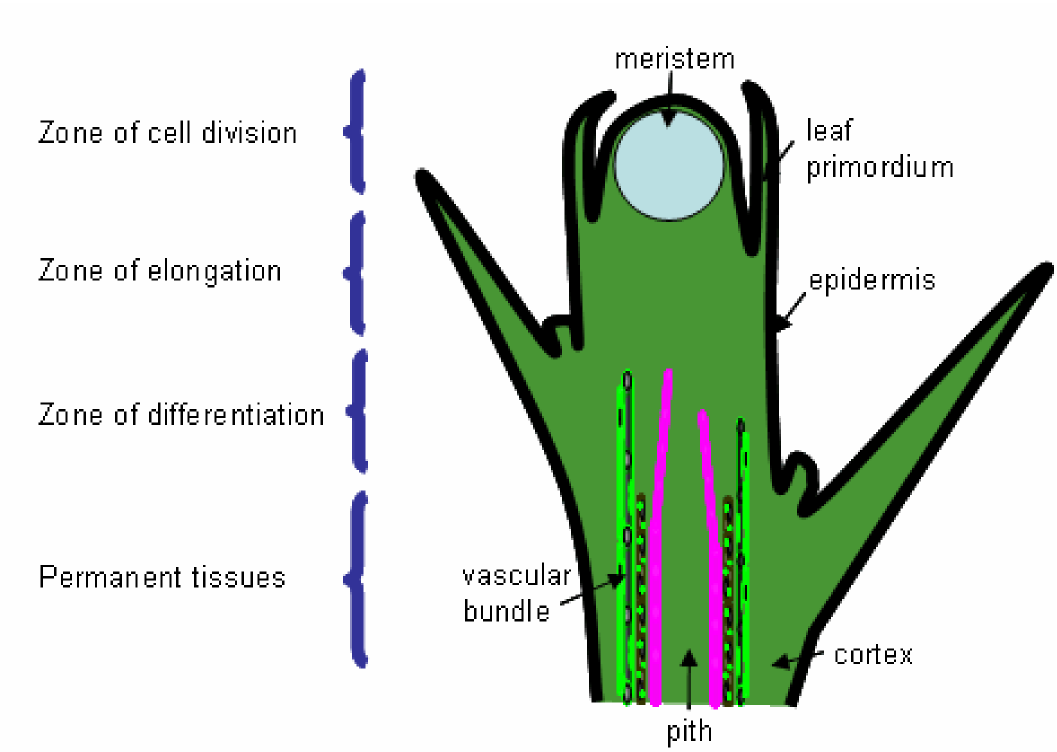
Plants grow by increasing the size of their existing cells but chiefly by creating new cells by **cell division.** The areas of the plant where active cell division is taking place are called **meristems.**

Apical meristems are found at the shoot and root apex (tip).

Primary growth takes place at these meristems causing the shoot and root to lengthen.

Cell division is followed by cell **elongation** and cell **differentiation**, where the cells form differing types of tissues; this takes place in the region immediately behind the meristem.

This is the **only** type of growth that many herbaceous plants, and most monocotyledons, will make.



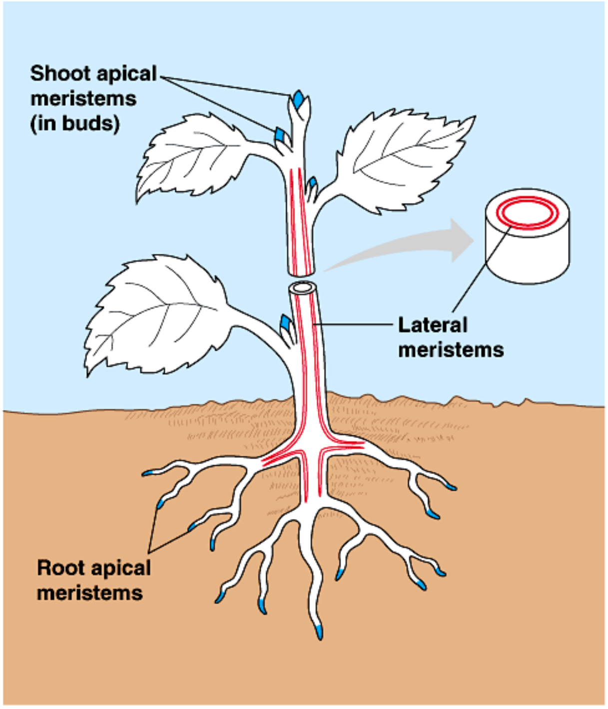
Secondary growth – secondary vascular tissue

The dicotyledonous stem may also increase in diameter to support and sustain a taller plant.

The increase in diameter is due to the activity of the **vascular cambium**, which now forms a complete cylinder of tissue.

A **lateral meristem** runs through the root and stem of the plant; in cross section ***(below, inset)*** it is a circle of cells which are actively dividing, producing new cells inwards and outwards, so that gradually the root and stem thicken.

This is **secondary growth.** It allows the plant to grow broader as it grows taller.

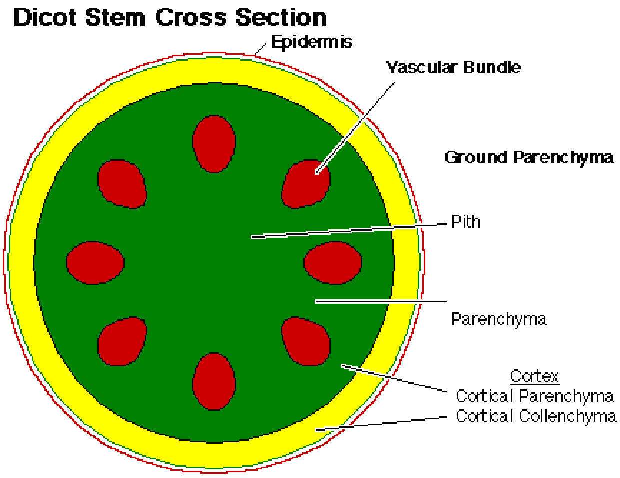


Cell division at meristems is by mitosis

Primary growth:
Apical meristems

Secondary growth:
Lateral meristems

Secondary growth takes place in both dicotyledonous plants (dicots) and gymnosperms (conifers).



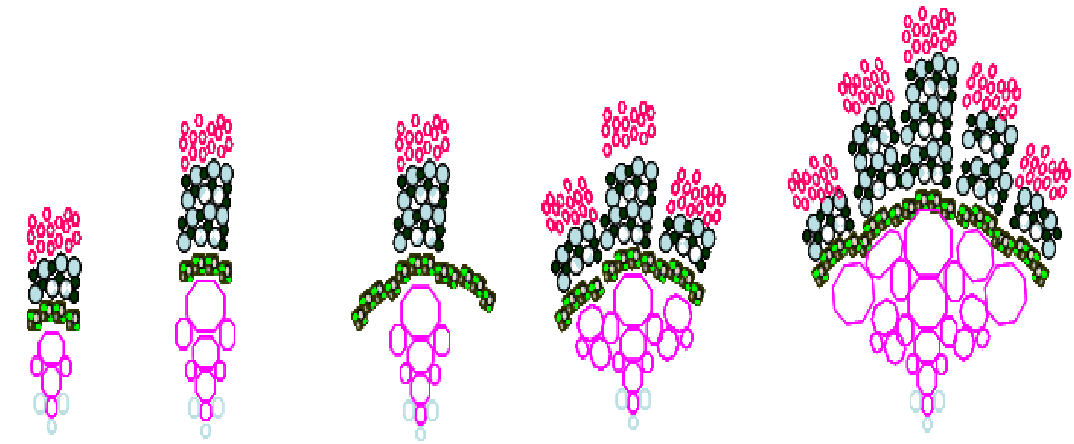
In the young dicot the vascular tissues are arrange in a ring around the stem.

As the plant enters the secondary growth stage, thickening begins.

The parenchyma tissue between the vascular bundles becomes meristematic and begins to divide as a layer of cambium between the bundles – (interfascicular) cambium.

This thickening takes place because new layers of cells are laid down continually either side of the cambium as the cells of the cambium undergo division.

The cambium produces new **secondary xylem tissue** towards the inside of the stem and **secondary phloem tissue** towards the outside.



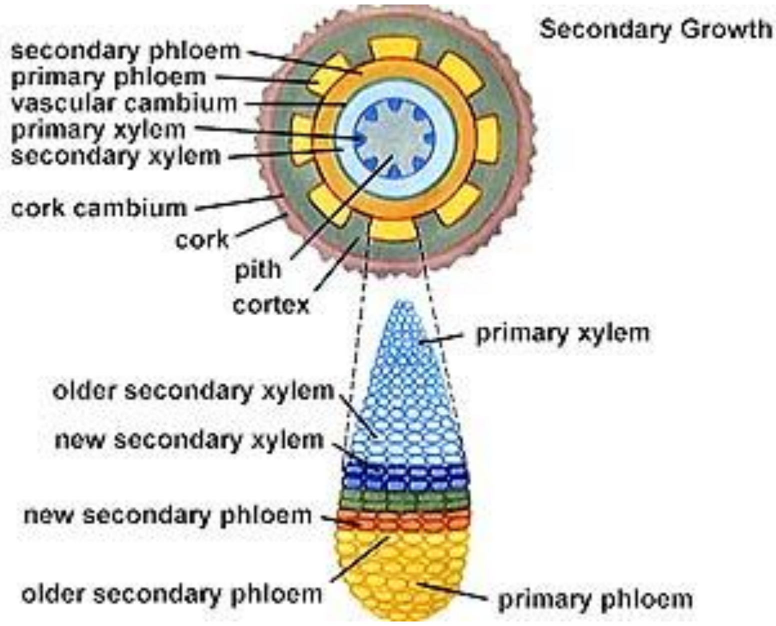
Primary vascular bundle

Cambium makes new ring of xylem and phloem

Cambium grows circumferentially

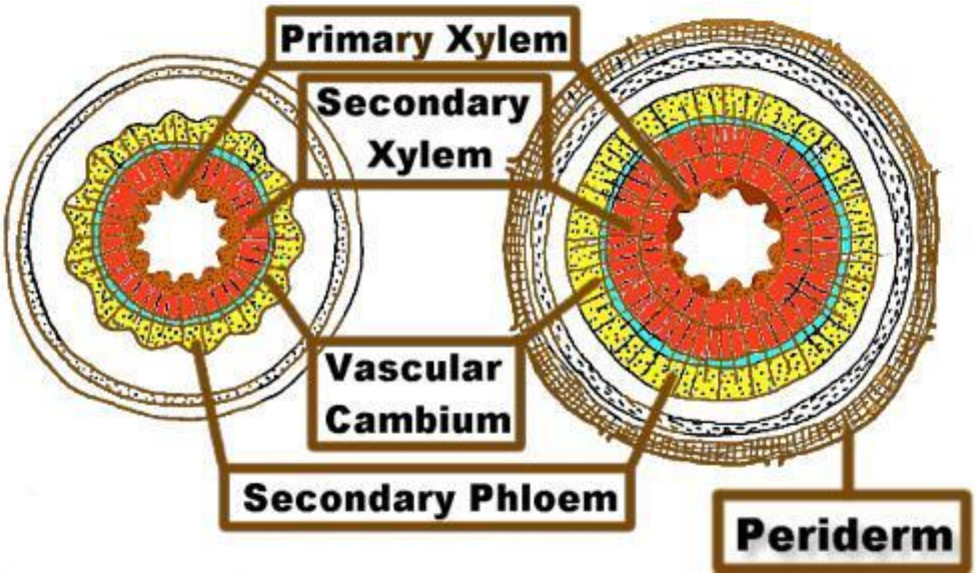
Cambium generates more secondary xylem and phloem

Cambium generates a second ring of xylem and phloem



The cambium between the bundles unites the whole meristematic tissue into a ring of cambium, which gradually compresses the xylem cells towards the inside if the stem, taking up the area originally filled with parenchyma (pith).

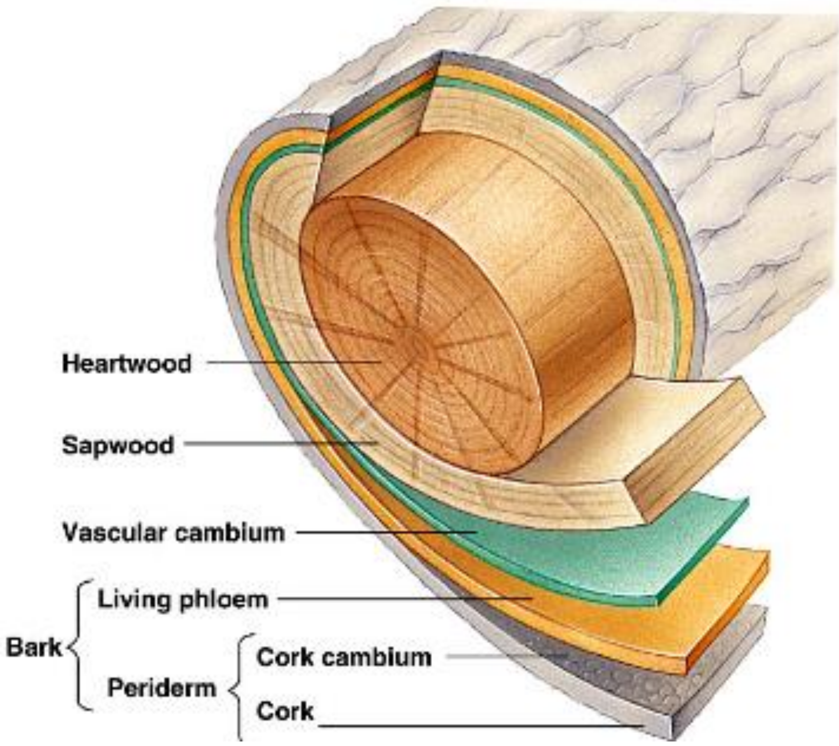
The new phloem cells do not take up as much room but they gradually replace the area of cortical tissue between the vascular bundles and the epidermis.



Secondary protective tissue – the periderm

The outermost tissues will eventually split under the pressure of the cambium's expansion. To compensate for this another layer of tissue becomes meristematic and starts to divide as a new cambial layer. This **cork cambium** (phellogen) develops in the cortex, just below the epidermis.

The cork cambium divides and produces new tissue in the same way as the vascular cambium: it gives rise to the **cork cells (phellem)** on the outside and the **secondary cortex (phelloderm)** on the inside. Together this is known as the **periderm.**



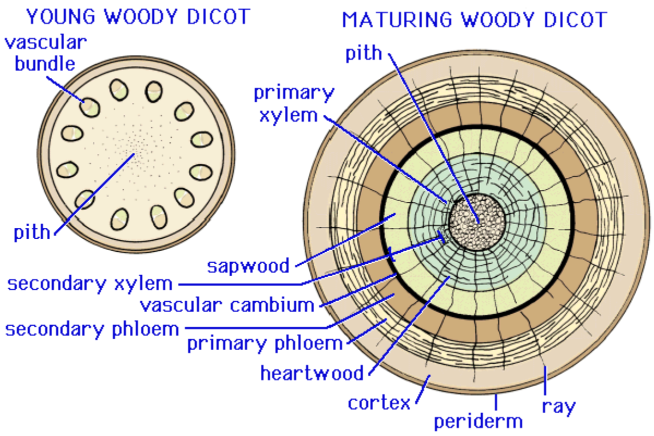
Cork cells are tightly packed and have walls impregnated with **suberin,** a fatty substance that is impermeable to water and gases.

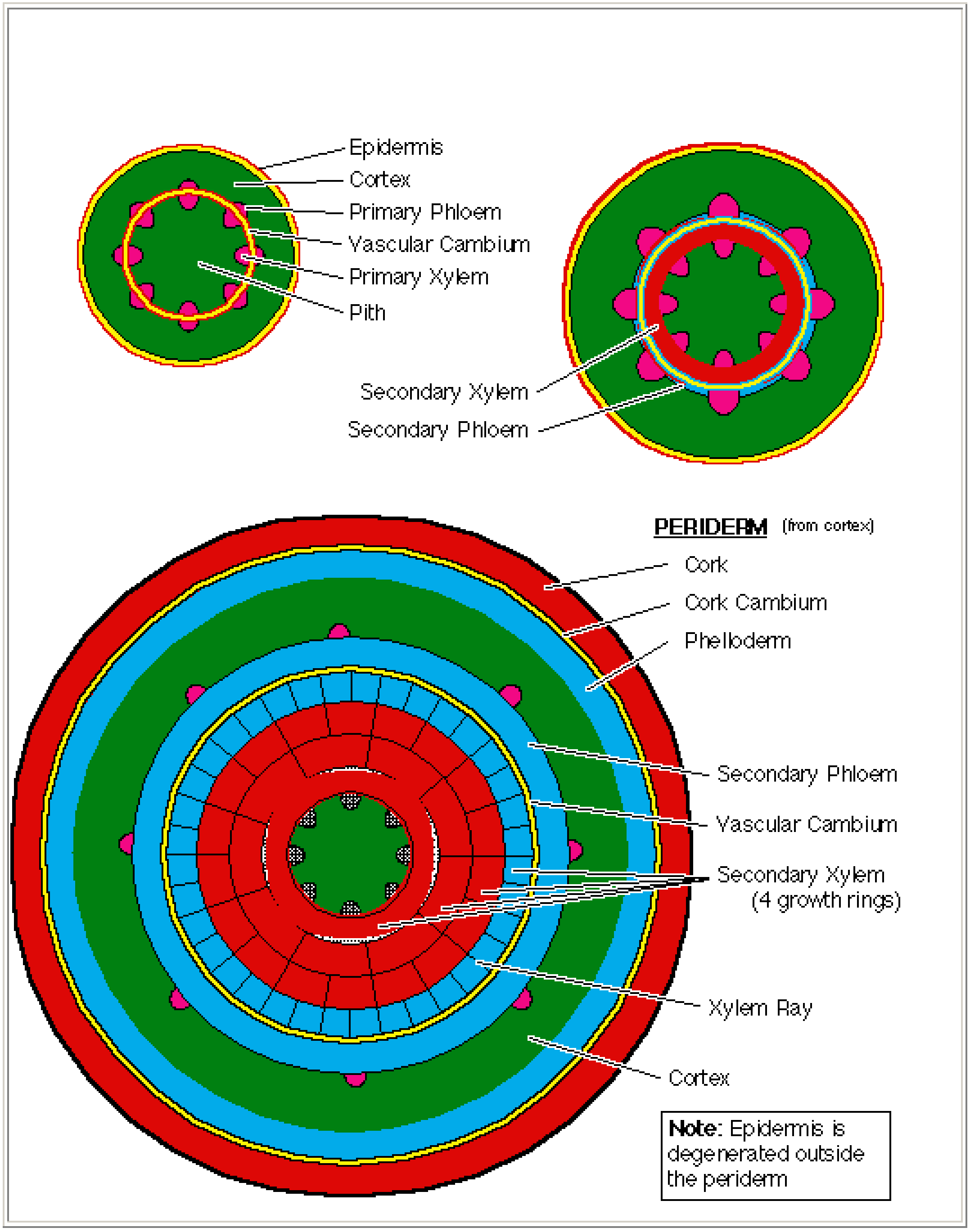
The function of the cork layer is to reduce water loss and prevent the entry of disease-causing organisms.

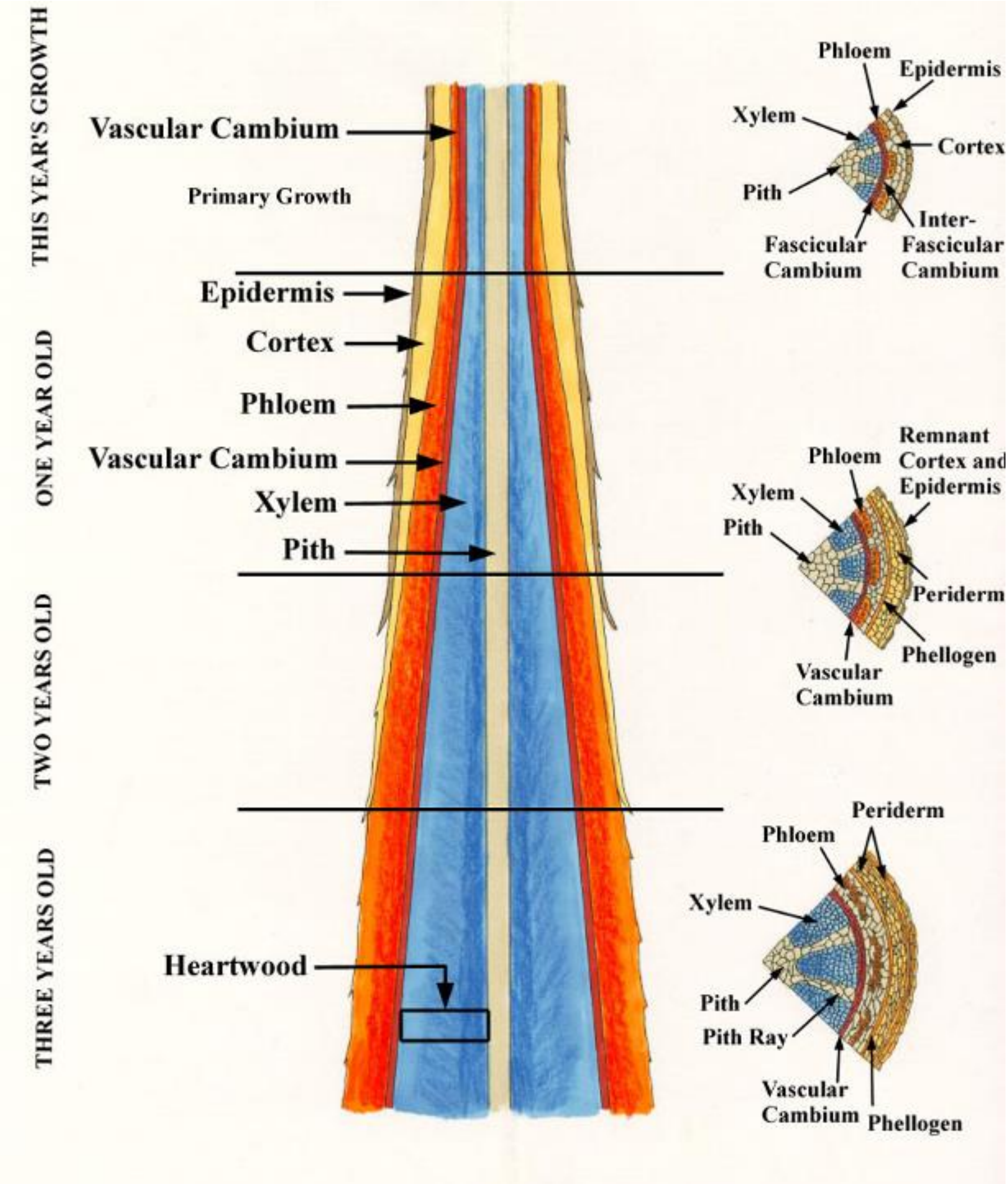
It also stops air from reaching the living tissues within the stem – a problem – **BUT** the cork cambium also produces patches of loosely packed cells at intervals round the stem. These are called **lenticels**. They help ventilate the tissues of the stem, and usually occur beneath gaps in the epidermis.

Some of the parenchyma cells between the vascular bundles continue to exist to form radially directed vascular rays.

Annual rings develop in the secondary xylem, each consisting of a **layer of spring wood** and a **layer of autumn wood**.



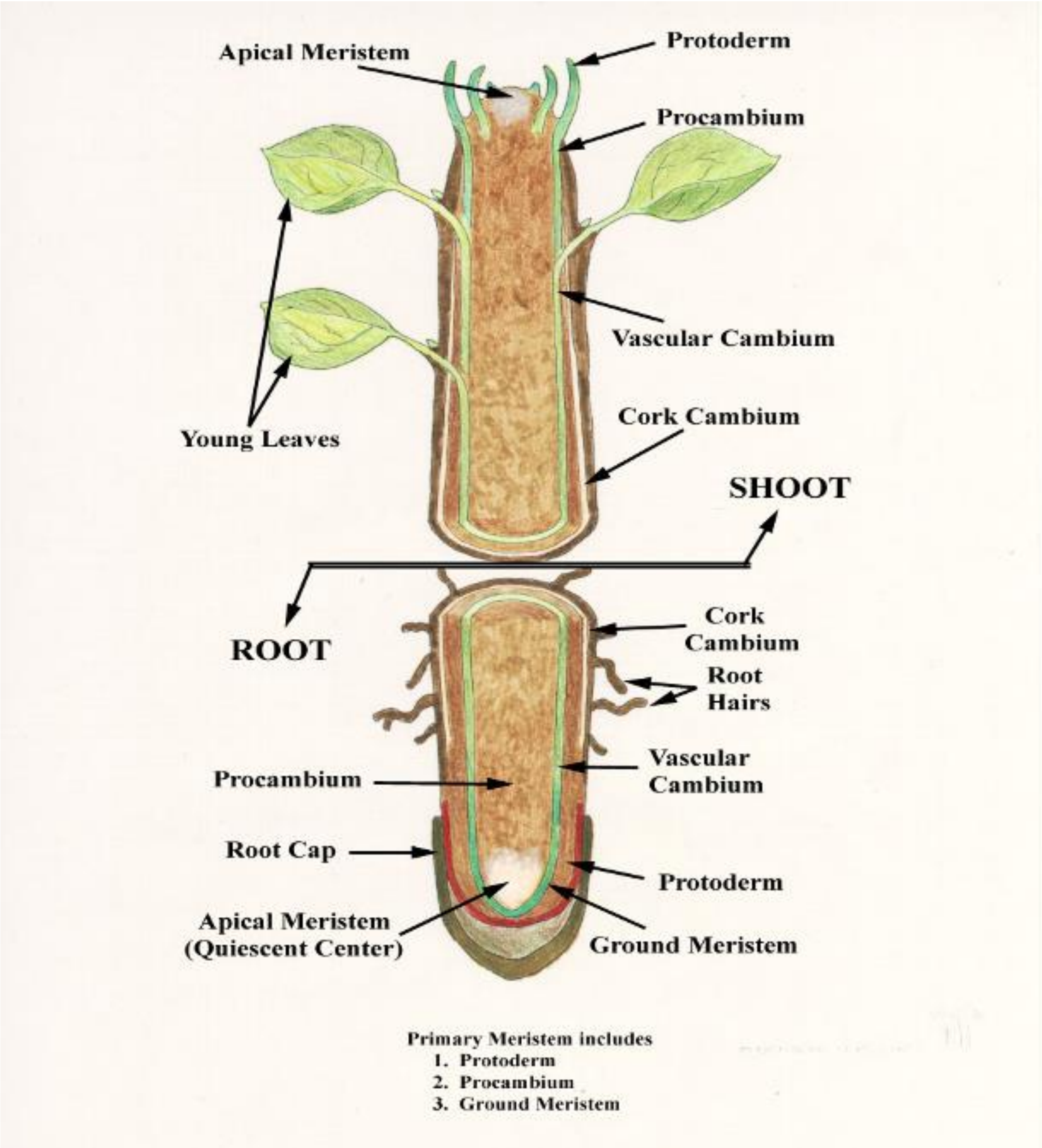




http://www.puc.edu/Faculty/Gilbert_Muth/art0062.jpg

Secondary thickening in roots

Dicotyledon roots also thicken as the plant grows, and layers of vascular cambium begin to divide to produce new xylem and phloem tissue. A new layer of cork cambium also produces a periderm to protect the root as it grows older and woodier.



http://www.puc.edu/Faculty/Gilbert_Muth/art0054.jpg

The diagram above shows vascular cambium and cork cambium in both roots and shoots NB *Protoderm* and *procambium* are terms that indicate newly divided cells still differentiating to become epidermis and cambium. ***You do not need to learn these terms.***

Monocotyledons

In monocot stems, there is no secondary thickening to produce new lateral layers of cells, and so no secondary growth. The scattered vascular bundles within the stem of a large monocot are each protected by sclerenchyma fibres. The 'trunk' is formed as new leaves grow upward from the meristem of the plant, and the existing leaf bases are compressed and dry out, forming a hard outer layer.

There is no real secondary thickening in monocots.

Bananas are actually giant herbs, with their trunks made of leaf bases.

Image from www.flickr.com/photos/34631156@N00/163219371/

The stem tissues of **bamboos and grasses** are strengthened by the fibres around vascular bundles, and the stems are hollow, which gives them great flexibility. At the nodes, where new leaves form, the stems are solid and heavily reinforced with fibres to prevent the stems from buckling. Sugarcane and maize are unusual members of the family Poaceae in having solid, fibrous stems.

Palms are the tallest of the monocots. They can grow in girth because at the apical meristem, the growth tip of the plant, they also have an area called a 'primary thickening meristem' which can increase the number of parenchyma cells and vascular bundles – the stem gets thicker from the outside, rather than from the inside out, so the base of stem near the ground is no thicker than it is at the top (unlike normal dicotyledon or conifer tree trunks).

This helps with their flexibility, so that palm trees are able to bend and withstand hurricanes where the woody trunks of dicots will crack and shatter.

The trunk of a California fan palm (*Washingtonia filifera*): the fibrous strands are vascular bundles composed of lignified cells.
Image from http://waynesword.palomar.edu/trjune99.htm

2.1 Identify a range of plant tissues and describe their structure and function.

Some additional diagrams from the internet, and where to see them online:
http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookplantanat.html

Summary:

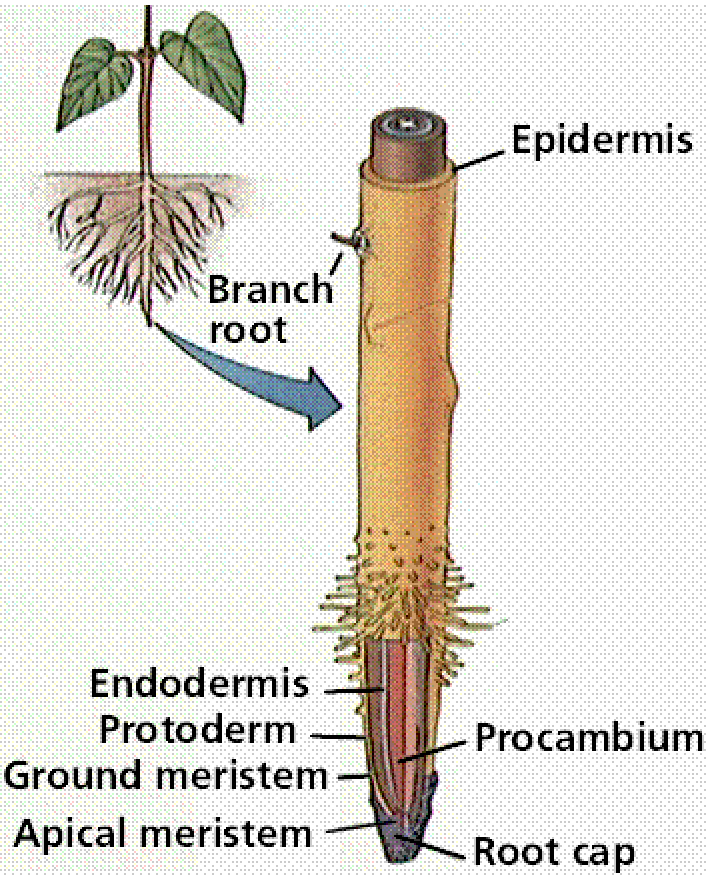
Plant cells are formed at **meristems**, and then develop into cell types which are grouped into tissues.

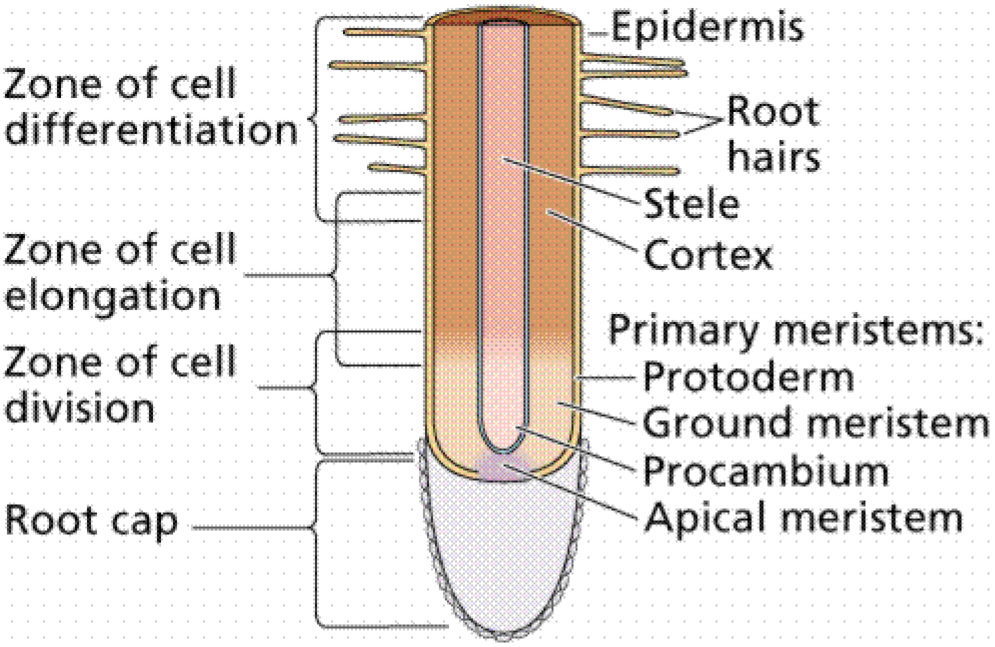
Plants have only three tissue types: **Dermal**; **Ground**; and **Vascular**.

Dermal tissue covers the outer surface of herbaceous plants. Dermal tissue is composed of epidermal cells, closely packed cells that secrete a waxy cuticle that aids in the prevention of water loss.

The **ground tissue** comprises the bulk of the primary plant body. Parenchyma, collenchyma, and sclerenchyma cells are common in the ground tissue.

Vascular tissue transports food, water, hormones and minerals within the plant. Vascular tissue includes xylem, phloem, parenchyma, and cambium cells.





Plant cell types arise by mitosis from a **meristem.**

A **meristem** may be defined as a region of localized mitosis. Meristems may be at the tip of the shoot or root (a type known as the **apical meristem**) or **lateral,** occurring in cylinders extending nearly the length of the plant.

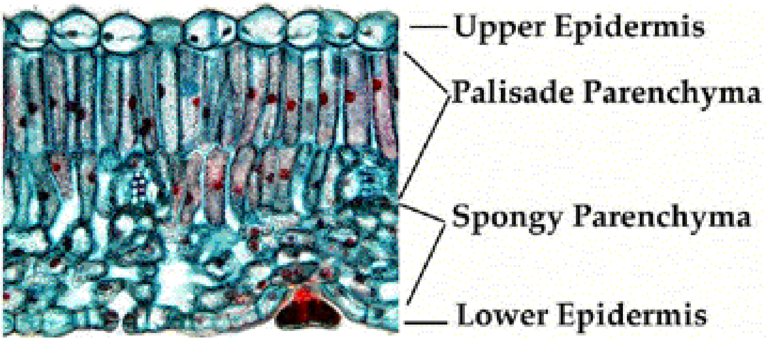
A **cambium** is a lateral meristem that produces (usually) secondary growth. Secondary growth produces both wood and cork (although from separate secondary meristems).

Parenchyma

A generalized plant cell type, parenchyma cells are alive at maturity. They function in storage, photosynthesis, and as the bulk of ground and vascular tissues.

- Palisade parenchyma cells are elongated cells located in many leaves just below the epidermal tissue. Spongy mesophyll cells occur below the one or two layers of palisade cells.
- Ray parenchyma cells occur in wood rays, the structures that transport materials laterally within a woody stem.
- Parenchyma cells also occur within the xylem and phloem of vascular bundles.
- The largest parenchyma cells occur in the pith region, often, as in corn (*Zea*) stems, being larger than the vascular bundles. In many prepared slides they stain green.

Cross-section of a stained leaf of *Syringa*.



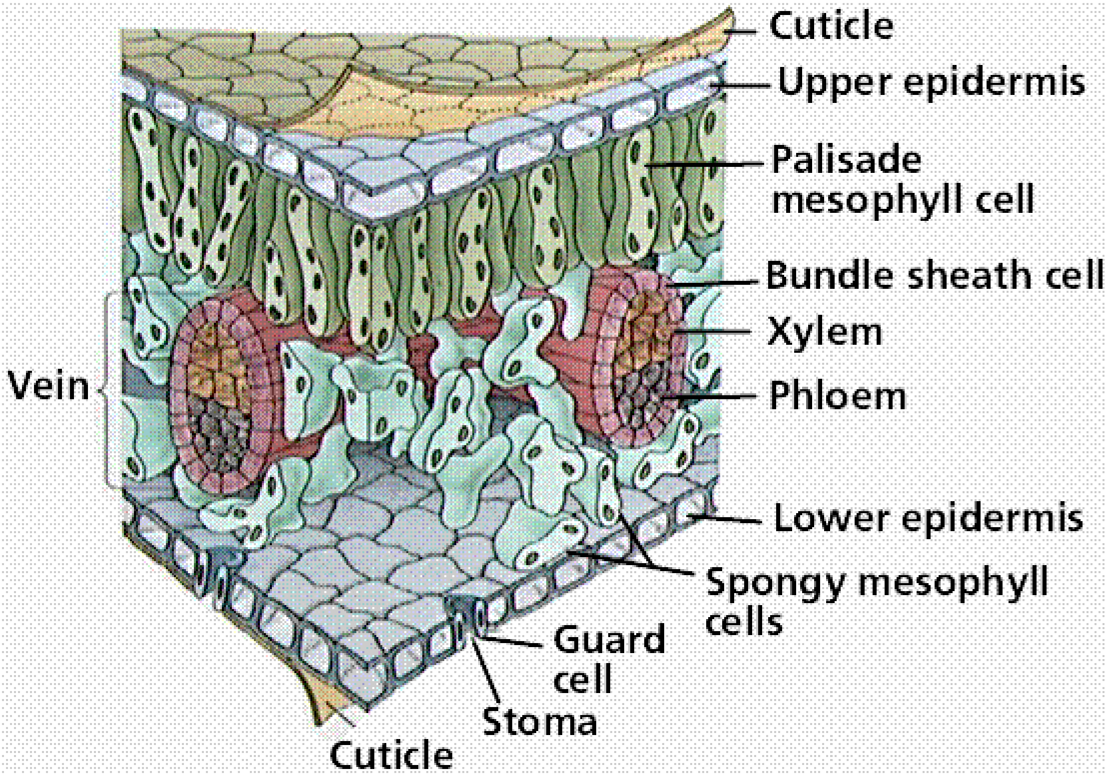
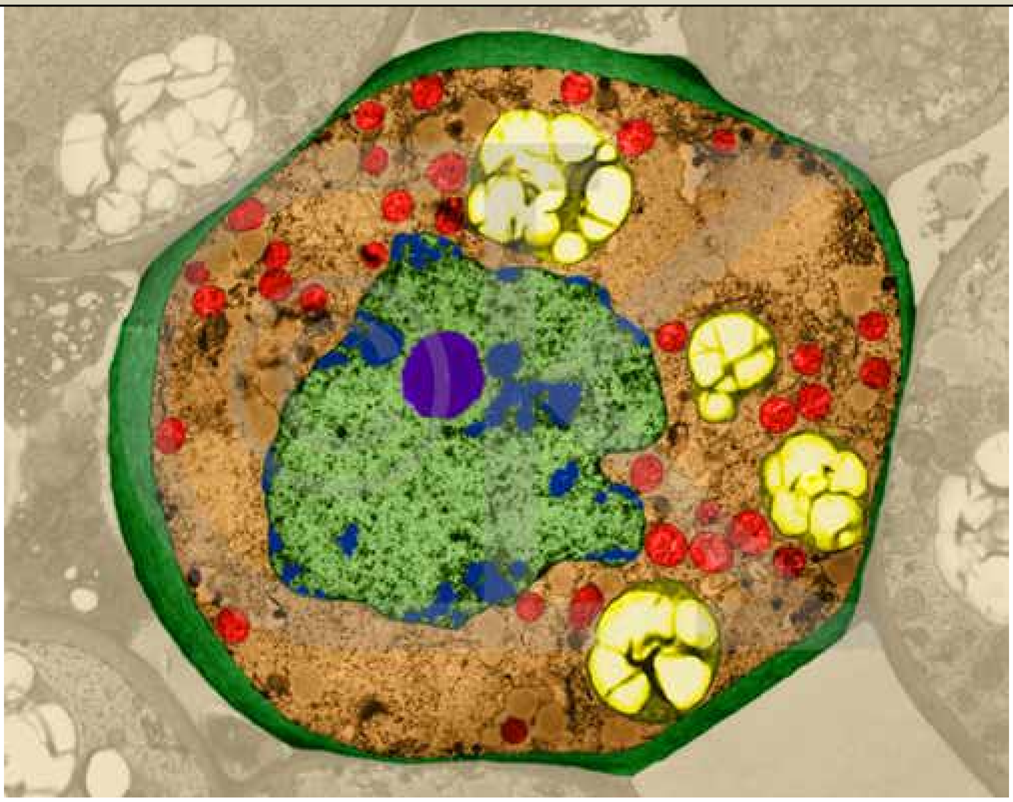


Diagram of leaf structure. Note the arrangement of tissue layers within the leaf.



Lily parenchyma cell(cross section): note the colour coded bodies – the large nucleus (green) in the centre of the cell, the mitochondria (red) and plastids (yellow) in the cytoplasm. Plastids are organelles which manufacture and store important chemical compounds used by the cell, and include **chloroplasts.**

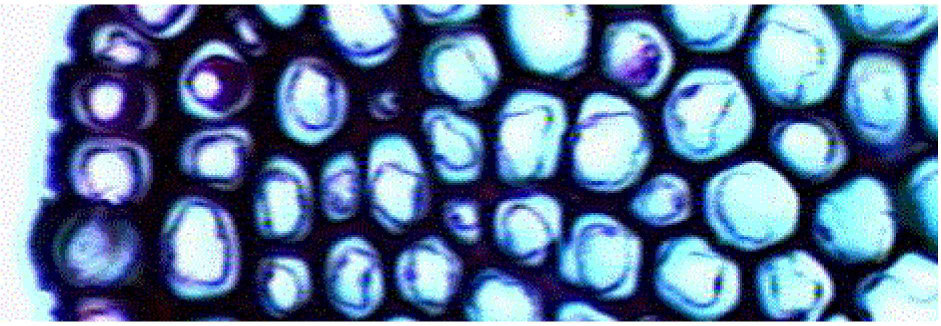
Collenchyma

Collenchyma cells support the plant.

These cells are characterized by thickenings of the wall, they are alive at maturity.

They tend to occur as part of vascular bundles or on the corners of angular stems.

In many prepared slides they stain red.



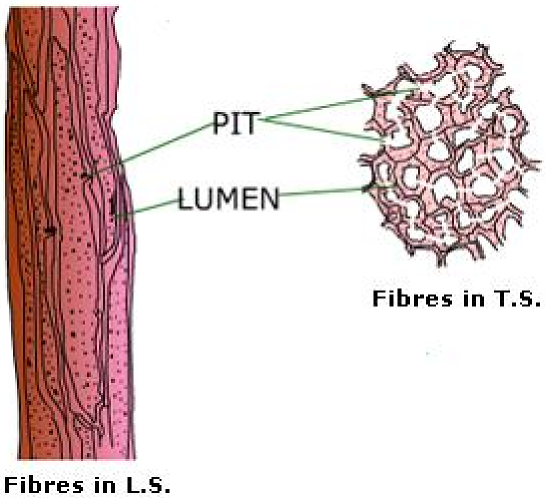
Collenchyma cells. Note the thick walls on the collenchyma cells occurring at the edges of the *Medicago* stem cross section.

Sclerenchyma

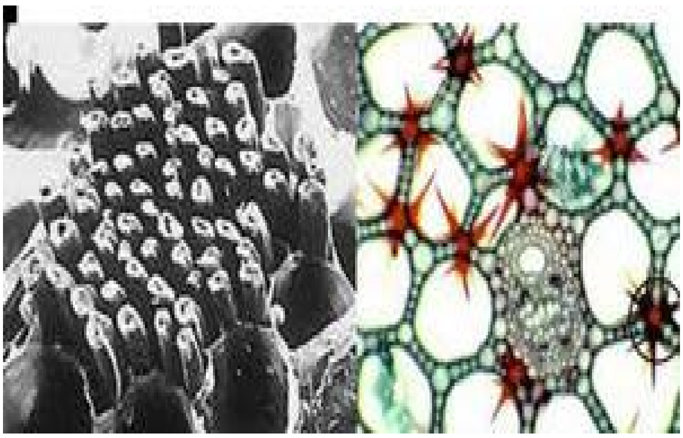
Sclerenchyma cells support the plant.

They often occur as bundle cap fibres. Sclerenchyma cells are characterized by thickenings in their secondary walls. They are dead at maturity. They, like collenchyma, stain red in many commonly used prepared slides.

A common type of sclerenchyma cell is the **fibre (below left)**.



Section left from http://images.tutorvista.com/content/plant-histology/sclerenchyma-fibres.jpeg



Some sclerenchyma cells occur in the fruits of Pear. These cells (**sclereids** or stone cells, far right) give pears their gritty texture.

Indicative content:

(the RHS lists what you should have covered for this assessment point)

2.1 Identify a range of plant tissues and describe their structure and function.

Identify and describe the structure and function of plant tissues, to include:

Simple tissues: parenchyma, collenchyma, sclerenchyma (fibres and sclereids), epidermis, meristem (cambium).

Complex tissues: xylem (vessels, tracheids, parenchyma, sclerenchyma fibres), phloem (sieve tube elements, companion cells, parenchyma, sclerenchyma fibres).

Secondary tissues: periderm (outer bark), phellem (cork), phellogen (cork cambium), phelloderm (secondary cortex), secondary phloem (inner bark) vascular cambium, secondary xylem, radial parenchyma (ray), annual rings.

Describe the process of secondary thickening in the stem of a woody perennial (e.g. Tilia), from primary tissues to two years old.