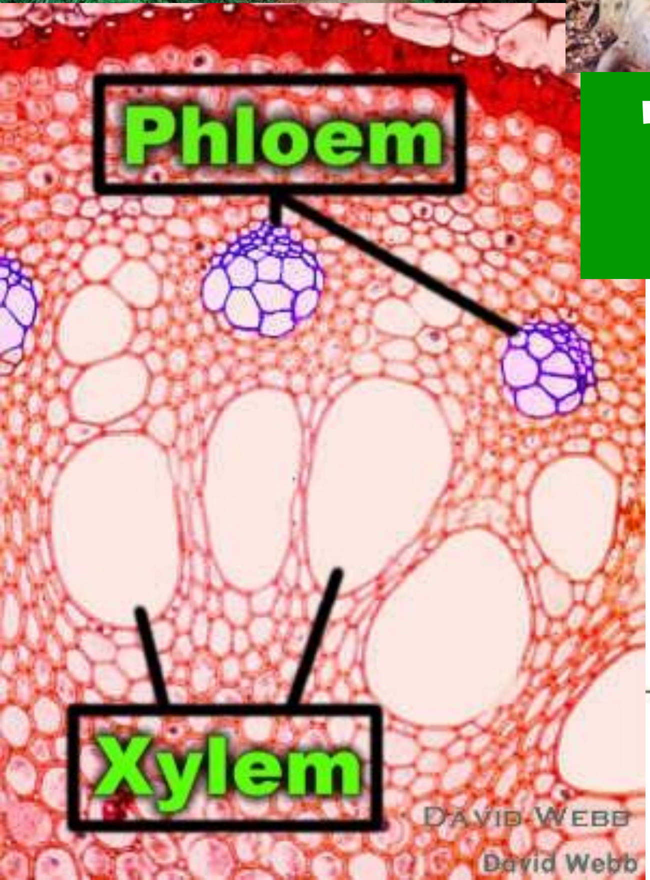
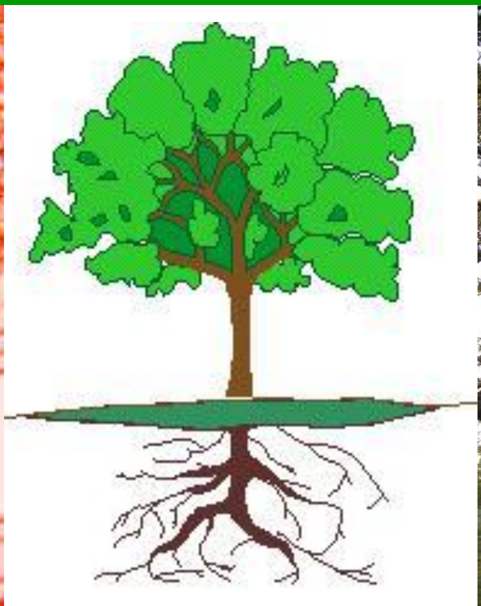
TRANSPORT IN PLANTS





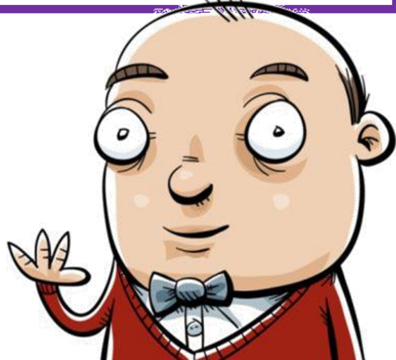
Homework for Monday:

- **Correct potometer questions**
- **Complete transport in plants worksheet**

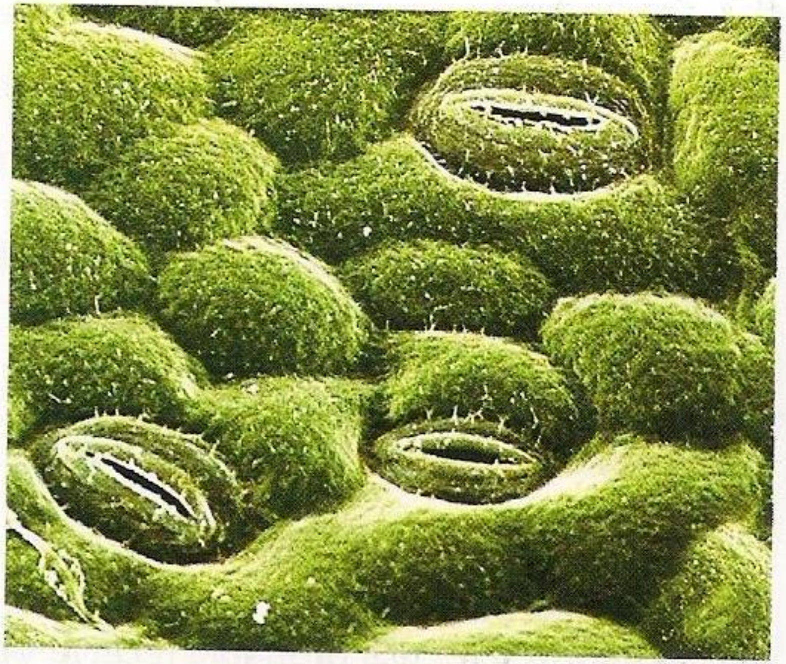
Transpiration – the loss of water from a plant through evaporation

Did you know?

- *A 15m maple tree in the USA was estimated to have 177,000 leaves, with a total surface area of 675 square metres*
- *On a summers day, it lost 220 litres of water **per hour** through transpiration through the leaves*
- *The roots then needed to absorb this much from the soil each hour to prevent the plant from wilting*



- Transpiration mostly happens through the stomata, although some is lost through the leaf cuticle and a little through the stem
- Internal and external factors influence the rate of transpiration:



SEM of lower leaf epidermis showing stomata

Internal factors

- Leaf surface area –

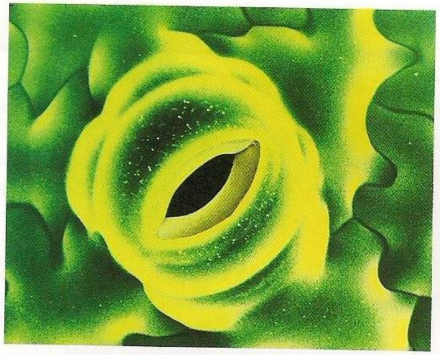
- Stomatal density –

- Cuticle thickness –

External factors

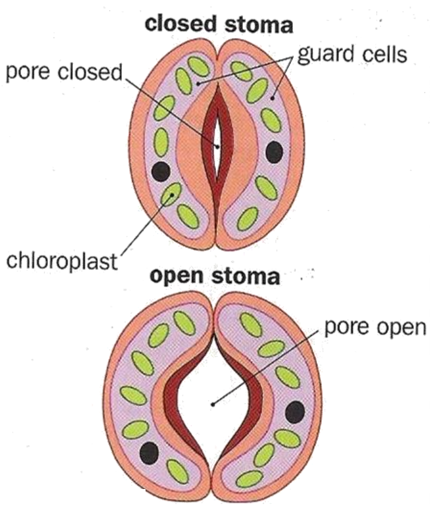
If it's light, the stomata are open

- (Light intensity)



SEM of a stoma with two guard cells

- Air currents –



- Temperature –

- Humidity (amount of water vapour in the air) –

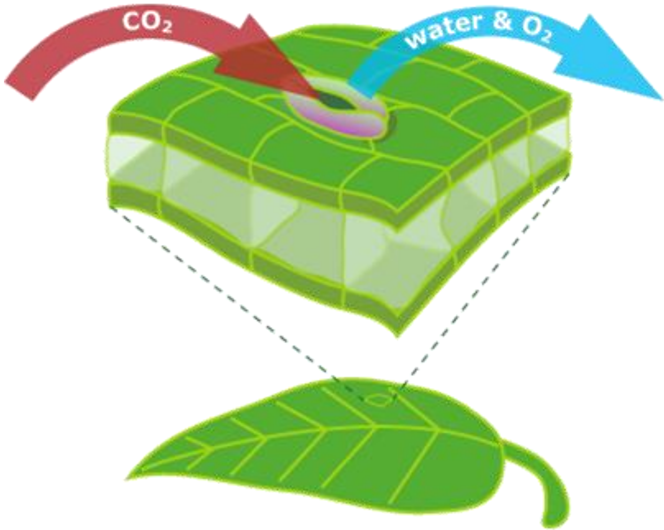
r

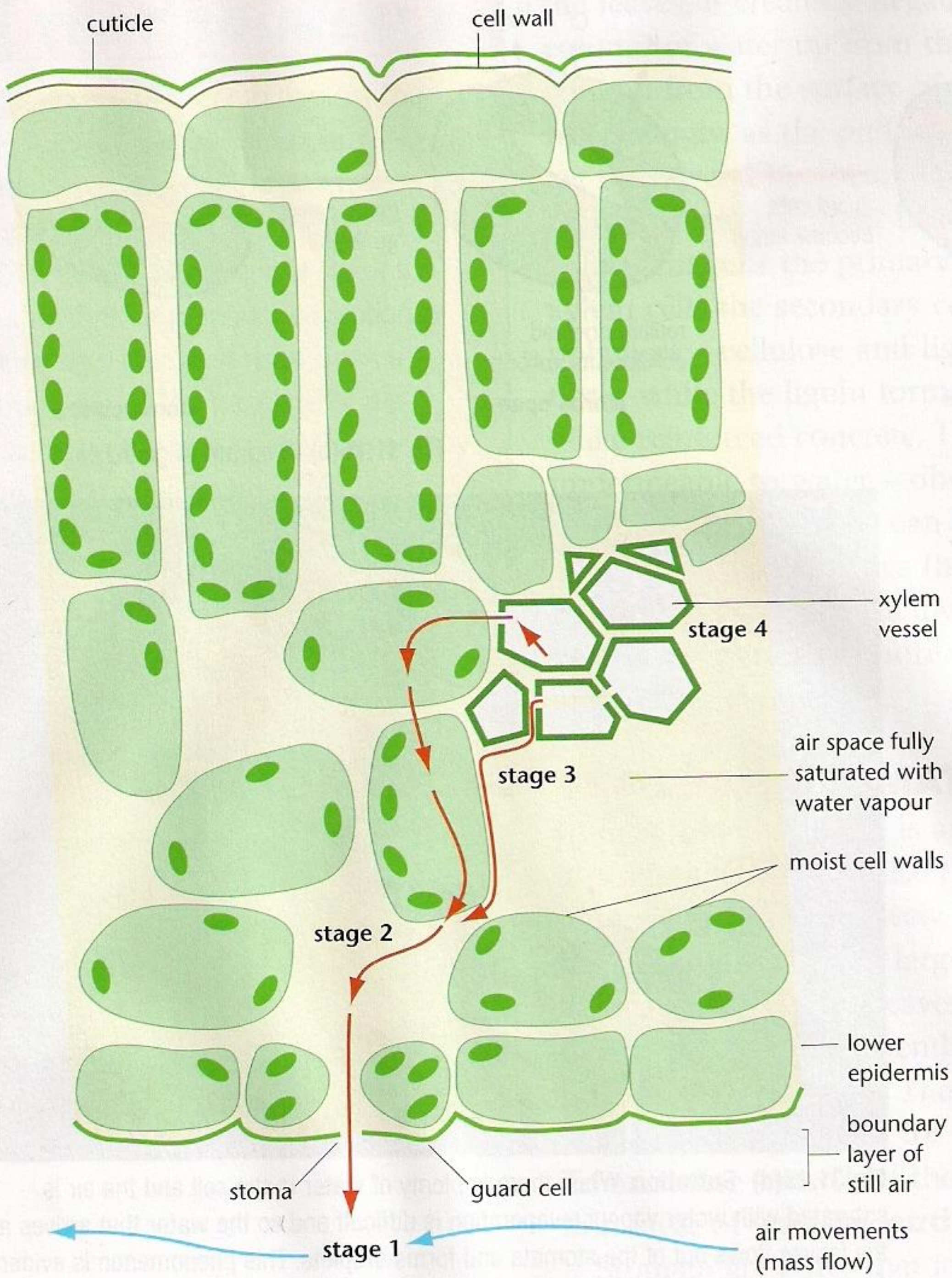
- Soil water availability –

REMEMBER THIS

The conditions that will increase the speed of drying of clothes on a washing line – warm, dry, windy – will also speed up transpiration.

Carbon dioxide enters, while water and oxygen exit, through a leaf's stomata:





Stage 1 Mass flow in air

Wind movements (mass flow) take air, fully saturated with water vapour, away from the leaf surface

The air replacing it contains less water vapour and this maintains a concentration gradient for water vapour leaving the air spaces of a leaf

Stage 2 Diffusion of water in still air

Water vapour diffuses down a concentration gradient through the leaf air spaces, through open stomata, and through the boundary layer of still air on the outside of the leaf

Stage 3 Diffusion of water through cells

Water loss from the surface of cells lowers the water potential inside the cells

Water at a higher potential diffuses from the nearest xylem vessel through leaf cells to replace lost water

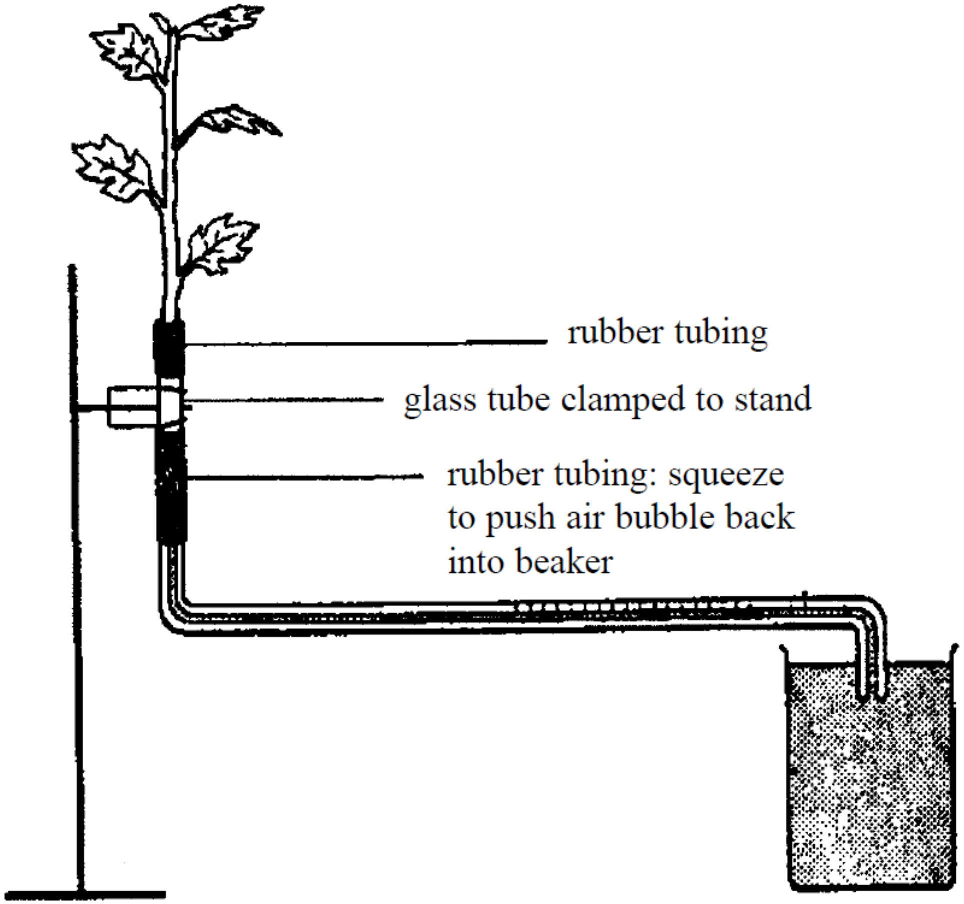
Stage 4 Mass flow of water in xylem vessels

Pressure in xylem vessels is lowered as water leaves them

Water moves up the xylem vessel from the roots where the pressure is higher

Fig 31.17 The flow of water through a leaf. Wind movements take away humid air and replace it with drier air, thus maintaining a water potential gradient

AS 2 Practical demo – the bubble potometer...



Potometer PPQ answers…

(a) Assume that the rate of water uptake is equal to the rate of transpiration

(b) - Prevents air from entering the xylem and creating an air lock

- Remove capillary tube from water/expose to air and air is drawn in as shoot takes up water
- Allows air bubble to be moved back to the origin
- Allow the rates of transpiration to acclimatise to the surrounding conditions

(c) Transpiration reduced when plant is covered by clear bag as air currents reduced

And more humid air outside stomatal pores

Diffusion gradient is therefore reduced / diffusion shells build up

Even less transpiration when black plastic bag is added as stomata close in the dark

Only cuticular traspiration can now happen (much less water lost in this way)

(ii) 90mm long X 0.8 mm^2 = 72 ^{mm3}

72 / 10 = 7.2 mm^3 minute $^{-1}$

(d) Different shoots have different sizes and surface areas with different stomatal densities and numbers of leaves

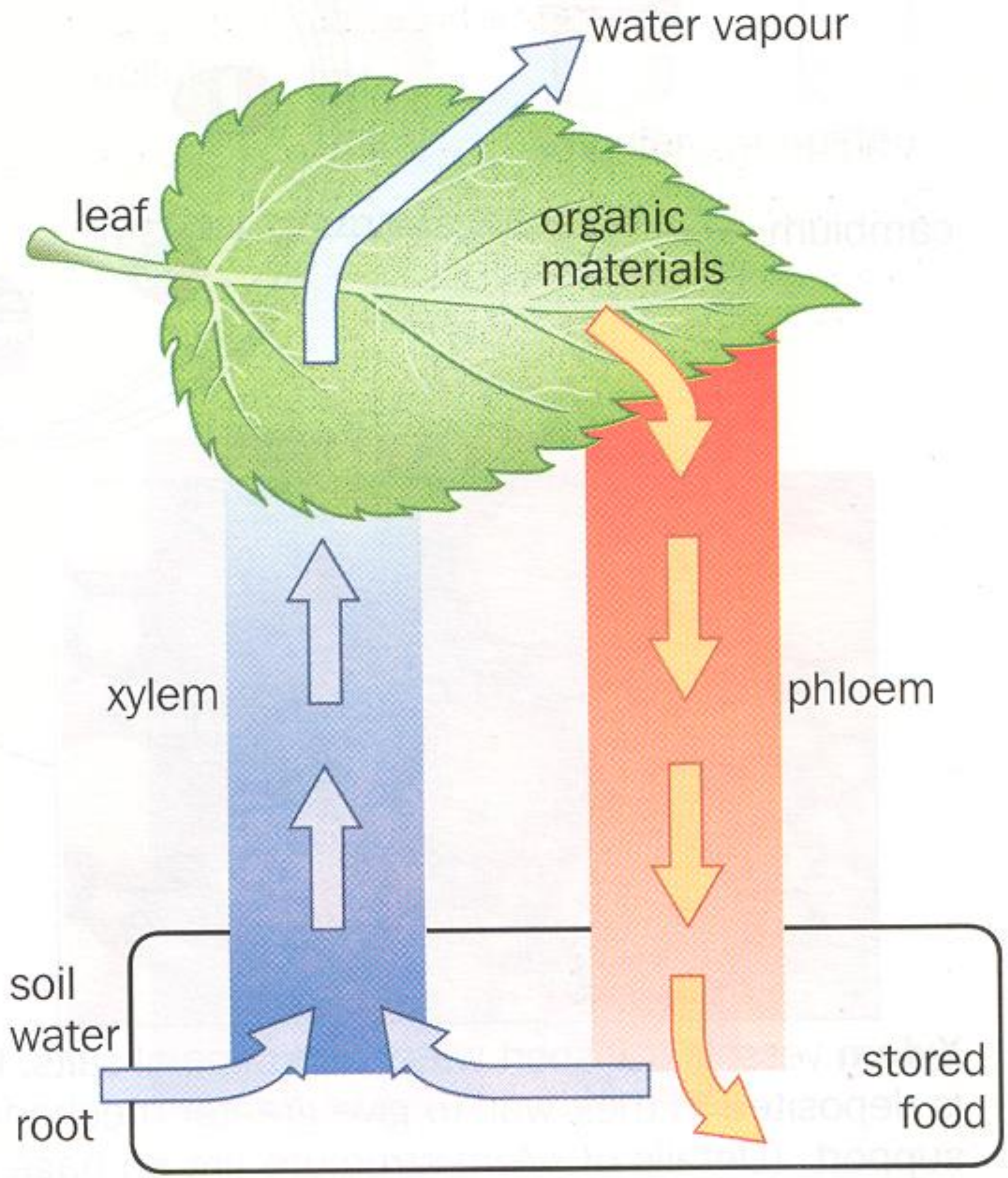
There are 2 systems of transport in plants:

- **XYLEM**

  transporting water and mineral ions

- **PHLOEM**

  transporting sugars and soluble organic products of photosynthesis


water vapour
leaf
organic
materials
xylem
phloem
soil
water
root
stored
food

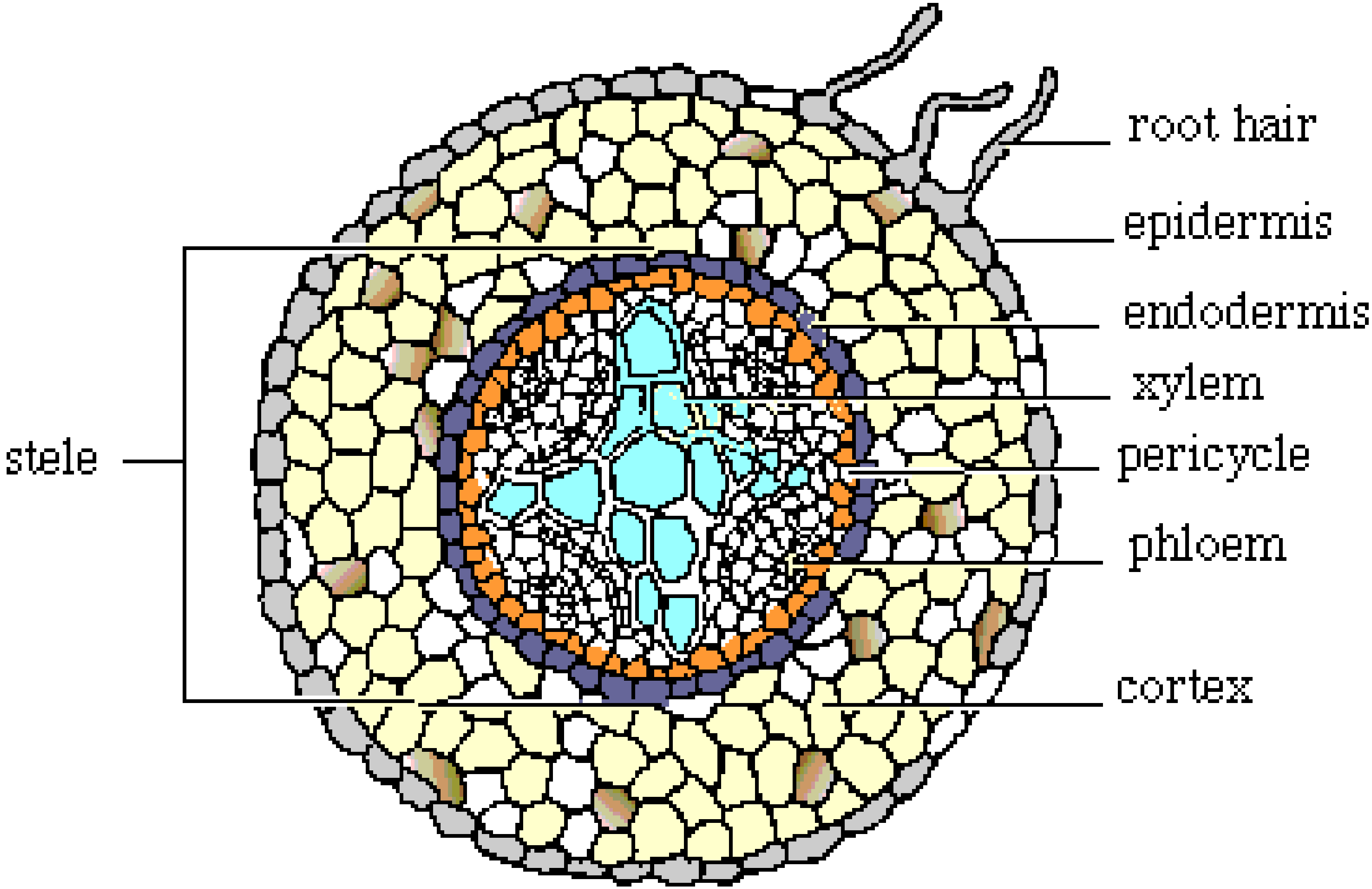
Plant tissues in relation to water (and ion) transport and translocation:

The root - regions include:

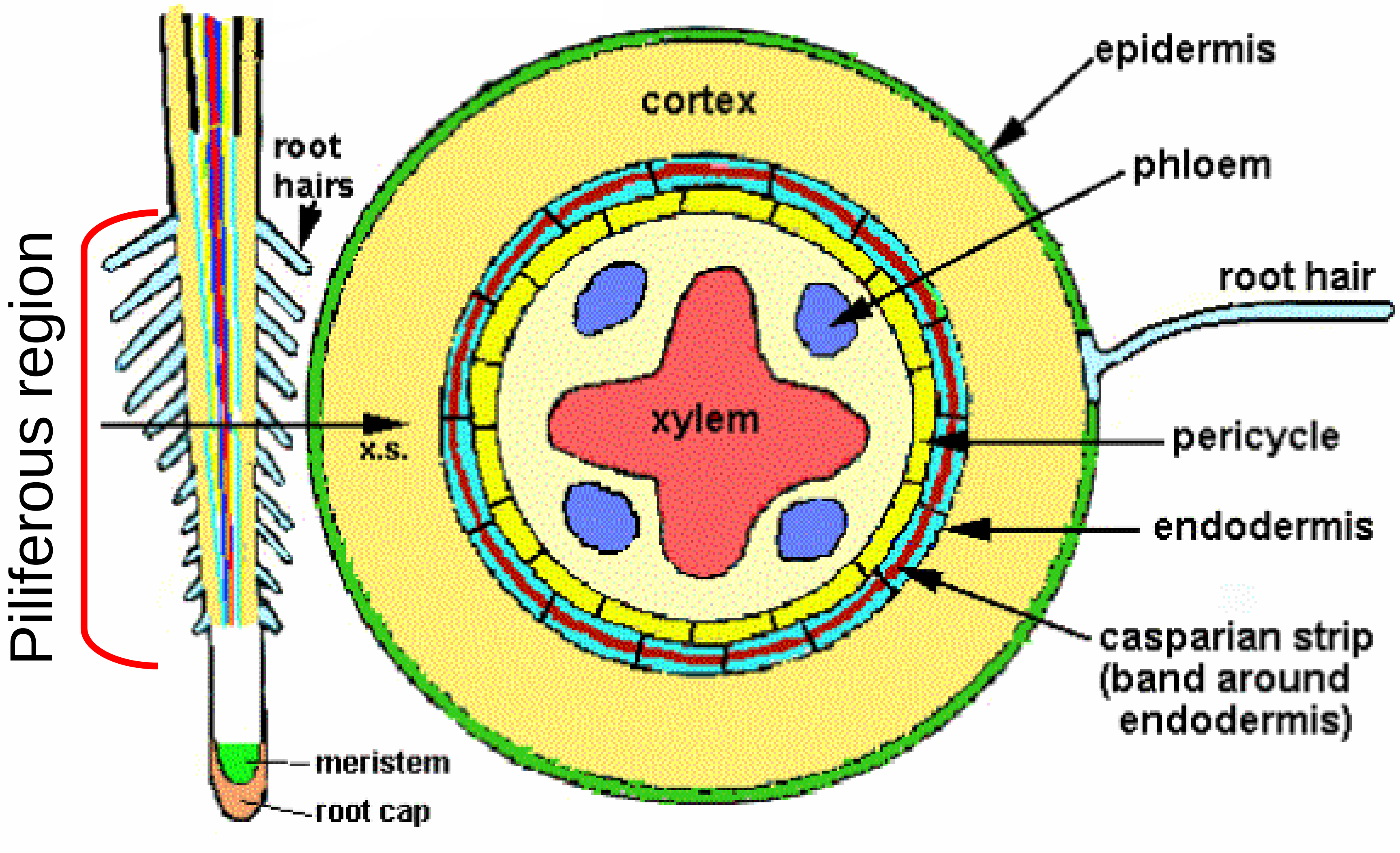
- Piliferous layer
- Cortex
- Endodermis
- Stele

The **piliferous region** contains the root hair cells

Important diagram - note the position of the vascular tissues:



Draw a block tissue diagram of this!


Piliferous region
root hairs
x.s.
meristem
root cap
cortex
xylem
epidermis
phloem
root hair
pericycle
endodermis
casparian strip (band around endodermis)

The tissues of the root

Epidermis – the outer layer of cells. Root hair cells (elongated epidermal cells) project into soil and increase surface area to absorb water and minerals

Cortex – a layer of UNDIFFERENTIATED CELLS (parenchyma /packing tissue) between the epidermis and the vascular (conducting) tissue. In the leaf, this tissue can photosynthesise. CORTEX CELLS USUALLY HAVE SMALL AIR SPACES BETWEEN THEM AND CAN BE RICH IN STARCH GRAINS.

Endodermis – thin, SINGLE layer of cells surrounding the vascular tissue (xylem and phloem). The endodermis contains a waterproof Casparian strip made of suberin

The stele – the endodermis and the vascular tissue that it surrounds

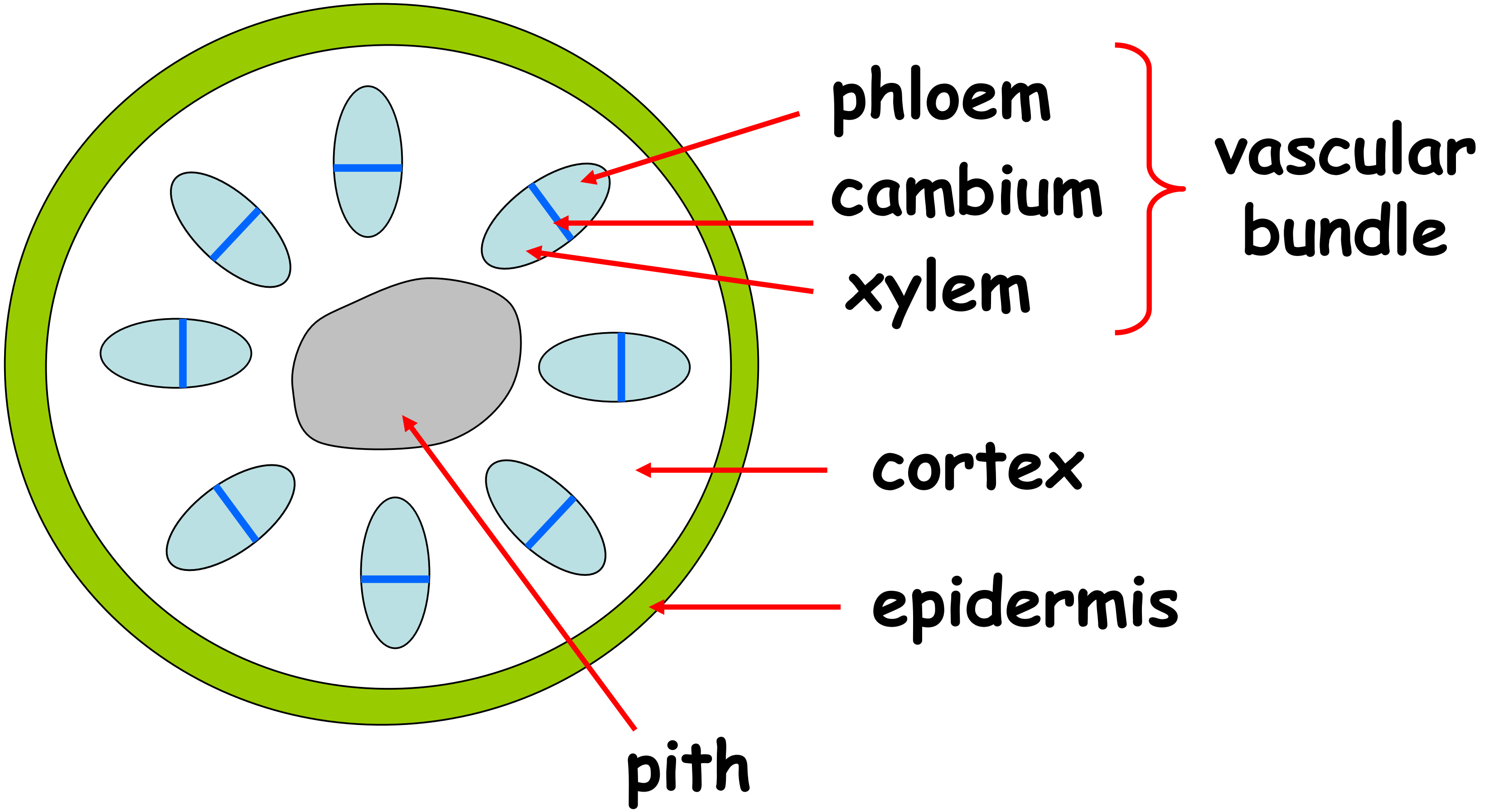
Xylem tissue – many dead, hollow vessels carrying water and dissolved mineral ions up the plant to the leaves and other organs

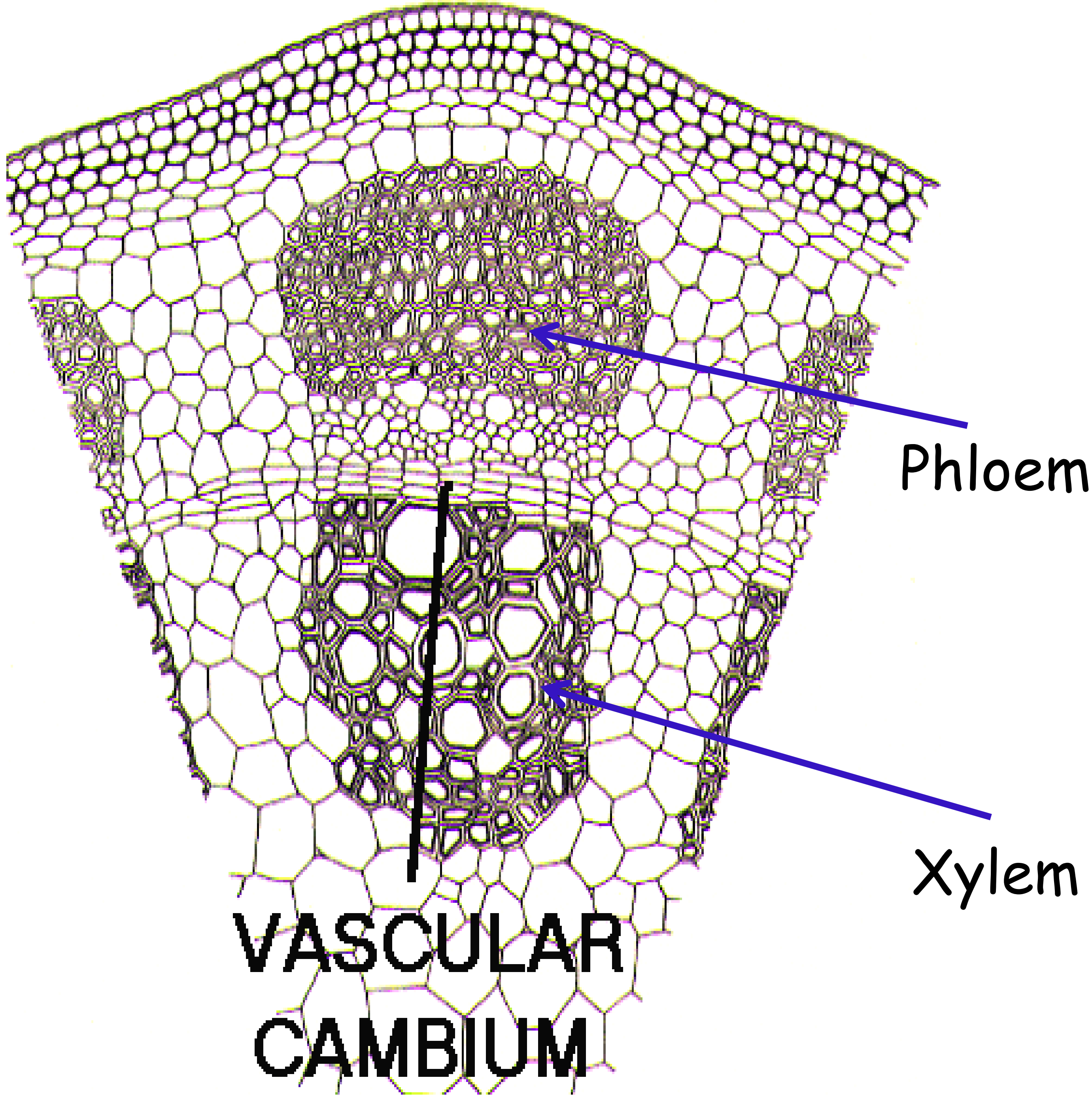
Phloem – tubular living cells that carry dissolved organic materials made through photosynthesis e.g. sucrose and amino acids, around the plant

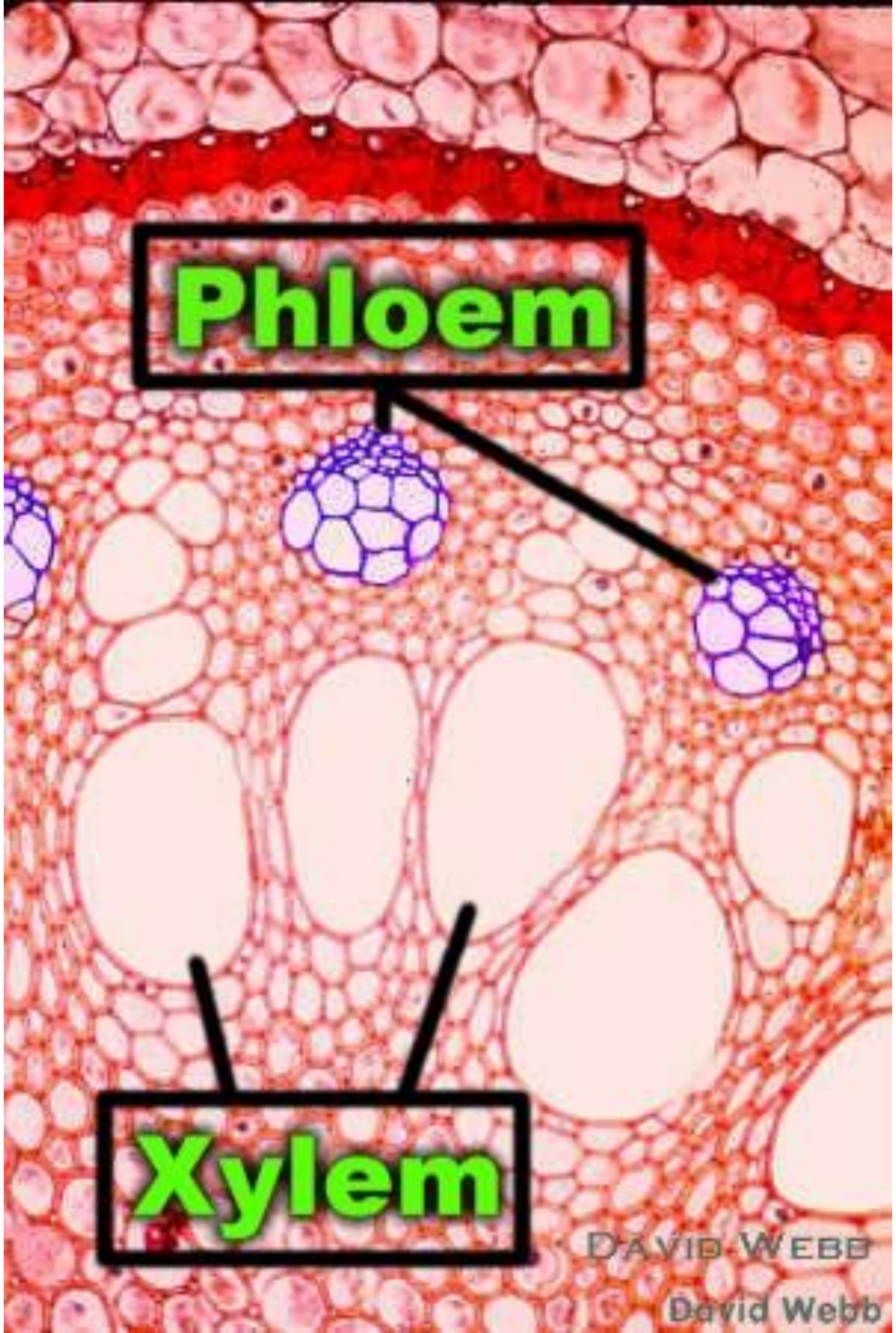
Piliferous region – the section of a young root which has root hairs as part of its epithelium (where water and mineral absorption occurs)

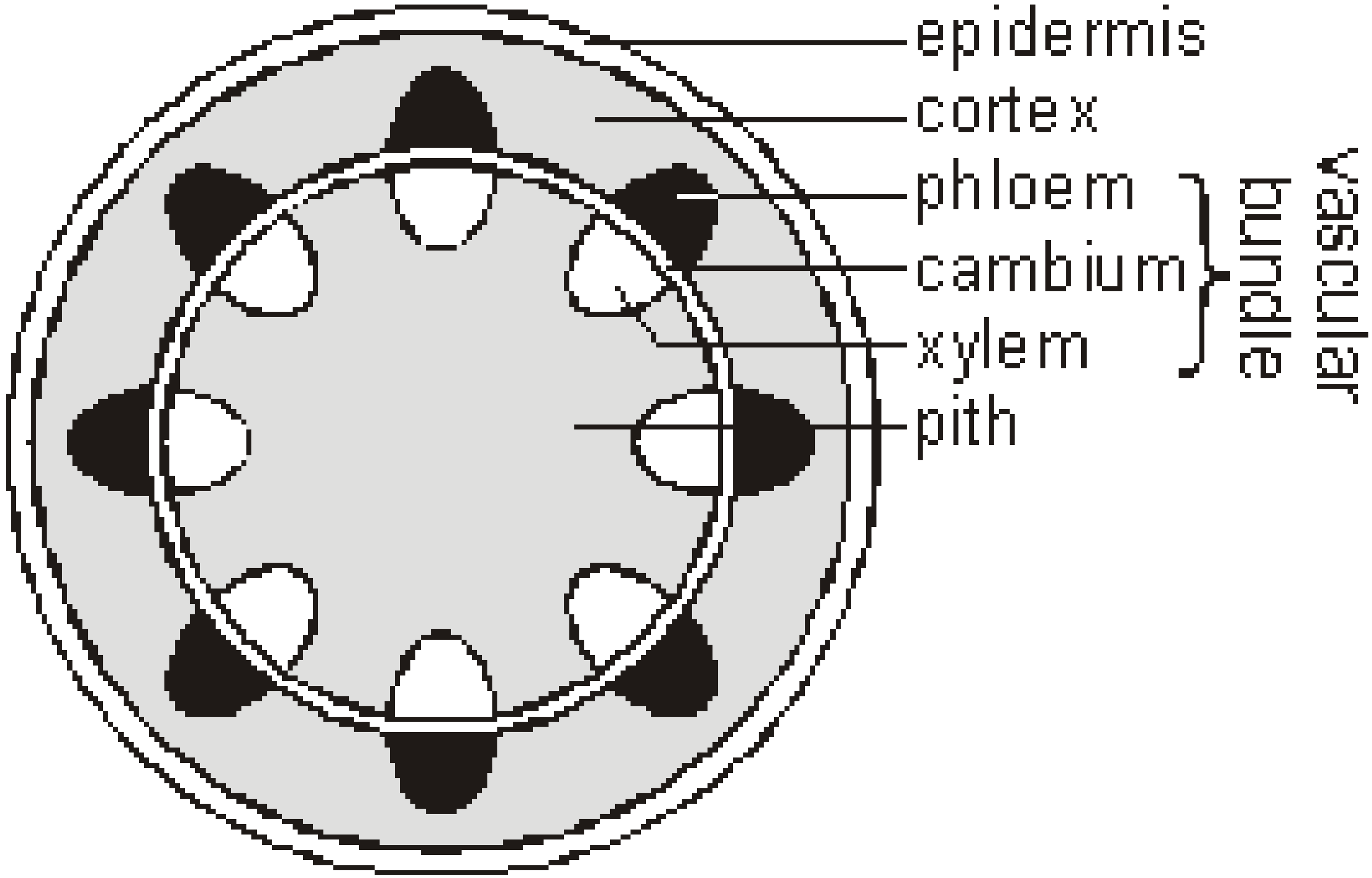
The stem – regions include:

- Epidermis
- Cortex
- Vascular bundles
- Pith




Phloem
Xylem
VASCULAR
CAMBIUM


Phloem
Xylem
DAVID WEBB
David Webb


epidermis
cortex
phloem
cambium
xylem
pith
vascular
bundle

Some extra tissues found in the stem:

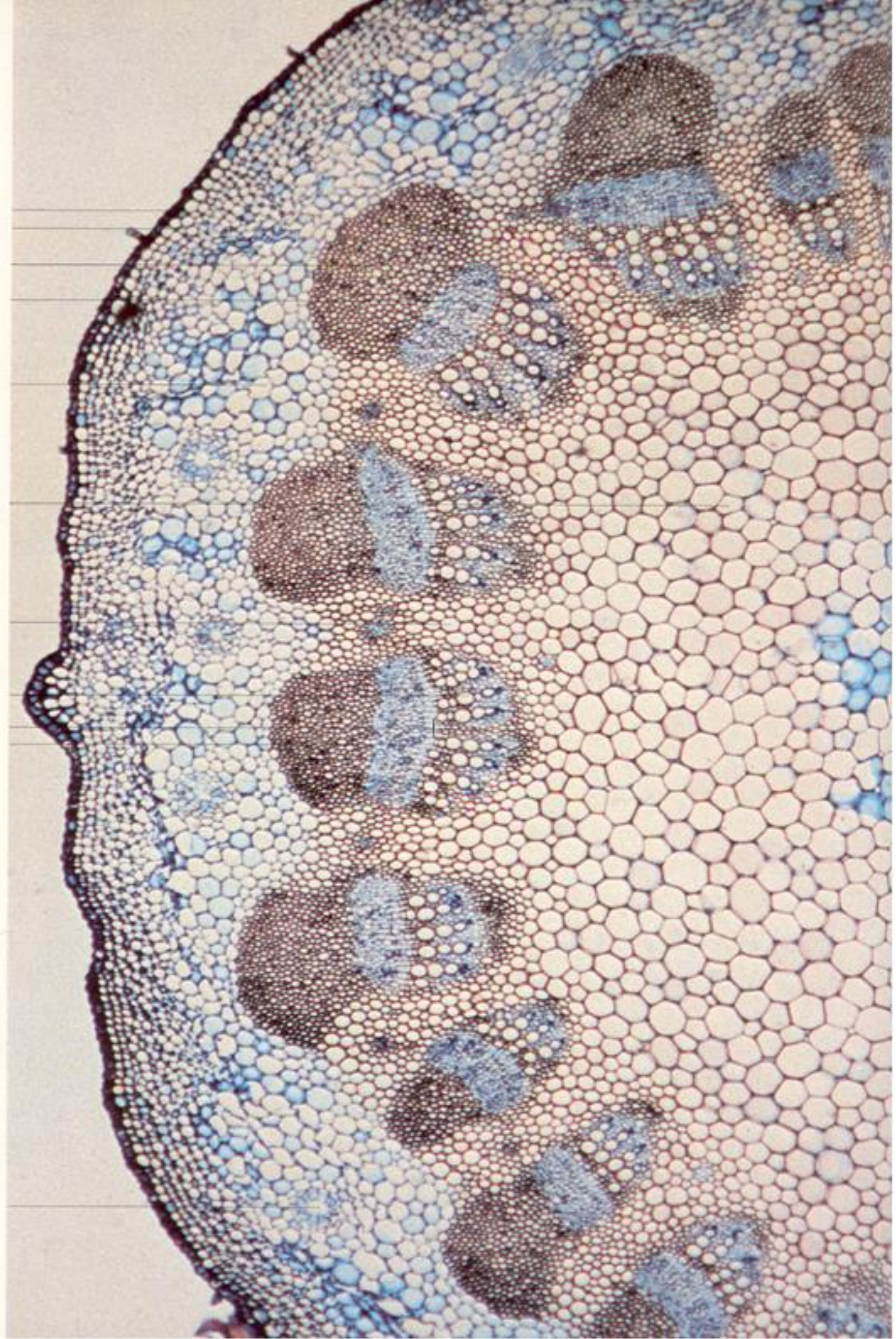
Vascular bundle – describes the "veins" in a plant that consist of xylem, phloem and cambium

Cambium – a third type of tissue in the vascular bundle (between the xylem and phloem). Cambium cells can divide to make new xylem cells to the inside or phloem cells to the outside

Pith – found at the very centre of the stem (inside the vascular region). Like the cortex, the pith is made of unspecialised packing cells called parenchyma. They can store products of photosynthesis and their turgidity provides non-woody plants with support

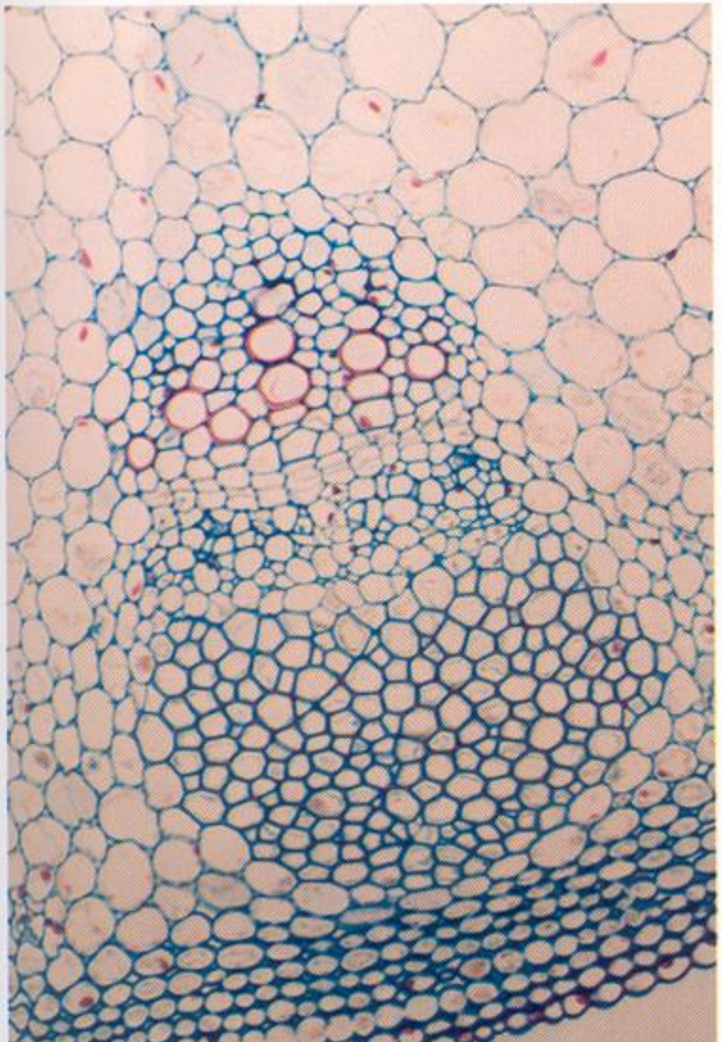
Stem (dicotyledon)

Helianthus (sunflower). × 70
Transverse section of the stem. The regular arrangement of the vascular bundles is very striking; each is strengthened by a group of sclerenchyma fibres that appears in transverse section as a cap.

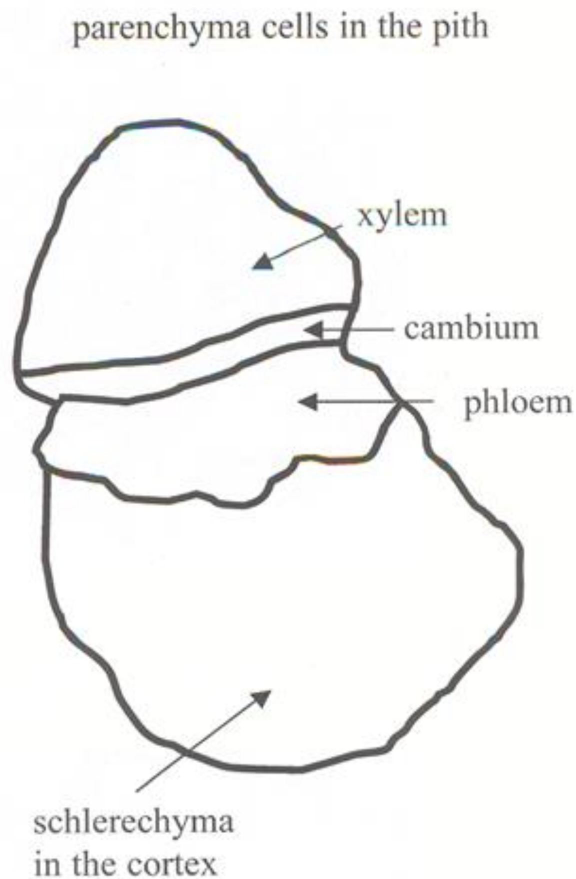


Staining Temporary Mounts: Sections of Stem

Photograph



Block diagram



Complete transverse sections of a stem are often difficult to produce. However, small areas can show a variety of tissues.

The leaf – regions include:

- Epidermis (+ waxy cutilcle)
- Palisade mesophyll
- Spongy mesophyll
- Vascular bundles (veins)
- Stomata + guard cells

Vascular tissues

There are two transport systems in flowering plants:

- **xylem** for water and inorganic ions
- **phloem** for organic molecules, such as sucrose and amino acids

These systems are contained within the plant's **vascular tissues**. Vascular tissues form a central **stele** (vascular cylinder) in the root, but peripheral **vascular bundles** in the stem. In the leaf, vascular tissues form a central large vascular bundle (midrib) from which smaller vascular bundles (veins) run through the leaf.

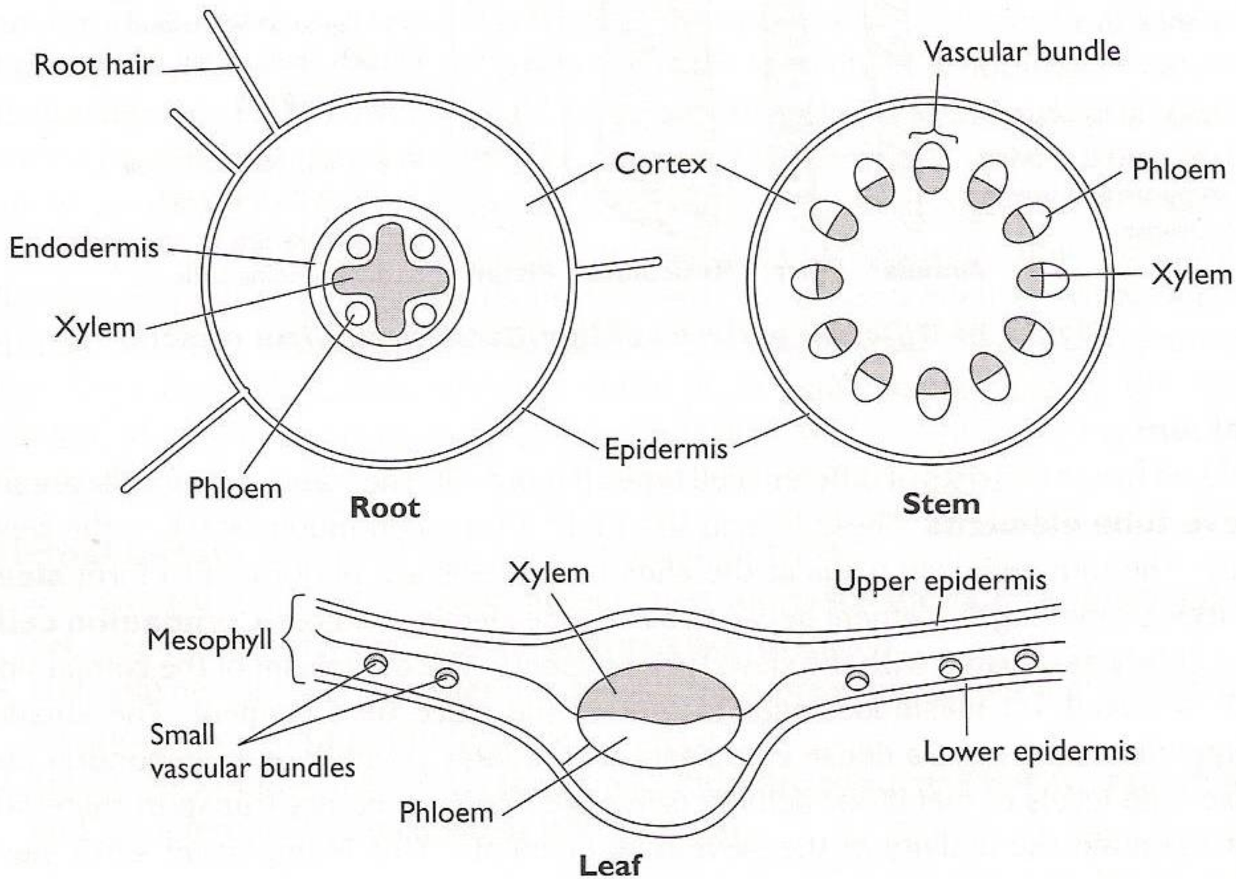
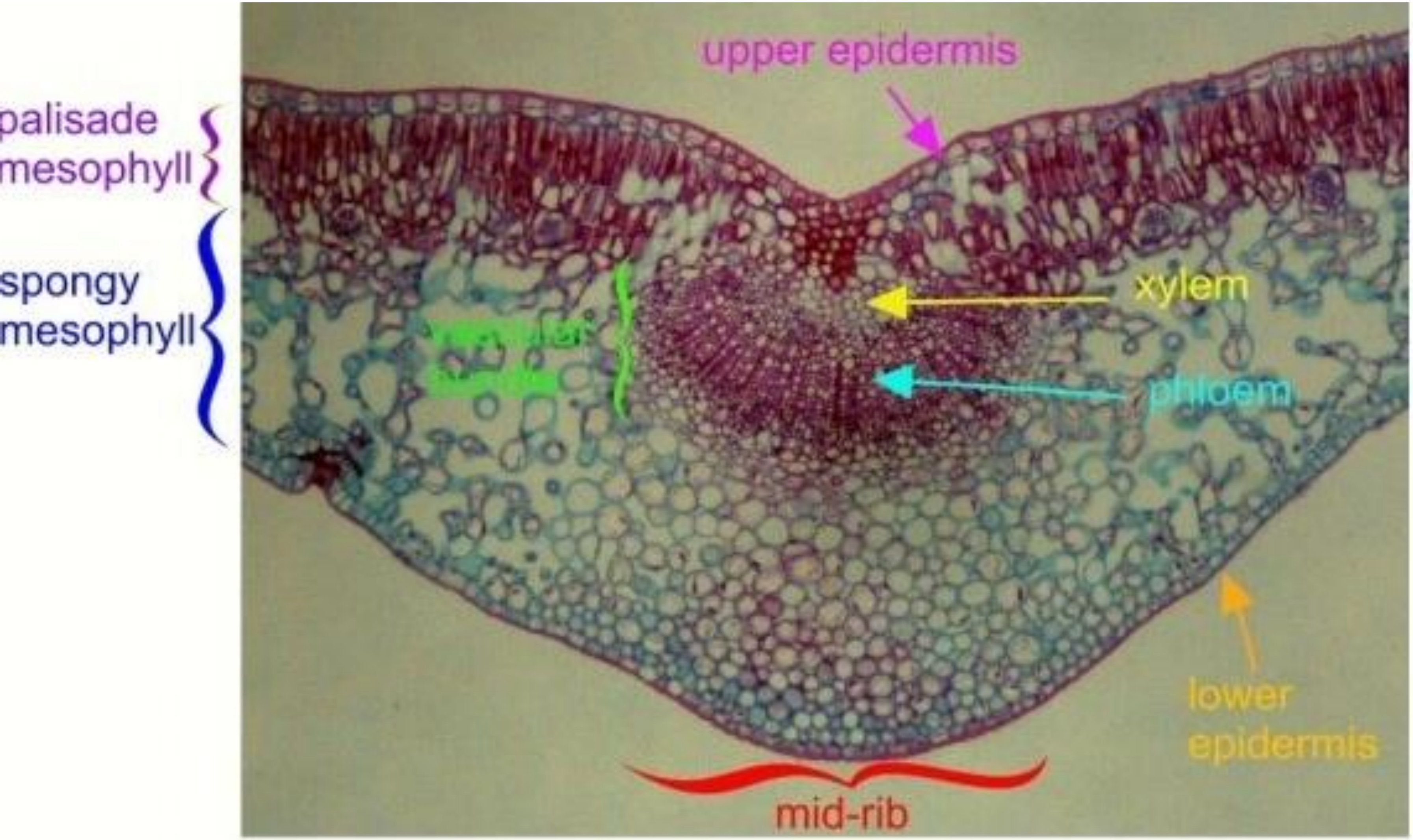


Figure 13 The distribution of vascular tissue (xylem and phloem) in cross sections of root, stem and leaf



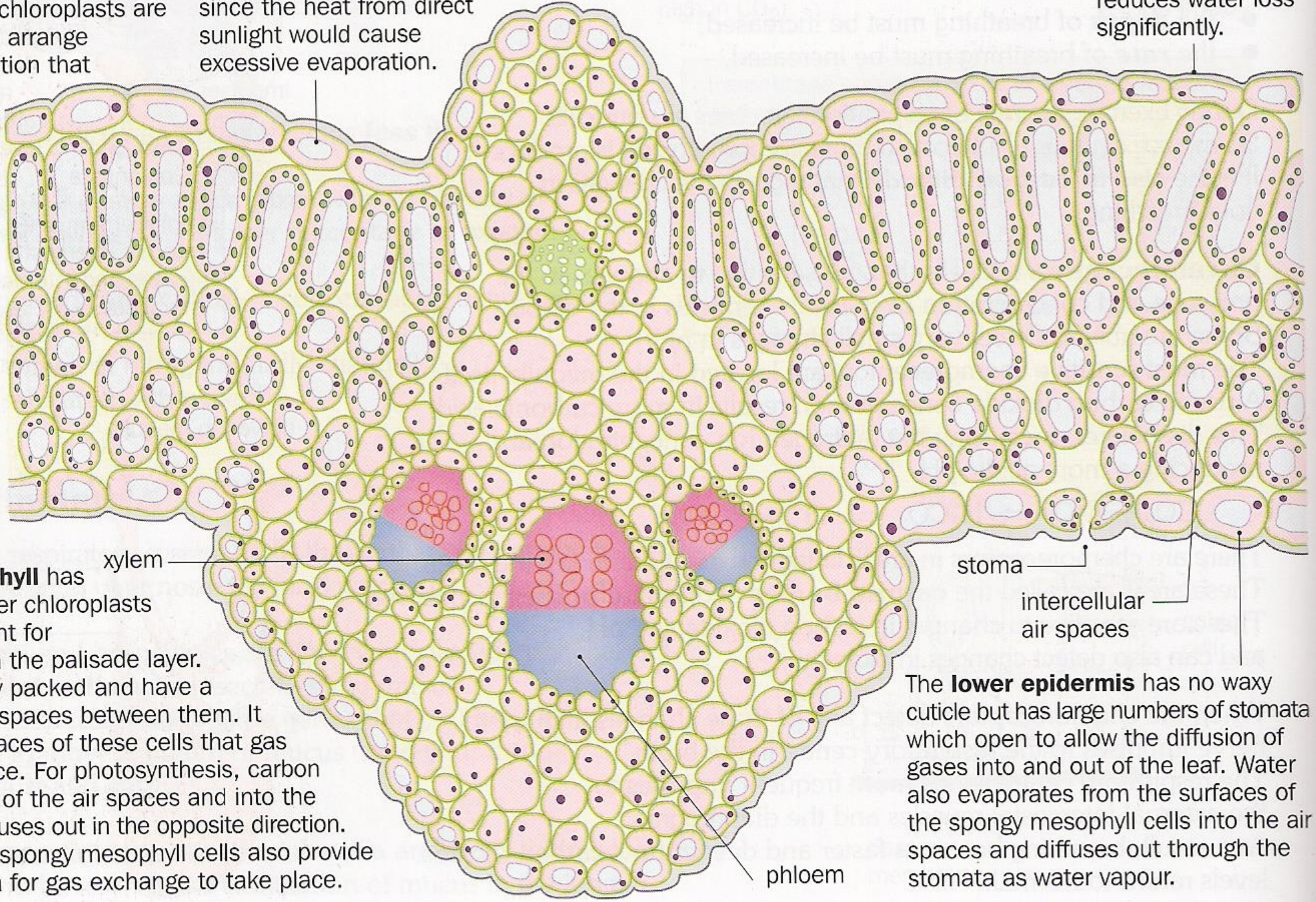
Leaf, mid-rib region. V.S.

Leaf structure

The **palisade mesophyll** is the main photosynthetic tissue. The cells are deep and packed full of chloroplasts. The chloroplasts are able to move and so arrange themselves in a position that gives maximum light absorption.

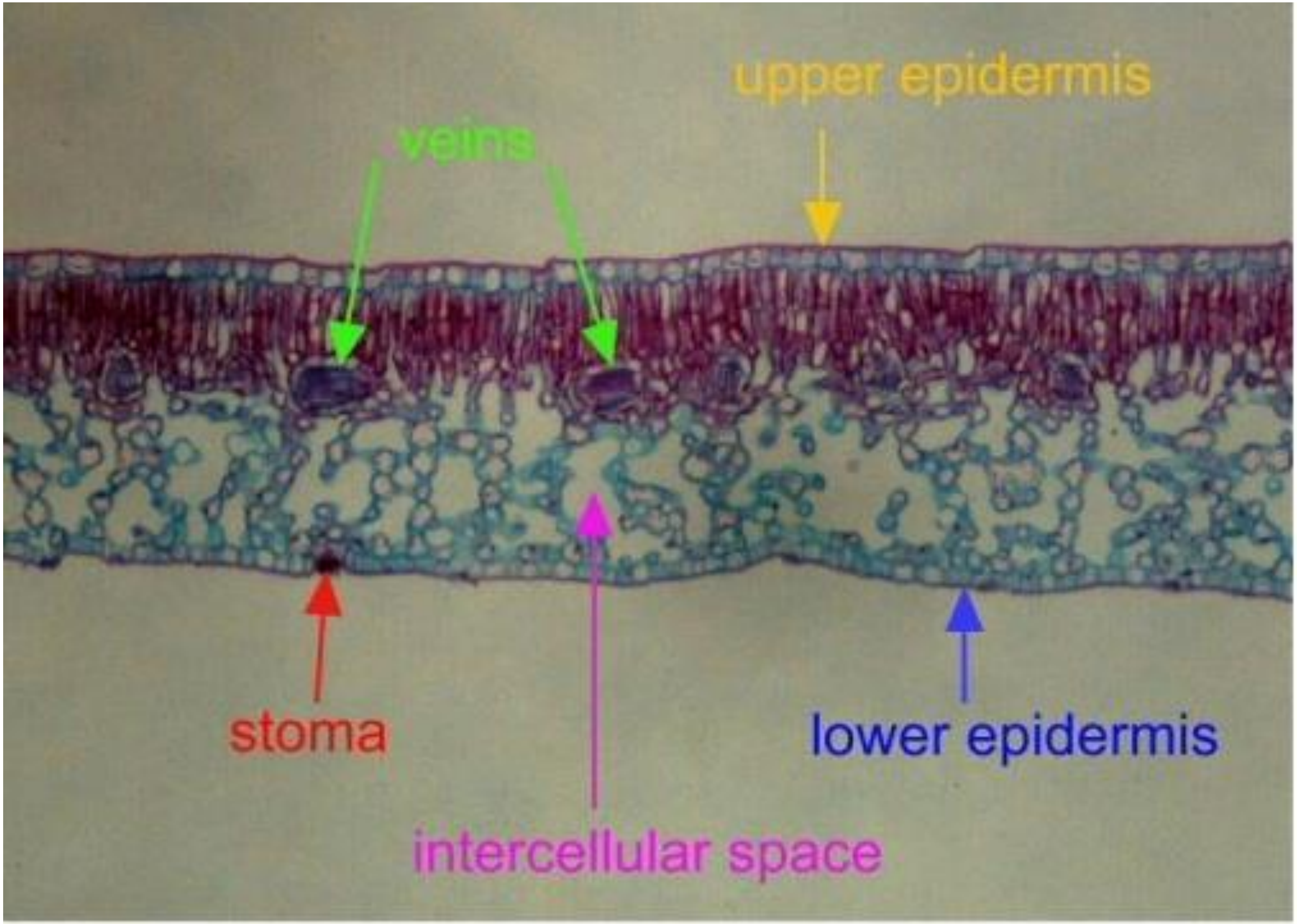
The **upper epidermis** is a single layer of cells. It is transparent since no chloroplasts are present and this means that light can pass straight through to the tissues below. There are not many stomata in the upper epidermis (if any at all) since the heat from direct sunlight would cause excessive evaporation.

The upper surface of a leaf is covered by a waxy **cuticle**. This reduces water loss significantly.

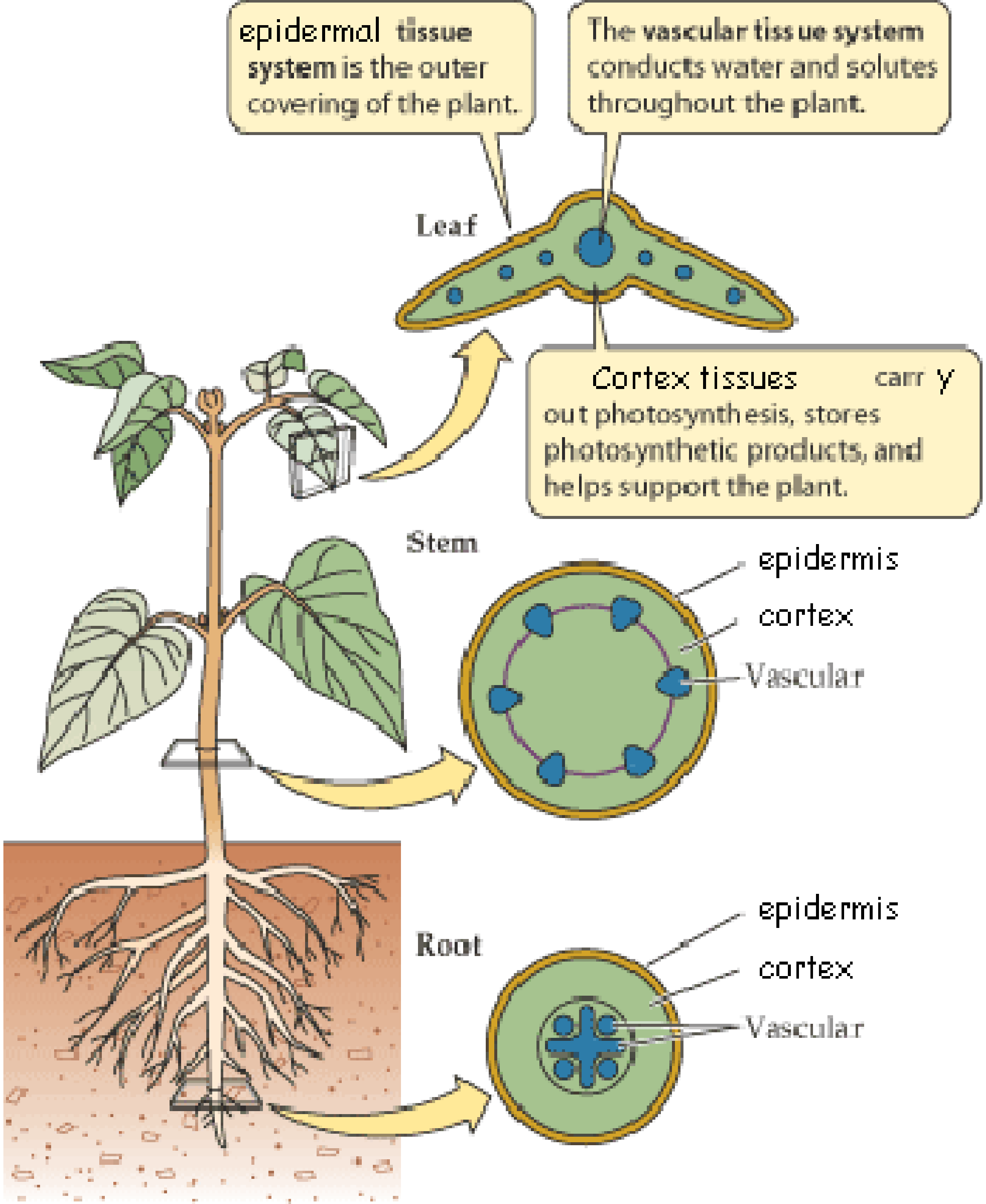


The **spongy mesophyll** has cells containing fewer chloroplasts so it is less important for photosynthesis than the palisade layer. The cells are loosely packed and have a large number of air spaces between them. It is on the moist surfaces of these cells that gas exchange takes place. For photosynthesis, carbon dioxide diffuses out of the air spaces and into the cells and oxygen diffuses out in the opposite direction. The surfaces of the spongy mesophyll cells also provide a large surface area for gas exchange to take place.

The **lower epidermis** has no waxy cuticle but has large numbers of stomata which open to allow the diffusion of gases into and out of the leaf. Water also evaporates from the surfaces of the spongy mesophyll cells into the air spaces and diffuses out through the stomata as water vapour.



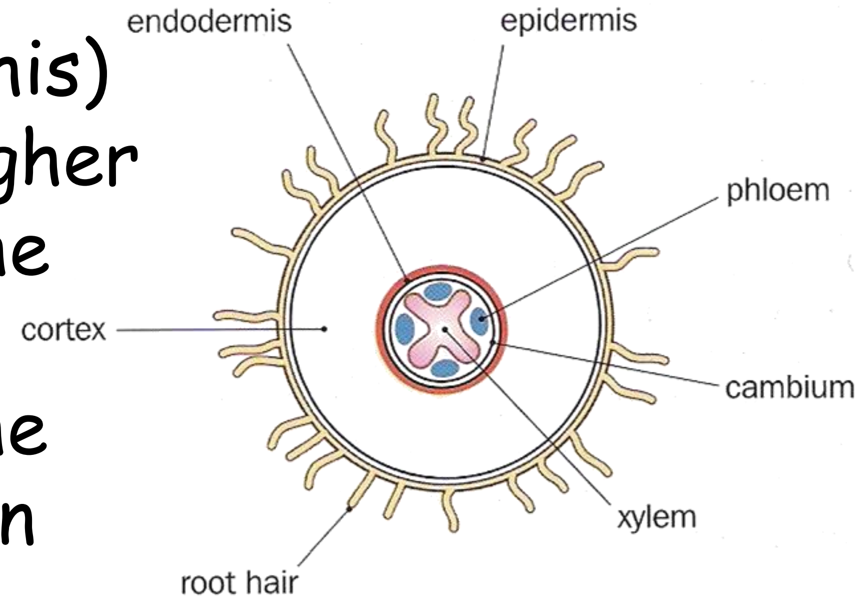
Leaf, blade region.



epidermal tissue system is the outer covering of the plant.
The vascular tiss ue system conducts water and solutes throughout the plant.
Leaf
Cortex tissues carr y out photosynth esis, stores photosynthetic products, and helps support the plant.
Stem
epidermis
cortex
Vascular
Root
epidermis
cortex
Vascular

The uptake of mineral ions by root hairs:

- Minerals can enter the root hairs passively by diffusion or actively by active transport (most ion uptake is through this)
- If the conc. of the ions is higher inside the root hair than in the soil, then energy from ATP is used to pump the ions in to the root against the concentration gradient

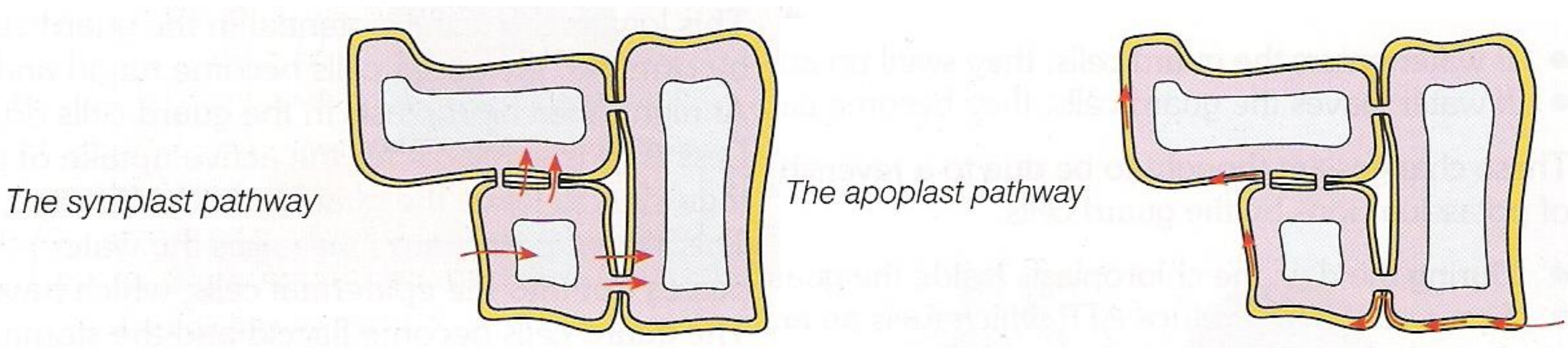


Transverse section through a young root

- Factors that affect the rate of respiration will therefore affect the rate of ion uptake e.g.?

Oxygen supply, temperature, presence of inhibitors e.g. cyanide

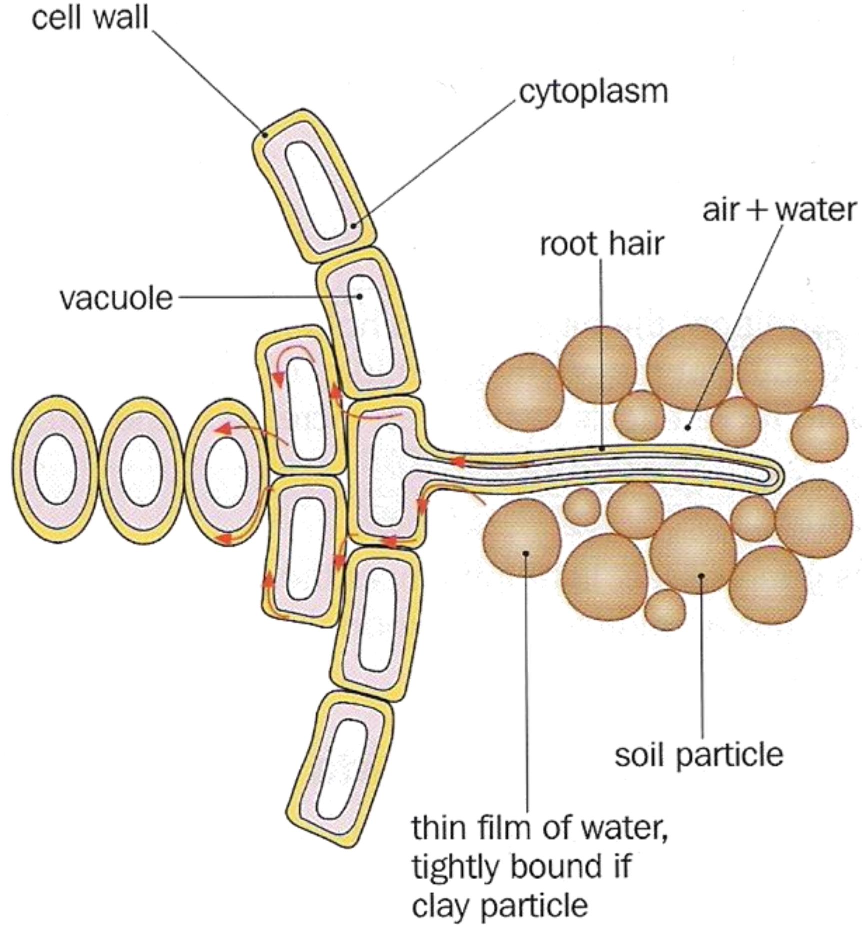
- Once inside the root hairs, mineral ions move across the cortex to the xylem by the symplast (by diffusion) and apoplast (by diffusion and active transport) routes
- After passing across the endodermis via the symplast route, mineral ions are thought to enter the xylem by a combination of active pumping and diffusion



Water uptake involving osmosis

- Water enters the root hair from the soil by osmosis and passes across the cortex to the xylem tissue
- The root hair cells in the piliferous region lack a waxy cuticle so that is why osmosis occurs here and nowhere else in the root (and have large SA)
- The root hair cells have a lower water potential than the soil due to the solutes in their vacuoles (e.g. mineral ions); thus water moves in, and follows a concentration gradient:
- When water enters a root hair cell, its water potential rises compared to the adjacent cells
- Water moves into the next cell by osmosis
- The water potential in the xylem is lower than that in the root cortex cells, so water travels across the cortex to the xylem vessels at the centre of the root

Root hairs have:
- Thin walls (short diffusion pathway)
- Large surface area to volume ratio for absorption



Absorption of water by a root hair

Water travels through the cortex of the root to the xylem along 2 different routes...

THE SYMPLAST AND APOPLAST PATHWAYS

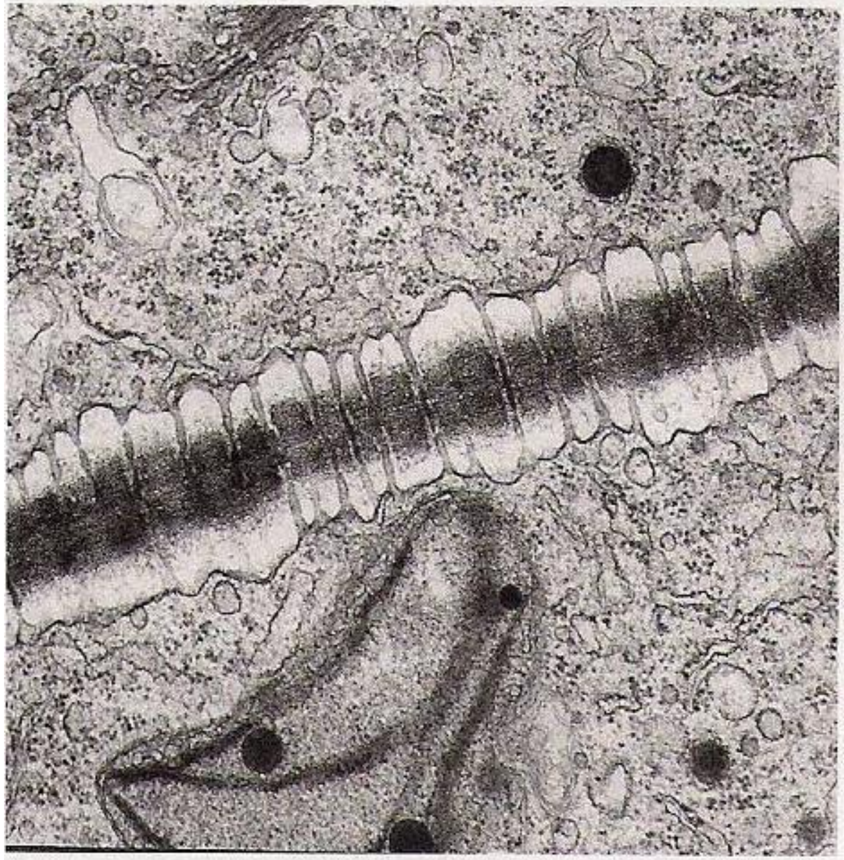
What we will learn...

Understand the apoplast and symplast pathways through plant tissues:
- The apoplast pathway along cellulose cell walls
- The symplast pathway through protoplasts connected by plasmodesmata
- The apoplast and symplast pathways in the root and leaf;
- The role of the endodermis in ensuring the symplast pathway into the stele

Symplast route

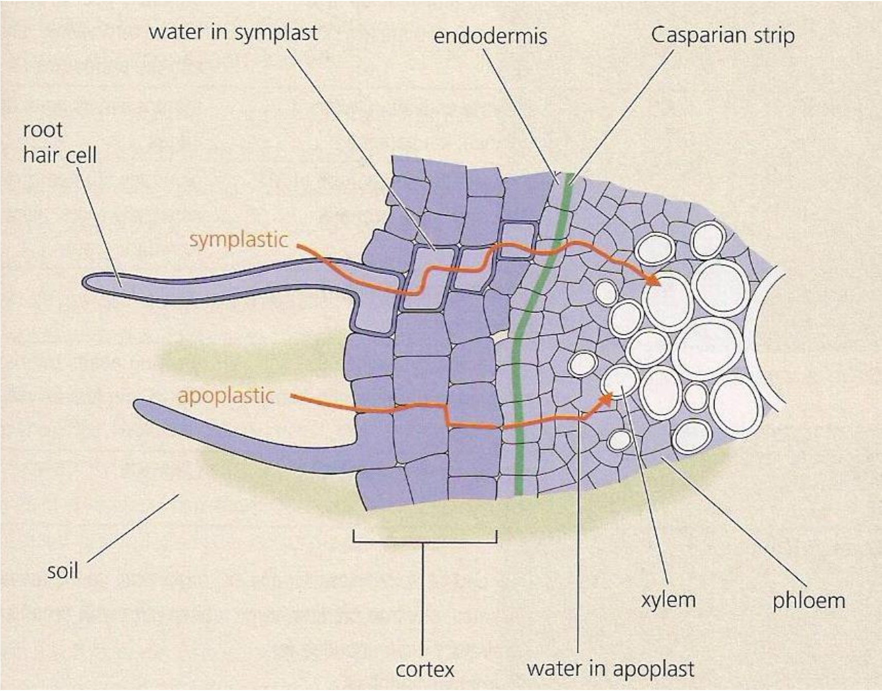
- Water moves through the **protoplasts** of the cortex cells **How?**
- Water can move through the **plasmodesmata** that connect the cytoplasm of one cell to the next

Fig 31.7(b) Plants cells are joined by thin threads of cytoplasm called plasmodesmata, which project through holes in the cell wall. These cytoplasmic strands allow materials to pass from cell to cell and are an important part of the symplast pathway



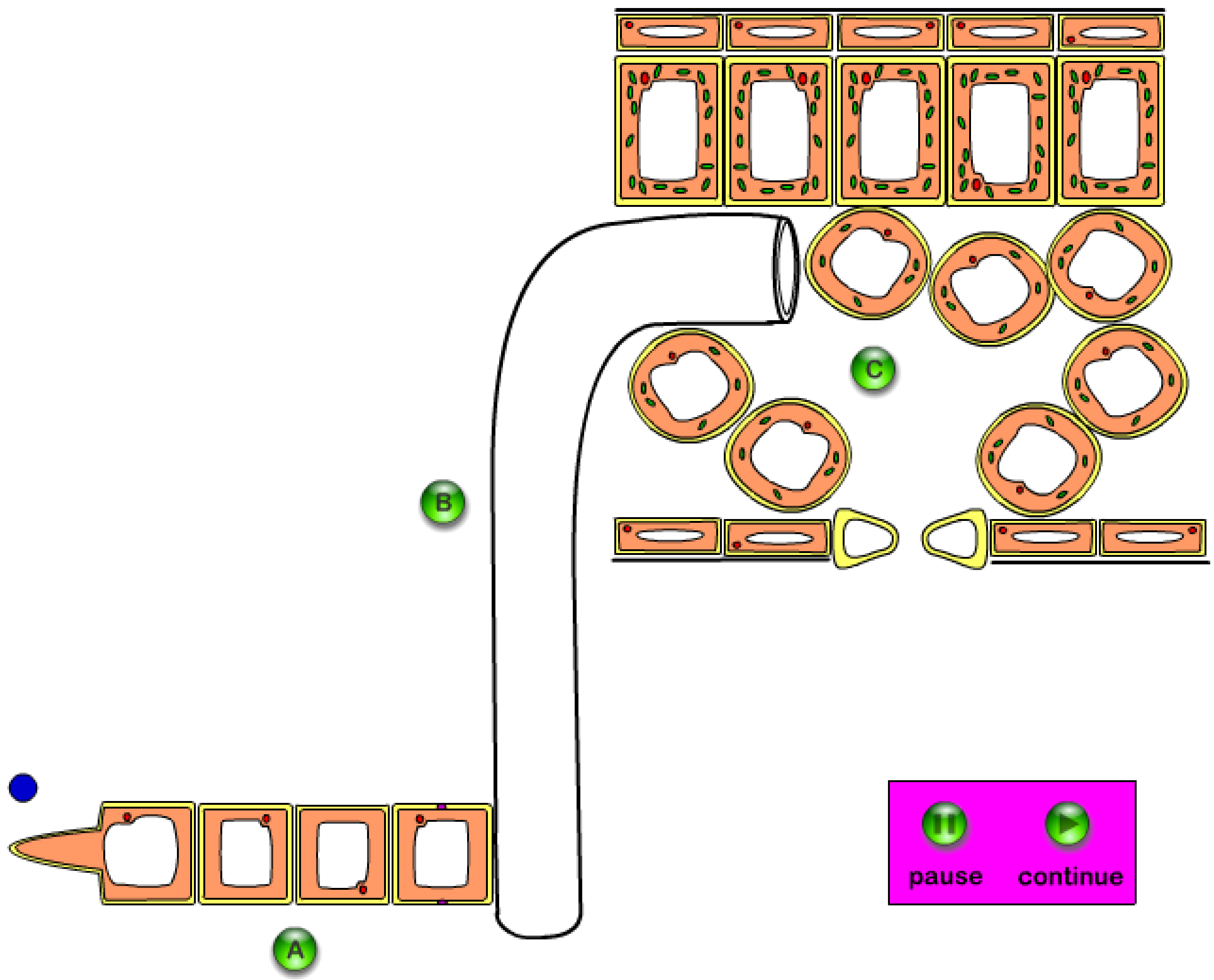
Apoplast route

- Water moves through the **cellulose fibrils of cell walls** of the cortex cells
- As water passes through the spaces between the cellulose fibres the cohesive forces between the water molecules means **more water is pulled along the apoplastic route as it offers less resistance** than the symplast route

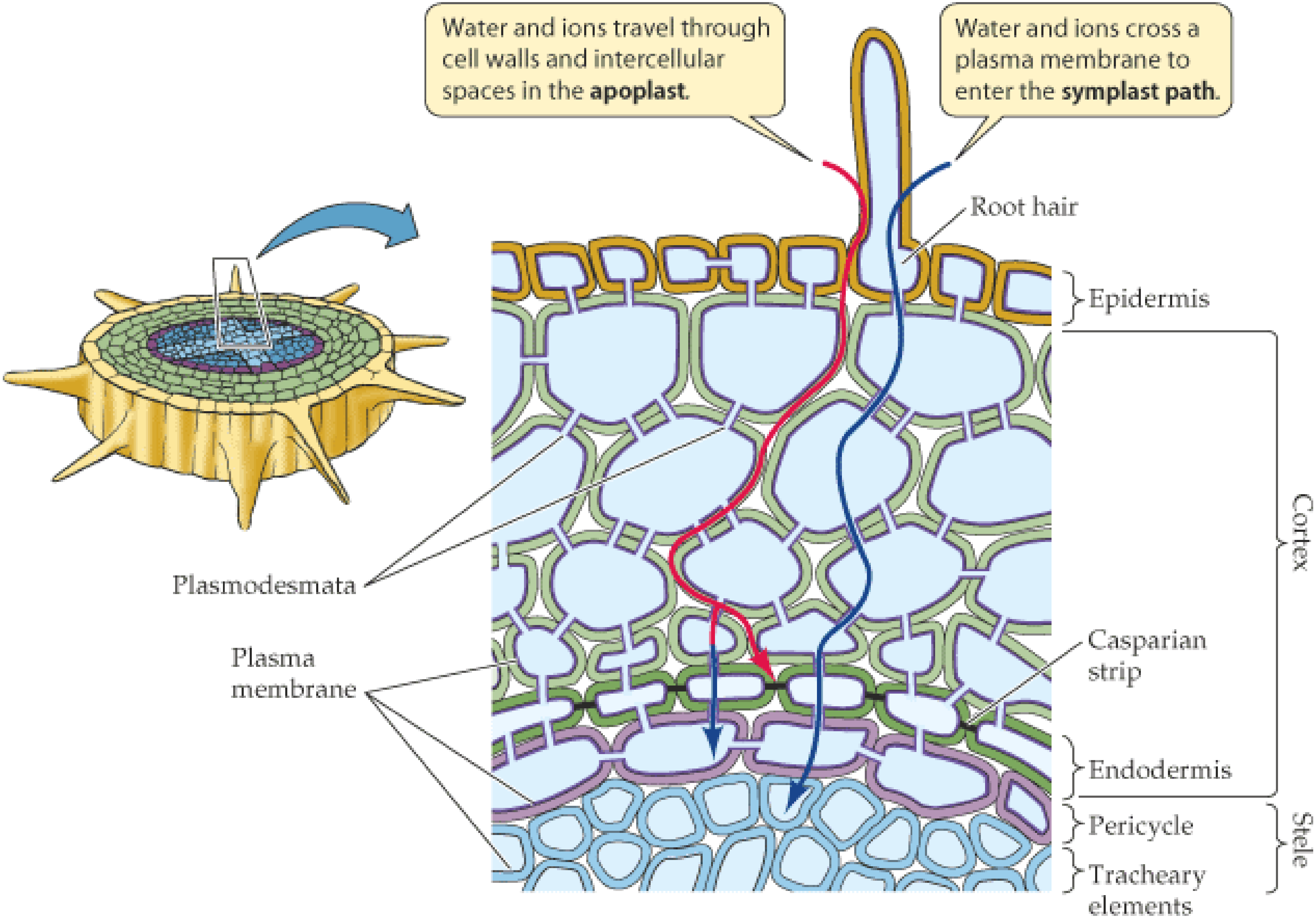


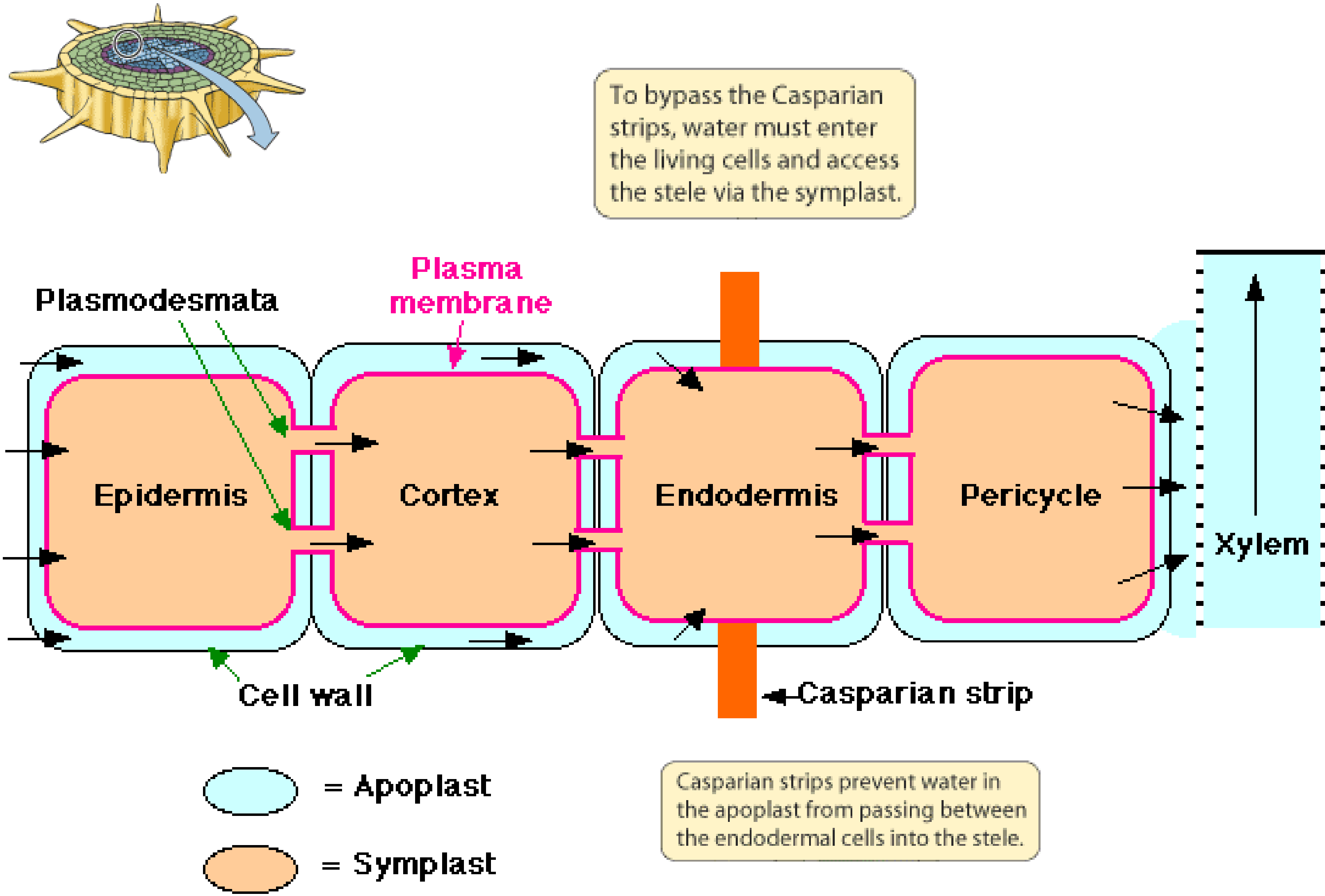
Qu: Does water move straight into the cell walls of epidermal cells when travelling by the apoplast route or does it enter the cytoplasm first and then travel through the walls?

Water goes directly into cell walls , which is why apoplast pathway is lots quicker than symplast – cellulose fibrils in cell wall offer no resistance to the movement of water, unlike the cytoplasm in the protoplast



A
B
C
pause
continue

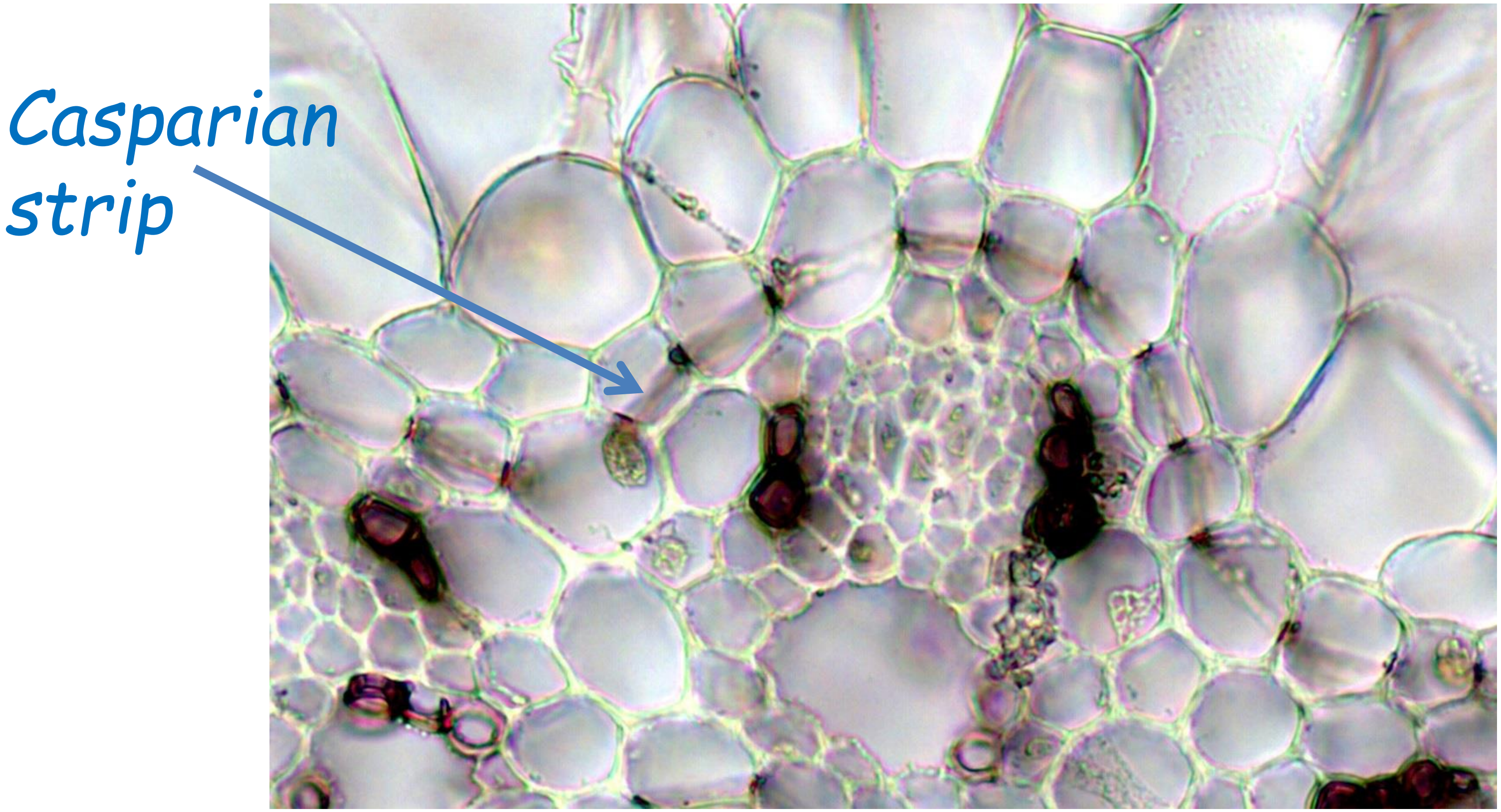

Water and ions travel through cell walls and intercellular spaces in the **apoplast**.
Water and ions cross a plasma membrane to enter the **symplast path**.
Root hair
Epidermis
Cortex
Plasmodesmata
Plasma membrane
Casparian strip
Endodermis
Pericycle
Stele
Tracheary elements


To bypass the Casparian strips, water must enter the living cells and access the stele via the symplast.
Plasmodesmata
Plasma membrane
Epidermis
Cortex
Endodermis
Pericycle
Xylem
Cell wall
Casparian strip
= Apoplast
= Symplast
Casparian strips prevent water in the apoplast from passing between the endodermal cells into the stele.

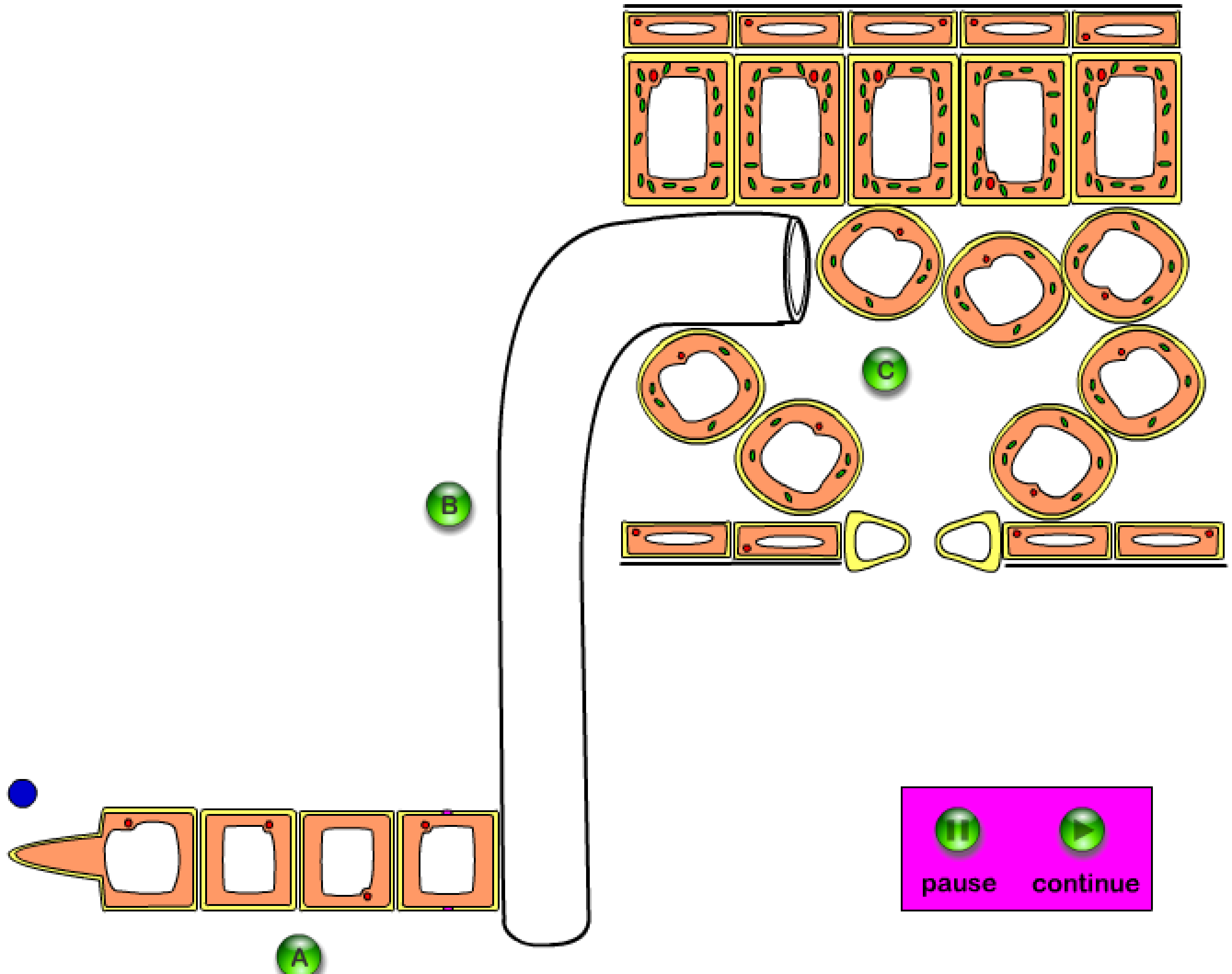
- The apoplast route is blocked at the endodermis
- The cell walls of the endodermis are impregnated with waxy **suberin**
- This forms a band of wax around the cells called the **casparian strip**
- As suberin is waterproof the Casparian strip stops water passing along the cell walls
- To pass through the CS water must cross the cell membrane and pass into the cytoplasm and continue along the symplast route into the stele

Why is this useful?

By forcing the water and ions through the symplast pathway before entering the xylem, the Casparian strip ensures the plant has control over what and how much water and dissolved mineral ions enter the xylem i.e. **important for regulating the plant's cellular metabolism**

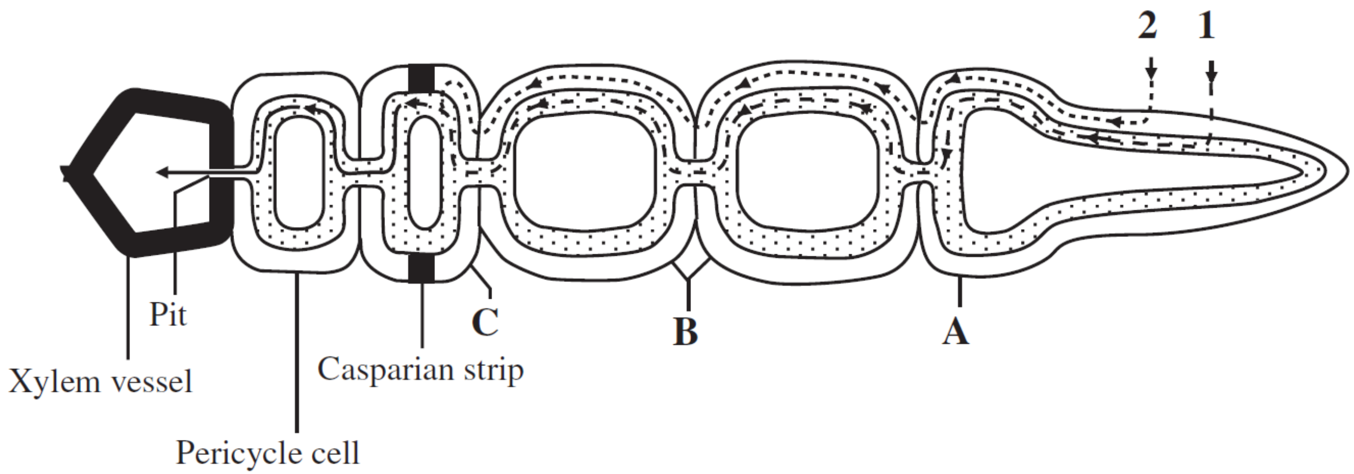


- **Water and ions entering the endodermis via the symplast pathway thus come under the control of the cells metabolism**
- **Ions are actively pumped into the xylem, which creates a lower water potential and then water follows along this water potential gradient**



B
C
A
pause
continue

4 The diagram below represents the arrangement of cells in part of the root of a dicotyledonous plant together with two possible routes taken by water entering the vascular tissue.



Source: Biology Principles and Processes, Roberts, Reiss and Monger, Nelson, 1993.

(a) Identify the cell types labelled **A** to **C**.

A ______________________________

B ______________________________

C ______________________________ [3]

Examiner Only	
Marks	Remark

June 06

(b) Which of the arrows, **1** or **2**, represents the symplast pathway of water movement?

____ [1]

(c) What makes up the Casparian strip in cell type **C** and what is its function in water transport?

____

____

____

____ [2]

(d) Describe **one** way in which xylem vessels are adapted for their function of water transport.

____

____ [1]

4 **(a)** A: root hair cell;
B: parenchyma cell/cortex;
C: endodermal cell/endodermis; [3]

(b) Arrow 1; [1]

(c) Contains waterproof material (suberin)/makes cell wall impervious to water;
diverts water from apoplast route to symplast route/offers plant some control over what enters pericycle/forces water to pass through semi-permeable membrane; [2]

(d) Hollow lumen with no living cytoplasm reduces resistance to water movement/lignified walls prevent collapse/small lumen to enhance capillarity/pits to allow lateral movement of water; [1]

The movement of water (and dissolved ions) through the xylem tissue

-Cohesion-tension theory

-Transpiration creating a negative pressure within leaf xylem vessels resulting in the transpiration stream

-The cohesive and adhesive forces of water

-The root pressure hypothesis

First we need to look at the structure of the xylem...

Homework for tomorrow:

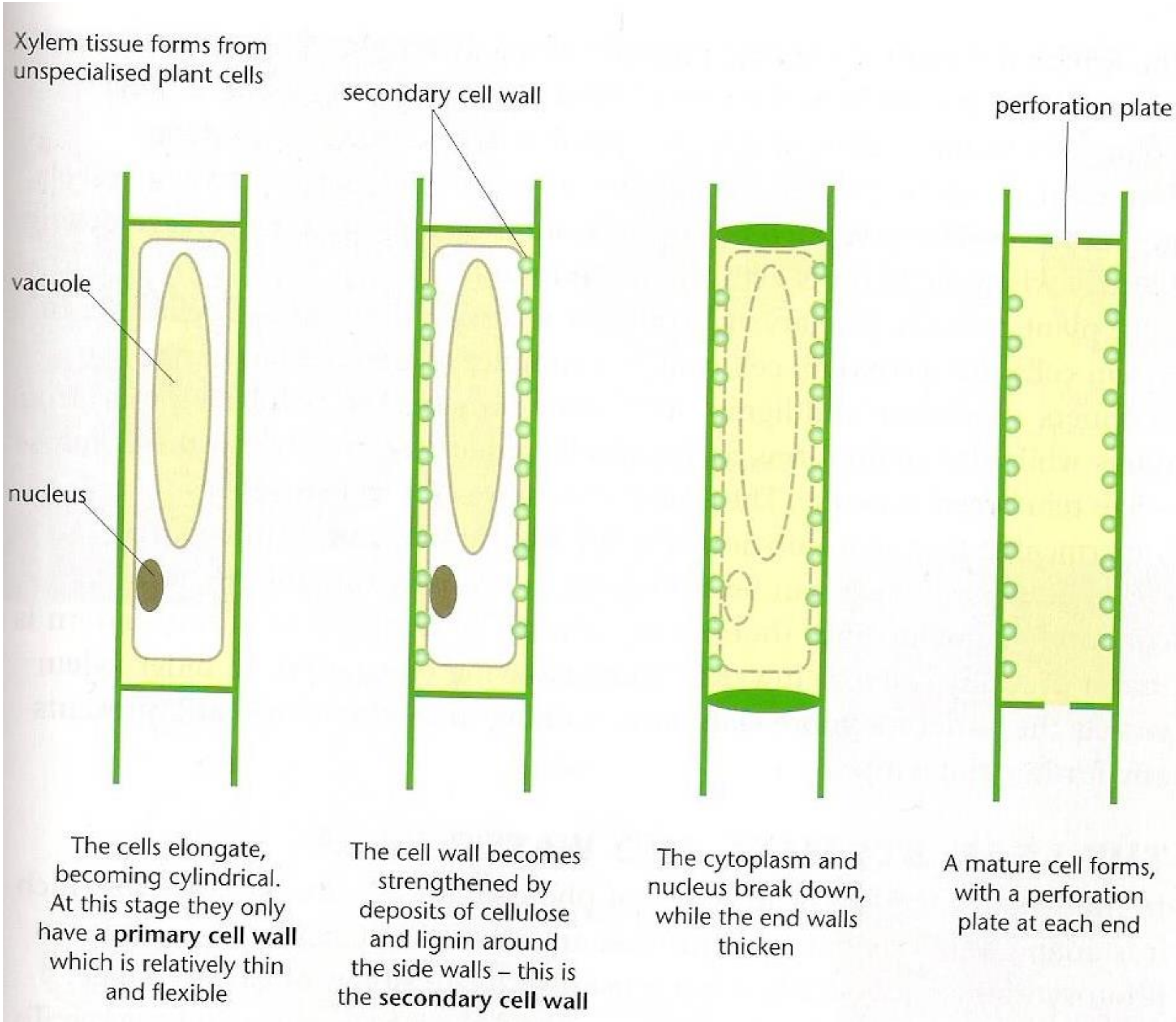
Finish plant transport notes

XYLEM TISSUE

is made of XYLEM VESSELS – these cells transport most of the water and mineral ions

- These are formed from a column of unspecialised cells which lose their end walls
- In these cells a secondary cell wall, impregnated with lignin is formed inside the primary cell wall
- This increases mechanical strength and is important if the vessels are to withstand the strong pressures that occur during water transport
- The lignin stops the xylem vessels from collapsing when under tension during water transport

How xylem tissue forms:



- Lignin is impermeable so materials cannot pass into the xylem cells and the protoplasm dies (what's inside the cell membrane) i.e. mature xylem vessels are dead!
- The cells are hollow and nothing restricts the flow of water so less pressure is required to move the water than in living cells
- No lignin is laid down where plasmodesmata were present in the original cell walls
- These non-lignified areas are known as pits and they allow water to pass sideways between one xylem vessel and the next

Homework for Monday:

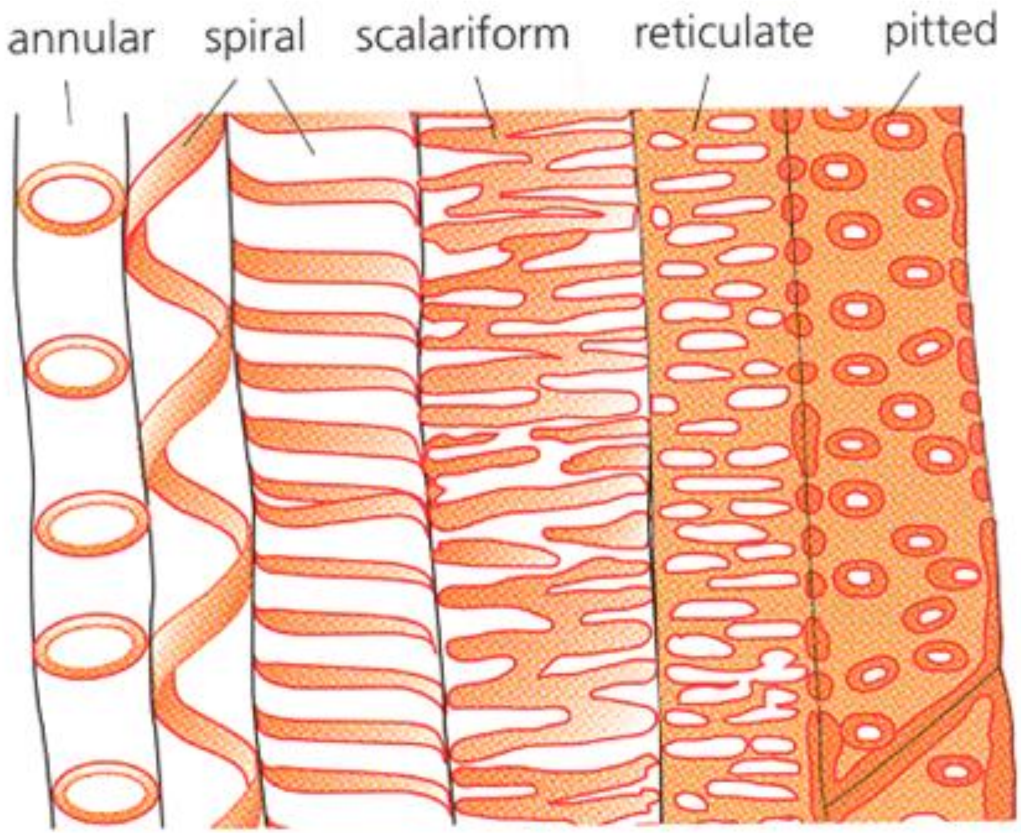
Complete past paper question

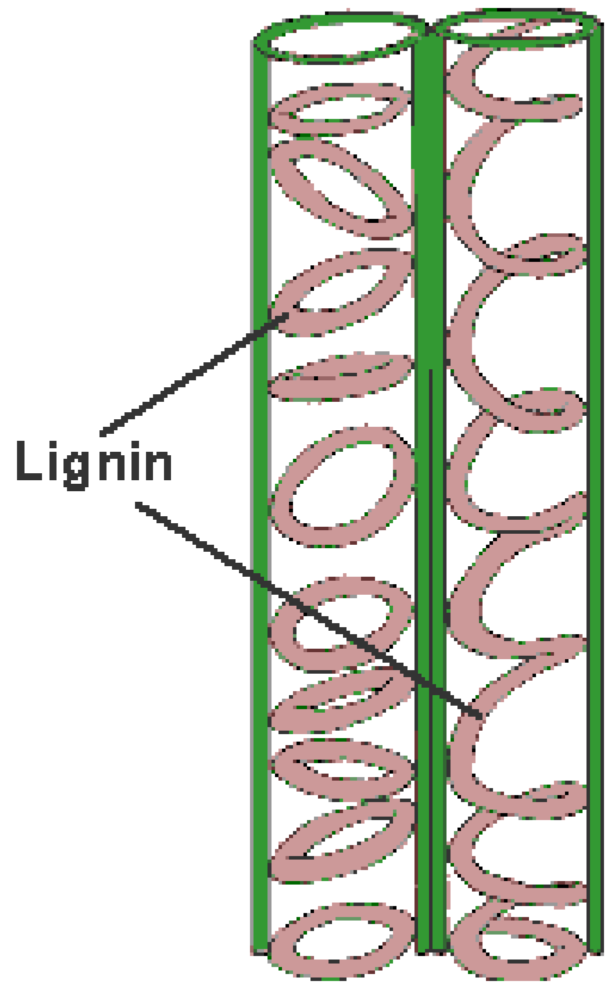
Homework for Thursday:

Revise for transport in plants test

NEW XYLEM ORIGINATES FROM THE MERISTEMATIC REGION BETWEEN THE XYLEM AND PHLOEM CALLED THE CAMBIUM.

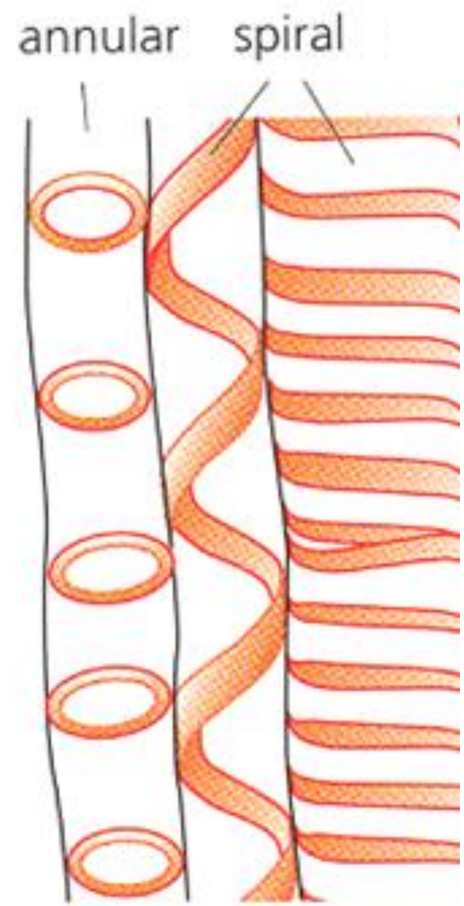
Different types of lignin deposition in xylem vessels occurs depending on the age of the xylem and where it is found in the plant:




Lignin

2 TYPES OF XYLEM TISSUE CAN EXIST TOGETHER ALTHOUGH PROTOXYLEM IS MORE ASSOCIATED WITH NEW GROWTH AN METAXYLEM WITH MORE MATURE TISSUE

1. **Protoxylem** – the first xylem to develop behind the **root and shoot tips**. Lignin is added in rings or spirals to form annular vessels (rings) and spiral vessels – this is to allow the vessels to elongate along with other tissue in the growth regions.



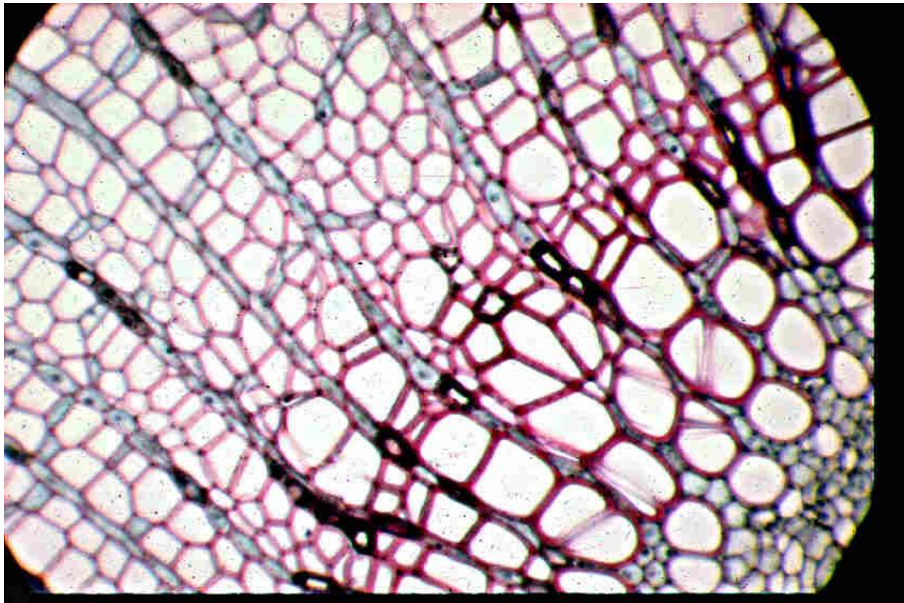
2. **Metaxylem** – is produced in the **more mature parts** of the plant and the walls are fully lignified (with the exception of pits). We see reticulated and pitted patterns of lignification here

- ***Reticulated vessels*** *are thickened by interconnecting bars of lignin*
- ***Pitted vessels*** *have a uniform (always the same) thickness, except at pores seen as pits – these allow for rapid movement of water and ions out of the vessels to the surrounding cells*

- Secondary xylem allows **woody plants** to increase their girth each year
- This is known as secondary thickening
- This seasonal growth shows up as annual rings
- A ring formed in the previous year transports little water, its main function being to support the plant's increasing biomass

Functions of the xylem:

- Conduction of water and mineral salts – water is drawn up under tension due to evaporation from leaves – there are different theories to explain this. Thickening prevents the collapse of the xylem vessels
- Mechanical support to the increasing biomass of the growing plant



Summary:

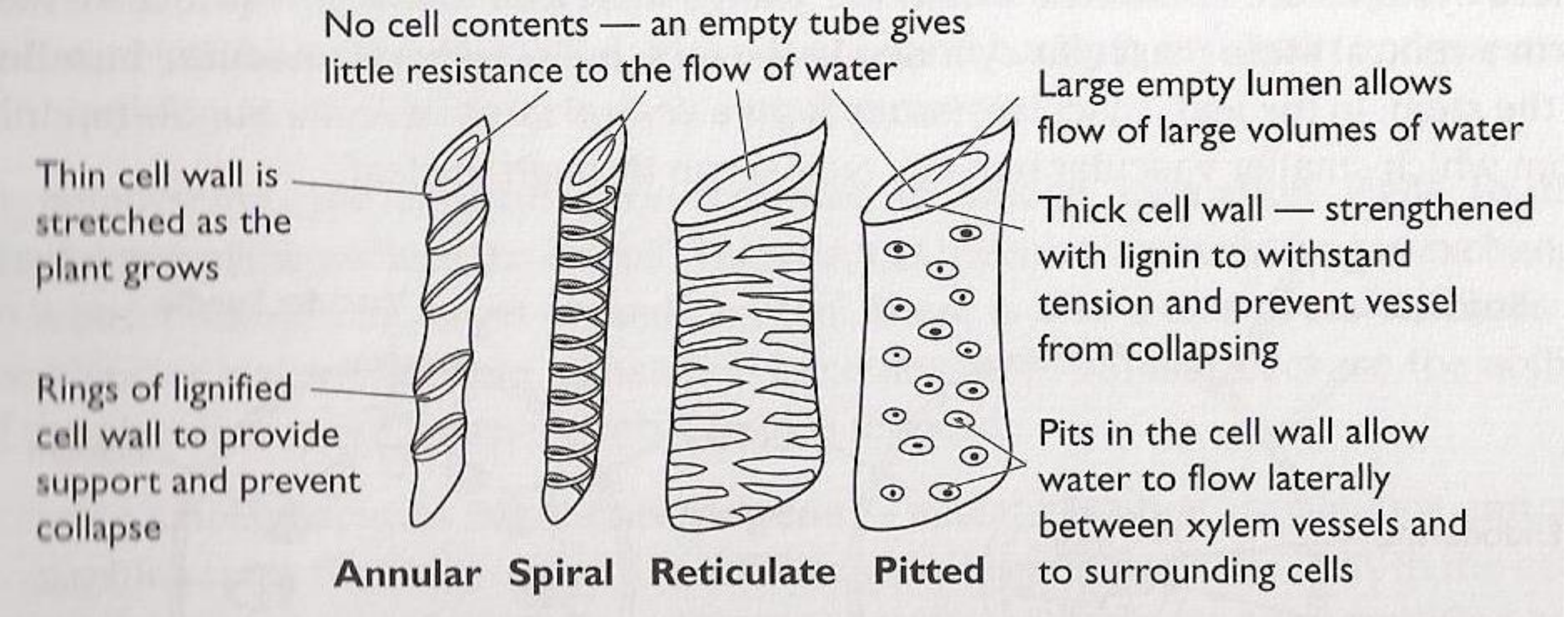


Figure 14 Different patterns of lignification in xylem vessels

Jan 07

3 (a) Describe **two** features of a xylem vessel that help it to carry out the function of water transport in plants.

1. ______________________________

____

2. ______________________________

______________________________ [2]

3 (a) Any two from

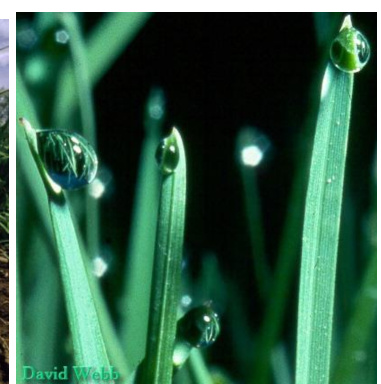
- hollow/no cytoplasmic contents
- continuous tubes/no cross walls
- lignified to waterproof/prevent collapsing
- pits for lateral movement of water

The movement of water (and dissolved ions) through the xylem

2 main theories are used to explain the movement of water through the xylem

1. Root pressure theory

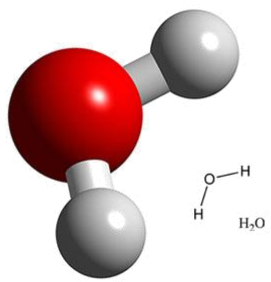
- Created when mineral ions dissolved in the water travelling along the apoplast route in the roots cannot travel along the endodermal cell wall and are actively secreted into the cytoplasm and xylem by the endodermal cells (**lowering the water potential in the xylem**)
- Water moves from the surrounding cells in to the lower water potential in the xylem and a positive hydrostatic pressure is created, which pushes water up the xylem
- This plays a minor role in the movement of water up the stem



2. Cohesion-tension theory

- Transpiration creates a negative pressure within the leaf xylem vessels resulting in the transpiration stream which PULLs water from the roots up the xylem. This is due to:

- COHESION: water molecule stick together due to H bonds
- ADHESION: water molecules stick to the sides of the xylem vessels
- TENSION: pressure created as molecules pull on each other



- The force needed to break this water column is very great
- The xylem vessels are thickened to withstand the tension
- Water eventually leaves the xylem in the leaf and moves through the mesophyll cells by the apoplast or symplast pathways
- The cohesion-tension theory is regarded as the main way in which water reaches the leaves of plants from the roots

Read page 206 of Froggy

A good summary of the movement of water through a plant:

LEARN!

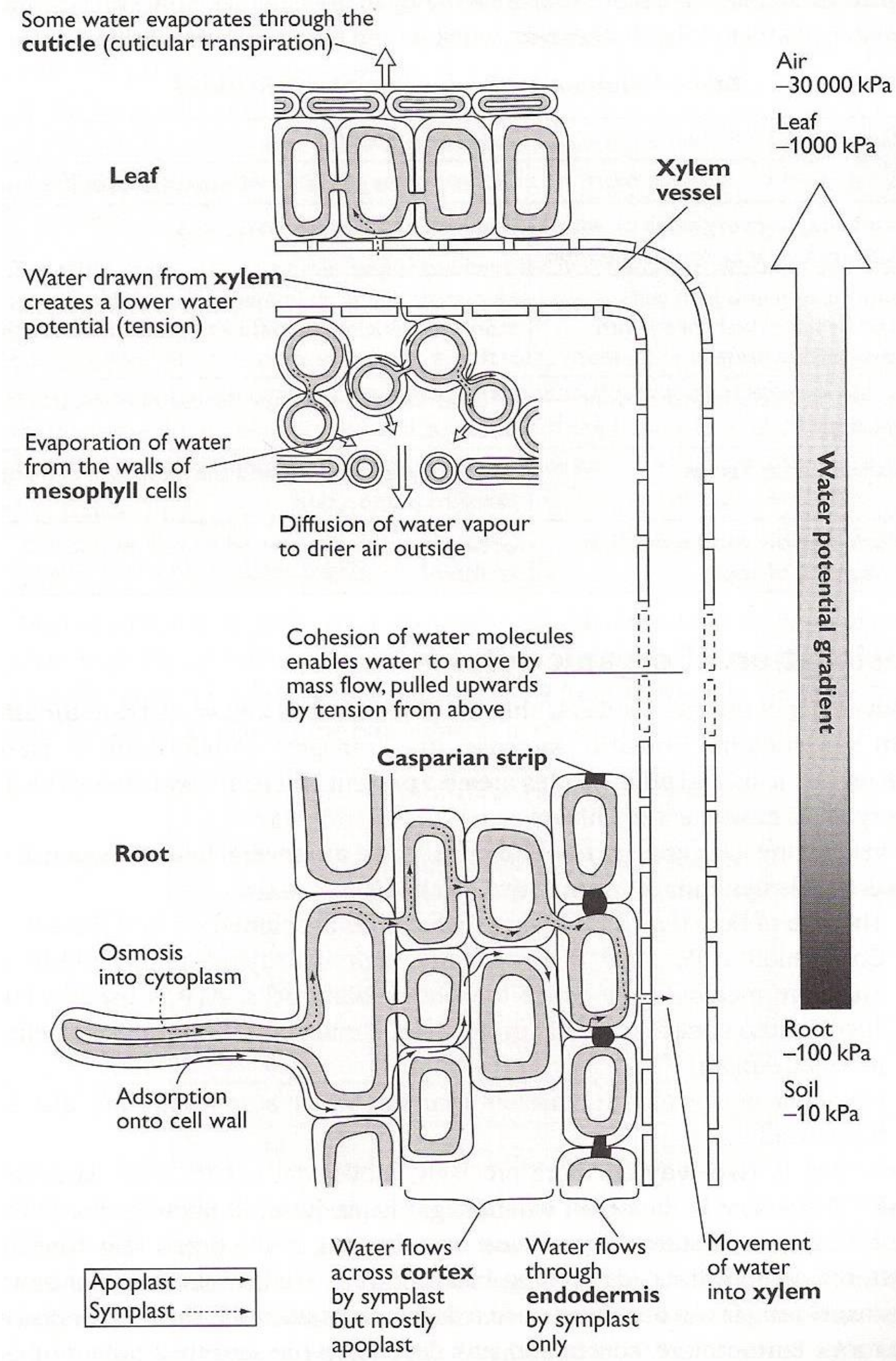


Figure 16 The movement of water through a plant

ESSAY:

Give an account of the processes involved in the movement of water

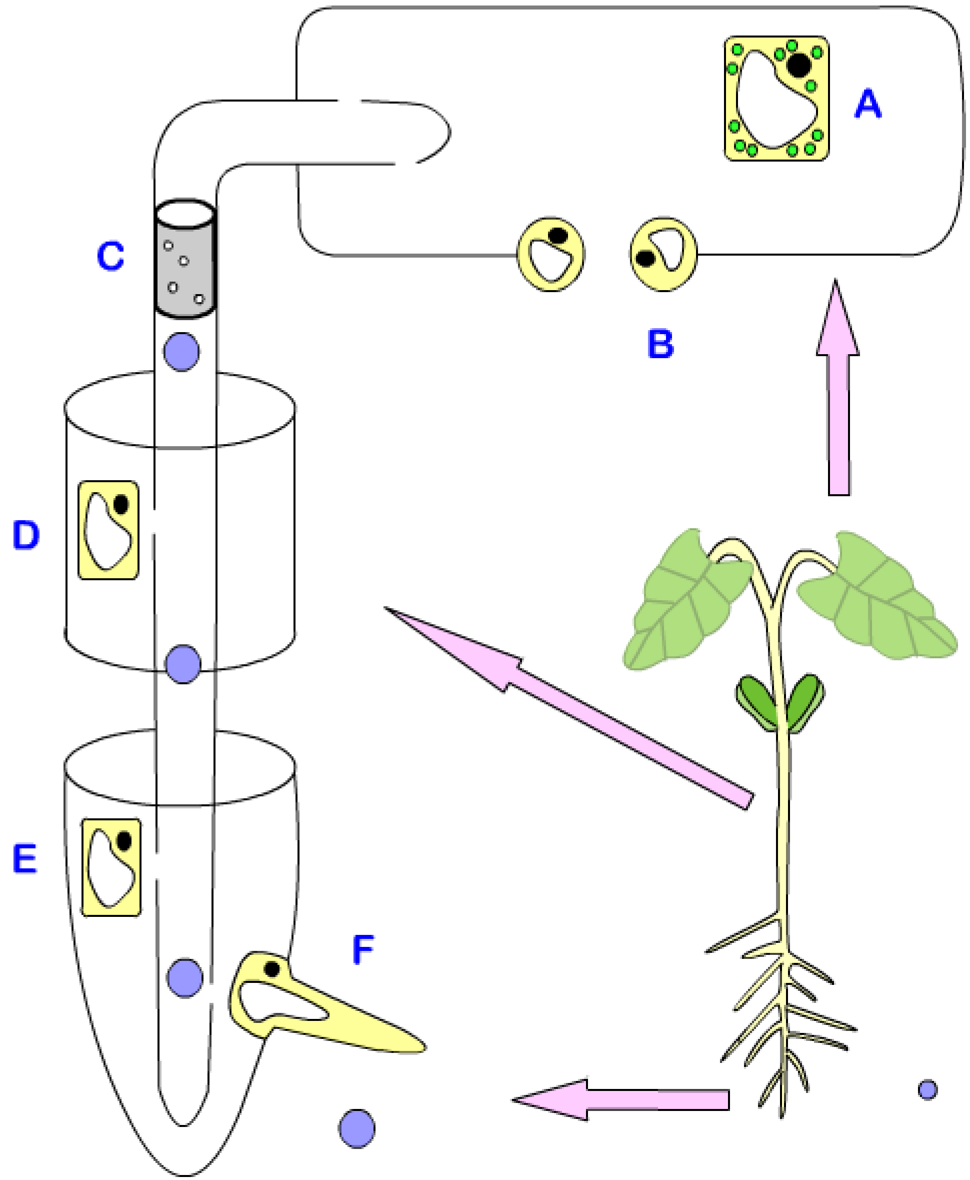
through a plant, to include:

- the uptake of water into and through the root
- the movement of water through the stem
- the movement of water through and out of the leaf

[13]

Understand the translocation of organic solutes through phloem:
- Involving energy expenditure and two-way flow
- Evidence for the above properties (Theories of translocation NOT required)

First we need to look at the structure of the phloem...


A
B
C
D
E
F

Phloem is therefore a living tissue

Transport of water through the xylem is a passive process but transport of materials such as sugars, amino acids and ions is an active process that requires energy (***from companion cells***)

PHLOEM

Phloem tissue is made from columns of parenchyma cells, each adapted to form a sieve tube element (a column of these joined together makes a sieve tube)

The movement of substances such as sugars and ions through the phloem is called translocation

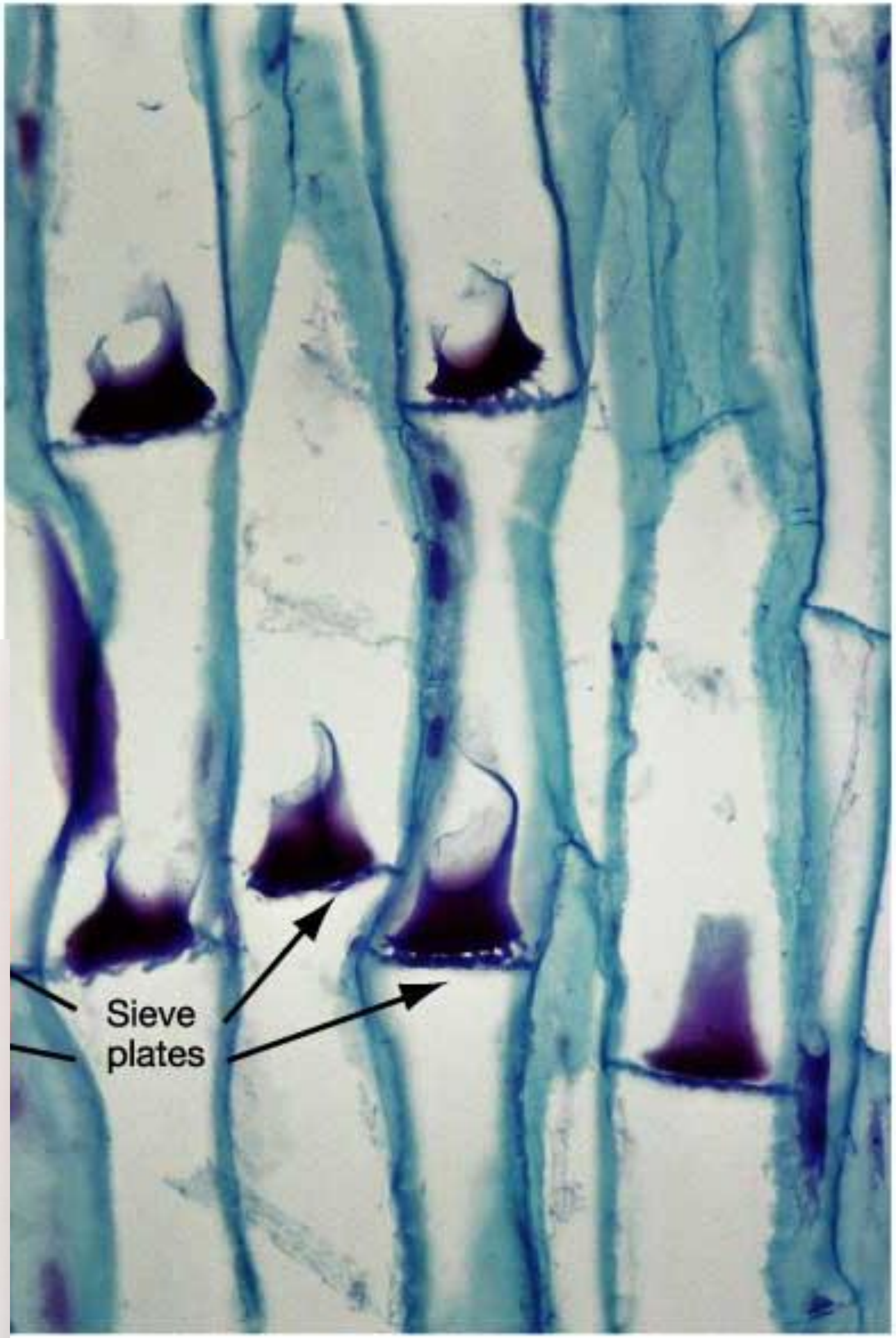
The most important phloem tissues in terms of transporting phloem sap are the...

sieve tube elements and **companion cells**

Sieve tube elements

- These lie end-to-end to form a continuous stack called the sieve tube
- To make transport through the elements easier, the thin cell walls at each end are perforated (have small holes) to form sieve plates

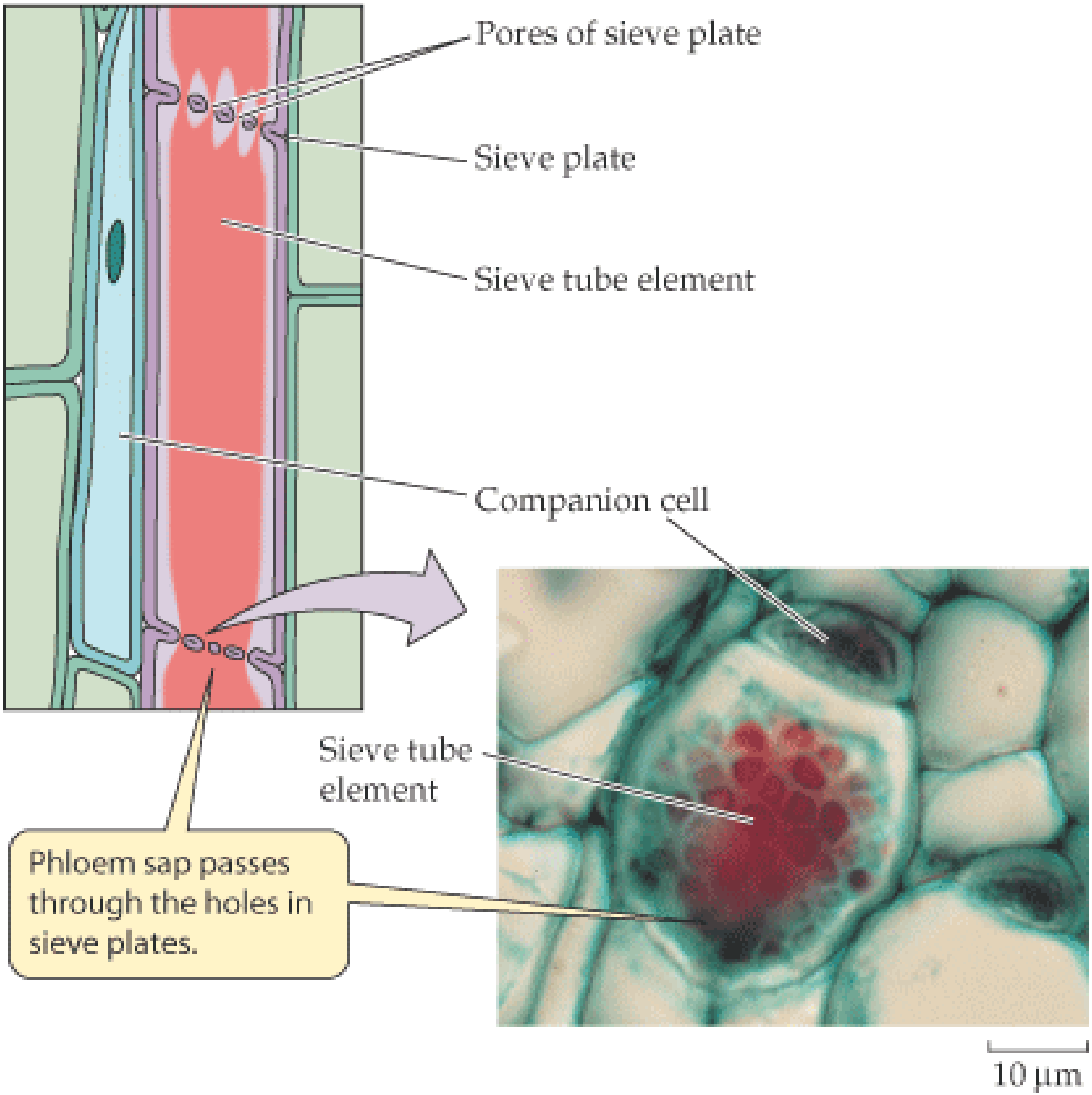
LONGITUDINAL SECTION



CROSS-SECTION

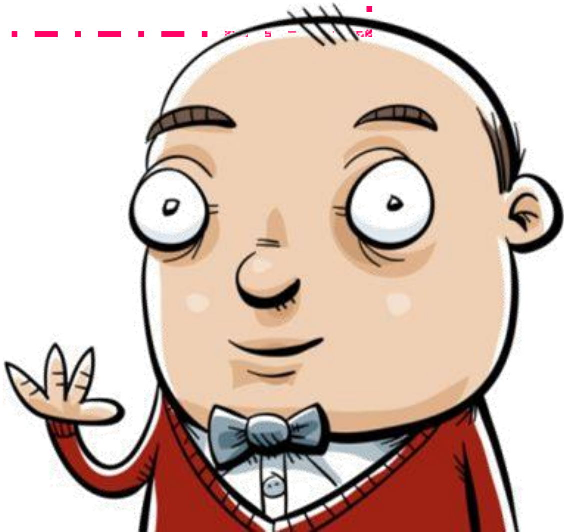
Sieve plates and sieve tubes are clearly visible in this transverse section of phloem

- Unlike xylem vessels – the sieve tube element is alive, although as it matures it loses several of the usual plant cell organelles -**the nucleus**, ribosomes and Golgi bodies all degenerate
- The loss of these structures allows material to flow more easily
- They **do** have a cell wall, a cell surface membrane and a slight amount of cytoplasm lining the inside of the cellulose cell wall


Pores of sieve plate
Sieve plate
Sieve tube element
Companion cell
Sieve tube
element
Phloem sap passes
through the holes in
sieve plates.
10 µm

Did you know?

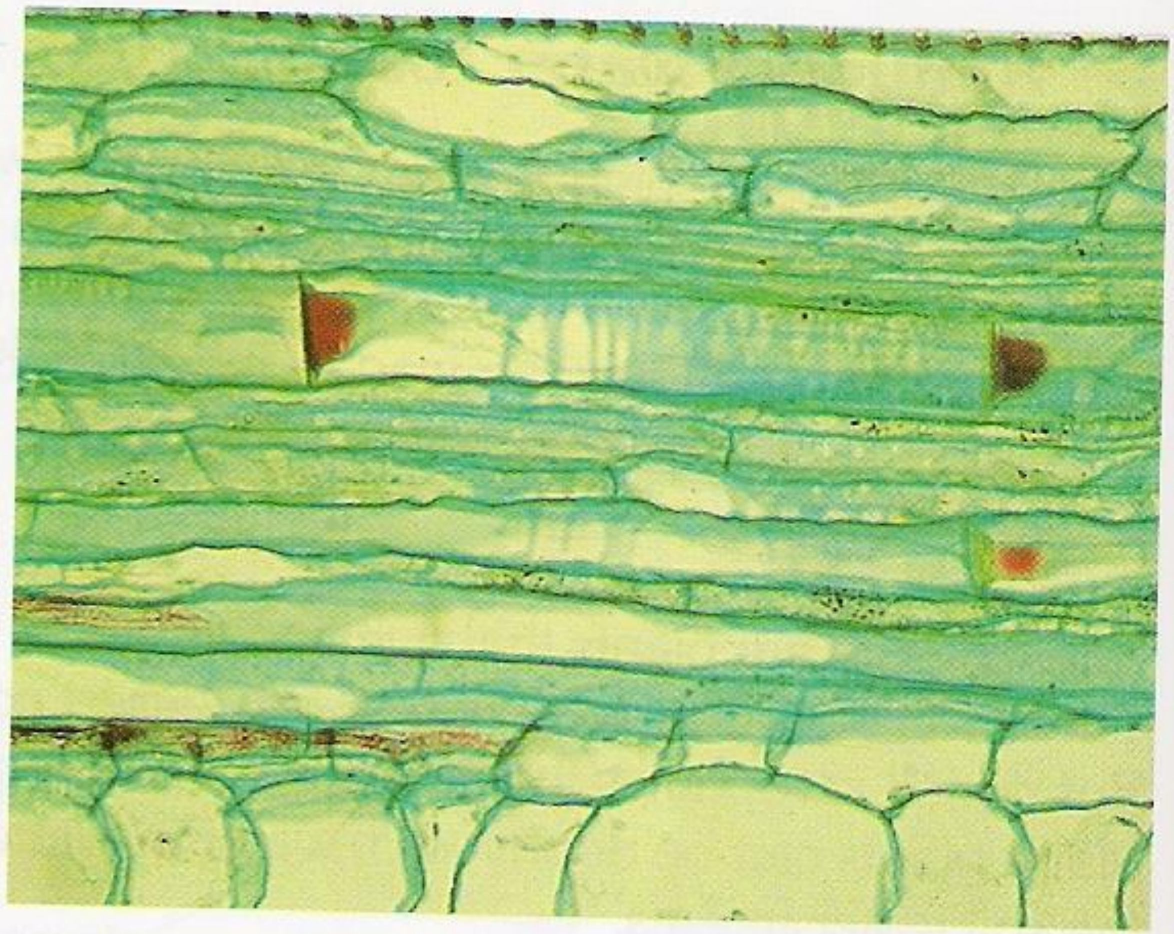
The pores can also be closed slowly in response to major changes in the environment, like the onset of winter in the Temperate Zone. Pores closed in this manner may open when growing conditions become more favourable



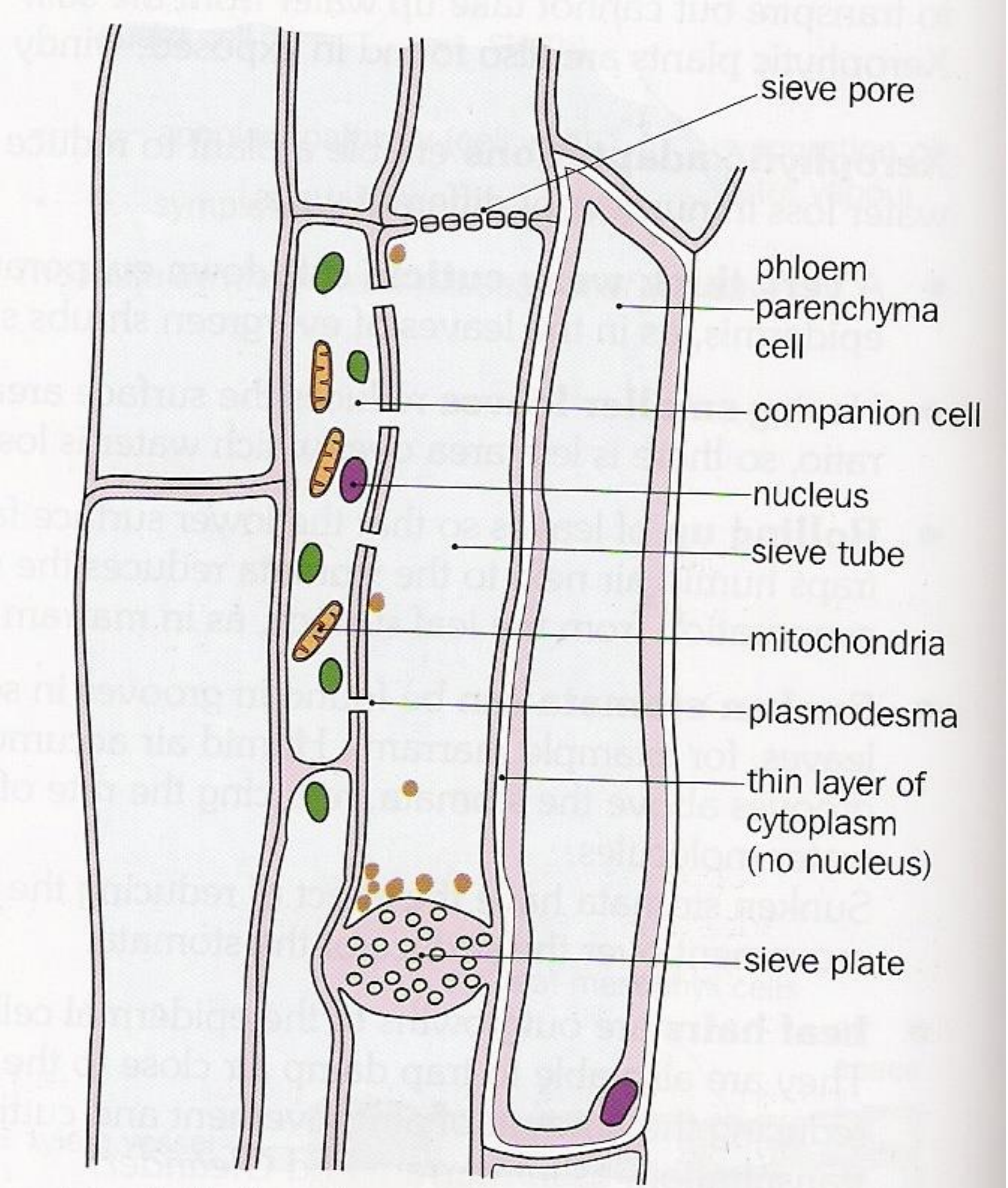
Companion cells

- These are closely associated with the sieve tube elements as their cytoplasms are linked by plasmodesmata
- Each sieve element has at least one companion cell adjacent to it
- Companion cell cytoplasm is more dense with more mitochondria so have higher levels of metabolic activity
- Companion cells have a typical cell structure with the exception of having more mitochondria and ribosomes than the usual plant cell
- This reflects the fact that they are very metabolically active (providing lots of energy for sugar movement in the sieve tube elements)

- The fact that the **sieve tube element** has lost so many of its organelles means that it **needs a companion cell with a nucleus to help it survive**



Photomicrograph of L.S. phloem



Longitudinal section of phloem tissue to show structure

The companion cells do not transport materials, but maintain the activity of the sieve tube elements

Summary:

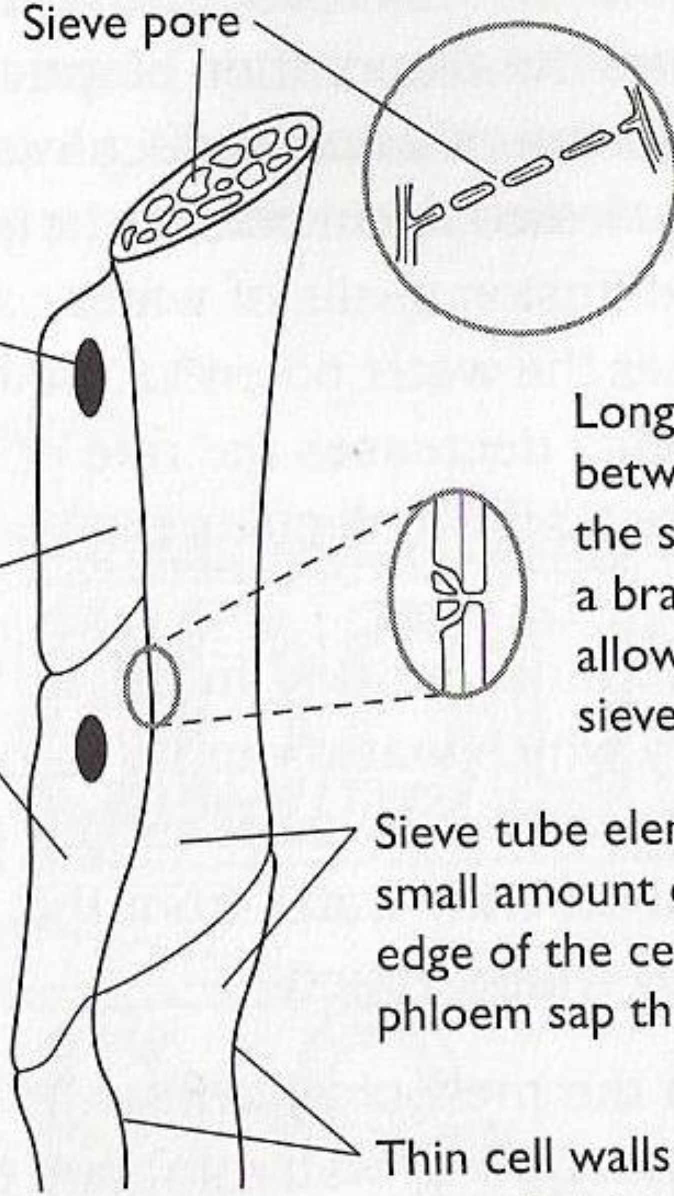


Figure 15 Phloem sieve tube and companion cells

Translocation

- This is the movement of organic solutes through the phloem
- It involves energy expenditure (using companion cells) and two way flow
- Evidence that sugars are transported in the phloem exists from a number of experiments...

Translocation of organic solutes (in phloem sap)

Sap contains mainly sucrose (although amino acids and other solutes can be present). There are 2 main principles relating phloem sap movement:

1) Movement involves energy expenditure – evidence suggests that mass flow is maintained by an active mechanism:

-Rate of flow is higher than that accounted for by diffusion

-Companion cells have a particularly high density of mitochondria. ATP is used to pump sucrose into companion cells where it enters the sieve tube element via plasmodesmata

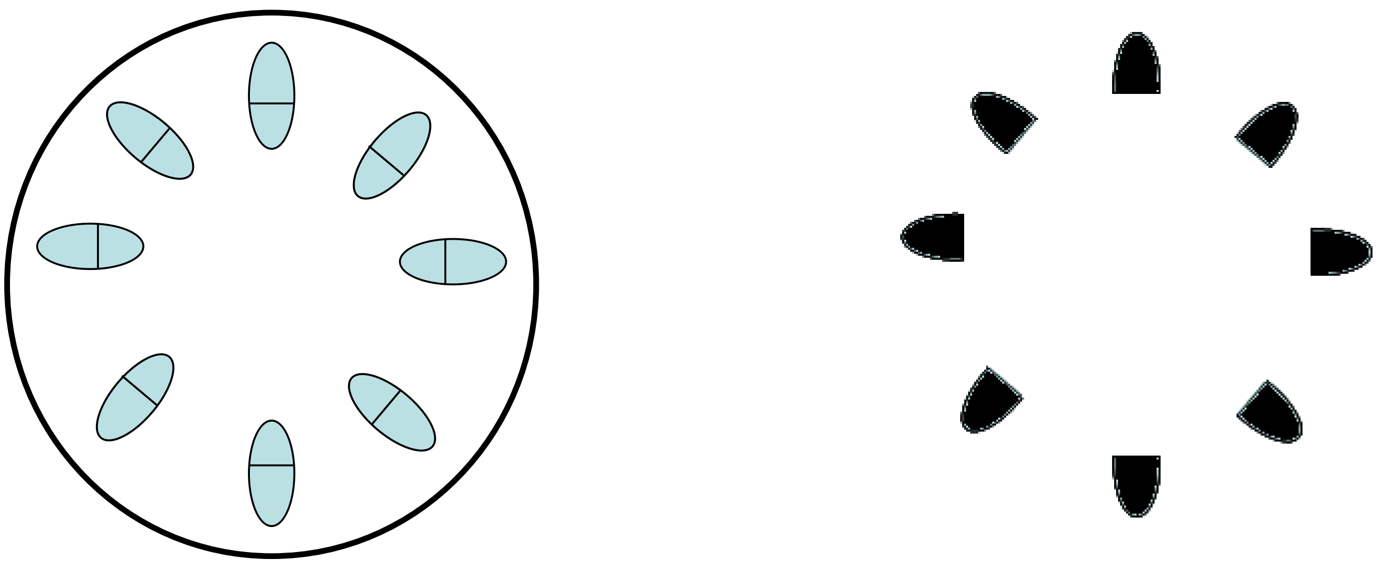
-Metabolic poisons e.g. potassium cyanide that stop respiration, also stop translocation

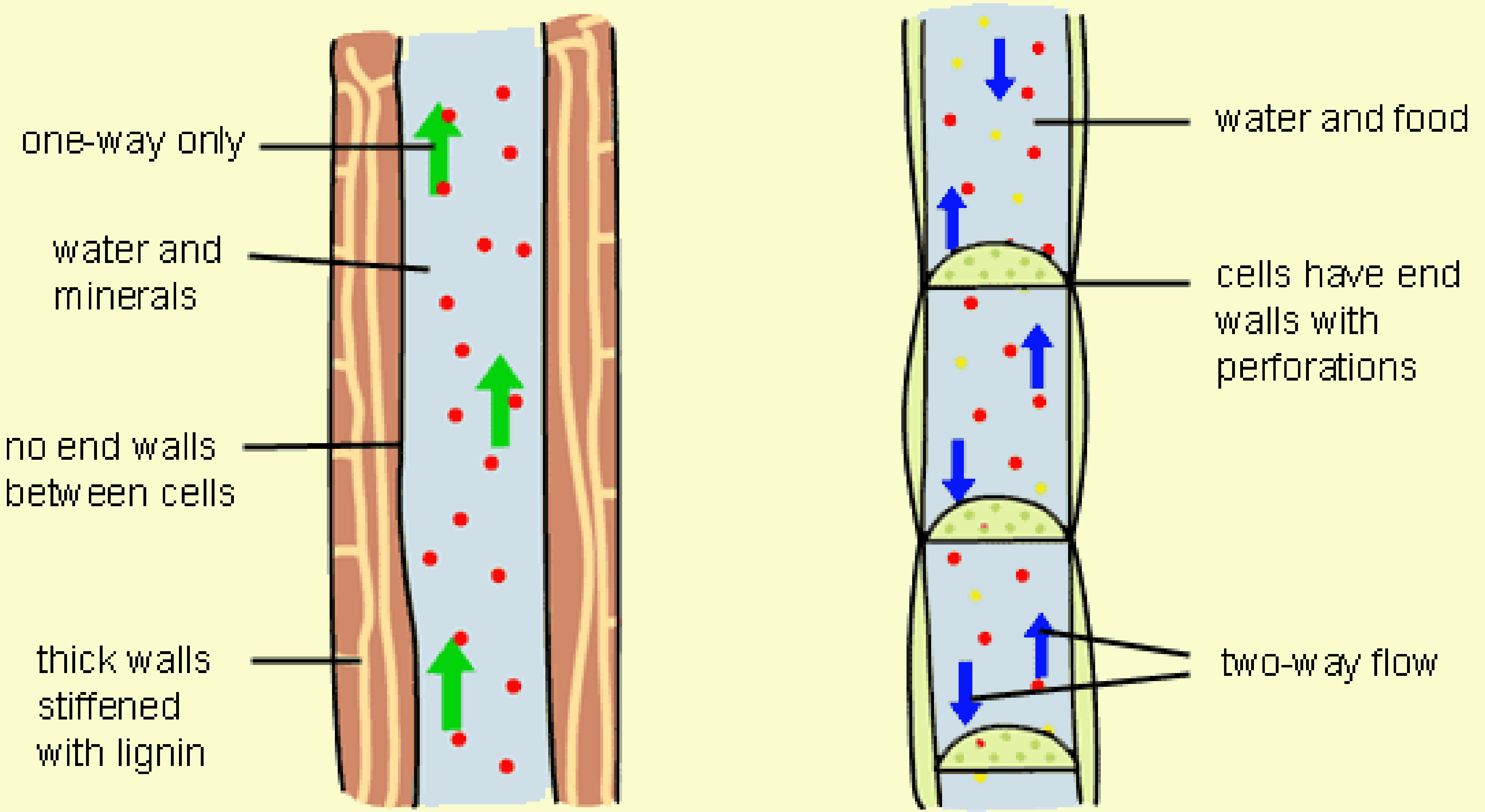
2) Movement is two-way (from "source to sink") - The source is the organ where the sugar is made by photosynthesis or by starch breakdown (e.g. in leaves) and the sink is the organ that consumes or stores the carbohydrate (e.g. developing buds, flowers, roots, and root storage organs). Therefore sugar can be moved up to a bud or down to the roots.

Depending on the season an organ may be a source or sink e.g. in summer the potato tuber is a sink but in the spring it is a source of carbohydrate (where starch is broken down to provide energy for growing shoots).

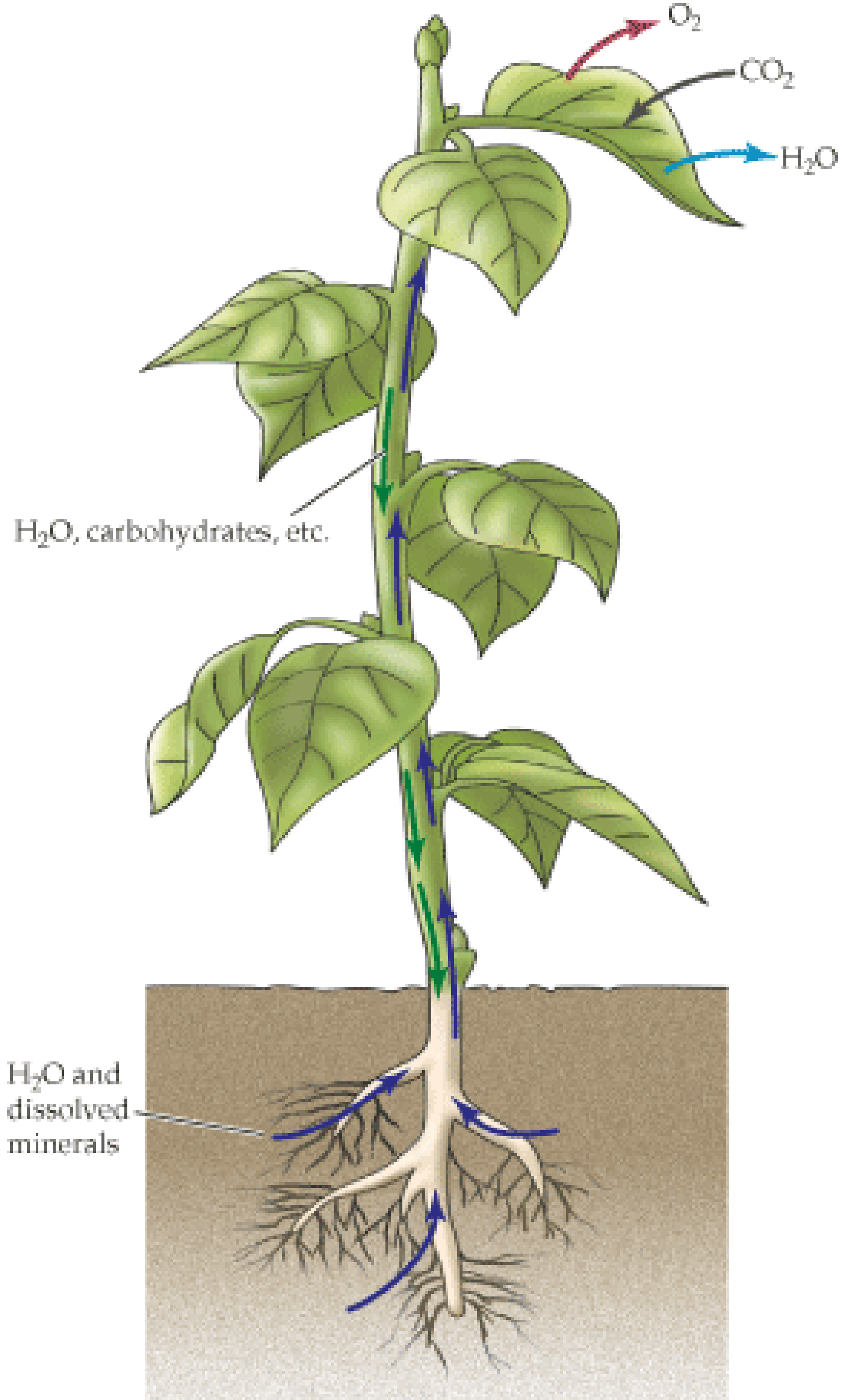
When given to a leaf, radioactively labelled sucrose has been seen to move to the shoot tip and the roots

Radioactive tracers - Carbon dioxide is labelled using radioactive Carbon 14 and given to plants. It becomes converted to radioactive sugars. The movement of these sugars can be detected by taking autoradiographs of plant sections





xylem vessel **phloem vessel**



O_2
CO_2
H_2O
H_2O, carbohydrates, etc.
H_2O and dissolved minerals

Homework for Friday 28/3/14

Revise for Transport in Plants

Transport in plants pp questions

June
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old
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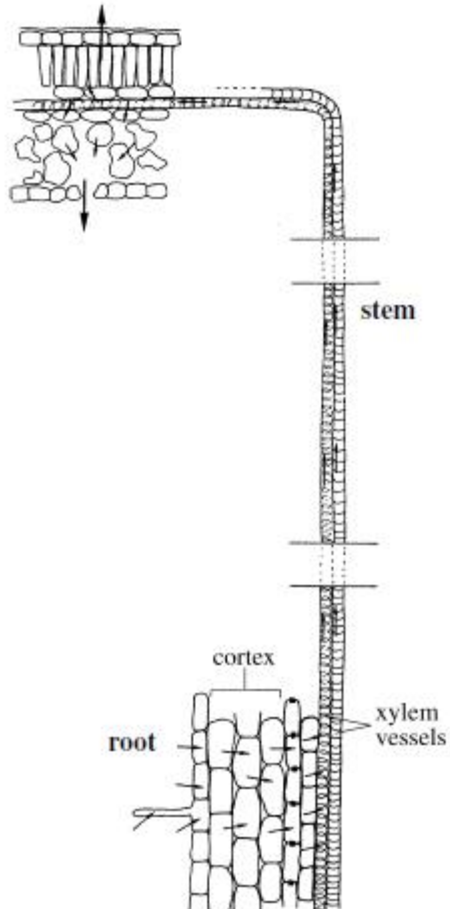
6 The diagram below summarises the movement of water through a plant.



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(a) Describe the movement of water through the root cortex and into the xylem vessels.

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____ [4]

(b) Describe how the loss of water by evaporation from the leaf creates a sequence of events which leads to its transport up the plant.

[4]

(c) Explain why xylem vessels are lignified.

[1]

(a)

(b)

(b) Explain how water moves through xylem vessels according to the cohesion–tension theory.

[4]

(b) Any four from

- reference to transpiration/evaporation of water (from mesophyll surface)
- creates a negative pressure/tension within xylem vessels (of the leaves)
- water column maintained by forces of cohesion
- intermolecular force of attraction between water molecules/reference to polarity of water
- reference to forces of adhesion
- intermolecular force of attraction between water and cell wall/lignin/ cellulose [4]

June 08

(b) (i) Suggest **one** way in which the epidermis of a xerophytic plant would be adapted to help reduce water loss from the stem.

____

____ [1]

(ii) Explain how this adaptation of the epidermis helps prevent water loss.

____

____ [1]

(b) (i) Thicker waxy cuticle/thicker epidermal cells/hairy epidermal cells/ sunken stomatal pores present/multilayered epidermis/reduced stomata/ smaller stomata; [1]

(ii) One explanation appropriate to epidermal adaptation

- longer distance for water to travel/longer diffusion pathway
- epidermal hairs trap a humid layer so increasing water diffusion shell
- humidity builds up on stomatal pits so increasing water diffusion shell
- less areas for diffusion of water out of stem [1]

6 (a) That the rate of transpiration is equal to the rate of water uptake (actually measured using the apparatus); [1]

(b) To prevent air collecting in the xylem vessels/air locks preventing water uptake;
the open end of the capillary tube is exposed to the air which is drawn up as the shoot takes up water;
to enable the air bubble to be moved back to the origin;
to allow the rate of transpiration to acclimatise to the surrounding conditions; [4]

(c) (i) **Any three from**

- transpiration is reduced when the plant is covered (with a clear plastic bag) since the air becomes more humid
- there are no air currents
- humid air reduces the diffusion gradient of moisture out of the plant/no air movement allows diffusion shells to build up
- transpiration is further reduced when the plant is covered with a black plastic bag since the stomata close in the dark
- thus the main route of water loss from the leaf is closed/only cuticular transpiration occurs [3]

(ii) $90 \times 0.8 = 72\,mm^3$;
$72 \div 10 = 0.72\,mm^3\,min^{-1}$; [2]

(d) Different shoots may be different sized/differ in the number of leaves/ differ in the size of leaves/other appropriate response; [1]

Section B

In this section you are expected to answer in continuous prose supported, where appropriate, by diagrams. You are reminded that up to two marks in this question are awarded for the quality of written communication. [2]

8 Give an account of the following transport systems in plants.

- Phloem
- Xylem [10]

Section B

8 Ten points (with at least four from each section)

Phloem:

- both tissues are forms of vascular tissue with phloem on the outside of the vascular bundle
- phloem is the tissue responsible for the transport of sugars and other organic substances
- the transport elements in phloem are the sieve tube elements
- the end walls of which are perforated/form sieve plates
- since sieve tube elements lie end-to-end (forming a tube) these facilitate transport
- sieve tube elements have a thin lining of cytoplasm and no nucleus/tonoplast
- next to each element is a companion cell, translocation relies on their metabolism
- movement through the sieve tubes may take place by mass flow/from source to sink or example
- movement is both up and down the plant
- phloem also contains parenchyma/fibres for support
- phloem is a living tissue

Xylem:

- xylem is the tissue responsible for the transport of water and mineral ions
- the conducting cells in xylem are the vessels
- which have a lignified secondary wall
- in mature xylem this is often pitted (or reticulate) to allow lateral movement of water into surrounding tissues
- in protoxylem (in growing regions) lignification is annular/spiral
- to allow for extension in the region of growth
- lignification prevents the vessels from collapsing/waterproof
- under the negative pressure generated by transpiration
- this pulls water up the xylem/movement unidirectional
- transport in vessels is also aided by forces of adhesion and cohesion/root pressure
- xylem also contains parenchyma/fibres/tracheids
- dead tissue/hollow/no cell contents
- no cross walls allows for a continuous column of water [10]