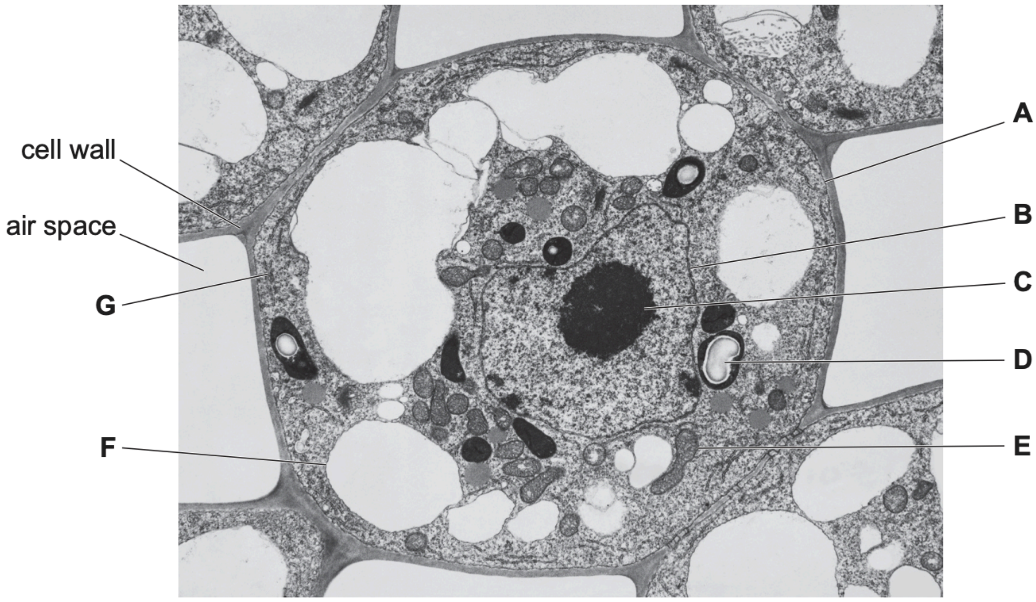
7. Transport in plants

1.

Fig. 1.1 is a transmission electron micrograph of a cell from the stem of sago pondweed, *Stuckenia pectinata*.



magnification ×2500

a. State the evidence from Fig. 1.1 that shows that the cell is from the stem of S. pectinata and not from the mesophyll of a leaf.

- No chloroplasts present
- Presence of many small vacuoles/ no large/central vacuole
- Central nucleus/ nucleus not located at the periphery/edge

b.

(ii) Complete each row in Table 1.1 to identify a cell structure shown in Fig. 1.1 that carries out the function listed.

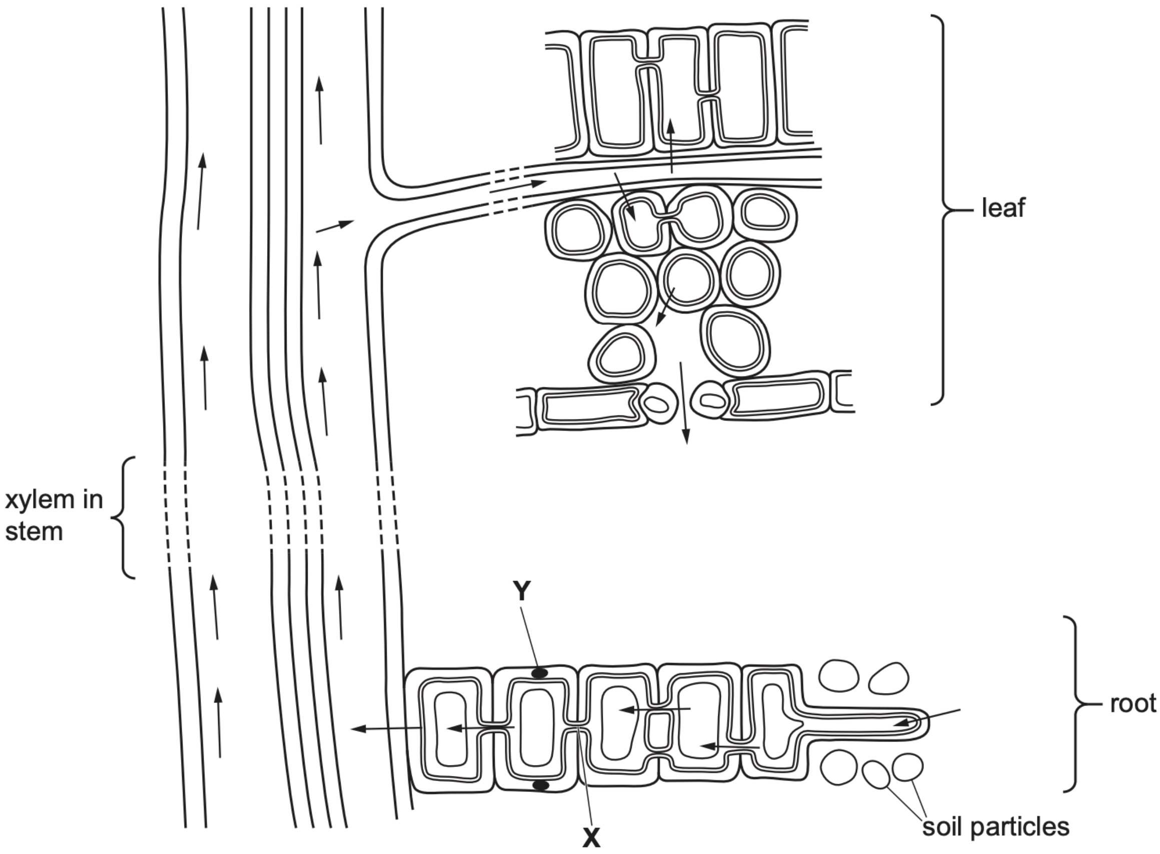
Table 1.1

function	name of cell structure	letter on Fig. 1.1
gas exchange		
production of subunits of ribosomes		
active transport of ions		
aerobic respiration		

function	name of cell structure	letter on Fig.1.1
gas exchange	cell surface membrane **I** phospholipid bilayer mitochondrial membrane(s)	**A** **E**
production of subunits of ribosomes	nucleolus / nucleoli	**C**
active transport of ions	cell surface membrane **ecf** for cell membrane **or** tonoplast / vacuolar membrane **or** mitochondrial membrane(s) **or** nuclear envelope **A** nuclear membrane(s)	**A** **F** **E** **B**
aerobic respiration	mitochondrion / mitochondria	**E**

2.

Fig. 6.1 is a diagram showing the passage of water through the tissues of a flowering plant from the soil to the atmosphere. The arrows show the direction of water movement.



The structure labelled X is part of the symplast pathway. State the name of structure X

- Plasmodesma

The structure labelled Y in the cell wall is a barrier to the apoplast pathway. State the name of structure Y.

- Casparian strip

3. Fill the table

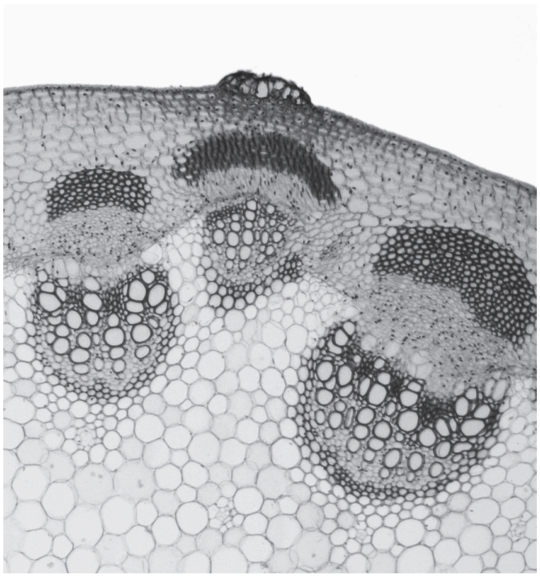
Water moves from the soil solution to the cytoplasm of root hair cells by	Osmosis
Water moves from the xylem in the root to the leaf by	Transpirational pull / cohesion-tension
Water moves from mesophyll cell walls to intercellular air spaces by	Evaporation
Water vapour moves from intercellular air spaces to the atmosphere outside	Diffusion

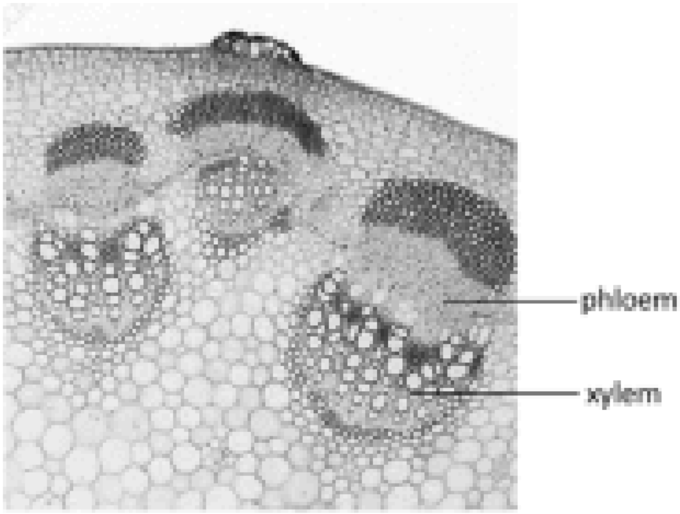
the leaf by	

4. Mucilage acts as a glue to bind tiny soil particles together, forming small clumps close to the root. These small clumps help to maintain the soil water around the root tip and prevent the loss of water. With reference to the cohesive and adhesive properties of water, suggest and explain how the formation of small clumps of soil helps to maintain the soil water around the root tip.
   - water molecules form hydrogen bonds
   - cohesion between water molecules in spaces
   - cohesion to water molecules adhering to soil particles / clumps
   - adhesion of water molecules to soil surface / particles / clumps
   - clumps provide areas / small spaces in which water collects
   - AVP: stable environment e.g. reduced movement

5.

(a) A photomicrograph of a transverse section of a dicotyledonous stem is shown in Fig. 5.1.





6. Describe how sucrose is transported in phloem sieve tubes from photosynthesising leaves to other parts of the plant.
   - (transport is by) mass flow: transport is down a hydrostatic pressure gradient– from high hydrostatic pressure to low hydrostatic pressure
   - assimilates diffuse/ enter into phloem sieve tube from companion cell through plasmodesmata
   - water potential in sieve tubes decreases as sucrose is dissolved in water
   - water enters from surrounding tissues, by osmosis / down water potential gradient
   - loading/ increase in volume at source increases hydrostatic pressure / hydrostatic pressure builds up / hydrostatic pressure difference created
   - at sink, assimilates are unloaded and water follows osmotically.
   - unloading at sink decreases / lowers hydrostatic pressure

7. Cyanide ions (CN–) inhibit the activity of an enzyme involved in respiration. Suggest why the treatment of photosynthesising leaves with CN– results in less sucrose being transported into phloem sieve tubes.

   respiration
   - less / no ATP produced from aerobic respiration
   - less ATP / energy for sucrose synthesis in mesophyll cell

   in context of companion cell
   - less / no ATP / energy for proton gradient / active transport of protons (H+ ions) out of companion cell
   - less sucrose cotransported with protons / hydrogen ions / H+ into companion cells
   - less sucrose in companion cells means decreased diffusion of sucrose via plasmodesmata into phloem sieve tubes

8. A student was asked to carry out semi-quantitative Benedict's tests on two solutions.
   • Solution A was extracted from the cytoplasm of cells in the mesophyll tissue of photosynthesising leaves.
   • Solution B was extracted from the phloem sap in phloem sieve tubes.

   The solutions were taken from the same plant, and other variables were standardised. For each solution, the student measured the time taken for the first colour change to appear.

   Suggest which of the two solutions, A or B, would change colour in the shortest time. Explain your answer.

   - Benedict's solution does not react with non-reducing sugar / sucrose // Benedict's solution only reacts with reducing sugar / glucose

   - Solution A: Sugar present in cytoplasm / solution A is mainly reducing sugars / glucose; sugar in phloem sap / solution B is mainly sucrose / non-reducing sugar

   OR

   - Solution B: Phloem sap / solution B contains a higher concentration of reducing sugar / glucose than cytoplasm / solution A. In cytoplasm glucose stored as polysaccharide / starch

NOTE:

Feature of cell	**Phloem sieve tube element**	**Companion cell**
Cytoplasm	✓	✓
Nucleus	x	✓
Mitochondria	few	many
Cellulose in cell wall	✓	✓
Ribosomes	x	✓

9. Explain why the plasmodesmata are important
   - connect the cytoplasm of cells for the symplast pathway
   - allows rapid diffusion of sucrose / named molecules from one cell to the adjacent cell
   - increases efficiency of loading into / unloading from sieve tubes

10. Describe the roles of hydrogen bonding in the movement of water through xylem vessels.
   - (hydrogen bonding) gives adhesion between water molecules and cellulose / hydrophilic parts of lignin in xylem wall
   - hydrogen bonding gives cohesion between water molecules
   - formation of continuous column // adhesion and cohesion prevent column of water collapsing
   - transpiration pull // water drawn up / pulled up by transpiration / pulled up by evaporation
   - idea of creates tension
   - Detail: e.g. water evaporating from spongy mesophyll surfaces OR water vapour lost by diffusion from leaf / plant during transpiration

11. Water that has travelled through xylem vessels reaches the leaves. Cooling of the leaf occurs as a result of the evaporation of water during transpiration. Water has a high latent heat of vaporisation because water molecules form hydrogen bonds. With reference to hydrogen bonding, suggest why cooling of the leaf occurs as a result of evaporation of water during transpiration.
   - hydrogen bonds between water molecules must break for water to change state / evaporate
   - loss of heat / energy for evaporation / transpiration will cool the leaf / plant

12. Name the specialised cells that are arranged end to end to form xylem vessels.
   - Xylem vessel elements

13. Explain how tension is created in the xylem vessels.
   - transpiration pull
   - water evaporates from spongy mesophyll surfaces & water vapour is lost from leaf / plant during transpiration
   - overall water potential gradient creates pulling force: low water pressure at top and high water pressure at bottom; hydrostatic pressure gradient
   - cohesion and adhesion of water molecules: cohesion between water molecules & adhesion between water molecules and cellulose / hydrophilic parts of lignin

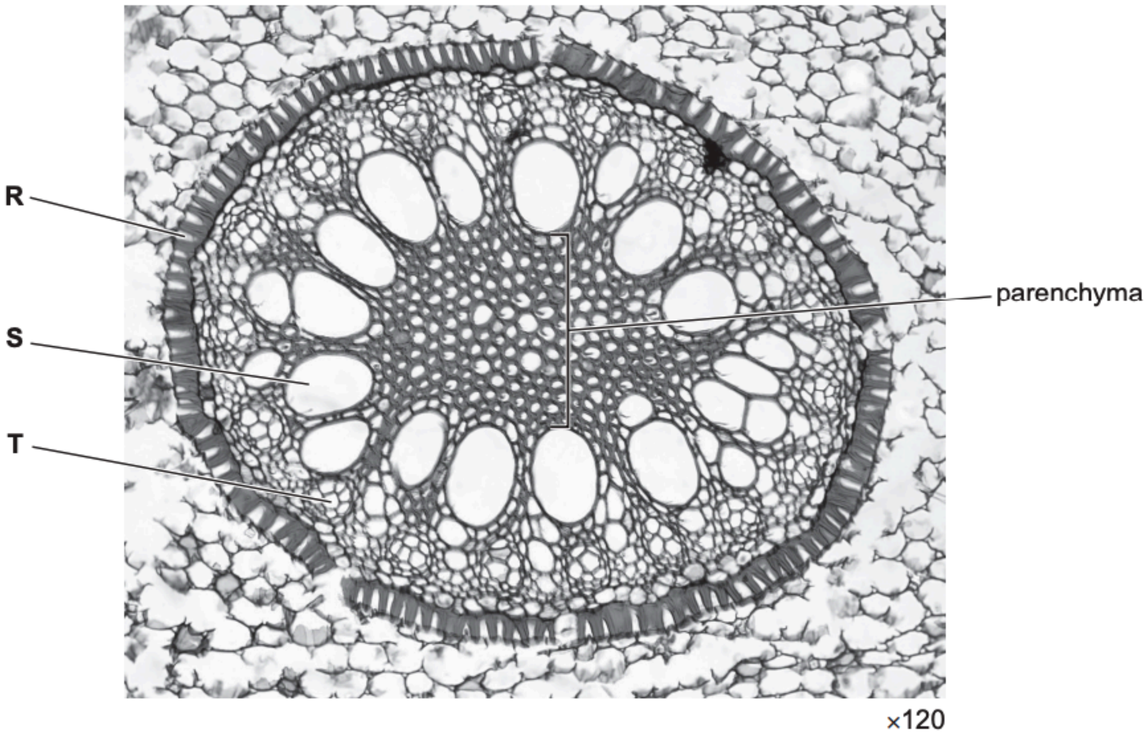
14. The walls of the cells forming the xylem vessel walls become lignified during development. Explain how this feature is important for the efficient transport of water.
   - lignified wall / lignin prevents inward collapse from tensions created
   - lignified wall / lignin is rigid / strong / secondary thickening for support of xylem vessels

- adhesion of water to hydrophilic groups in lignin to maintain column of water / for water pathway / for transpiration stream
- waterproofing properties of lignin: water prevented from leaving xylem vessel
- lignification associated with cell death / allows formation of hollow cells / allows formation of hollow tubes (for minimum resistance to flow)

15. Describe changes that need to occur to xylem vessel element cells so that their structure becomes suited to their function.
    - the end walls break down
    - cell death / apoptosis
    - loss of cell contents / become hollow
    - loss of cytoplasm
    - loss of nucleus
    - formation of pits

16.

(a) Fig. 3.1 is a photomicrograph showing part of a transverse section through the root of an iris, *Iris germanica*. Irises are herbaceous monocotyledons. These plants have the same transport tissues as herbaceous dicotyledons, but the transport tissues are distributed differently. In monocotyledons, the central tissue in the root is parenchyma (packing tissue).



Name the tissues in which the cells labelled R, S and T are found

- Cell R: endodermis
- Cell S: xylem
- Cell T: phloem

17. Outline the role of endodermis tissue in root
    - to stop water moving through the apoplast / to force water movement to be symplastic
    - so that water moves from the cell wall to the cytoplasm
    - AVP: allow control of substances into root (stele)
    - ref. to Casparian strip / suberin

NOTE:
- Root hairs grow from cells in epidermis of root
- Water moves into root hair by osmosis
- Root hair cells are adapted for rapid osmosis
  - Densely packed root hairs increase surface area : volume ratio of root
  - Surface of root hair only consists of cell wall & cell membrane – very thin, so allows rapid osmosis
  - Water in soil contains dissolved mineral ions, which have lower concentration in soil than in root hair, so are moved into root hair cell by active transport. This lowers water potential in root hair cell compared to surrounding soil, so water moves into root hair cell by osmosis down water potential gradient.
- Water moves through root cortex by 2 pathways:
  - Symplast pathway:
    - water moves from cytoplasm of 1 cell to cytoplasm of adjacent cell, via plasmodesmata (microscopic channels through cell wall, connecting cytoplasm of cells).
    - Symplast pathway is driven by water potential gradient between root hair cells and xylem.
    - As water moves into root hair cells by osmosis, water potential of root hair cell > water potential of cortex > water potential in xylem
    - Water moves by osmosis down water potential gradient across cortex
    - Symplast pathway is relatively slow since pathway for water in cytoplasm is obstructed by organelles.
  - Apoplast pathway:
    - Water moves within cell walls & spaces between cells
    - Cellulose cell walls have open structure, allowing water to easily move between cellulose fibres
    - As water moves into xylem and is carried away, more water moves along apoplast pathway due to cohesion.
    - Before water can pass into xylem, it must pass through layer of cells called endodermis

    - Cells in endodermis have a band of waterproof material (suberin) suberin which runs around cell wall = casparian strip
    - Casparin strip acts as barrier to apoplast pathway: water now passes through cell membrane and into cytoplasm, and becomes part of symplast pathway.
    - By forcing all water into cytoplasm, this allows cell membrane to control which substances can enter xylem.
  - Cells in endodermis use active transport to pump mineral ions into xylem.
  - This lowers water potential in xylem, so water follows osmotically.
  - This effect = root pressure

18. Describe the transport of water from the soil solution to the endodermis of roots by the apoplast pathway and explain why this pathway cannot continue at the endodermis.
    - cell wall pathway / route
    - movement also through intercellular spaces / in spaces between cells
    - named cell layer in apoplast pathway to endodermis: e.g. epidermal cells // root hair cells // cells of cortex / cortical cells / parenchyma cells
    - cannot cross / stops at Casparian strip of endodermal cells
    - Casparian trip: waxy / waterproof / impermeable layer / substance / material in cell walls, made of suberin
    - overall movement down a water potential gradient
    - context of across root or from root to xylem
    - AVP: non-living pathway / does not cross membranes until the endodermis
    - water needs to pass across a cell (surface) membrane to control substances entering xylem

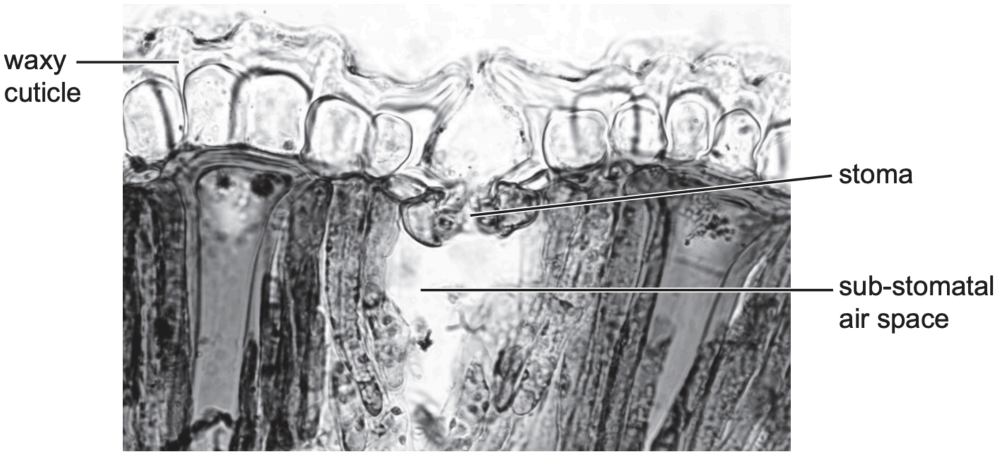
19. Suggest and explain why the quantity of sugar taken up by a developing leaf decreases to zero over time, but the need for water increases.
    <u>decrease in sugar</u>
    - changing / transition from sink to source: leaf becomes the source/ no longer the sink / sugars are now being moved away from leaf
    - photosynthesis provides enough sugar / rate of photosynthesis increases

    <u>increase in water</u>
    - increase in size / more cells / increase in leaf surface area, so proportionate increase in water
    - more cells that need water to maintain turgidity / prevent flaccidity / prevent wilting because of transpiration
    - increased transpiration / greater number of stomata
    - water is a reactant / needed for photosynthesis

feature	companion cells	phloem sieve tube element	xylem vessel element
cytoplasm	✓	✓	x
cell surface membrane	✓	✓	x
lignified cell wall	x	x	✓
nucleus	✓	x	x

20.

(a) Fig. 3.1 is a photomicrograph of a transverse section of part of a leaf of *H. laurina*.



Describe the xerophytic features of the waxy cuticle and the stoma shown in Fig. 3.1 and explain how these features adapt the plant to a xerophytic mode of life.

- decreases / reduces transpiration
- thick (waxy) cuticle
- increased waterproof layer
- increased diffusion distance for water vapour / less water vapour lost
- sunken stoma
- moist / humid air collects in area near to external environment
- decreases water potential gradient between sub-stomatal air space or area above stoma and external environment
- reduces diffusion of water vapour (out) via the stoma

21. Explain why a root can be a source and a sink.
- root as source: root provides (named) assimilates for other parts of the plant
- root as sink: root is for storage / root is a storage organ OR root receives (named) assimilates to store / grow
- ref. to bidirectional transport in phloem

- direction of movement changes with demands of plant

22. Adaptations of xerophytic plants
    - thick walled epidermis: reduces diffusion of water vapour to atmosphere / cuticular transpiration / increases the distance for water vapour to diffuse
    - no stomata on upper surface / stomata only on lower surface: stomata not exposed to direct sunlight
    - stomata in pits: creates humid atmosphere in pit / reduces diffusion / water potential gradient for water vapour
    - thick waxy cuticle on epidermis / surface: reduces diffusion of water vapour through cuticle / waxy cuticle is waterproof
    - epidermal hairs / trichomes: reduces air movement / traps still air / creates humid atmosphere / traps water vapour or reduces the diffusion / water potential gradient for water vapour

23. Outline and explain the sequence of events that occurs, which allows amino acids to be transported from the apoplast into the cytoplasm of a companion cell.
    - protons moved by active transport / pumped out of (companion) cell using energy / ATP
    - protons moved into / enter cell wall / apoplast
    - proton gradient builds up in apoplast / cell wall – higher concentration
    - protons move back into companion cell by facilitated diffusion, down concentration gradient
    - protons cotransport amino acids OR amino acids move with protons through a cotransporter / cotransport protein
    - amino acids transported against their concentration gradient

24. Suggest and explain why the quantity of sugar taken up by a developing leaf decreases to zero over time, but the need for water increases.
    Decrease in sugar
    - changing / transition from sink to source: sugars are now being moved away from leaf
    - photosynthesis provides enough sugar / rate of photosynthesis increases

    Increase in water
    - increase in size / more cells / increase in leaf surface area, so proportionate increase in water
    - more cells, so more water needed for cellular reactions
    - more cells that need water to maintain turgidity / prevent flaccidity / prevent wilting, because of transpiration
    - increased transpiration / greater number of stomata
    - water is a reactant / needed for photosynthesis

feature	**companion cells**	**phloem sieve tube element**	**xylem vessel element**
cytoplasm	✓	✓	**x**
cell surface membrane	✓	✓	**x**
lignified cell wall	**x**	**x**	✓
nucleus	✓	**x**	**x**