7. Transport in Plants

7.2 Transport Mechanisms

Paper 2

Marking Scheme

Q1.

(a)	*both units must be used at least once* *any **three** from:* **1** no transpiration when LVPD is 0 kPa ; **2** (both) increase in transpiration rate until 2.5 kPa ; **3** *H. annuus* rate remains constant between 2.5 and 3.0 kPa, *N. oleander* rate decreases slightly ; **4** *H. annuus* has higher rate of transpiration (at all LVPDs) ; **ora** for *N. oleander* **5** *H. annuus* has a higher rate of increase (between 0 and 2.5 kPa) ; **A** steeper gradient **6** any comparative data quote from Fig. 5.1 ; *must include figures and units from both axes and data must come from both species*	**3**
(b)	*if a correct adaptation does not match the figure, allow ecf for the explanation Fig. 5.3* *any **four** from:* **1** three layers of thick-walled cells at, upper / lower, surface ; **A** two layers of cells under epidermis / epidermis and (two layers of) hypodermis **2** reduces, diffusion of water vapour to atmosphere / cuticular transpiration ; **A** increases the distance for water vapour to diffuse **3** no stomata on upper surface / stomata only on lower surface ; **4** stomata not exposed to direct sunlight / AW ; **5** (stomata in) pits / depressions / cavities / chambers / crypts / infoldings / grooves / AW (on lower side of leaf) ; **6** creates humid atmosphere in, pit / AW *or* reduces the, diffusion / water potential, gradient (for water vapour) ; **A** vapour pressure gradient **A** minimises effect of, external air currents / wind *Fig. 5.3 or Fig. 5.4* **7** thick walled epidermis ; **8** reduces diffusion of water vapour through lower epidermis ; **9** thick (waxy) cuticle (on epidermis / surface) ; **10** reduces diffusion of water vapour through cuticle / reduces cuticular transpiration ; **A** (waxy) cuticle is waterproof **11** (epidermal) hairs / trichomes (around stomata / fill pits) ; **12** reduces air movement / traps still air / creates humid atmosphere / traps water vapour *or* reduces the, diffusion / water potential, gradient for water vapour ;	**4**

Q2.

(c)(i)	*accept hydrogen ions / H^+, for protons* *max 3 if no ref. to amino acids* *any **four** from:* **1** protons, moved by active transport / pumped, out of (companion) cell ; **A** using, energy / ATP *for active transport* **2** protons, moved into / enter / AW, cell wall / apoplast ; **R** if moved out to phloem sieve tube **3** proton gradient builds up in, apoplast / cell wall ; **A** higher concentration **A** high concentration if mp4 gained **4** protons move back (into companion cell), by facilitated diffusion / AW ; e.g. down, electrochemical / concentration, gradient from high(er) to low(er) concentration **A** diffuse *if movement is described through a transport protein in mp5* **5** protons cotransport amino acids **or** amino acids move with protons through, a cotransporter / a cotransport protein / (amino acid) transporter ; **6** amino acids, transported / AW, against their concentration gradient ;	**4**

Q3.

(a)	*any **four** from:* **1** cell wall, pathway / route / AW ; **R** crossing membranes / passing through vacuoles / passing through cytoplasm, *in context of passage to endodermis* **I** diffuses / osmosis / active transport **2** movement (also), through intercellular spaces / in spaces between cells ; **R** intracellular spaces **3** named cell layer in <u>apoplast</u> pathway to endodermis ; e.g. epidermal cells / root hair cells cells of cortex / cortical cells / parenchyma cells *must be in context of cell walls* **4** cannot cross / stops at, Casparian strip (of endodermal cells) ; **5** detail ; made of, suberin **or** described as a, waxy / waterproof / impermeable (layer / substance / material in cell walls) **6** (overall) movement down a water potential gradient ; **R** ref. to osmosis / active transport *context of across root or from root to xylem (owing to overall root to, leaf / atmosphere, gradient)* **7** AVP ; e.g. non-living pathway / does not cross membranes, until the endodermis idea that water needs to pass across a cell (surface) membrane to control substances entering xylem	**4**

Q4.

(b)(ii)	*any **four** from:* **1** carbohydrate is transported in (phloem) sieve tubes ; **A** sucrose transported **A** sieve tube elements **2** as the percentage of outer stem tissue removed increases, the quantity of phloem (sieve tubes) remaining decreases ; **3** less, mass flow / translocation ; **4** 0 mg at 100% removal because all phloem removed / AW ; **5** carbohydrate is not transported in xylem tissue, as there is no transport when xylem tissue is left intact ; **6** *ref. to* movement to lower part of stem from source to sink ; **7** AVP ; e.g. *suggestion that* most of the (active) phloem is in the inner part of the outer stem *idea that* phloem sieve tubes are arranged in layers	**4**

Q5.

(a)	plasmodesma ;	1
(b)	Casparian strip ; **I** suberin / endodermis	1
(c)	**R** if choice of terms given osmosis ; transpiration pull / cohesion-tension ; **I** mass flow / adhesion / down a water potential gradient evaporation ; diffusion ;	4

Q6.

(b)	*any **two** from:* transpiration pull ; **A** water, drawn up / pulled up owing to / AW, water evaporating from spongy mesophyll surfaces / water vapour lost from, leaf / plant, during transpiration ; *ref. to transpiration not required if transpiration pull stated* (overall) water potential gradient ; *in context of creates pulling force* *low water pressure at top and high water p at bottom* **A** pressure gradient **A** hydrostatic pressure gradient cohesion <u>and</u> adhesion (of water molecules) / cohesive and adhesive forces (of water) ; **A** cohesion between water molecules **or** adhesion between water molecules and (xylem vessel) walls / cellulose / hydrophilic parts of lignin	2

Q7.

(c)	*any **three** from:* (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 / AW ; **A** adhesion, prevents column of water collapsing / AW transpiration pull ; **A** water, drawn up / pulled up by transpiration / pulled up by evaporation detail ; e.g. water evaporating from spongy mesophyll surfaces water vapour lost from, leaf / plant, during transpiration *idea of* creates tension AVP ; *if mp 1 and mp 2 are not awarded, allow one mark for reference to cohesion <u>and</u> adhesion*	3

Q8.

(a)	*any **three** from:* at (phloem) source, mineral ion entry (with water), from xylem / through plasmodesmata from companion cells ; dissolved in water / as solutes in water / in solution / in sap solution ; *in context of entry from xylem or within phloem sap* (transport) as part of mass flow ; *must be in context of phloem* flow down a pressure gradient / AW ; **R** differences in pressure gradient **R** from high pressure gradient to low pressure gradient AVP ; e.g. suggestion that mineral ions are needed for transport of some assimilates (e.g. complexed with) *idea of* reallocation of resources / arrive at (phloem) source and are moved to other parts, for use / when needed ;	**3**

Q9.

(c)(ii)	*any **three** from:* **1** movement of sucrose with, protons / H^+ ions, into companion cells ; **A** correct *ref. to* (other named) assimilates **2** (sucrose moved) from, apoplast / cell wall / mesophyll cell ; **3** sucrose moves against its concentration gradient (into companion cell) ; **4** (needs cotransporter protein because) sucrose is polar so cannot pass through membrane ; **5** maintain concentration gradient for sucrose between companion cell and sieve tube (element) ;	**3**

Q10.

(b)	**A** phloem sieve tube element ; **B** companion cell ; **C** companion cell ;	**3**

Q11.

(a)	*one mark for named pathways* ; *one mark for outline of apoplastic pathway* ; **name of pathway** / **outline of pathway** symplast / symplastic — movement of water from cell to cell via plasmodesmata apoplast / apoplastic — movement of water via, cell walls / intercellular spaces	**2**

Q12.

(a)	*any three from* *decrease in sugar* 1 *idea that* changing / transition, from sink to source e.g. leaf becomes the source leaf no longer the sink sugars are (now) being moved away from leaf was a growing area, now translocating (sugars) 2 photosynthesis provides enough sugar / (rate of) photosynthesis increases ; **A** leaf (now) makes enough sugar **I** makes own food *increase in water to max 2* 3 increase in size / more cells / increase in (leaf) surface area, (so proportionate increase in water) ; 4 (more cells that need) water to, maintain turgidity / prevent flaccidity / prevent wilting, (because of transpiration) ; 5 increased transpiration / greater number of stomata ; **A** increased evaporation (greater internal leaf area) 6 water is, a reactant / needed, for photosynthesis ; *(in context of increased photosynthesis, more water needed)* 7 AVP ; e.g. maturing leaf growth rate slows / mature leaf no growth (more cells, so more) water needed for, cellular reactions / AW e.g. for hydrolysis of starch (more) water needed for, cell elongation / enlarging vacuoles	**3**

Q13.

(a)	cohesion ; adhesion ;	**2**
(b)(i)	*any **two** from:* **1** higher rate of transpiration during the day / lower rate of transpiration during the night / AW ; **A** flow of xylem sap *for transpiration* **2** stomata are open during the day ; **ora** *must be in context of transpiration* *if mp1 and mp2 not gained, allow one mark for idea that results are related to pattern of, light / daylight / day, and, dark / night (use an ordinary tick)* **3** *idea that* all three vines were kept in the same conditions so a changed condition that affects transpiration will affect all three ; **A** all three vines have the same external factors acting that affect transpiration **4** AVP ; e.g. (during daylight) stomata open, to obtain carbon dioxide / for photosynthesis *idea that,* increasing / decreasing, rate is related to degree of opening of stomata varying with light intensity	**2**

(b)(ii)	*allow (xylem sap) flow rate for rate of transpiration* *any **two** from:* **1** the greater the (total) area of leaf, the higher the rate of transpiration ; **ora** **A** grapevine 1 has largest leaf area and highest rate of transpiration *accept other comparisons* **R** *ref. to* SA:V but allow ecf in mp2 **2** the greater the (total) area of leaf, the more stomata are present ; AW **A** more leaves means more stomata **3** detail of any one grapevine ; e.g. grapevine 1 = highest transpiration rate and, highest number of / most, stomata grapevine 3 = lowest transpiration rate and, lowest number of / least, stomata *allow use of comparative data to support mp* *(if detail includes ref. to (total) leaf area then check to see if mp2 can also be awarded)* **4** *ref. to* relationship between (total) internal surface area and (total) leaf area ; e.g. larger leaf surface area means internal surface area increased **5** *ref. to* relationship between internal surface areas and rates of evaporation ; **6** AVP ; higher rate of flow of xylem sap for largest leaf area as (overall) more water used in metabolism AW **ora** (greater area so) more leaves so more xylem vessels **ora**	**2**
(b)(iii)	overcast / cloudy / rain / shade / AW ; **A** lower wind speed / temperature **A** higher humidity **R** if described as stomata close (transpiration is still occurring)	**1**

(b)(iv)	*valid method e.g.* draw around / place, leaf on, squared paper / graph paper / grids ; **A** square ruler count number of (full) squares ; **R** multiply by two / do it on other side method for part squares ; e.g. add up all part squares and divide by 2 match a larger part square with a smaller and count as one square use graph paper with larger and smaller squares **or** photocopy leaves, cut out and weigh (cut out) ; divide mass by mass of 1 cm^3 of same paper ; **or** *ref. to* using an App ; further detail ; e.g. place leaf, flat / on white surface ; take photo of single leaf with smart phone / AW	**2**

Q14.

(c)(ii)	*any **three** from:* *similarities max 2* both have a (co-)transport protein ; both involve H^+ / hydrogen ions / protons ; H^+ move down the concentration gradient / by facilitated diffusion ; (sucrose and nicotine both) move against the concentration gradient ; *differences max 2* in nicotine transport, H^+ ions and nicotine, move in opposite directions ; **ora** for sucrose transport H^+ ions move from, the apoplast / cell wall, in sucrose transport (from the cytoplasm in nicotine transport) ; AVP ; e.g. ref to ATP	**3**

Q15.

(a)	*in context of from a plant* loss of water vapour ; **I** evaporation unqualified from, the aerial parts / leaves ;	**2**
(b)	1.2 ($mm\ min^{-1}$) ;	**1**
(c)	*any **two** from:* humid air / water vapour, moves away from the leaves ; water potential gradient is steeper ; higher rate of evaporation into the air spaces in the leaf ;	**2**

(d)	*any **four** from:* movement by, cohesion-tension ; cohesion / hydrogen bonds, between water molecules ; **A** cohesive force (water moves as an) unbroken column / AW ; transpiration pull **or** column of water, under tension / pulled up ; *ref. to* adhesion of water molecules to, cellulose / lining / walls (of xylem vessels) ; **A** adhesive force *ref. to* hydrophilic / polar, property of cellulose (fibres) ; **A** hydrophilic / polar, parts of lignin *ref. to* water potential ; e.g. (evaporation results in) lower water potential at the top of the xylem vessel (water moves) down a water potential gradient / from a region of high water potential to a region of lower water potential	**4**

Q16.

(a)	presence of sucrose (in sieve tube) lowers water potential (of phloem sap) ; **A** makes water potential more negative water enters (sieve tube), by osmosis / down water potential gradient ; increases volume (in sieve tube) ; increases hydrostatic pressure (in sieve tube at source) ; **A** turgor pressure *ref. to* lower hydrostatic pressure (in sieve tube at sink) ; *allow ecf for no ref. to, hydrostatic / turgor* detail ; e.g. sucrose removed at sink water follows sucrose that exits sink movement of, (phloem) sap / sucrose, down pressure gradient / from high to low hydrostatic pressure ; mass flow ;	**4**

Q17.

(b)(ii)	*allow sucrose for assimilates throughout* *any **five** from:* viruses / assimilates, enter via plasmodesmata ; movement / diffusion, of assimilates into (phloem) sieve tubes, lowers water potential / AW ; (so) water enters, by osmosis / down water potential gradient / AW ; hydrostatic pressure increases (at source) ; **A** turgor pressure *for hydrostatic pressure* unloading at, sink / named sink, lowers hydrostatic pressure (at sink) ; detail ; e.g. assimilates move out and water follows osmotically pressure gradient created / higher pressure in source (than sink) / lower pressure in sink (than source) ; (so) mass flow; *term to be used in context* from source to sink ; *allow mp if terms source and sink used in correct context within complete response* AVP ; (viruses and assimilates travel) through sieve pores	**5**

Q18.

(a)(i)	plasmodesmata ; **I** cytoplasmic strands / cytoplasm **R** if other structures also given	**1**

(a)(iii)	symplastic (pathway) ; **I** vacuolar / vacuole, pathway **A** symplast	**1**

(b)	*max 3 if no ref. to evaporation or water vapour and ref. only to water* *any **four** from:* **1** evaporation of water / water to water vapour ; *must be in context of* **P** **2** **P** described as, surface / cell wall, of (spongy) mesophyll (cell) ; **R** palisade mesophyll cell **A** film / layer, of moisture / water (for surface of cell) **3** water vapour enters (substomatal) air space ; **R** intracellular air space **A** other correct refs. to air space in sequence of events **4** diffusion of water vapour (out) through stoma / stomatal pore (to **Q**) ; **R** through guard cells **R** diffusion by osmosis **5** (towards **Q** because) down water potential gradient / from high to low water potential / to lower water potential ; **I** potential gradient alone **A** down (water) vapour pressure gradient **A** Ψ *for water potential* *context is movement out to atmosphere, not movement from* **P** *to air space* **6** AVP ; e.g. stoma stated as open heat energy required for evaporation / *ref. to* latent heat of vapourisation air space described as, intercellular / saturated / substomatal	**4**

Q19.

(b)	transport / translocation, of, assimilates / photosynthates / sucrose / sugars / amino acids / other named nutrient ; **I** food from, source / areas of synthesis, to, sink / areas of growth / areas of (high) activity / areas of storage ; **A** areas where they are needed *for sink* **I** 'where they used'	**2**

Q20.

(d)	*allow assimilates / AW for sucrose* **1** movement of sucrose from, mesophyll / parenchyma / source, cells ; **A** movement of sucrose to (named) sink cells **2** move sucrose, into / out of, sieve tubes (through plasmodesmata) ; **3** pump, protons / hydrogen ions / H^+, out of cell / into cell wall/into apoplast ; **A** *ref. to* secondary active transport **4** provides, ATP / proteins, for sieve tubes ; **A** maintain metabolism of sieve tubes	**2**

Q21.

(d)(i)	*two from:* cell wall, pathway / route / AW ; **A** involves only cell walls **R** if only in roots movement / AW, through intercellular spaces / spaces between cells ; further detail ; e.g. water does not, enter cells / cross membranes / cross cytoplasm / move through plasmodesmata osmosis does not occur membranes not involved **R** osmosis once only	**2**
(d)(ii)	*four from:* hydrogen bonding (between water molecules) ; water molecules are polar ; *movement to spongy mesophyll cells* adhesion / attraction, to, cellulose / cellulose fibres / cell walls ; *this is in context of leaf cells but also allow for xylem* **R** cell walls of lignin **A** hydrophilic parts of lignin cohesion between water molecules / (water molecules are) cohesive ; *idea that* movement of water (molecules) towards, spongy / mesophyll, cells, pulls / AW, other water molecules ; **A** transpiration pull / continuous column / unbroken column **I** continuous stream *movement to intercellular air spaces* water molecules absorb heat (energy) ; bonds break between water molecules ; evaporation / water to water vapour ; **I** latent heat of vapourisation from spongy cell, walls / surfaces ;	**4**

(d)(iii)	*two from:* transpiration occurs ; *in context of via stomata or via cuticle* diffuses / moves / AW, to, (external) environment / atmosphere / outside / out of the leaf / from leaf surface ; **R** evaporation / osmosis **R** from cell surface via (open) stomata (for, gas exchange / carbon dioxide entry / photosynthesis) ; *accept* Ψ *for water potential* **I** solute potential / ref. to concentration (movement of water vapour) down water potential gradient ; **A** down water vapour potential gradient **A** high to low water potential / to lower water potential / from higher water potential **R** from high to low water potential gradient	**2**

Q22.

(c)	*hydrostatic required once only in the answers* *four from:* 1 diffusion, into phloem sieve tube (element), from companion cell (through plasmodesmata) ; 2 presence of sucrose (in phloem sieve tube element), lowers water potential / makes water potential more negative ; **R** if in context of xylem vessels or companion cells 3 water enters (sieve tubes), by osmosis / down water potential gradient (into sieve tubes) ; 4 increase in, hydrostatic, pressure (in sieve tube elements) ; **A** turgor pressure 5 low hydrostatic pressure in, storage tissues / root / sink, by removal of sucrose ; 6 movement of, (phloem) sap / sucrose (in solution), down hydrostatic pressure gradient / from high to low hydrostatic pressure ; 7 mass flow ;	**4**

Q23.

(a)	**A** – endodermal (cell) ; **A** endodermis / passage cell **B** – apoplast(ic) ;	**2**

(b)	*five from:* 1 water potential gradient, between leaves and roots ; **A** water potential gradient across the root (root hair to xylem / across cortex) 2 diffusion out (via stomata) of water vapour ; 3 evaporation of water from mesophyll cell, surfaces / walls / membranes ; 4 (transpiration from leaves) creates transpiration pull ; 5 tension is, set up / present, in xylem vessels ; 6 cohesion between water molecules (*in xylem or in roots)* ; 7 hydrogen bonding between water molecules ; 8 adhesion of water molecules to cellulose (in wall of xylem vessels) ; **A** to hydrophilic parts of lignin 9 movement of water from apoplast through endodermis by osmosis ; 10 AVP ; e.g. *idea that* water columns extend from centre of root to root hairs (and to soil water)	**5**
(c)	*two from:* *pathway C is slower* ***accept ora** for pathway B is faster* greater resistance ; water passes across membranes ; water flows through, cytoplasm / plasmodesmata ; **A** ora ref. to intercellular spaces **A** protoplast osmosis occurs ; **R** through plasmodesmata ref. to water passes through vacuoles ;	**2**

Q24.

(a)	xerophyte / xerophytic ; **R** succulent / cactus / named	**1**

(b)(ii)	*any two from* **1** for, transport / translocation, } *accept assimilates / products* **or** } *of metabolism, if in context of* movement / AW, from source to sink ; } *cardiac glycosides* **I** *ref. to* transport of, amino acids / sucrose **2** *ref. to* source, is place of synthesis / AW **or** sink is / movement to, area where not manufactured / storage area / area where they are required ; **3** as defence mechanism (e.g. against sap feeders) ;	**2**

Q25.

(b)	*any two from* transport of sucrose / assimilates / products of photosynthesis (in phloem), is prevented / AW ; *ref.* starch synthesised in root from transported assimilates / AW ; starch not converted in leaf to sugars / sucrose, (for transport) ; idea that pathogen and phloem present in, all organs / many organs / leaves / roots ; AVP ; e.g. reason(s) why it cannot be xylem	**2**