SB6a Photosynthesis

Student Book

5th **1** Animals need to eat biomass/food (they cannot make it). Plants and algae can produce their own biomass/food.

7th **2** They make glucose using photosynthesis. They use glucose to make all other substances they need.

6th **3** carbon dioxide, water

9th **4** Energy has entered from the surroundings/photosynthesis is an endothermic process.

7th **5** glucose

9th **6** Towards evening, because the plant will have been making starch all day, and it only gets broken down (into sucrose) when photosynthesis stops.

7th **7** When it is light, water enters the guard cells, making them expand and so opening the gap between them. The opposite happens when it is dark.

8th **8** They have stomata on the tops of their leaves, since stomata on the bottom would be covered by water meaning much less gas exchange.

S1 An explanation is needed to cover the majority of these points:

- plants need carbon dioxide to photosynthesise
- this produces oxygen
- this produces glucose
- we need oxygen for aerobic respiration
- we need the biomass produced from glucose for food.

S2 List three from:

- stomata to allow gas exchange
- chloroplasts/chlorophyll to trap energy transferred by light
- large surface area to trap more light energy transferred by light
- thin, so that gases do not have to travel far into/out of the leaf
- contain xylem tissue to bring water to the leaf (although this is not mentioned in this topic).

E1 Energy transferred by light is trapped in the glucose produced by photosynthesis. Plants can release this energy by respiration whether it is light or dark.

Exam-style question

They are packed with chloroplasts/chlorophyll (1). Chloroplasts/chlorophyll trap energy transferred by light (1).

Activity and Assessment Pack

SB6a.3 Photosynthesis – Strengthen

1 **a** carbon dioxide/water + carbon dioxide/water → oxygen/glucose + oxygen/glucose
b light
c chlorophyll
d starch
e oxygen

2 **a** stoma
b C

3 **a** algae
b all of them (algae, clam, green sunfish, bass)

4 The products contain more energy than the reactants.

SB6a.4 Leaf structure and photosynthesis – Homework 1

1 carbon dioxide/water + carbon dioxide/water → oxygen/glucose + oxygen/glucose

2 **a** B
b B
c E

3 **a** glucose
b one of cellulose, lipids, proteins, chlorophyll or any other substance produced by plants
c storage (of energy)

4 (aerobic) respiration

5 **a** the materials in an organism
b Animals cannot produce their own food and so need to eat plants (or other animals that have eaten plants).
c the Sun

6

Feature	How this helps photosynthesis
large surface area	provides big surface for light to hit/be transferred
chlorophyll	traps energy (transferred by light)
stomata	allows gas exchange/carbon dioxide to get to the cells that need it

7 endothermic

SB6a.5 van Helmont's willow tree – Homework 2

1 **a** The mass of the tree came from water.

b Carbon dioxide is also needed to produce the biomass of a tree.

2 One of:

- He measured the dry weight of soil in both cases, to get a comparable measure at the start and end of the experiment.
- He made sure nothing could get into the pot except the water that he was adding.

3 Plants take in nutrients/mineral salts/minerals/mineral ions from the soil. The missing amount probably represents the amount of nutrients taken in over five years.

4 Any two sensible suggestions, e.g.:

- He could have collected the leaves to measure the total mass of growth during the time.
- He could have kept the plant enclosed in a large container and measured the change in amounts of gases taken in and released over that time.
- He could have just used distilled water.
- He could have repeated the experiment with more than one tree.

5 A good letter should contain some of the following points.

- word equation for photosynthesis
- need for energy transferred by light
- need for chlorophyll (which makes plants green)
- glucose stores energy
- photosynthesis is a series of enzyme-controlled reactions
- photosynthesis is endothermic, and glucose stores energy
- use of glucose to make all other plant biomass
- including starch, used for storage
- glucose used for respiration
- large flat leaves to provide a large surface area to trap energy
- thin leaves so that carbon dioxide from the air does not have to travel far to reach cells that need it
- stomata to allow gas exchange

6

- The organisms in each step on the pyramid rely on biomass from the step below.
- At each step, some biomass is lost ('used up' for respiration or lost as waste or not eaten).
- So not all the biomass is able to be transferred from one set of organisms to the next set.

SB6b Factors affecting photosynthesis

Student Book

5th **1** carbon dioxide

7th **2** **a** the speed at which it happens

6th **b** Two of: temperature, carbon dioxide (concentration), water (availability – more likely to be frozen for more of the year).

9th **3** **a** Enzymes control the rate of photosynthesis. These enzymes work more slowly if it is too cold.

9th **b** Photosynthesis uses up carbon dioxide. If the amount of carbon dioxide in a certain volume of air is less, then less photosynthesis will take place.

9th **c** Photosynthesis requires energy transferred by light. The greater the light intensity, the more energy it transfers (and the faster photosynthesis occurs).

9th **4** Increase the temperature. Look for an increase in the rate of photosynthesis.

10th **5** H Original graph sketched, with another line added to show rate increasing past the existing horizontal line.

The new line also levelling off (because only a set amount of additional carbon dioxide is added).

9th **6** H Stage A: temperature is limiting because when the experiment is repeated at a higher temperature (as shown by stage B) the rate increases.

Stage B: light intensity is limiting at this stage, because as the light intensity increases so does the rate.

Stage C: carbon dioxide is probably limiting now, since the temperature is high and the light intensity is no longer making a difference (although the temperature could potentially still be lower than optimum).

10th **7** **a** H It will increase by 3 times, because (without limiting factors) the rate of photosynthesis is directly proportional to the light intensity.

8th **b** H If you divide the distance from a light source by √3, light intensity is $\frac{1}{(1/\sqrt{3})^2} = \frac{1}{1/3}$ = 3 times the original.

S1 increased levels of chlorophyll/chloroplasts (*dark* green leaves) and large surface area of leaves to collect as much energy transferred by light as possible to stop that becoming a limiting factor

E1 H $I_{new} = \frac{2000 \times 13^2}{20^2}$ = 845 lux

Exam-style question

Artificial lighting: so that photosynthesis can happen for longer/24 hours every day/so that lower light levels at the end of the day do not limit the rate of photosynthesis (1).

Artificial heating: so that low temperatures do not limit the rate of photosynthesis (1).

SB6b Core practical – Light intensity and photosynthesis

1 Loss of carbon dioxide (for photosynthesis) (1) makes the solution less acidic/more alkaline (1).

2 the rate of photosynthesis (1)

3 **a** the change in pH (1)

b light intensity/distance of lamp (1)

c Increasing temperatures increase photosynthesis (1), which would cause readings to be higher than they would if only light intensity were increasing (1).

d Yes, because a tank of water is used to absorb the heat from the lamp (1).

e Two sensible suggestions, such as: amount of hydrogen carbonate indicator, number of algal balls, lamp, bottles (2).

4 So that carbon dioxide does not become a limiting factor (1).

5 **a** Put algal balls in different water temperatures (1); keep light intensity/distance from lamp the same (1).

b Lowest value 1–5 °C (1) because below 0 °C, the solution may freeze (1).

Highest value 50–60°C (1) because these are values well in excess of what algae would normally experience/this is the point at which enzymes start to denature (1).

6 Control (1) that ensures that the change in pH is due to differences in light intensity and not something else (1).

7 **a** oxygen (1)

b correctly plotted points (1), line graph with suitable axes and labels (1)

c The further the distance from the lamp, the fewer the bubbles (1) because photosynthesis is powered by energy transferred by light (1), and so the greater the light intensity the faster the rate of photosynthesis (1).

d Repeated readings (1), so you can be more sure that the results/trend/pattern is correct (1).

e Correct calculations for $\frac{1}{d^2}$ (see below) (1), points correctly plotted on a scatter graph (1), with suitable axes and labels (1) and a line of best fit (1).

Distance (cm)	$\frac{1}{d^2}$	Rate of photosynthesis (bubbles per minute)
10	0.01	100
15	0.0044	60
20	0.0025	30
30	30	10
40	40	6
50	50	4

f Light intensity is proportional to $\frac{1}{d^2}$ (1); since photosynthesis is directly proportional to light intensity, it will also be proportional to $\frac{1}{d^2}$ (1).

Activity and Assessment Pack

SB6b.1 How light intensity affects photosynthesis

5 The part of an experiment in which the *independent* variable is not applied is called the control. A control is used to check that the *independent* variable has an effect (and that the effect is not due to another variable). In this experiment, the independent variable is the *light* intensity. The control is the *tube covered in foil*. We know that the independent variable has a direct effect on the final pH of the indicator because *when light could not get to the algae, the indicator colour did not change* (or words to that effect).

SB6b.2 The rate of photosynthesis

1 **a** at about 2 minutes – after this time oxygen concentration rises, as it is produced by photosynthesis when it is light

b at about 13 minutes – after this time oxygen concentration falls, as photosynthesis stops producing it and respiration uses it up

c working shown to work out the gradient of the line of best fit, e.g.:

$$\frac{5.96 - 5.3}{12 - 2.5} = \frac{0.66}{9.5} = 0.07 \text{ mg/dm}^3\text{/min}$$

d $y = 0.07 \times 4.2 + 5.1 = 5.4$ mg dm^3

e Photosynthesis needs light, and the greater the light intensity, the faster the rate of photosynthesis.

f The light intensity is not the limiting factor/ something else is a limiting factor.

g Either increase carbon dioxide concentration or increase temperature.

2 a bubbles per minute

b scatter diagram correctly plotted

c smooth curve of best fit drawn

d As the distance from the lamp is increased, the rate of photosynthesis decreases.

e As the lamp is moved further away, the light intensity decreases and so the rate of photosynthesis decreases.

f H scatter diagram of bubbles per minute plotted against 1/distance^2 and a line of best fit drawn through the origin

Number of bubbles in one minute	150	65	38	17	9	6
$\frac{1}{\text{distance}^2}$	0.01	0.0044	0.0025	0.0011	0.0006	0.0004

SB6b.3 Factors that affect photosynthesis – Strengthen

1 a the speed of photosynthesis

b something that stops rate increasing

2 *y*-axis (a), sloping line (e)(c), horizontal line (d)(b)

3 broad, surface, palisade, chloroplasts, adaptations

4 a increase

b decrease

c increase

d decrease

5 a g/dm^3

b
- Photosynthesis uses carbon dioxide as a raw material.
- If carbon dioxide is a limiting factor, increasing the concentration will increase the rate of photosynthesis.

SB6b.4 Limiting factors and photosynthesis – Homework 1

1 a energy, transfers, faster/higher

b carbon, low, high

c enzymes, faster, higher

2 a bubbles/minute

b oxygen

c light

d line drawn so that the horizontal part is above that in the original, possibly also showing a steeper line leading up to this

3
- tube B
- Carbon dioxide is acidic.
- Carbon dioxide is removed as the algae photosynthesise.
- So the pH increases (the higher the pH the higher the rate of photosynthesis).
- The closer to the lamp, the greater the light intensity.
- The greater the light intensity, the higher the rate of photosynthesis.

SB6b.5 Investigating photosynthesis Homework 2

1
- tube B
- Carbon dioxide is acidic.
- Carbon dioxide is removed as the algae photosynthesise.
- So the pH increases (the higher the pH the higher the rate of photosynthesis).
- The closer to the lamp the greater the light intensity.
- The greater the light intensity, the higher the rate of photosynthesis.

2 a The two variables have a linear relationship and are directly proportional.

b something that stops the rate of a reaction increasing

c light

d Photosynthesis is powered by (the energy transferred by) light.

e temperature

f
- Photosynthesis relies on enzymes.
- Enzymes work faster at higher temperatures (up to a point).

g carbon dioxide concentration

3 **a** Working is not needed.

Distance from lamp (cm)	Relative light intensity	Volume of gas collected after 40 minutes (mm^3)	Rate of photosynthesis (mm^3/hour)
30	10	20	30
60	$= 10 \times \frac{1}{2^2}$ $= 2.5$	5	7.5
90	$= 10 \times \frac{1}{3^2}$ $= 1.1$	2	3
120	$= 10 \times \frac{1}{4^2}$ $= 0.625$ (or 0.63)	1	1.5
150	$= 10 \times \frac{1}{5^2}$ $= 0.4$	0.8	1.2

b graph drawn with a straight line of best fit between the points

c It is a straight line and goes through the origin.

4

$$d_{new} = \sqrt{\frac{I_{orig} \times d_{orig}{}^2}{I_{new}}}$$

so, $d_{new} = \sqrt{\frac{4000 \times 5^2}{750}}$

= 11.5 cm

SB6c Absorbing water and mineral ions

Student Book

5th **1** by evaporation through their leaves

6th **2** photosynthesis (which should be correctly spelt)

7th **3** They extend over a large distance (to get water from many different parts of the soil).

They have a large surface area (to speed up water absorption).

7th **4** **a** from the soil (higher concentration) into the root (lower concentration)

8th **b** Water is constantly being removed from the root (into the xylem, and transported up the stem).

8th **5** **a** osmosis (through the cell membrane)

9th **b** diffusion (There are cytoplasmic connections between the cells.)

10th **6** Osmosis, through cell membrane into cells next to the xylem, osmosis from those cells into the xylem.

7th **7** Because they cannot diffuse against their concentration gradient.

S1 A good answer will include some or all of these points:
- higher concentration of solutes inside the cell (fewer water molecules)
- lower concentration of solutes in the soil water (more water molecules)
- molecules are randomly moving
- so there is a net movement from a region where there are more of them to a region where there are fewer
- when this happens to solute molecules across a semi-permeable membrane, it is osmosis.

E1 A good answer will include some or all of these points:

- root hair cells increase the surface area of the roots
- so allow more water to be taken up by the plant
- in a shorter space of time
- water is needed for photosynthesis
- and to support parts of the plant (including leaves)
- so adequate water is needed before photosynthesis starts
- extra water is needed to fill up the cells in the new leaves (and help them unfurl)
- water carries mineral ions
- these are needed to help make substances in parts of the plant that will start actively growing.

Exam-style question

A good answer will include at least two of these points:

- osmosis
- concentration of solvent/water molecules is higher in soil than in root hair cell (or vice versa, or an explanation in terms of solute concentration)
- water/solvent flows down this concentration gradient
- through a semi-permeable/partially permeable membrane (2).

Activity and Assessment Pack

SB6c.2 Active transport in roots

1 It should go up.

2 from the water in the soil

3 osmosis

4 higher concentration of water in the soil than in the root hair cells, so that water molecules diffuse into the plant cells down their concentration gradient

5 The concentration of mineral ions inside the cells is higher than in the soil water surrounding the cells, so the mineral ions cannot move into the cells by diffusion.

6 Passive means it happens without the use of energy. Active means that energy is needed for the process to happen.

7 Taking in minerals increases the concentration of minerals in root hair cells and decreases the concentration of water in the cells. This will draw more water into the cells by osmosis.

8 any suitable experiment that uses identical apparatus and the application of a poison to the plant root to kill the cells

SB6c.3 Absorbing water and mineral ions – Strengthen

1 **a** particles, fewer
b random
c semi
d solvent, partially
e osmosis, right, left

2 **a** root hair cells
b drawing of a root hair cell, labelled to show: nucleus, cell (surface) membrane, cell wall, cytoplasm, vacuole, root hair, mitochondria
c mineral ions
d It lets them absorb substances/water and mineral ions into the cell more quickly.

SB6c.4 In the roots – Homework 1

1 **a** labels to show: nucleus, cell (surface) membrane, cell wall, cytoplasm, vacuole, root hair, mitochondrion
b cell (surface) membrane
c osmosis
d It has a large surface area, to speed up the absorption of water.
e Two of: carrying dissolved mineral ions, keeping cells rigid/preventing wilting, photosynthesis, cooling the leaves

2 xylem

3 **a** nitrate
b nitrate ions are in greater concentration inside the cell than in the soil; so nitrate ions need to be moved against the concentration gradient; this requires active transport

4 **a** 13 g/100 cm^3
b This is the concentration at which there was no overall change in mass. If there is no overall flow of water by osmosis there will be no overall change in mass.

SB6c.5 Root cells – Homework 2

1 a

Potato core	A	B	C	D	E
initial mass of potato core (g)	13.5	21.0	16.1	16.0	14.2
final mass of potato core (g)	16.5	23.5	16.4	14.9	12.5
concentration of sucrose (g/dm^3)	0	50	100	150	200
percentage gain/ loss in mass	22%	12%	2%	−7%	−12%

b Students should produce a correctly drawn graph, with the line extending above and below the *x*-axis. The axes should be labelled, with 'Sucrose concentration (g/dm^3)' on the *x*-axis and 'Percentage gain/loss in mass (%)' on the *y*-axis. Better graphs will include an appropriate title, such as 'How the percentage change in mass of a potato core depends on sucrose concentration'.

c Answer in the region of 110 g/dm^3. This is the concentration at which there was no overall change in mass. If there is no overall flow of water by osmosis, there will be no overall change in mass.

2 a
- The cell (surface) membrane is partially permeable.
- Solvent/water molecules pass through it, but large solute molecules do not.
- overall/net diffusion of water molecules only
- from outside (where there are more solvent molecules/weaker solute concentration) to inside (where there are fewer solvent molecules/stronger solute concentration)

b It has a root hair, giving it a large surface area in order to absorb water quickly.

c diffusion

3 a
- The root hair cell gives it a large surface area to increase the speed of transport.
- lots of mitochondria to release energy to power the transport

b
- There is greater concentration of mineral ions inside the cell than in the soil.
- So mineral ions need to be moved against the concentration gradient.
- This requires energy to pump the ions, since diffusion will move the ions in the opposite direction.

4
- The greater the surface area : volume ratio, the faster a cell can fill up with the substances it needs.
- Cell B has a surface area : volume ratio of

$$\frac{2(15 \times 15) + 2(15 \times 20) + 2(15 \times 20)}{15 \times 15 \times 20}$$
$$= \frac{450 + 600 + 600}{4500}$$
$$= \frac{1650}{4500} = 0.37.$$

- Cell A has a surface area : volume ratio of $\frac{4000}{8000} = 0.5$.
- The higher surface area : volume ratio of cell A means that it can more quickly fill with the substances it needs/more quickly increase the solvent in the cytoplasm/the concentration of the mineral ions in the cytoplasm.

SB6d Transpiration and translocation

Student Book

5th **1** stomata

6th **2** Stomata are closed at night.

8th **3** If enzymes get too hot, they don't work so efficiently/so photosynthesis would slow down.

5th **4** Two from:
- carrying dissolved mineral ions
- keeping cells rigid
- cooling leaves
- photosynthesis.

9th **5 a** The stomata are open (during the day). There is a concentration gradient from inside the leaf to the outside. The concentration gradient is maintained because wind blows water molecules away from the stomata.

9th **b** There is a concentration gradient from inside the xylem to the air spaces in the leaf. The concentration gradient is maintained because water molecules are diffusing out of the leaf.

9th **6** It is hotter at midday than at the end of the day and so water molecules move faster/diffuse faster. Light levels are higher at midday and so the stomata are open wider/allow more space for diffusion to occur.

6th **7** no cytoplasm (so water flows through the 'cells' easily)/no cell walls (so water flows from 'cell' to 'cell' easily)

6th **8** so there is more space for sugar solution to flow/so that sugar solution can flow more easily

9th **9** Mitochondria release energy, for active transport of sucrose into sieve tubes, against the concentration gradient.

S1 A good table will contain points such as these:

	Translocation	Transpiration
substance transported	sucrose/solutes	water
method of transport	in phloem	in xylem
transport cells – living or dead	living	dead
direction of flow	up and down	up
mainly uses active transport?	yes	no

E1 Sucrose in the sieve tubes creates a more concentrated solution than is outside of them. Water flows from a more dilute solution to a more concentrated solution, by a process called osmosis.

Exam-style question

At least two of these points are needed:

- the faster the wind speed, the more quickly water molecules are removed from around the stomata
- the steeper the concentration gradient/the greater the difference in concentration between the inside and outside the leaf
- the faster diffusion occurs (2).

Activity and Assessment Pack

SB6d.2 Plant cell adaptations

Cell type	Functions	Adaptations for functions
root hair cell	absorbs water	large surface area increases the rate of absorption
	absorbs mineral ions	large surface area increases the rate of absorption
		many mitochondria to release energy for active transport
xylem cell	carries water up the plant to tissues	no cell walls at the ends, so liquids pass easily from cell to cell
		dead cells with no cytoplasm join to form hollow tubes
	carries dissolved mineral ions up the plant to tissues	tiny pores in side walls allow water and dissolved ions to exit
	supports the plant	thick side walls and rings of lignin for strength
phloem sieve cell	carries sucrose around the plant	holes in the end cell walls allow liquids to pass from cell to cell
		large central channel due to lack of nucleus and much cytoplasm
guard cell	pairs open and close stomata	difference in cell wall thickness causes shape change
phloem companion cell	supplies sugars to sieve cells	many mitochondria to release energy to pump sucrose

SB6d.3 Transpiration and translocation – Strengthen

1 **a** mineral ions/salts

b sucrose

c companion

d living

e active transport

2 cellulose, lignin

3 **a**

Distance travelled by bubble	Rate of transpiration (mm/min)
4 – 1 = 3	3/20 = 0.15
8 – 3 = 5	5/20 = 0.25
11 – 3 = 8	8/20 = 0.40
16 – 1 = 15	15/20 = 0.75

b The higher the wind speed, the faster the rate of transpiration.

c The faster the water molecules are removed, the less time there is for the concentration gradient to be reduced. Accept other explanations in terms of maintaining the concentration gradient.

d When humidity increases, the rate of transpiration slows.

4 **a** weak forces of attraction (between the water molecules)

b Water evaporates from the leaves and so from the xylem in the leaves; the loss of water pulls the water up the xylem.

SB6d.4 Transport in plants Homework 1

1
- increasing light intensity – increases – the stomata open wider
- increasing temperature – increases – evaporation and diffusion are faster
- increasing wind speed – increases – water vapour outside stomata is reduced, maintaining the concentration gradient
- increasing humidity – decreases – additional water vapour decreases the concentration gradient

2 **a** $\frac{12.9 + 13.4 + 13.2}{3} = 13.2\ mm^3$ (to 1 decimal place)

b $13.2/3 = 4.4\ mm^3/min$

c xylem (vessels/cells)

d The molecules are held together by weak forces of attraction.

3 companion, sieve, active, mitochondria, translocation

SB6d.5 Transport of water and sucrose – Homework 2

1 **a & b**

Fan power setting (W)	Distance moved by bubble in five minutes (mm)				
	Trial 1	Trial 2	Trial 3	Mean (mm)	Mean rate (mm/min)
10	22	27	26	25	5
15	35	36	34	35	7
20	42	44	49	45	9
25	55	57	56	55	11

c correctly drawn graph with a line of best fit

d Gradient should be in the region of 0.4.

e 1

f $y = mx + c$, so $y = (0.4 \times 12) + 1 = 5.8$

g
- The higher the power, the faster the fan.
- And the faster the water molecules will be moved away from the stomata.
- So making the concentration gradient higher and higher.
- The higher the concentration gradient, the faster the water vapour diffuses through the stomata.

2 **a**
- Water vapour diffuses through the stomata.
- Water vapour evaporates from the cells and xylem in the leaf.
- This pulls more water up through the xylem tubes.
- The water molecules are held together by weak forces of attraction.

b xylem (vessels/cells)

c One of:

- They are dead and have no cytoplasm, so can carry a lot of water.
- They have thick walls and so withstand the pressure of the water inside them.
- They have no cell walls at their ends, so water can flow freely between the cells.

d Two from: xylem cells are dead, xylem cells have no cytoplasm/mitochondria, xylem cells have thick walls/rings of thickening, xylem cell walls contain lignin, xylem cells have completely open ends.

e sucrose

3 $V = \pi r^2 h$ so, V/min = πr^2 × mean rate (from table above)

V/min = $\pi 0.65^2 \times 5 = 6.6$ mm^3/min

V/mn = $\pi 0.65^2 \times 7 = 9.3$ mm^3/min

V/min = $\pi 0.65^2 \times 9 = 11.9$ mm^3/min

V/min = $\pi 0.65^2 \times 11 = 14.6$ mm^3/min

SB6e Plant adaptations

Student Book

6th **1** Move upwards/towards the light/Sun; to get more light for photosynthesis.

7th **2** Starch is produced from the glucose that is made in photosynthesis. Photosynthesis occurs in chloroplasts.

7th **3** In the palisade layer/cells; because these cells have the most chloroplasts.

7th **4** They don't fit together very well/there are air spaces between them; to allow diffusion of gases inside the leaf.

7th **5** They allow light to reach the palisade cells (where most photosynthesis occurs).

7th **6** So that dirt does not reduce the amount of light reaching the palisade cells (where most photosynthesis occurs).

6th **7** The trees above them cause shade/less light; they need bigger leaves to be able to get enough light.

8th **8** Reduced surface area and so less surface for water to escape/evaporate from the leaf; sunken stomata in pits so that water vapour collects around the stomata and reduces further diffusion; very thick cuticle to prevent water escaping/evaporating through the cells.

7th **9** The stomata only open when it is cooler; so that less water vapour is lost; as diffusion is slower at lower temperatures.

7th **10** Water vapour can be trapped between the plants (slowing the rate of diffusion out of the plants).

S1 Table, such as:

Adaptation	Explanation
stomata in valleys (between ribs of stem)	Water vapour is trapped in the valleys, slowing diffusion from the stomata.
hairs	Water vapour is trapped by the hairs, slowing diffusion from the stomata.
spines instead of leaves	Reduces the surface area of the plant from which water can be lost.
stomata only open at night	Stomata are not open at the hottest times, when water vapour diffusion would be greatest.
thick cuticle	Prevents uncontrolled evaporation
stem stores water	Keeps water available for photosynthesis.

E1 Water vapour collects in pits around the sunken stomata, and is trapped in the pits by the hairs, and can be further trapped by curling of the leaves; each of these features reduces the effect of air movements blowing the water vapour away/reduces diffusion of water vapour away from the leaves; this reduces the rate of diffusion of water vapour from the leaves into the air; and so the plant does not lose so much water.

Exam-style question

An explanation that includes any three of the following points: dry conditions in the desert mean that the plant has to avoid water loss; small leaves to reduce surface area; smaller surface area, less area for water loss; thick cuticle reduces water loss from cells (3).

Activity and Assessment Pack

SB6e.1 Investigating leaf structure

2 **a** the second/palisade layer and the third/spongy layer

b These layers are green/contain chloroplasts.

3 **a** on the bottom surface

b They allow the entry of carbon dioxide, which is a raw material for photosynthesis.

4 It means that the cells have a lot of surface area exposed to air containing carbon dioxide, and/or it allows the easy diffusion of gases/carbon dioxide inside the leaf.

5 It means that carbon dioxide does not have to diffuse very far in order to reach cells that need it.

SB6e.2 Leaf surface area

4 Well-lit leaves are exposed to more direct sunlight and so heat up more, which will increase the rate of evaporation from the cells near the tops of their leaves. A thicker layer of cuticle stops this evaporated water escaping.

5 The greater amount of light hitting leaves from the Sun means that some of the light will pass through a single palisade layer and may pass through the leaf without being used. The additional palisade layers ensure that more energy from the light is trapped and is not wasted.

6 Steps should include taking a sample of leaves and measuring their surface area, using squared paper. A mean/'average' leaf surface area is then worked out, and this result is multiplied by two (because each leaf has two surfaces). Then work out the number of leaves on the tree (e.g. by counting the leaves on a sample branch and then estimating the number of branches). Then the number of leaves is multiplied by the total surface area of one average leaf.

SB6e.3 Plant adaptations Strengthen

1 No leaves – water loss is reduced, because the plant has less surface area.

Stomata only open at night – less water loss occurs during the heat of the day.

Stem stores water – it provides a raw material for photosynthesis when there is no rain.

Thick cuticle – cuts down the evaporation of water from cells on the plant's stem.

Stomata are hidden in dips in the stem – water vapour is trapped and the rate of diffusion of water out of the plant is reduced.

2 **a** chloroplasts

b creating air spaces

c xylem tissue

3 **a** Leaves are thin.

b carbon dioxide or water vapour

c The stomata are opened or closed.

4 The reduction of the surface area means that they lose less water than an equivalent leaf with a flat shape. (If unit SB8 has been covered, some students may answer in terms of SA : V ratio.)

SB6e.4 Adaptations of leaves Homework 1

1 **a** oxygen, carbon dioxide, water vapour

b to cut down water loss through evaporation of water from cells near the leaf surface

c Palisade cells are packed with chloroplasts – to trap a lot of the energy transferred by light.

Stomata open during the day – to allow carbon dioxide to enter when there is light for photosynthesis.

The leaf is very thin – so that carbon dioxide does not have far to diffuse before reaching a cell that needs it.

Spongy cells create air spaces inside the leaf – so that cells have a lot of surface area exposed to air containing carbon dioxide and/or it allows the easy diffusion of gases/carbon dioxide inside the leaf.

2 **a** A $1 \times 1 \times 50 = 50$ mm^3

B $0.1 \times 10 \times 50 = 50$ mm^3

b A $2(1 \times 1) + 4(1 \times 50) = 202$ mm^2

B $2(10 \times 0.1) + 2(0.1 \times 50) + 2(10 \times 50) = 1012$ mm^2

c Tree A. For the same volume, it has less surface area and so will lose less water. (If unit SB8 has been covered, some students may answer in terms of SA : V ratio.)

SB6e.5 Leaves and stomata Homework 2

1 **a** active transport

b diffusion

c osmosis

2 Because it does not absorb very much green light – it reflects it instead.

3 Violet, because this colour is best absorbed by chlorophyll.

4 **a** So that the stomata are only open (for carbon dioxide to enter) when there is enough light for photosynthesis (and not open when photosynthesis is not occurring, which would result in water loss).