ST ANDREW'S SECONDARY SCHOOL

Secondary 3 Biology (6093)

Chapter 7: Nutrition in Plants

Name: _____ ( ) Class: _____ Date: _____

5. Nutrition in Plants

Content

• Leaf Structure

• Photosynthesis

Learning Outcomes

Candidates should be able to:

a) identify and label the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the
   - distribution of chloroplasts in photosynthesis
   - stomata and mesophyll cells in gaseous exchange
   - vascular bundles in transport

b) state the equation, in words and symbols, for photosynthesis

c) describe the intake of carbon dioxide and water by plants

d) state that chlorophyll traps light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent uses

e) investigate and discuss the effects of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plant)

f) discuss light intensity, carbon dioxide concentration and temperature as limiting factors on the rate of photosynthesis

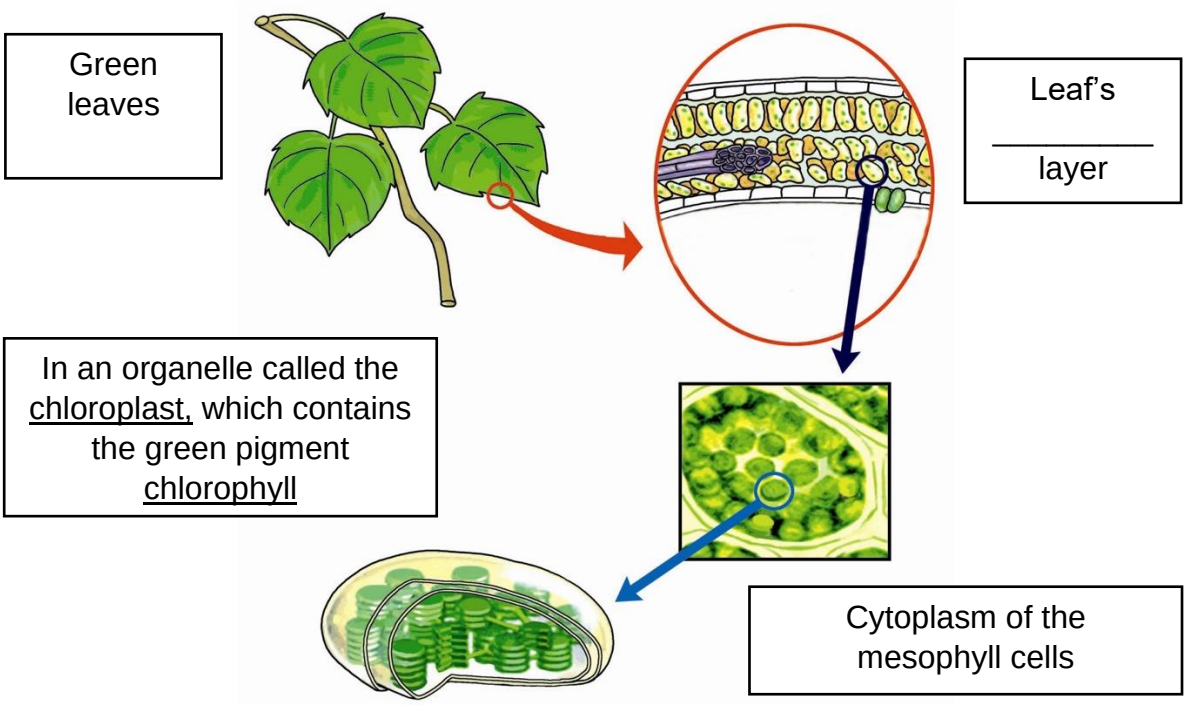
Use the knowledge gained in this section in new situations or to solve related problems.

7.1 Photosynthesis

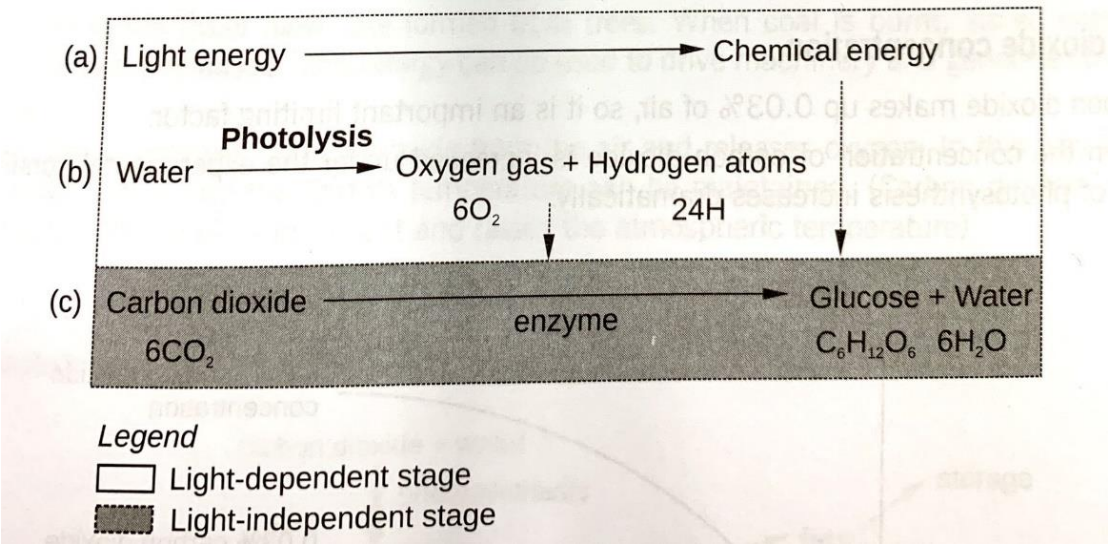
- Plants are able to synthesise their own food by the process of photosynthesis.
- Photosynthesis is a process in which light energy is absorbed by chlorophyll and converted to chemical energy.

- Inorganic molecules of carbon dioxide and water are used for the synthesis of an organic molecule of glucose.
- Oxygen is released as a by-product.

Where does photosynthesis occur?



The light-dependent (light) and light-independent (dark) stages in photosynthesis.



1. Enzymes catalyse a series of reactions involved in the light and dark stages of photosynthesis.

2. During the light stage of photosynthesis, the following processes occur:
   a. Trapping of light energy by chlorophyll
   b. Conversion of light energy to chemical energy
   c. Splitting/photolysis of water into hydrogen atoms and oxygen gas.
3. During the dark stage of photosynthesis, the chemical energy and hydrogen atoms produced from the light stage are used to reduce carbon dioxide to form glucose.

The overall word equation of photosynthesis:

carbon dioxide + water → glucose + oxygen **[do not state energy as a product!]**

The overall chemical equation of photosynthesis:

$6\ CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6\ H_2O$

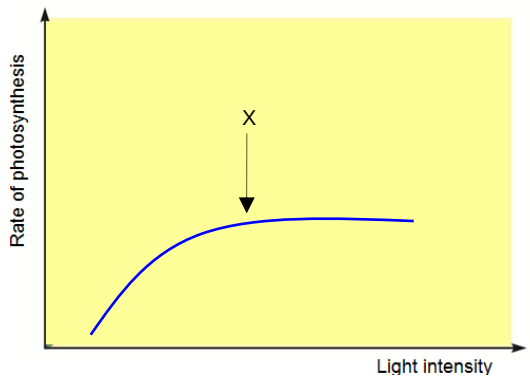
The simplified chemical equation for photosynthesis:

$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Limiting factors

- Any factor that directly affects or limits a process if its quantity or concentration is changed is called a limiting factor.
- Some factors affecting rate of photosynthesis are:
  - Light intensity
  - Carbon dioxide concentration
  - Temperature

A. Light intensity

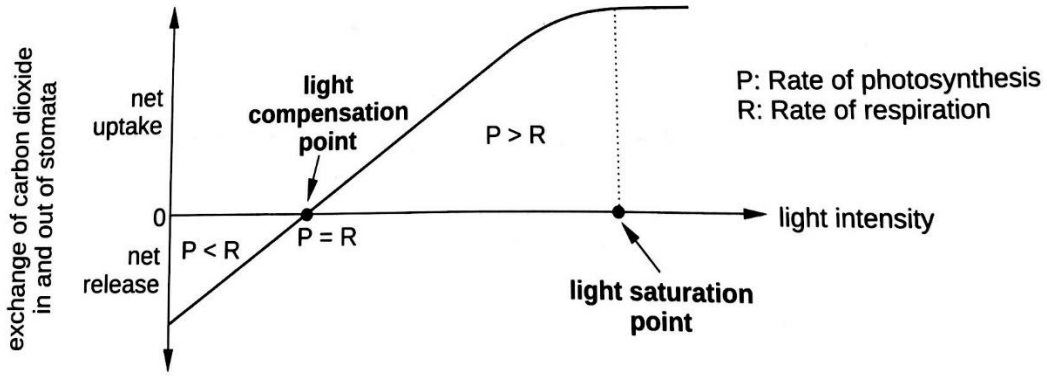


Beyond point X, the rate of photosynthesis…

remains constant, does not increase any further even when the light intensity increases.

Increasing the light intensity will <u>increase</u> the rate of photosynthesis up till a certain point. This is known as the <u>light saturation point.</u>

Plants respire (a process that releases carbon dioxide gas) simultaneously when they photosynthesize (a process that takes in carbon dioxide), the light intensity at which net gaseous exchange equals zero is known as the <u>light compensation point.</u>



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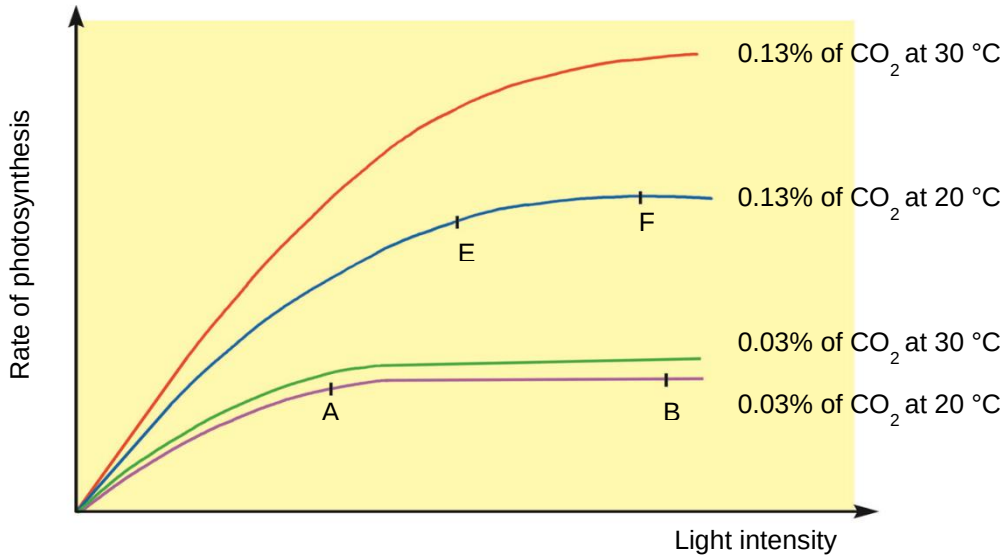
B. Carbon dioxide concentration

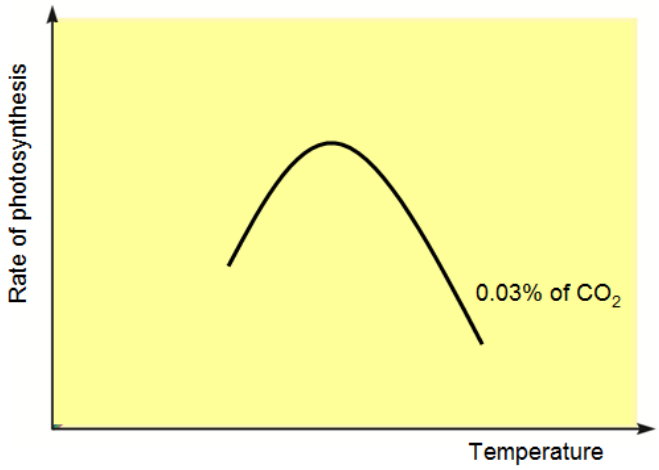


When the carbon dioxide concentration is raised from 0.03% to 0.13% while keeping the temperature constant at 20°C, the rate of photosynthesis will <u>increase.</u>

Considering a different <u>point of view</u>: At which concentration of CO_2 is temperature a significant limiting factor? Explain why.

0.13%. At that concentration of carbon dioxide, increasing temperature from 20℃ to 30℃ led to a significant increase in rate of photosynthesis. On the other hand, doing the same at 0.03% of CO_2 did not lead to a significant increase in rate of photosynthesis.

C. Temperature



Enzymes catalyse the reactions in photosynthesis. Therefore at temperatures lower or higher than optimum temperatures, enzymes are inactive or denatured respectively, thus affecting the rate of photosynthesis.

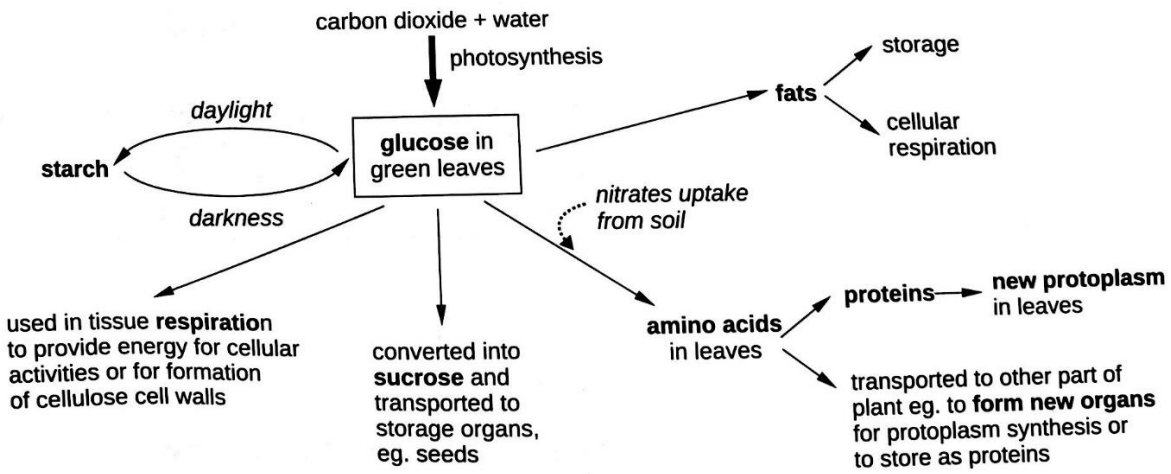
Practice #1

State and explain the relationship between temperature and photosynthesis. [N11/2/6] (use PEEL strategy. Ensure answers fulfil intellectual standards.)

State: Photosynthesis is a chemical reaction that requires the involvement of enzymes. Enzymes are dependent on temperature since they are made of proteins. Therefore, the rate of photosynthesis will be affected on by temperature changes.

Explain: At low temperatures such as 0°C, enzymes are inactive, due to enzymes having low levels of kinetic energy, hence rate of photosynthesis is slow. As temperature increases, enzymes gain kinetic energy and move faster, thereby increasing the rate of formation of enzyme-substrate complexes and increasing rate of reaction, until the optimum temperature of about 37°C. At optimum temperature, rate is the highest. As temperature increases beyond the optimum, enzymes start to lose the nature of their active sites, causing denaturation of the enzyme, and therefore rate of activity drops quickly to zero as temperature continues to increase further.

Fates of glucose in leaves



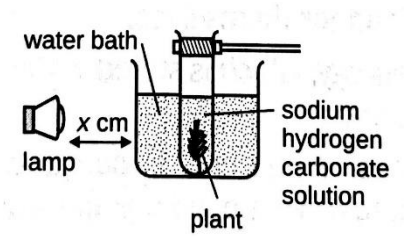
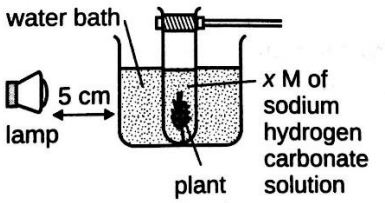
1. Glucose is used by plant cells for tissue respiration or to form cellulose cell walls.
2. Excess glucose is converted either into sucrose and transported to storage organs or changed into starch for temporary storage in the leaves.
3. Glucose can react with nitrates to form amino acids which are combined to form proteins for the synthesis of new protoplasm in the leaf.
4. Glucose can be used to form fats for storage, cellular respiration or synthesis of new protoplasm.

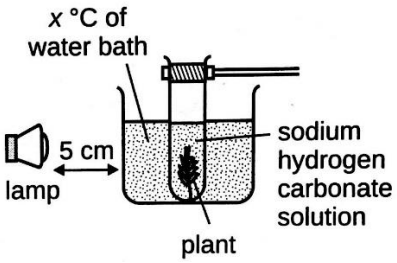
How can we study photosynthesis?

To do photosynthetic experiments, the following basic knowledge is required:

1. Glucose is first formed from carbon dioxide during photosynthesis.
2. Presence of starch in the leaves suggests that photosynthesis has taken place.
   - When glucose is formed more quickly than it is used up, the excess glucose is changed to starch for storage.
   - Test for starch using the iodine test.
3. Destarching must be carried out on the plants before the experiments.
   - This ensures that starch is removed in the leaves prior to the experiments.
   - Put the plants in the dark for two days to stop photosynthesis and change starch to glucose, which is used up by the plant.

Experiments to investigate factors affecting the rate of photosynthesis

Factor	Experimental set-up	Key steps
		**Objective** To investigate the effect of light intensity on the rate of photosynthesis **Factors kept constant** **(a)** carbon dioxide concentration **(b)** temperature **Manipulation of factor being investigated** Vary the distances between the lamp and the plant at intervals of 10cm, 20cm, 30cm, 40cm **How to check the effect on the rate of photosynthesis** Count the number of bubbles released per unit time
		**Objective** To investigate the effect of different carbon dioxide concentration on the rate of photosynthesis **Factors kept constant** **(a)** light intensity **(b)** temperature **Manipulation of factor being investigated** Prepare samples of sodium hydrogen carbonate of varying concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 M. **How to check the effect on the rate of photosynthesis** Count the number of bubbles released per unit time
		Objective To investigate the effect of different temperatures

		on the rate of photosynthesis **Factors kept constant** **(a)** light intensity **(b)** carbon dioxide concentration **Manipulation of factor being investigated** Prepare water baths of various temperatures of 10◦C, 20◦C, 30◦C, 40◦C and 50◦C **How to check the effect on the rate of photosynthesis** Count the number of bubbles released per unit time

N2010/P2/B8

(a) Describe the role of chlorophyll in photosynthesis. [2]

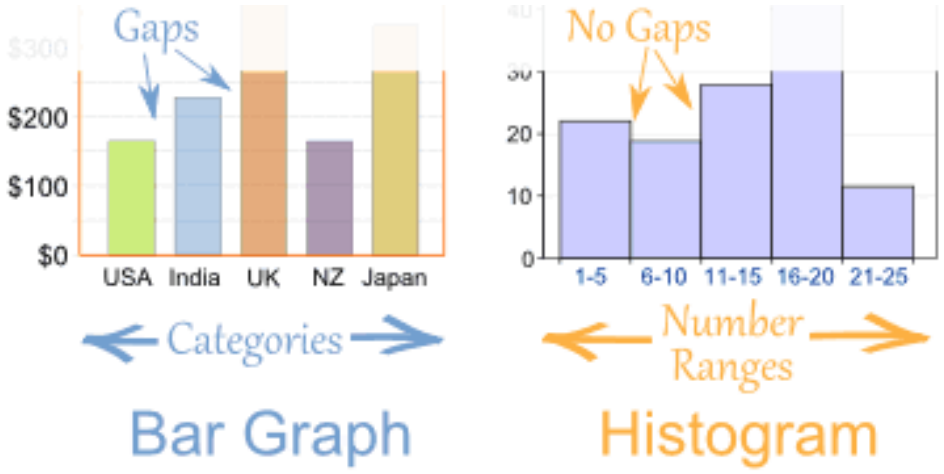
State: Chlorophyll is a green pigment that absorbs light energy from the sun and converts it into chemical energy.
Elaborate: This chemical energy is used to convert water and carbon dioxide into glucose during the dark stage of photosynthesis.
Exemplify and illustration: *skip for 2 marks*
Link: Therefore, chlorophyll plays an important role in the light-dependent stage of photosynthesis.

(b) The rate of photosynthesis in six tropical crop plants was measured when the plants were growing outside under normal conditions (rate **X**). The measurements were repeated again when the plants were grown under controlled optimum conditions in a glasshouse (rate **Y**). The results are shown in Table 1.1.

Table 1.1

crop plant	rate of photosynthesis (X)/µmol per m^2 per second	rate of photosynthesis (Y)/µmol per m^2 per second	difference in rate of photosynthesis (Y-X)/µmol per m^2 per second
cassava	13.7	23.1	9.4
eucalyptus	18.4	26.0	7.6
maize	23.4	26.0	2.6
soya bean	18.3	25.1	6.8
sugar cane	24.0	26.8	2.8
sunflower	24.3	31.7	7.4

i. Draw a bar chart of the difference (**Y-X**) in the rate of photosynthesis of each plant. [4]
Draw this on graph paper, or on the graph provided on the TYS.
Note the differences between bar graphs and histograms.



ii. Which two crop plants show the greatest difference between rate **X** and rate **Y**? [2] Cassava and Eucalyptus

iii. The measurements of the rate of photosynthesis (**X**) of the plants when grown outside are means of 10 readings. Suggest a reason why mean measurements were used.

Mark the following sample answers true/false. Explain why the incorrect ones are wrong using intellectual standards of clarity, accuracy, precision and/or relevance.

Sample answers	*√ or x*
A: Using mean numbers allowed extreme values to be eliminated. *Anomalous/extreme values would be discarded before the mean was calculated. Answer lacks accuracy.*	***x***
B: This makes the measurements more accurate. *Taking several measurements and then finding the mean does not make the actual measurements taken any more accurate. Answer lacks clarity and accuracy.*	***x***
C: Taking 10 readings improves the reliability of the conclusion drawn on the rate of photosynthesis of each type of plant. This is because plants might vary in length, height and positions when grown outside. Therefore, taking 10 readings would minimise the impact of these other variables on the rate of photosynthesis. This allows a more reliable comparison of rates of photosynthesis between crop plants.	*√*

iv. Suggest two factors that were changed when the plants were grown in controlled optimum conditions.
Temperature, light intensity, volume of water, carbon dioxide concentration (any 2)

(c) The rate of photosynthesis can be measured by:

- calculating the rate per unit area of the leaf
  or
- calculating the rate per unit mass of the leaf.

Suggest why these measurements may give different results.

Consider the differences between the two concepts "rate per unit area" and "rate per unit mass". How do these two differ? You may illustrate your thoughts.

<u>Command/purpose of qn</u>
Suggest: Give a good reason with your biological contextual knowledge.

<u>Using different points of views</u>
Are there situations when area of two leaves are the same, but mass differs? When do such situations happen?

You may use the SEEI method to help you answer your question.

State: The area of a leaf is not proportional to the mass of the leaf.
Elaborate/Exemplify: In other words, two leaves of the same area may have different mass due to different volume/thickness of the leaves.

_____

_____

7.2 Leaf Structure and Function

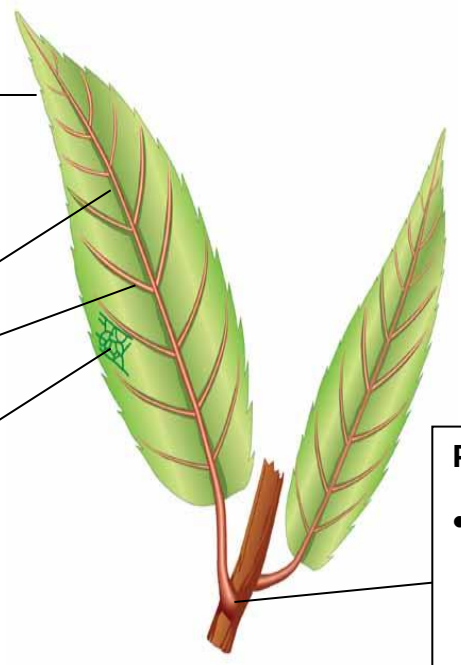
External structure of the leaf

Lamina:

- Has large surface area for maximum absorption of sunlight
- Thin to allow rapid diffusion of carbon dioxide into the leaf

Veins:

- Network of veins branching out from the vein in the mid-rib.
- Allow transport of water and mineral salts to the leaves as well as transport of manufactured food away from the leaves.



Petiole:

- Positions the leaf away from the stem to allow maximum absorption of sunlight.

Practice #2

2 (a) (i) In the space provided, write the word equation for photosynthesis.

carbon dioxide + water → glucose + oxygen

(ii) State the name of the structures in which photosynthesis takes place.

Chloroplasts

(iii) State the type of cell in which most of these structures are found.

Mesophyll cells

[N12/2/4]

Internal structure of the leaf

Epidermis:

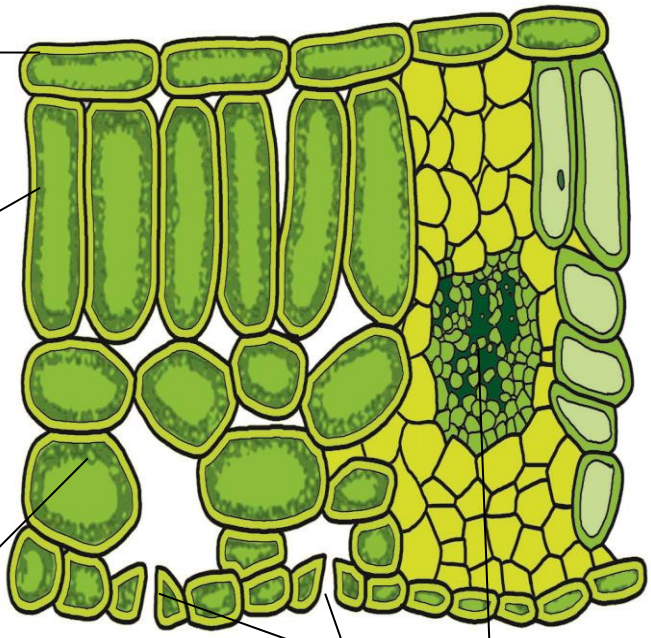
- Single layer of closely packed cells.
- Covered by a waxy cuticle to prevent excessive water loss

Palisade mesophyll:

- Layers of closely packed, long and cylindrical cells containing numerous chloroplasts for photosynthesis.

Spongy mesophyll:

- Layers of loosely packed cells with intercellular air spaces for gaseous exchange and few chloroplasts.



Stomata:

- An opening controlled by guard cells.
- In the presence of light, allows carbon dioxide to enter and oxygen to be released

Vascular bundle:

- Xylem to transport water and mineral salts to the leaves
- Phloem to transport sugars away from the leaf

How is the structure of the leaf adapted to its function?

Upper epidermis

Structure	Function
Single uppermost layer of cells	Protects inner layer of cells
Covered by a layer of waxy cuticle	Reduces evaporation of water from the leaf Prevents entry of disease causing microbes
Cells do not contain chloroplasts and are transparent	Allows light to penetrate into the inner layers

Mesophyll layer

Palisade mesophyll layer

Structure	Function
Long and cylindrical cells packed vertically	Vertical arrangement exposes many cells to light rays
Contains numerous chloroplasts	Photosynthesis takes place mainly in this region

Spongy mesophyll layer

Structure	Function
Irregularly shaped, loosely arranged cells with many air spaces in between	Air spaces allow rapid diffusion of CO_2 and O_2 in and out of mesophyll cells
Cells are surrounded by a thin film of water	Gases entering the cells can dissolve in the water
Chloroplasts present	Photosynthesis takes place in these cells

Veins (Vascular bundle)

Structure	Function
Extend throughout the leaf, within short distance of every mesophyll cell	Supports leaf and keeps it flat
Xylem: Cylindrical, hollow and thick walled cells	Carries water and mineral salts absorbed by the roots to the leaves
Phloem: Cylindrical, thin walled cells with cytoplasm	Transports products of photosynthesis to other parts of the plant

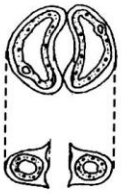
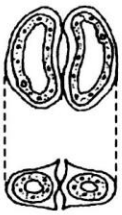
Lower epidermis

Structure	Function
Lowest layer of cells	Protects the inner tissues
Covered by waxy cuticle	Slows down loss of water
Guard cells surround stomata	Regulate opening and closing of stomata for diffusion of CO_2 and O_2 in and out of the leaf

Guard cells

- The guard cells surround the stomata.
- They are bean-shaped and have uneven thickness of walls.
- They contain chloroplasts and are the only epidermal cells that photosynthesise.
- They control the size of the stoma which affects the rate of gaseous exchange in the leaf in the day and at night.
- The concentration of potassium ions has an effect on the opening and closure of stomatal pores.

Control of the stomata by guard cells

Time of day	Pore of stomata	Explanation
In the day	 • Guard cells turgid • Stoma open	• Potassium ions enter the guard cells, so their concentration increases in the cells. • This result in a lower water potential in the cells than in the surroundings. • Water moves into them by osmosis, causing the cells to become turgid and swell, opening the stoma.
At night	 • Guard cells flaccid • Stoma closed	• Potassium ions leave the guard cells, so their concentration decreases in the cells. • This result in a higher water potential in the cells than in the surroundings. • Water moves out of the cells by osmosis, causing the cells to become flaccid and the stoma closes.

In sunlight:

- Guard cells photosynthesize and produce chemical energy that pumps ions into the cells.
- The ions decreases the water potential in the guard cells. Water moves into the guard cells until they become turgid.
- The turgidity of guard cells causes them to open the stomata.

At night:

- The ions diffuse out of the guard cells. This increases the water potential in the guard cells.
- Water moves out of the guard cells by osmosis. The guard cells become flaccid, which causes the stomata to close.

Practice #3

(a) Label one stoma (**A**) and one adjacent guard cell surrounding it (**B**). [2]

(b) Describe the function of stomata and guard cells. [4]

[modified N12/2/4]

The stomata functions to control gaseous exchange between the plant and the environment.

In the day, they open to allow carbon dioxide to enter the leaf and allow oxygen and water vapour to diffuse out.

At night, they close to reduce the loss of water vapour from the leaf.

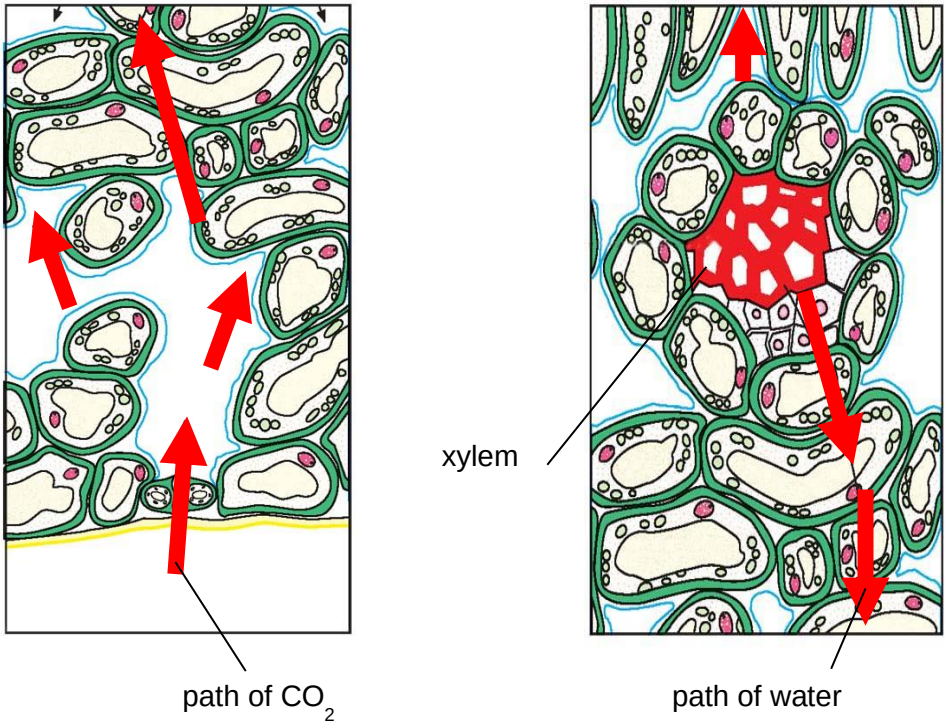
Guard cells control the size of the stomata.

Practice #4

Answer *True* or *False* for each of the following statements given below.

(a) Photosynthesis involves enzyme reactions that takes place in chloroplasts.	True
(b) Sunlight, carbon dioxide and chlorophyll are the only three important conditions for photosynthesis (water and suitable temp are the other two impt conditions as well)	False
(c) Placing a plant in darkness for two days is to deplete the existing glucose in it. (it is to destarch the plant)	False
(d) The rate of oxygen released gives an indication of the rate of photosynthesis	True
(e) Starch formation is not part of photosynthesis because starch can be formed in other parts of the plants besides in the leaves	True
(f) Potassium hydroxide solution and soda lime pellets have the same function in the investigation of photosynthesis in the laboratory settings.	True

Entry of carbon dioxide and water into the leaf



1. During the day, the plant carries out photosynthesis and carbon dioxide is rapidly used up.
2. The carbon dioxide concentration inside the leaf is lower than the atmosphere, causing carbon dioxide to enter into the leaf via the stomata
3. The carbon dioxide dissolves in the thin film of moisture surrounding the mesophyll cells and diffuses into cells.
4. Water and mineral salts move into the leaf through the xylem. Once out of the vein, these substances move from cell to cell right through the mesophyll of the leaf.

Practice Questions – AFL

On a piece of foolscap paper, attempt the following questions on your TYS, *without reference to answer key*:

1. Pg 57 Q1(c) [N12/2/4]
2. Pg 59 Q3 [N08/2/6]
3. Pg 60 Q1 [N14/2/9] – use critical thinking