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GCSE Biology

AQA Topic – Bioenergetics

Overview
Bioenergetics

Photosynthesis

- Photosynthetic reaction
- Rate of photosynthesis
- Use of glucose from photosynthesis

Respiration

- Aerobic and anaerobic respiration
- Response to exercise
- Metabolism

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Bioenergetics
Part 1

- Photosynthetic reaction
- Rate of photosynthesis
- Use of glucose from photosynthesis

Bioenergetics part 1 – Photosynthetic reaction

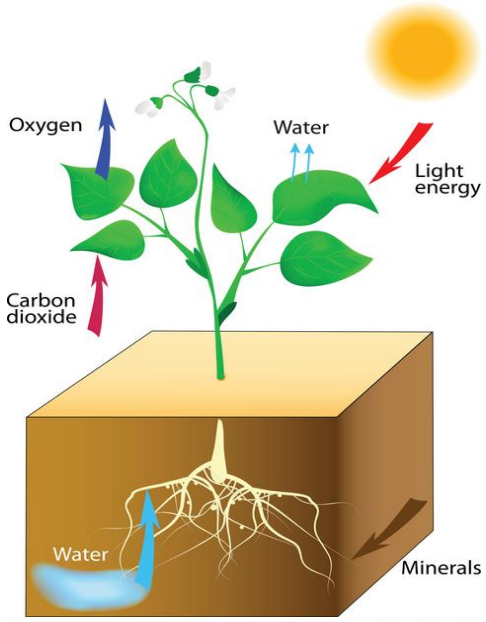
Plants make use of the **Sun's energy** to make **food** (glucose)

This process is called **photosynthesis**.

photo = light **synthesis** = to make

The plant manufactures **glucose** from carbon dioxide and water using **energy transferred** from the environment to the **chloroplasts** by light.

This is an **endothermic** reaction because photosynthesis needs an input of energy from the environment.



Bioenergetics part 1 – Photosynthetic reaction

The **word equation** which represents photosynthesis is:

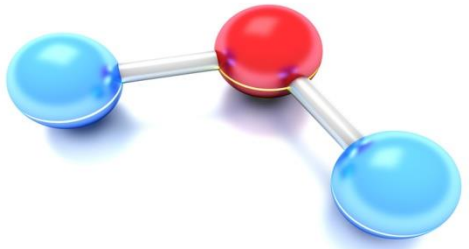
carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen

The balanced **symbol equation** which represents photosynthesis is:

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

Molecule name	Chemical Symbol
Carbon dioxide	**CO_2**
Water	**H_2O**
Oxygen	**O_2**
Glucose	**$C_6H_{12}O_6$**

You need to be able to recognise the chemical symbols for these molecules.

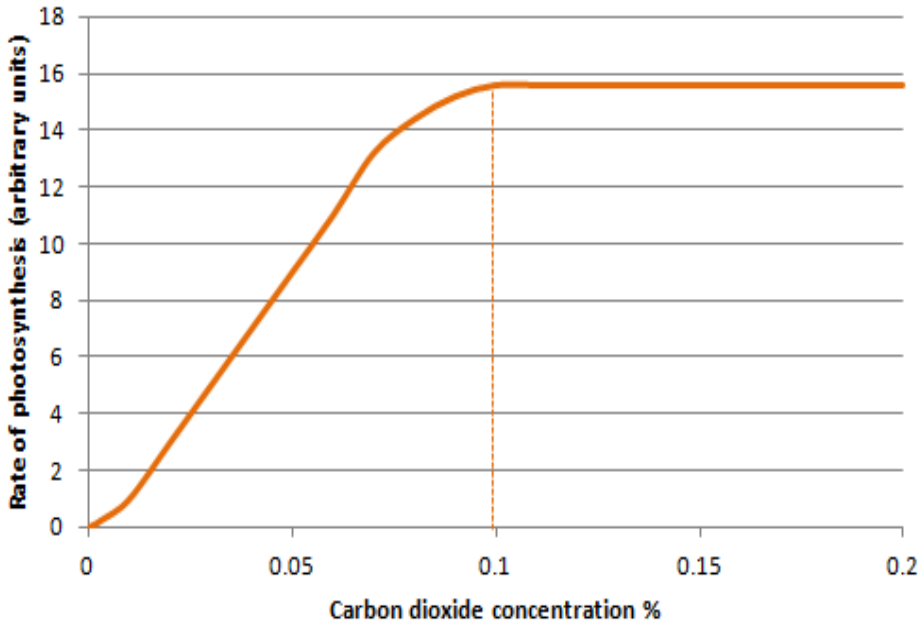


Video - Van Helmont's experiments

Bioenergetics part 1 – Rate of photosynthesis

Carbon dioxide is one of the **reactants** needed for plants to make glucose. The **rate** of photosynthesis will **increase** when a plant is given **higher** concentrations of carbon dioxide **up** to a point.

Carbon dioxide + Water $\xrightarrow{\text{light}}$ Oxygen + Glucose



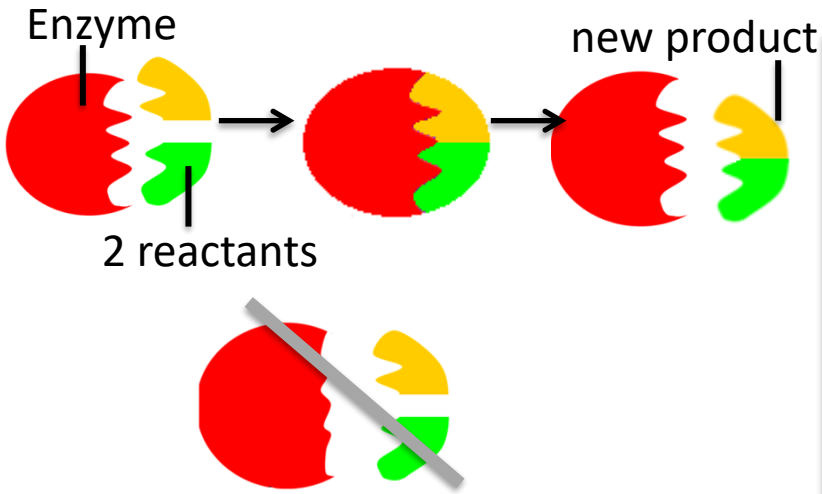
For this plant, the **maximum rate** of photosynthesis is achieved at a concentration of **0.1%** carbon dioxide.

Another factor is now preventing the rate of photosynthesis from increasing. This is called a **limiting factor**.

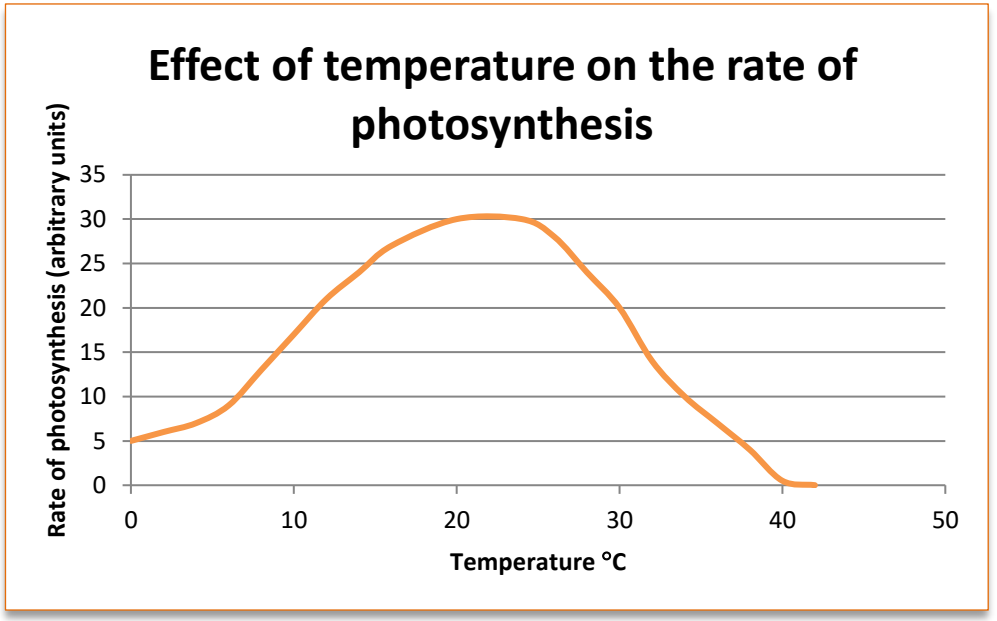
Possible limiting factors could be **light intensity**, **temperature** or amount of **chlorophyll**.

Bioenergetics part 1 – Rate of photosynthesis

Temperature affects the rate of all chemical reactions including photosynthesis. As the environment warms up, chemical reactions speed up. Photosynthesis is an **enzyme controlled reaction**. If the temperature increases too much, then the enzymes become **denatured** and the rate of reaction will **decrease** and stop. **Temperature is a limiting factor of photosynthesis.**



As temperature rises the enzyme is denatured. The active site is damaged so no reaction can occur.



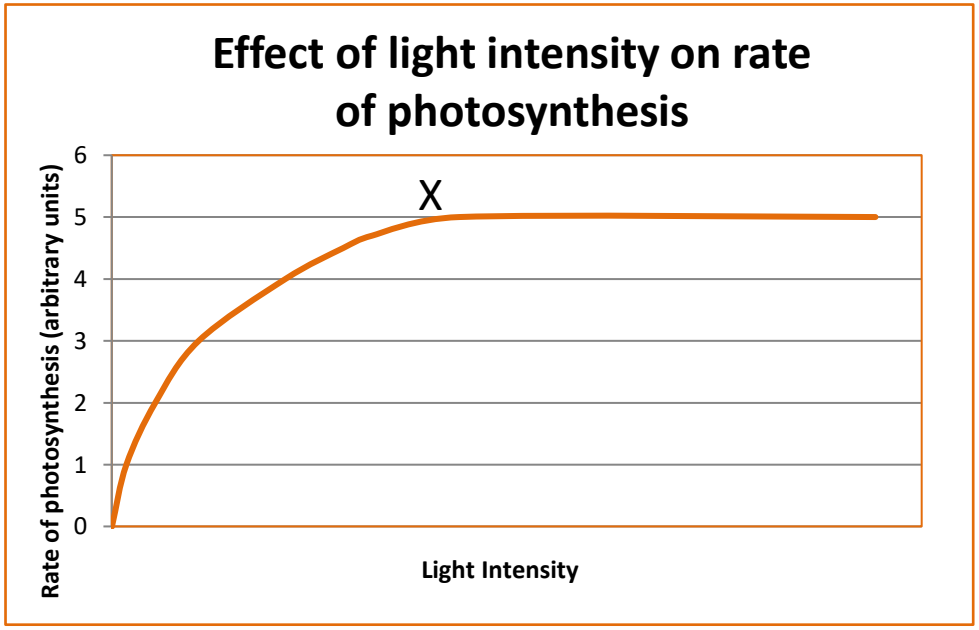
Bioenergetics part 1 – Rate of photosynthesis

The **amount of light** a plant receives affects the rate of photosynthesis. Plants found in areas of lower light do not tend to grow as tall.

Light intensity decreases as the distance between the plant and the light source increases.

The graph shows that as **light intensity increases** so does the **rate** of photosynthesis up to a point. At **point X** another **factor** is **limiting** the rate of photosynthesis. This could be carbon dioxide concentration, temperature or amount of chlorophyll.

Light intensity is a limiting factor.



Bioenergetics part 1 – Rate of photosynthesis

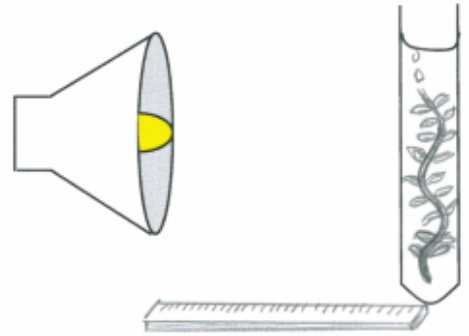
Water plants produce **bubbles of oxygen** when they photosynthesise. The bubbles can be **counted** over time and used to **calculate** the **rate** of photosynthesis. video

Investigating the effect of light intensity on photosynthesis in pondweed.

1. Fill a boiling tube with 0.2% **sodium hydrogen carbonate solution**.
2. Freshly cut a **10 cm piece of pondweed** and place it in the boiling tube with the cut end at the top.
3. Set up an **LED lamp** at a distance of **10 cm** to the boiling tube and leave to settle for 5 minutes.
4. **Start** the stopwatch and count the number of **bubbles** released in **one minute**.
5. Repeat twice and calculate the mean number of bubbles.
6. Repeat steps 1-6, altering distance of the lamp so it is 30 cm, 40 cm and 50cm away from the boiling tube.

Why do we use sodium hydrogen carbonate solution?

This provides excess dissolved carbon dioxide for the plant to use in photosynthesis so it is not a limiting factor.



Why is an LED lamp used?

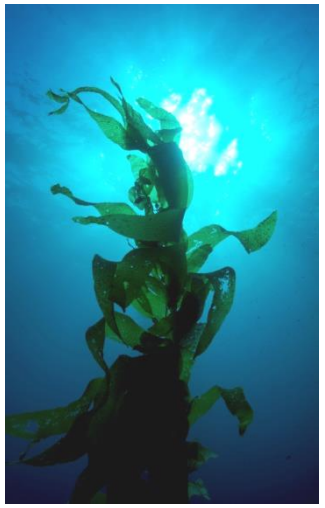
LED lamps produce less heat and this reduces the effect of temperature on the experiment.

Bioenergetics part 1 – Rate of photosynthesis HT only

Light is **a limiting factor** when the light intensity is too low, but very **high light intensities** may slow the rate of photosynthesis too. This may be caused by:

a) **saturation** of the **active sites** in the enzymes catalysing the reactions,

b) bleaching of chlorophyll.



Light intensity obeys the **inverse square** law. This means if you **double the distance** between the plant and the light source you **quarter the light intensity.**

To calculate light intensity use the formula:

Light Intensity = $1/distance^2$

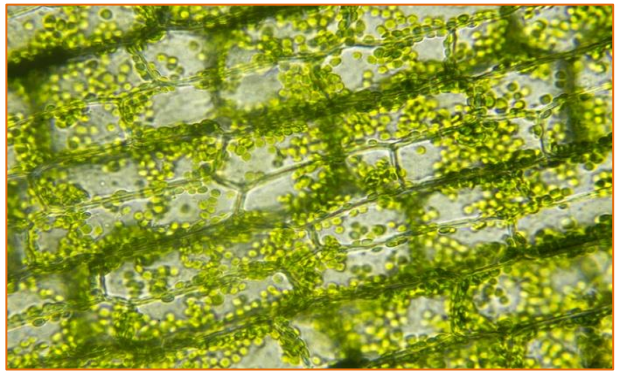
Distance (d) of lamp from pond weed (m)	0.4	0.2
Light Intensity $1/d^2$	**d^2 = 0.4 x 0.4 =0.16 $1/d^2$ = 1/0.16 = 6.25**	**25**

Bioenergetics part 1 – Rate of photosynthesis

If sunlight shines onto water and carbon dioxide, a reaction will **not** occur.
The energy must be transferred from the environment, to the **chlorophyll,** by light.

This energy is used to convert carbon dioxide and water into glucose and oxygen. Chlorophyll is **essential** to the process of photosynthesis.

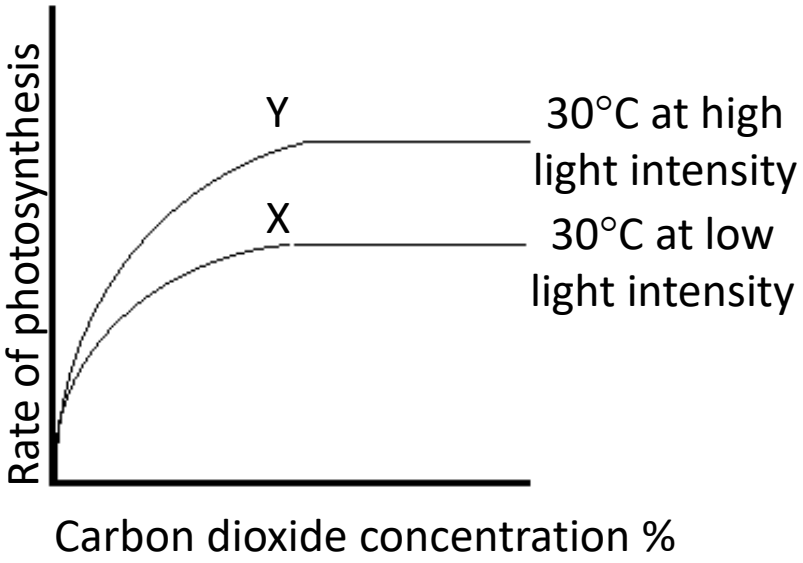
If there is a **reduction** in the amount of chlorophyll available to the plant then the amount of glucose made by photosynthesis will reduce. The plant will not grow as well.



Variegated leaves are white and green.
The white areas do not have any chlorophyll.

Bioenergetics part 1 – Rate of photosynthesis HT only

In **laboratory** investigations, plants experience variation in only **one** environmental factor.
Normally in **nature**, **more than one** environmental factor will vary and the rate of photosynthesis is due to the **interaction** of these factors.
Any one of the environmental factors may **limit** the rate of photosynthesis.

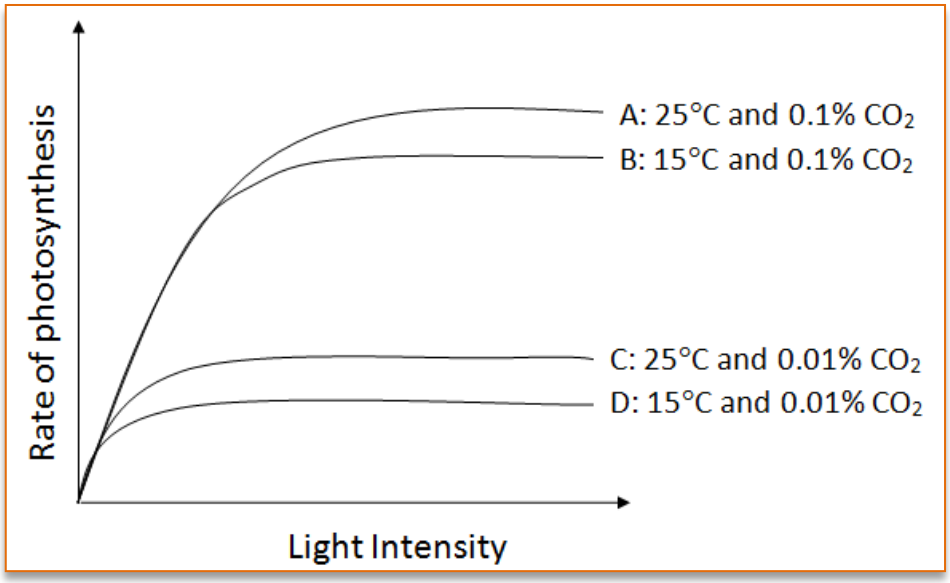


Carbon dioxide is not the limiting factor

In this experiment **temperature** is controlled.
At **low light intensity** the photosynthetic reaction becomes limited at point X.
If the light intensity is increased the reaction rate also increases.
Light intensity is therefore the limiting factor at point X.
A different factor is now limiting the rate of photosynthesis at Y.
This could be environmental **temperature** or the amount of **chlorophyll.**

Bioenergetics part 1 – Rate of photosynthesis HT only

Graph line A: Rate could be limited by temperature and/or amount of chlorophyll. Plant tissue can be damaged when carbon dioxide concentrations exceed 0.1%



Light intensity is <u>not</u> a limiting factor

Graph lines A and D: If carbon dioxide concentration **and** temperature are increased the rate of photosynthesis increases significantly up to a point.

Graph Lines A and B: If carbon dioxide concentration is increased from 0.01% to 0.1%, then a large increase in rate occurs up to a point.

Graph lines C and D: If temperature is increased by 10°C then a slight increase in rate of photosynthesis occurs.

Bioenergetics part 1 – Rate of photosynthesis HT only

Farmers apply their understanding of limiting factors to **improve** crop **yields**.
They can control conditions inside greenhouses more easily than in the fields.

- **Heating** can be used to provide optimum temperatures for maximum plant growth.
- **Artificial lighting** enhances the natural sunlight especially overnight and on cloudy days.
- **Extra carbon dioxide** gas can be pumped into the air inside the greenhouses.

In commercial greenhouses the environmental factors are often controlled by computerised systems to minimise cost. The farmer must balance the **economics** of **additional costs** of heating, lighting and computer systems to achieve maximum photosynthesis whilst still making a **profit.**

Video - Improving crop yields

Bioenergetics part 1 – Use of glucose from photosynthesis

All living cells need energy. This energy is released from glucose by a process called respiration.

Uses of glucose made from photosynthesis

To produce **cellulose** which strengthens plant cell walls.

To be converted into insoluble starch for storage inside cells or special areas like roots or bulbs.

To be converted into **amino acids** for protein synthesis.
Glucose is combined with **nitrate** ions absorbed from the soil.
Specific amino acids join in long chains to make a named **protein**.

To produce **fat or oil** for storage.
Seeds and nuts contain lots of fat or oil as an energy store.

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QuestionIT!

Bioenergetics
Part 1

- Photosynthetic reaction
- Rate of photosynthesis
- Use of glucose from photosynthesis

Bioenergetics part 1 – QuestionIT

1. Write down the word equation for photosynthesis.

2. Copy and complete this table

Name of molecule	Chemical Symbol
Water	
Oxygen	
Carbon dioxide	
Glucose	

3. Photosynthesis is affected by limiting factors.

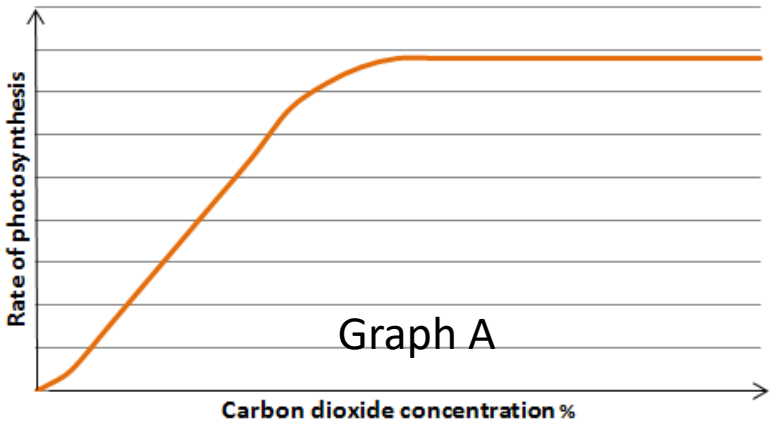
   What is meant by the term ‘limiting factor’?

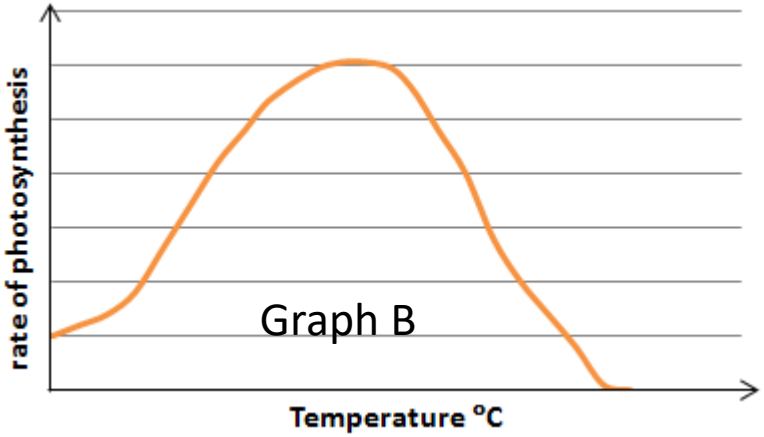
4. Name the raw materials needed by a plant for photosynthesis?

5. Name the green pigment present in plant cells.

6. What is the role of this green pigment?

7. For the graphs below - identify what the limiting factor(s) might be in the experiments.





8. Sketch a line onto Graph A showing what might occur if the experiment was repeated at a lower light intensity.

9. List three ways commercial farmers improve the environmental conditions to maximise photosynthesis and ensure they make a profit.

10. How is the glucose produced by photosynthesis used in plants?

Higher Tier Questions

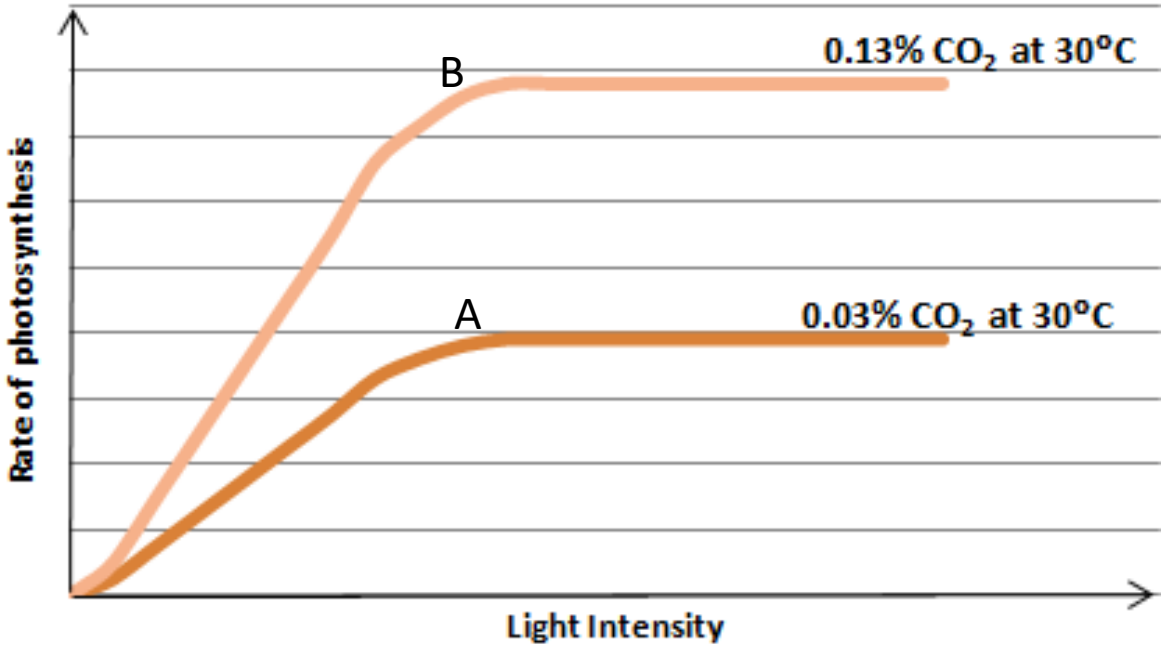
HT 11. Calculate the light intensity for the following student data. Use the formula:

Light Intensity = 1/distance^2

Distance (d) of lamp from pond weed (m)	0.3	0.5
Light Intensity $1/d^2$		

HT 12. a) What is the limiting factor at A?

b) What might the limiting factor(s) be at point B?



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AnswerIT!

Bioenergetics
Part 1

- Photosynthetic reaction
- Rate of photosynthesis
- Use of glucose from photosynthesis

Bioenergetics part 1 – AnswerIT

1. Write down the word equation for photosynthesis.

   Carbon dioxide + Water $\xrightarrow{\text{light}}$ Oxygen + Glucose

2. Copy and complete this table

Name of molecule	Chemical Symbol
Water	H_2O
Oxygen	O_2
Carbon dioxide	CO_2
Glucose	$C_6H_{12}O_6$

3. Photosynthesis is affected by limiting factors.

   What is meant by the term 'limiting factor'?

   A factor which is not at an optimum level to enable maximum rate of photosynthesis e.g. temperature

Bioenergetics part 1 – AnswerIT

4. Name the raw materials needed by a plant for photosynthesis?

   Carbon dioxide and water

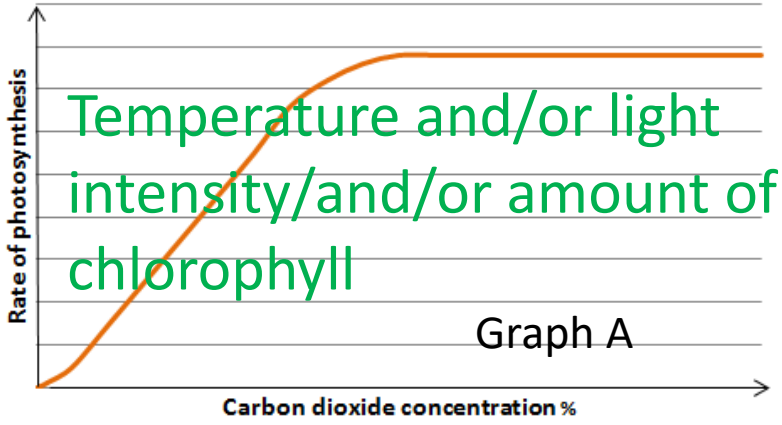
5. Name the green pigment present in plant cells.

   Chlorophyll

6. What is the role of this green pigment?

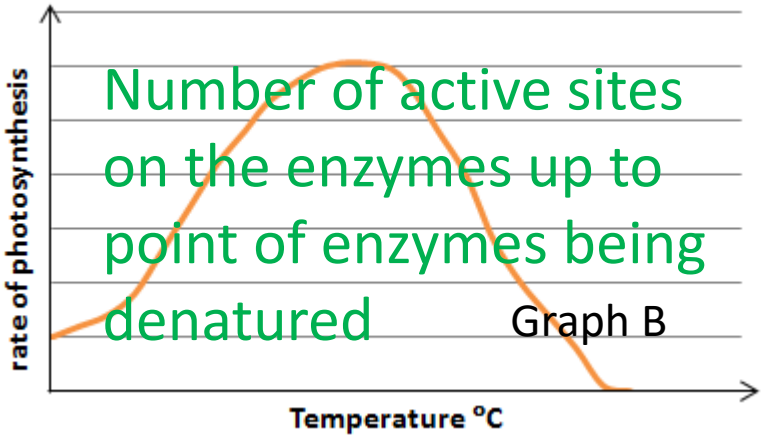
   To transfer energy from the environment and use it to synthesise glucose from carbon dioxide and water.

7. For the graphs below - identify what the limiting factor/s might be in each experiment.



Temperature and/or light intensity/and/or amount of chlorophyll

Graph A



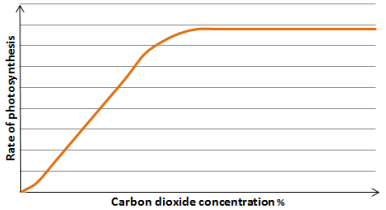
Number of active sites on the enzymes up to point of enzymes being denatured

Graph B

Bioenergetics part 1 – AnswerIT

8. Sketch a line onto graph A showing what might occur if the experiment was repeated at a higher light intensity.

Line drawn below that in Graph A but mirroring shape.



9.List **three** ways commercial farmers improve the environmental conditions in large greenhouses to maximise photosynthesis and ensure they make a profit.

Increase the air temperature with heaters.

Provide artificial lighting to supplement the sunlight and through the night.

Increase the amount of carbon dioxide in the atmosphere.

10. List **three** ways glucose produced by photosynthesis is used in plants?

Used for respiration; used to produce fats or oils for storage; used to produce amino acids for protein synthesis; converted into insoluble starch for storage; used to produce cellulose to strengthen cell walls.

Higher Tier Questions

HT 11. Calculate the light intensity for the following student data.
Use the formula: **Light Intensity α 1/ distance^2**

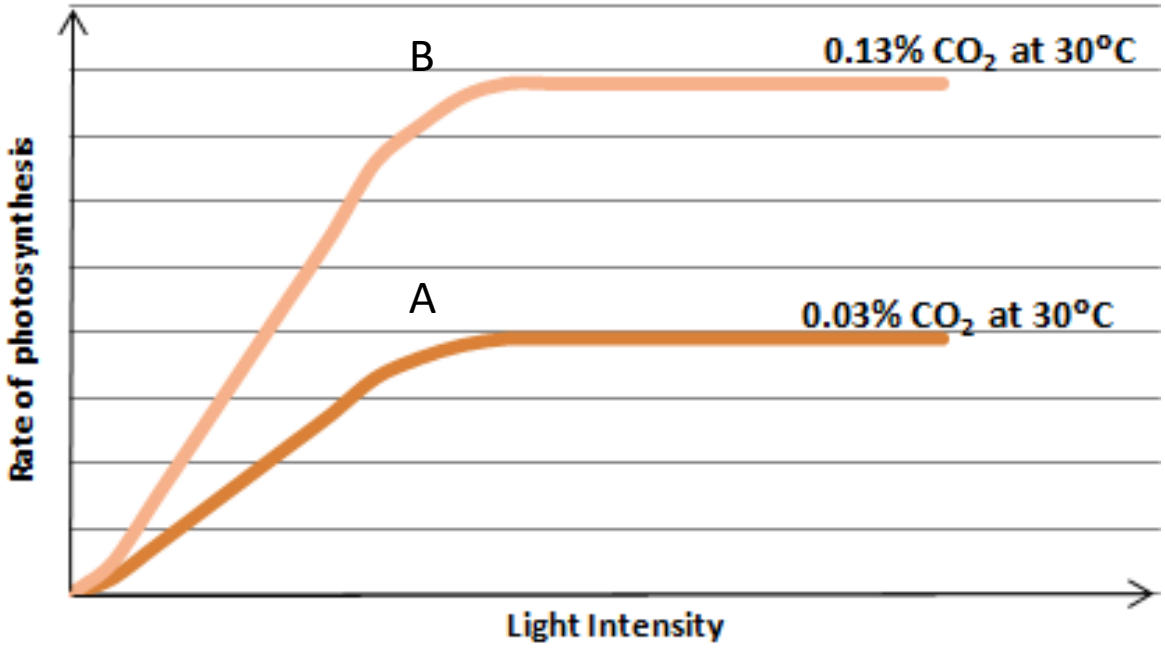
Distance of lamp from pond weed (m)	0.3	0.5
Light Intensity	11.11	4

HT 12. a) What is the limiting factor at A?

Carbon dioxide

b) What might be the limiting factor(s) be at point B?

Temperature/ amount of chlorophyll



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Bioenergetics Part 2

- Aerobic respiration
- Anaerobic respiration
- Response to exercise
- Metabolism

Bioenergetics part 2 – Aerobic respiration

Respiration is also sometimes called **cellular respiration**. This is because the reactions of respiration occur inside cells.

Every **living cell** needs energy and this energy is released from food (glucose) by a series of chemical reactions called respiration.

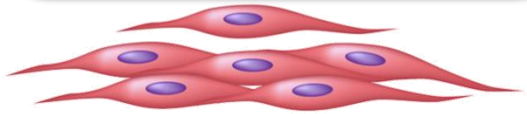
The reactions of respiration occur **24 hours a day,** continuously, in **all** living cells.

Respiration is **an exothermic** reaction which means energy is transferred to the environment. Some of the **energy** is used inside cells and the rest will be transferred **out of the cell.**

An organism will receive all the energy it needs for living processes as a result of the **energy transferred** from **respiration**.

Bioenergetics part 2 – Aerobic respiration

For movement
To enable muscles to contract in animals.



Smooth muscle cells

For keeping warm
To keep a steady body temperature in a cold environment

Why do living organisms need energy?

For chemical reactions
To build larger molecules from smaller ones

Bioenergetics part 2 – Aerobic respiration

Respiration can transfer energy in cells **aerobically** (with oxygen).

The **word equation** which represents aerobic respiration is:

glucose + oxygen ⟶ carbon dioxide + water

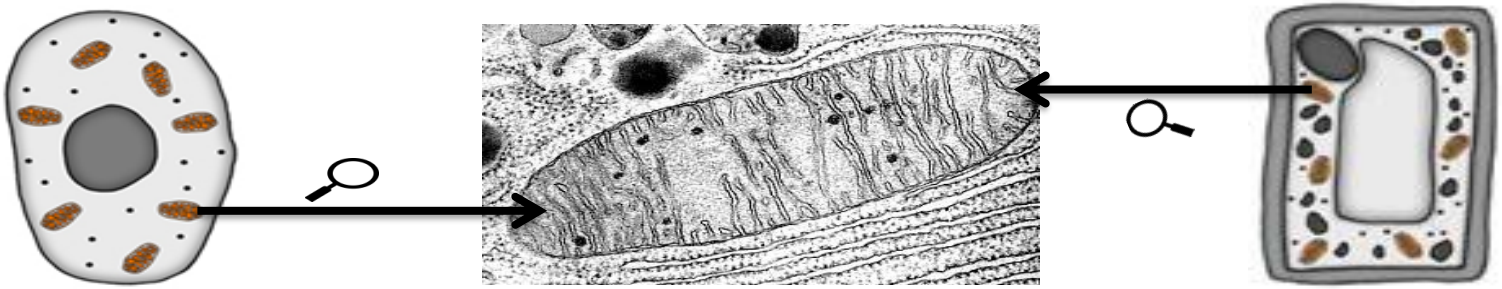
The balanced **symbol equation** which represents aerobic respiration is:

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

Aerobic respiration occurs inside **mitochondria** continuously.

Glucose is **oxidised** by **oxygen** to **transfer the energy** the organism needs to perform its functions.

Aerobic respiration releases a **large amount of energy** from each glucose molecule.



Animal cell

Electron micrograph of a mitochondrion

Plant cell

Bioenergetics part 2 – Anaerobic respiration

Respiration can transfer energy in cells **anaerobically** (without oxygen).

During **hard exercise**, muscles cells are respiring so fast that the blood cannot transport enough oxygen to meet their needs.

The muscle cells switch to use **ANAEROBIC RESPIRATION** to transfer energy.

Glucose is **not** completely broken down to carbon dioxide and water, so **less energy** is transferred. An end product called **lactic acid** is formed. This builds up in the muscle cells.

glucose ⟶ lactic acid

After exercise the lactic acid must be combined with oxygen to convert it to carbon dioxide. The amount of oxygen which must be taken in to convert all the lactic acid to carbon dioxide is called the oxygen debt.

During long periods of vigorous exercise the muscles become **fatigued** and stop contracting efficiently.

Bioenergetics part 2 – Anaerobic respiration

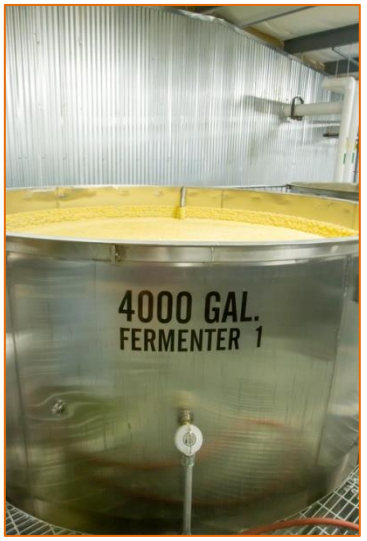
Anaerobic respiration also occurs in plant and yeast cells.

The end products are ethanol and carbon dioxide.

glucose ⟶ ethanol + carbon dioxide

Anaerobic respiration in yeast cells is called **fermentation**.

This process is economically important in the manufacture of alcoholic drinks and bread.



Bioenergetics part 2 – Respiration summary

	Aerobic respiration	Anaerobic respiration in animal cells	Anaerobic respiration in plant and yeast cells
Oxygen	Required	Not required	Not required
End products	Carbon dioxide and water	Lactic acid	Ethanol and carbon dioxide
Oxidation of glucose	Complete	Incomplete	Incomplete
Efficiency of energy transfer	High	Low	Low

Video - Respiration summary

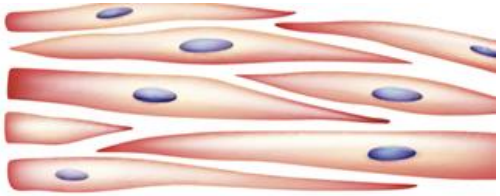
Bioenergetics part 2 – Response to exercise

During **exercise** the **human body** reacts to the **increased** demand for energy. If **insufficient oxygen** is supplied to the muscle cells then **anaerobic respiration** occurs.

The **heart rate increases** to pump oxygenated blood faster through the muscle cells.

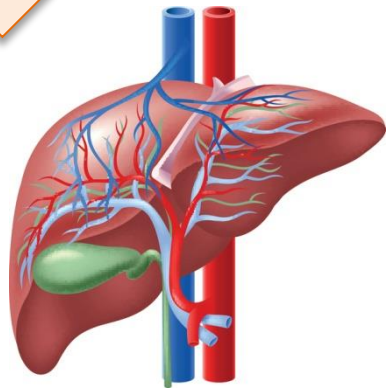
Breathing rate and breath **volume** increase. This increases the amount of oxygen entering the bloodstream.

Bioenergetics part 2 –Response to exercise HT only



Lactic acid builds up in the muscle **cells** during **exercise**.

Blood flows through the muscle cells and **transports** the **lactic acid** to the **liver**.



The **liver** oxidises the **lactic acid** and **converts** it back to **glucose**.

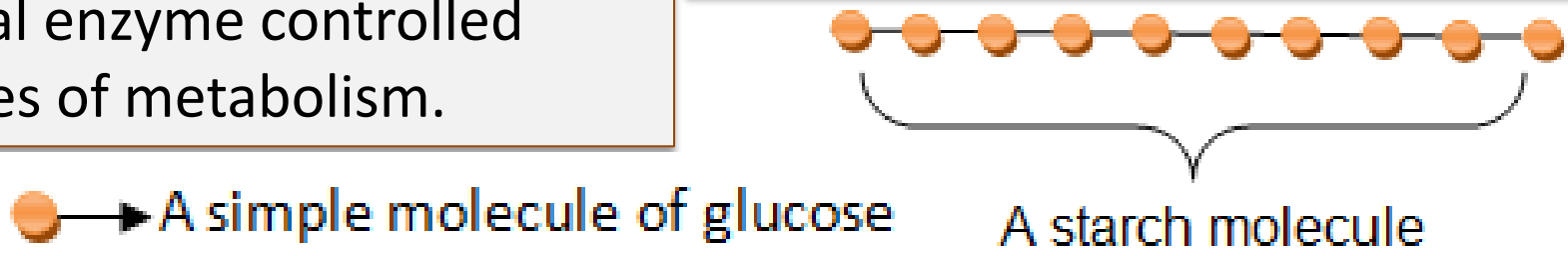
Glucose is used in **aerobic respiration** or it is converted to **glycogen** and stored in the **liver** for later use.

The extra amount of oxygen required to remove all lactic acid from the cells is called the **oxygen debt**.

Bioenergetics part 2 – Metabolism

Organisms use the energy transferred by respiration for the continual enzyme controlled processes of metabolism.

The conversion of glucose to starch is a metabolic reaction.



Metabolism = the sum of all reactions in a cell or body

Glucose and nitrate ions from the soil form amino acids. Amino acids are used to synthesise proteins. These are metabolic reactions.

Other examples of metabolic reactions that you **need to know** are:

- The conversion of **glucose to cellulose** in plants to strengthen cell walls;
- The conversion of **glucose to glycogen** in animal cells for storage;
- The **formation of lipids** from a molecule of glycerol and three molecules of fatty acids;
- The **breakdown of proteins** to form **urea** for excretion
- Respiration.

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QuestionIT!

Bioenergetics
Part 2

- Aerobic respiration
- Anaerobic respiration
- Response to exercise
- Metabolism

Bioenergetics part 2 – QuestionIT

1. When does respiration occur in cells?
2. Copy and complete the table below:

	Aerobic respiration	Anaerobic respiration in animal cells	Anaerobic respiration in plant and yeast cells
Oxygen required?			
End products			
Oxidation of glucose complete/incomplete?			
Efficiency of energy transfer is high or low?			

Bioenergetics part 2 – QuestionIT

3. Name **three** processes that organisms require energy for.

4. What does the chemical formula $\mathbf{C_6H_{12}O_6}$ represent?

5. Write down the word equation for aerobic respiration in a plant cell.

6. Write down the word equation for anaerobic respiration in a yeast cell.

7. Why is fermentation of economic importance?

8. Describe **three** ways in which the body responds to vigorous exercise in order to ensure sufficient oxygen reaches the muscle cells.

9. If exercise carries on for a long time, what happens to the muscles?

10. Why is respiration described as an exothermic reaction?

11. Copy and complete the table below:

Name of large molecule	Made from subunits of ?
Carbohydrate	Glucose
Lipid	?
Protein	?

12. What is the definition of metabolism?

Higher tier questions

HT 13. Describe the process for removing lactic acid from the body.

HT 14. What is meant by the term 'oxygen debt'?

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AnswerIT!

Bioenergetics
Part 2

- Aerobic respiration
- Anaerobic respiration
- Response to exercise
- Metabolism

Bioenergetics part 2 – AnswerIT

1. When does respiration occur in cells? Continuously

2. Copy and complete the table below:

	Aerobic respiration	Anaerobic respiration in animal cells	Anaerobic respiration in plant and yeast cells
Oxygen required?	Yes	No	No
End products	Carbon dioxide and water	Lactic acid	Ethanol and carbon dioxide
Oxidation of glucose complete/incomplete?	complete	incomplete	incomplete
Efficiency of energy transfer is high or low?	high	low	low

Bioenergetics part 2 – AnswerIT

3. Name three processes that organisms require energy for.

Chemical reactions to build larger molecules, keeping warm and movement.

4. What does the chemical formula $C_6H_{12}O_6$ represent? Glucose

5. Write down the word equation for aerobic respiration in a plant cell.

glucose + oxygen ⟶ carbon dioxide + water

6. Write down the word equation for anaerobic respiration in a yeast cell.

glucose ⟶ carbon dioxide + ethanol

7. Why is fermentation of economic importance?

Used in the manufacture of bread and alcoholic drinks.

8. Describe **three** ways in which the body responds to vigorous exercise in order to ensure sufficient oxygen reaches the muscle cells.

Increase in heart rate; increase in breathing rate and increase in breath volume.

9. If exercise carries on for a long time, what happens to the muscles?

Muscles become fatigued and stop contracting efficiently.

10. Why is respiration described as an exothermic reaction?

Respiration is an exothermic reaction because it transfers energy to the environment.

11. Copy and complete the table below:

Name of large molecule	Made from
Carbohydrate	Many glucose molecules
Lipid	1 molecule of glycerol and 3 molecules of fatty acid
Protein	Many amino acids

12. What is the definition of metabolism?

Metabolism is the sum of all reactions which occur in a cell or body.

Higher tier questions

HT 13. Describe the process for removing lactic acid from the body.

Blood flows through the muscle cells and transports the lactic acid to the liver where it is converted back into glucose. The glucose is then used in aerobic respiration or stored as glycogen.

HT 14. What is meant by the oxygen debt?

The amount of extra oxygen which is needed to remove all lactic acid from the body is known as the oxygen debt.