Biochemistry

L1 What is photosynthesis

Photosynthesis is a chemical reaction that happens in plants and green algae. It is one of the most important chemical reactions in the history of life on this planet. It was responsible for creating an oxygen-rich atmosphere approximately 2.3 billion years ago and the evolution of humans, and most other complex life, would not have been possible without it.

The word photosynthesis means "putting together using light". Light from the sun (or artificial lights) is the energy source which powers photosynthesis. This is why you often see it written above the arrow in the word or symbol equation for photosynthesis.

Where does photosynthesis occur?

Plants carry out photosynthesis in their leaves to create their own food. Photosynthesis occurs in the chloroplast of these cells. The chloroplasts contain chlorophyll which absorbs light. The chlorophyll also gives a leaf its distinctive green colour. Algae can also photosynthesise if they contain chloroplasts. Photosynthesis is an **endothermic** reaction meaning it requires an input of energy from the environment.

What are the reactants and products of photosynthesis?

The reaction for photosynthesis can be written as a word equation of a formula equation.

Word Equation

light

carbon dioxide + water → glucose + oxygen

Symbol Equation

light

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

It is easy to tell when photosynthesis is happening in water-based plants as the oxygen they produce is visible as bubbles in the water. For land-based plants it is harder to tell because we can't see or smell oxygen. We can test for the presence of oxygen (a glowing splint will re-light) or we can test for the presence of glucose or starch, which is how the glucose is stored.

Independent practice

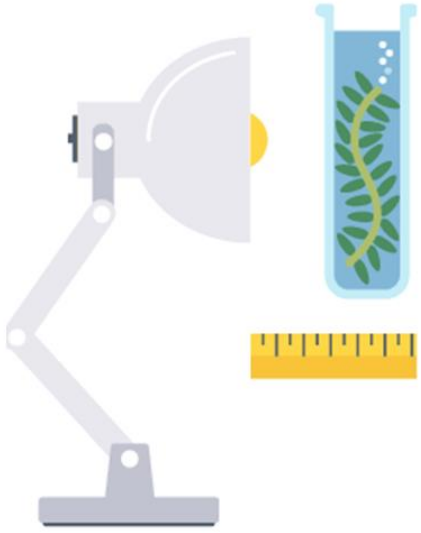
1. In what organisms can photosynthesize occur?
2. Name the two reactants of photosynthesis?
3. Name the two products of photosynthesis?
4. Name the organelle responsible for photosynthesis.
5. **Extended writing (paragraph needed). Explain what a plant needs to be able to carry out photosynthesis.**
6. Some reactions, including photosynthesis, are endothermic. What does this mean?
7. What colour is chlorophyll?
8. Cells found in the root of plants do not contain chloroplasts. Suggest why.
9. What colour will the algae in my pond be if it can photosynthesise?
10. What is the chemical formula of glucose? What does it tell you about glucose?
11. Complete the sentences below
    Leaf cells can photosynthesise because…..
    Leaf cells can photosynthesise but…..
    Leaf cells can photosynthesise so…..
12. Sally is trying to grow some plants in her garden. They are not growing very well. Suggest what Sally could do to improve the growth of her plants.
13. **Extended writing (paragraph needed)** Explain why photosynthesis is important to your own everyday life, and what would be the consequence if no more photosynthesis ever happened.
14. Imagine another planet was found that had organisms that carry out photosynthesis. What would this tell you about the planet?

L2 Measuring photosynthesis

Photosynthesis is a fascinating process in which plants and some other organisms use sunlight to make food for themselves. To understand this process better, scientists often conduct experiments, and one of them involves pondweed. In this experiment, we'll explore how pondweed uses light to produce food and oxygen.

Method

1. Get a boiling tube containing sodium hydrogen carbonate solution (this will provide the plant will carbon dioxide).
2. Allow the tube to stand for a few minutes and shake to disperse any air bubbles that might form.
3. Cut a piece of the pondweed and place into the boiling tube,
4. Position the boiling tube so that the pondweed is 10 cm away from the light source. Allow the boiling tube to stand for five minutes.
5. Count the number of bubbles emerging from the cut end of the stems in one minute.
6. Repeat 3 times and record your results.
7. Calculate the mean number of bubbles produced per minute. Repeat the experiment at different distances away from the light source.



What Happens:

As the experiment begins, the pondweed will start to produce tiny bubbles. These bubbles are oxygen, a byproduct of photosynthesis. The pondweed uses carbon dioxide from the sodium hydrogen carbonate and the energy from the light source to convert water into oxygen and glucose. The oxygen bubbles are released into the water, and this is a sign that photosynthesis is happening.

What You Can Learn:

The Role of Light: The experiment shows that light is essential for photosynthesis. Without light, the pondweed won't produce oxygen and food. Oxygen Production: You can measure how much oxygen the pondweed produces by counting the bubbles. More bubbles mean more oxygen is being released. As the pondweed gets further away from the light source the number of bubbles produced decreases, showing that there is less photosynthesis.

Why 3 times?

An experiment is ideally repeated at least 3 times. This allows for anomalies (a result that is different from the others) to be identified, and allows for the mean to be recorded.

Independent practice

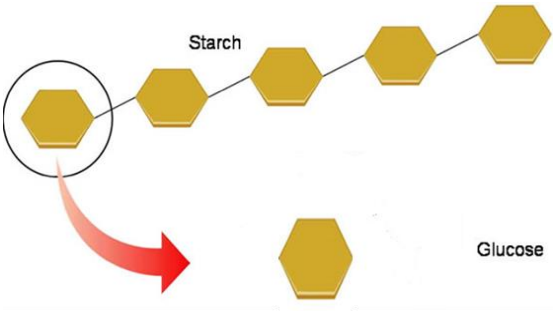
1. What plant is used in the investigation of photosynthesis.
2. Explain why a plant like a rose can not be used.
3. Explain why it is important to add sodium hydrogen carbonate to the water.
4. Suggest why it is important to remove air bubbles before completing the experiment.
5. **Extended writing (paragraph needed).** Fatima completed this experiment using distances 10cm, 20cm, 30cm 40cm. Explain the expected results from Fatimas experiment.
6. Fatima has completed the experiment 3 times, her results for 10cm were 10 bubbles, 13 bubbles and 30 bubbles. Which was the anomaly.
7. Using the results above explain why it is important to test at least 3 times rather than twice.
8. Give the independent variable of the experiment.
9. Give the dependent variable of the experiment.
10. Give 2 control variables for the experiment.
11. The light bulb gives out heat, suggest how this could affect the rate of photosynthesis.
12. What could cause no bubbles to be produced.
13. **Extended writing (paragraph needed)**. Give a method to investigate how different coloured lights could affect the rate of photosynthesis.
14. Suggest a better way to measure the rate of photosynthesis.

L3 Testing for starch

The equation for photosynthesis tells us that there are two products from the reaction; oxygen and glucose. It's quite easy to understand what the oxygen does. The plant uses some of the oxygen to respire and release energy from its mitochondria. The extra oxygen is released int the atmosphere and all other life, including ours uses this oxygen to respire. The fate of the glucose is more complex.

The most important role of glucose is in the plant cells respiration. Plants must respire all the time to ensure they survive, just like all other living things. In the daytime photosynthesis is much faster than respiration so an excess of glucose and oxygen is built up. In the night-time photosynthesis stops but respiration continues.

Spare glucose is stored as starch. Starch is a polymer of glucose. A polymer is a long chain molecule made of many repeating smaller molecules. Some of the glucose is used to make cellulose, which is tough and found in cells walls.

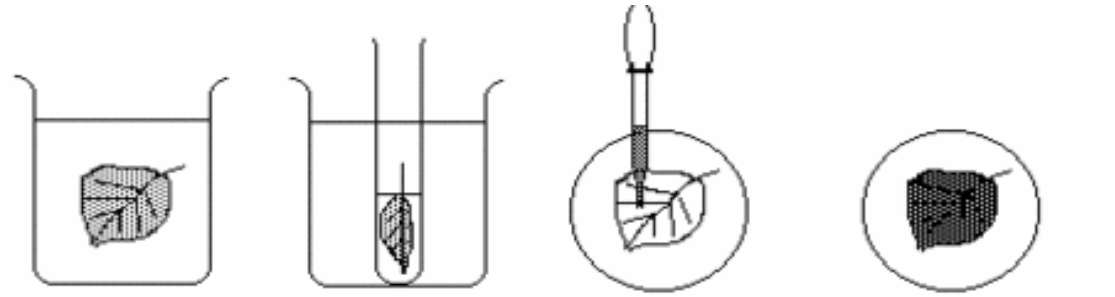


Plants can also turn the glucose into proteins and fats. This allows the plants to make all the structures and compounds needed to help the plant grow and reproduce.

Testing for starch

Leaves produce glucose during photosynthesis. When tested, leaves contain very little sugar. We are aiming to find out if the leaves contain starch – which is a **polymer** of glucose

<u>Method</u>



1. Set up a water bath containing more than 100cm^3 of water and get it roaring hot.

2. When the water is boiling, put the leaf you are testing into the hot water for around 30 seconds.

3. Turn off the Bunsen.

4. Using forceps, remove the leaf from the hot water and transfer it to a boiling tube. Cover the leaf with ethanol. The ethanol will dissolve the chlorophyl.

5. Put the boiling tube into the beaker of hot water The Bunsen should NOT be on at this point.

6. Leave the leaf for around 10 minutes, then tip the ethanol away and put the leaf back into the hot water just to soften it.

7. Spread the leaf as flat as possible onto a white tile or petri dish and cover it with iodine.

Independent practice

1. What is a polymer?
2. Starch is a polymer made up of what molecule?
3. **Extended writing (paragraph needed)**Describe your results. Use all of the terms below.

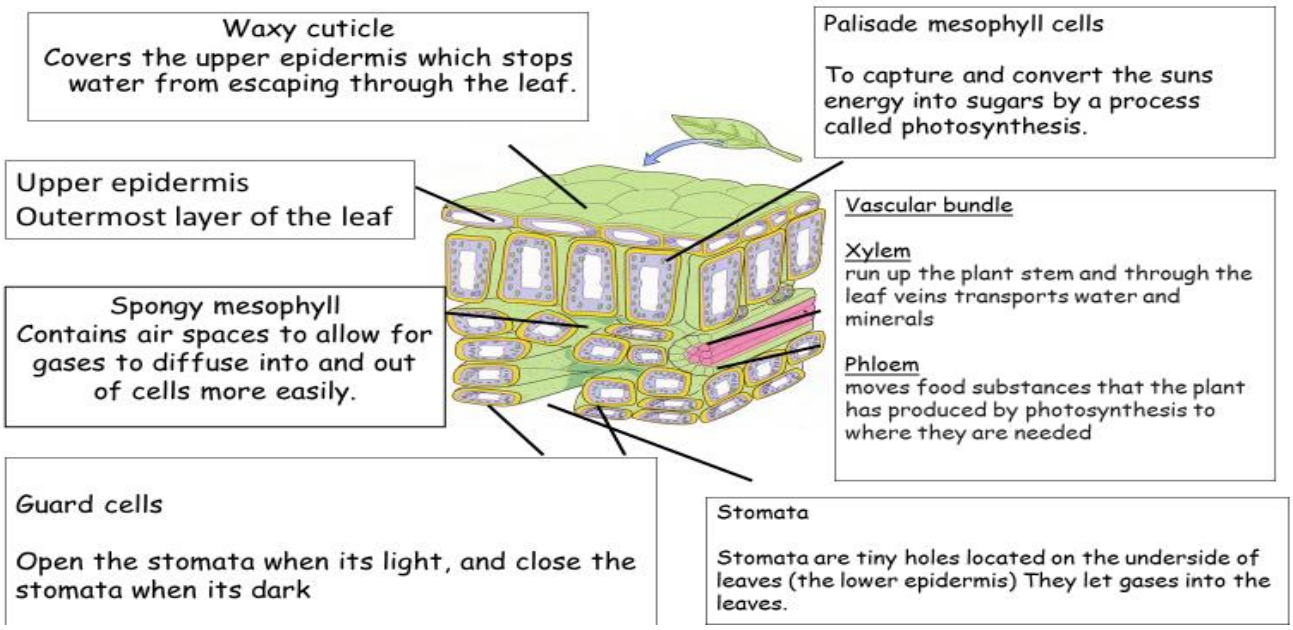
   Leaf, iodine, starch, glucose, brown, blue-black, photosynthesis
4. Why did the leaf have to be put into ethanol?
5. Why are leaves green?
6. Why is it important to remove the colour from the leaf before applying the iodine?
7. What does iodine test for?
8. IF the does not contain starch what colour will the leaf turn when iodine is added?
9. **Extended writing (paragraph needed)** Explain how to carry out this practical as safely as possible.
10. Ethanol is a compound, explain what this means.
11. The formula for ethanol is C_2H_5OH. What does this tell you about ethanol?
12. When else have you learnt about using iodine to test substances for starch.
13. What chemical could be used to test leaves for glucose?
14. The concentration of starch varies throughout the day. Suggest when the leaf is most likely to have a high concentration of starch.

L4 Leaf adaptations

Photosynthesis is the primary purpose of a leaf. This means leaves are well adapted to achieve two things: collect as much sunlight and carbon dioxide as possible.

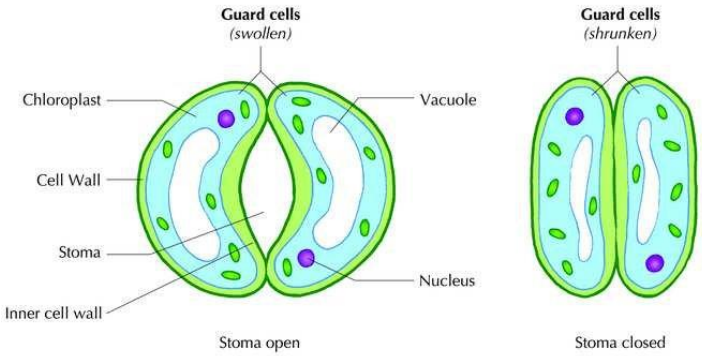
- To collect as much sunlight they a wide, long and angled towards the sun. This gives them a large surface area to absorb as much light as possible.
- To collect as much carbon dioxide as possible they are thin and have stomata. The thin leaves make it easy for carbon dioxide to diffuse into the cells. Stomata are small holes in the underside of the leaf which allow the carbon dioxide in from the atmosphere.

Tissue structure of the leaf: The leaf is made of a number of tissues, each with its own purpose.



The role of the stomata and guard cells.

The underside of the leaf has tiny holes called stomata. These allow gas exchange to happen. Gas exchange is the name for the diffusion of carbon dioxide into the leaves and the recently made oxygen out of the leaves through the open stomata. The stomata are controlled by guard cells. These cells open and close the stomata to control the diffusion of the gases. During the day the stomata are open to let in carbon dioxide, and the stomata are closed at night.



Independent practice

1. Why do leaves need to be well adapted to absorb as much sunlight as possible.
2. State how a leaf is well adapted to absorb carbon dioxide.
3. A leaf is made up of tissues, what are tissues made up of?
4. Why is it important that the leaf is made up of different tissues?
5. **Extended writing (paragraph needed)** Describe the structure of the leaf.
6. What would happen if a leaf did not have a waxy cuticle layer?
7. Which layer of the leaf will have the most chloroplasts?
8. Explain why the underside of the leaf has less chloroplasts.
9. What will happen if the xylem in a leaf is damaged?
10. Cacti don't have leaves, but have a green fat stem, called a succulent stem. Cacti live in deserts. Explain why cacti can still photosynthesise even though they don't have leaves.
11. **Extended writing (paragraph needed)** A lily pad is a plant that floats on water. Explain why it is important that the stomata and guard cells are located on the top layer of the leaf.
12. Why do the stomata close at night?
13. Stomata are also referred to as pores, explain what this term means.
14. Deciduous trees are trees that lose their leaves, how will this impact the plant?

L5 Investigating the structure of a leaf

Aim/introduction: To view stomata and observe the differences between the top and bottom of the leaf.

Method

1. Paint a thin film of clear nail varnish on the top and bottom surface of a leaf such as laurel

2. Whilst it dries, sketch your leaf below and note it's physical characteristics (thin, veins, colour difference between top and bottom?

3. When it has dried, put a piece of cellotape over the top of the nail varnish and press firmly.

3. Unpeel the cellotape, bringing the nail varnish with it, and stick it down onto a clean microscope slide.

4. Make two slides – one for the top of the leaf and one for the bottom. Make sure you know which is which.

5. Observe the slide from the bottom first. Focus on the stomata and sketch and label a few of the surrounding guard cells.

6. Observe the top slide for comparison.

How to use a microscope

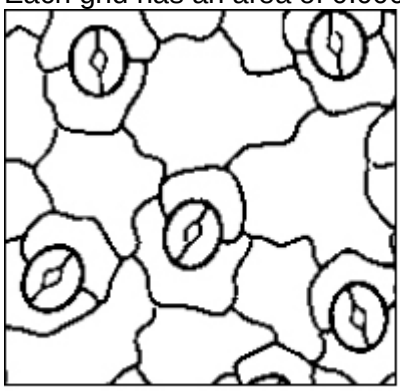
1. Use the lowest objective power lens first.
2. Angle the mirror or adjust your light to let in plenty of light.
3. Place the slide you want to look at on the stage.
4. Turn the course focusing wheel until you can see your slide clearly.
5. Then adjust your image with the fine course focusing wheel
6. You may now use the higher objective lens, taking care to move the stage slowly so as to avoid the slide touching the lens.

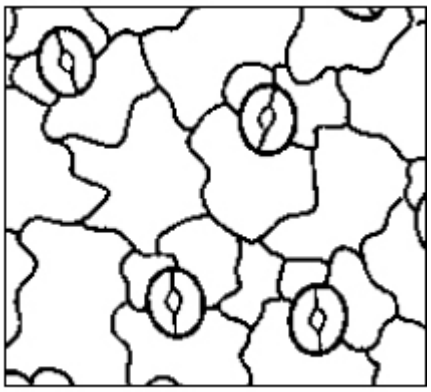
Independent practice

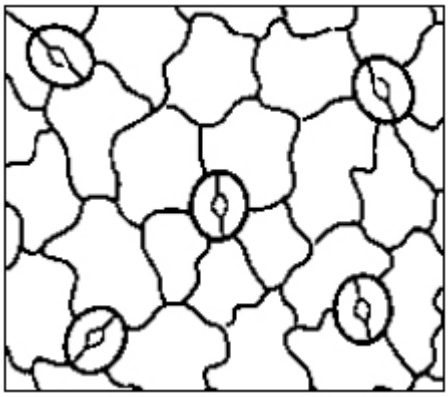
1. Why must clear nail varnish be used?
2. Why is it important to have a thin layer of nail varnish?
3. What does the term “lowest power objective lens” mean?
4. Compare the fine focus and the coarse focus wheel.
5. **Extended writing (paragraph).** Look at the number of stomata on the top and bottom of the leaf. Explain the difference in results.
6. Awaiz carried out the method on a petal from a rose. State and explain his results.
7. Suggest what the term stomata density means.
8. If this method was carried out on a lily pad (a plant that floats on water) which side of the leaf would you expect to have a greater stomata density.
9. Explain why if comparing leaves from a different plant it is important the similar sized leaves are used if possible, and I f using similar sized leaves is not possible, suggest what a scientist could do to overcome the issue?
10. Explain why a scientist would investigate the number of stomata on at least 3 leaves from each plant.
11. **Extended writing (paragraph needed)** Explain whether a leaf from a desert plant or a rainforest plant would have more stomata.

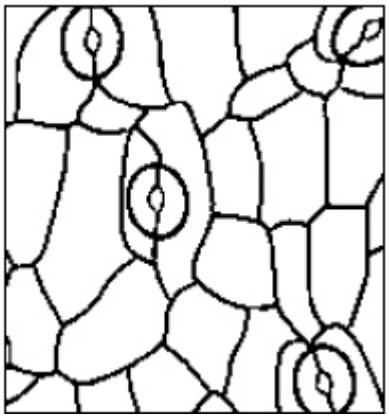
A student used a grid on a microscope to estimate the number of stomata in some leaf epidermis. The drawings show four of the grid squares the student observed.

12. Each grid has an area of 0.0001 mm^2.









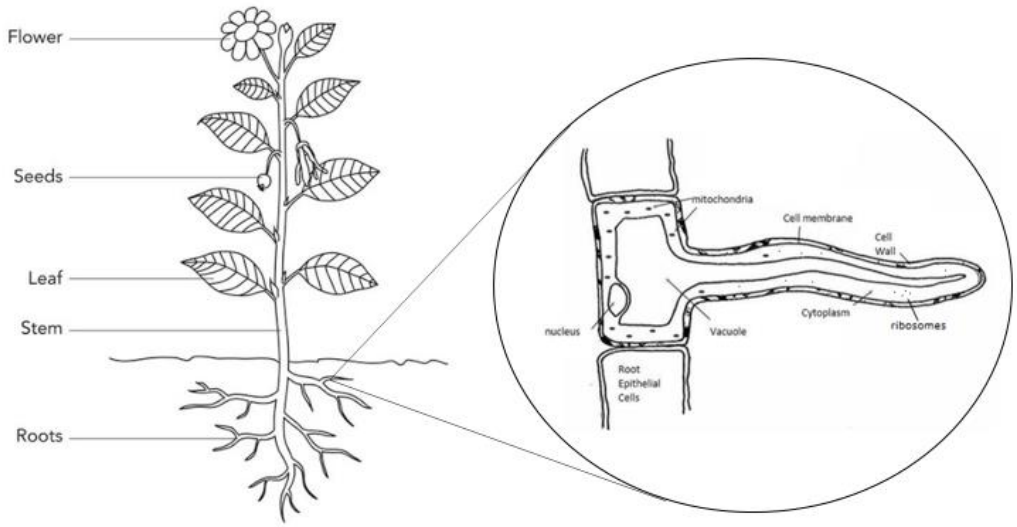
12. (i) Calculate the mean number of stomata per grid square.
13. (ii) Calculate the mean number of stomata per 1 mm^2 of leaf epidermis.
14. Each side of a grid square has a length of approximately 0.003 mm. Use this information to estimate the length of a guard cell.

L6 Root hair cells

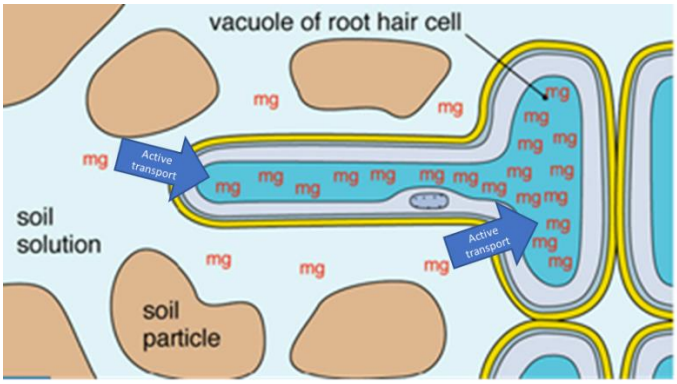
It's common knowledge that plants need water. If you don't water a plant its leaves begin to droop and eventually the plant dies. Plants need water for many different reasons but two of the most important are;

- To provide a raw material for photosynthesis
- To provide pressure in the vacuole to give the plant strength.

Plants absorb water through specially adapted cells in their roots. These cells are called *root hair cells*. Root hair cells cover the roots of the plant. They have special finger-like 'hairs' that stick out of the side of their cell wall. These 'hairs' increase the surface area of the rot hair cell. By having a large surface area, the roots are well adapted to absorb the water from the soil. Water moves from areas where there is a large volume of it to areas where there is less. This is a special form of diffusion called *osmosis*. Large surface areas allow osmosis to happen faster than small ones. Looking at the labelled diagram of the root hair cell you can see it has no chloroplasts. This is because the roots are usually under the ground. As no light hits them the chloroplasts would be useless, so the root hair cell does not waste energy in building them.

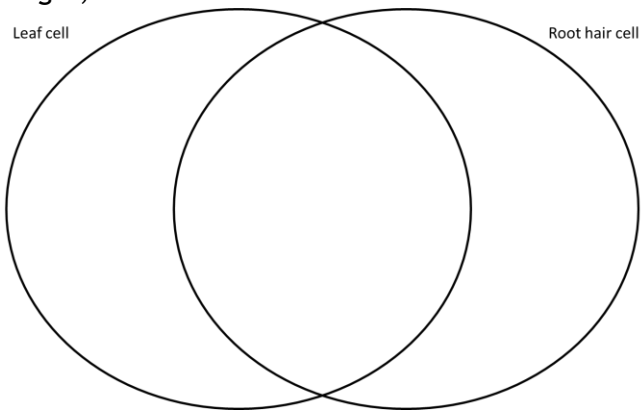


The roots also absorb small amounts of minerals from the soil. These are used to form important chemicals, like chlorophyll, that help the plant stay healthy. These minerals are in low concentration in the soil so the plant cannot absorb them by diffusion. Instead they need to use energy to pump them in by a process called *active transport*.



Independent practice

1. Why do plants need water?
2. What is osmosis the movement of?
3. What is the difference between active transport and diffusion.?
4. Copy and complete the Venn diagram below with the following words:
   Chloroplasts, nucleus, cell wall, cell membrane, mitochondria, vacuole, cytoplasm, hair like finger,



5. **Extended writing (paragraph needed)** Compare a root hair cell to a typical plant cell. Explain the similarities and the differences in terms of the jobs the parts of the cell do.
6. Explain why root hair cells are called root hair cells and not root cells.
7. How does surface area affect the rate of osmosis
8. Why do cacti have very long roots?
9. Certain plants do not have roots. Suggest where these plants may be found and how they might get water.
10. **Extended writing (paragraph needed)** Explain why it's important for plants to have efficient root hair cells in their roots?
11. Explain why the term “root vegetables” used to describe vegetables such as carrots and potatoes is tencially incorrect.
12. Roots help anchor plants, explain what this means.
13. Root rot is a disease that can affect plants, explain what would happen to a plant with root rot.
14. Why is it important to care for and protect plant roots in our environment?

L7 Aerobic respiration

Asleep, awake, eating, bathing, thinking or running you need energy, which is supplied from your diet in the form of calories. Additionally energy is needed for your body's internal functions, for example building and maintaining cells and body tissues. Think of your body as a power plant. The fuel it uses to give you energy comes from the food you eat, like pizza, burgers, and fruit, a special sugar called glucose. Water helps facilitate the chemical reactions that produce energy from food.

Respiration is a chemical reaction that happens in all living cells, including plant cells and animal cells. It is the way that energy is released from glucose so that all the other chemical processes needed for life can happen, and to allow you to interact in the world. There are 2 types of respiration, aerobic and anaerobic. Aerobic respiration requires energy and anaerobic does not. Do not confuse respiration with breathing (which is properly called ventilation).

Aerobic respiration occurs in the mitochondria of cells. Cells which need more energy like sperm cells, which swim, or muscle cells which contract and relax, have more mitochondria.

The aerobic respiration equation is:

glucose + oxygen → carbon dioxide + water.

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

Energy is not an element or a compound. In fact it isn't even a tangible (touchable) thing. As energy is not an substance it is not included in the equation for respiration, even though it is released by the process. It is important to use the word release, not made or produced. This is because you can't make energy.

As you respire you also release heat. This is partly why you feel hotter while doing vigorous activity, and why you shiver to stay warm.

Independent practice

1. Where do we as humans get our energy from?
2. Suggest some reasons why your body needs energy?
3. What is respiration?
4. Which product in food is energy released from during respiration?
5. **Extended writing (paragraph needed)** Write the equation for aerobic respiration and explain what information it gives you. Use the key terms, reactants and products in your answer.
6. Complete the following sentences:
    a. Respiration is similar to breathing because…
    b. Respiration is similar to breathing but…
    c. Respiration is NOT the same as breathing so…
7. When you watched the screaming jelly baby demonstration, describe how did you know that a chemical reaction was taking place?
8. What substance was burning in the jelly baby to cause the reaction?
9. **Extended writing (paragraph needed)** Explain how the jelly baby demonstration was similar and different to the respiration reaction that takes place in your body?
10. Prokaryotic cells do not have mitochondria. What does this tell you about prokaryotic cells?
11. Imagine a scientist has found a microorganism on another planet. The microorganism has mitochondria. What does this suggest about the atmosphere on the other planet?
12. Explain why a person with a lung condition will often feel tired.
13. Suggest the link between the circulatory system (heart, blood and blood vessels) and respiration.
14. Suggest and explain which type of respiration evolved first. Aerobic or anaerobic.

L8 Anaerobic respiration in animals

Anaerobic respiration is like the backup power source for your cells when they can't get enough oxygen. Just like how you might use a flashlight when the electricity goes out, cells use anaerobic respiration to keep producing energy when oxygen is in short supply.

During normal, everyday activities, your cells use a process called aerobic respiration, which needs oxygen to produce energy. But sometimes, like when you're exercising really hard and your body can't supply enough oxygen quickly, your cells switch to anaerobic respiration.

Glucose → lactic acid

Anaerobic respiration will allow the cell to release energy without using oxygen as a reactant, however it does not produce as much energy and produces lactic acid. It does not produce water or carbon dioxide, which is what is produced by aerobic respiration. Another difference is that it does not take place in the mitochondria, instead it takes place in the cytoplasm.

Lactic acid builds up in the muscle cells and prevents the muscles doing their job. This causes fatigue, pain and sometimes cramping. Lactic acid is a mild poison. Lactic acid is broken down by oxygen. After activity that has lead to anaerobic respiration, the person involved breathes heavily and their heart rate remains high to supply the body with the extra oxygen it needs to break the lactic acid down. The amount of oxygen needed to remove all the lactic acid after exercise is called an oxygen debt.

Anaerobic respiration helps your body in short bursts of intense activity, like when you sprint or lift something heavy. But it can't sustain your energy for a long time, and produces a mild poison, so your body prefers aerobic respiration when it's possible. So, anaerobic respiration is like a quick but not-so-efficient energy source that your cells use when oxygen is running low, helping you power through short bursts of strenuous activity.

Independent practice

1. In a situation where there is plenty of oxygen what type of respiration will occur?
2. Name 3 situations where anaerobic respiration will occur.
3. State where each type of respiration occurs.
4. State the products formed in anaerobic respiration.
5. **Extended writing (paragraph needed)** Explain the similarities and differences between aerobic and anaerobic respiration.
6. Correct and improve this statement "Respiration does not need oxygen and makes energy"
7. Why does the body need to break down lactic acid.
8. Explain the term oxygen debt.
9. **Extended writing (paragraph needed)** During a football match a player may get muscle cramp. Explain what is occurring inside their cells.
10. Are there any long-term effects or health implications of relying on anaerobic respiration too often?
11. How do different types of athletes, like sprinters and long-distance runners, use anaerobic and aerobic respiration during their sports?
12. Athletes often incorporate interval training into their routines. This involves alternating between short bursts of high-intensity exercise and periods of lower-intensity exercise or rest. How will the rest periods help the athletes prevent cramping.
13. How would your life be different if suddenly you were unable to carry out aerobic respiration, and could only do anaerobic respiration.
14. The chemical formula for glucose is $C_6H_{12}O_6$. During anaerobic respiration it breaks down into two molecules of lactic acid. Work out what the formula for lactic acid. Hint: in a reaction the number of atoms for each element does not change.

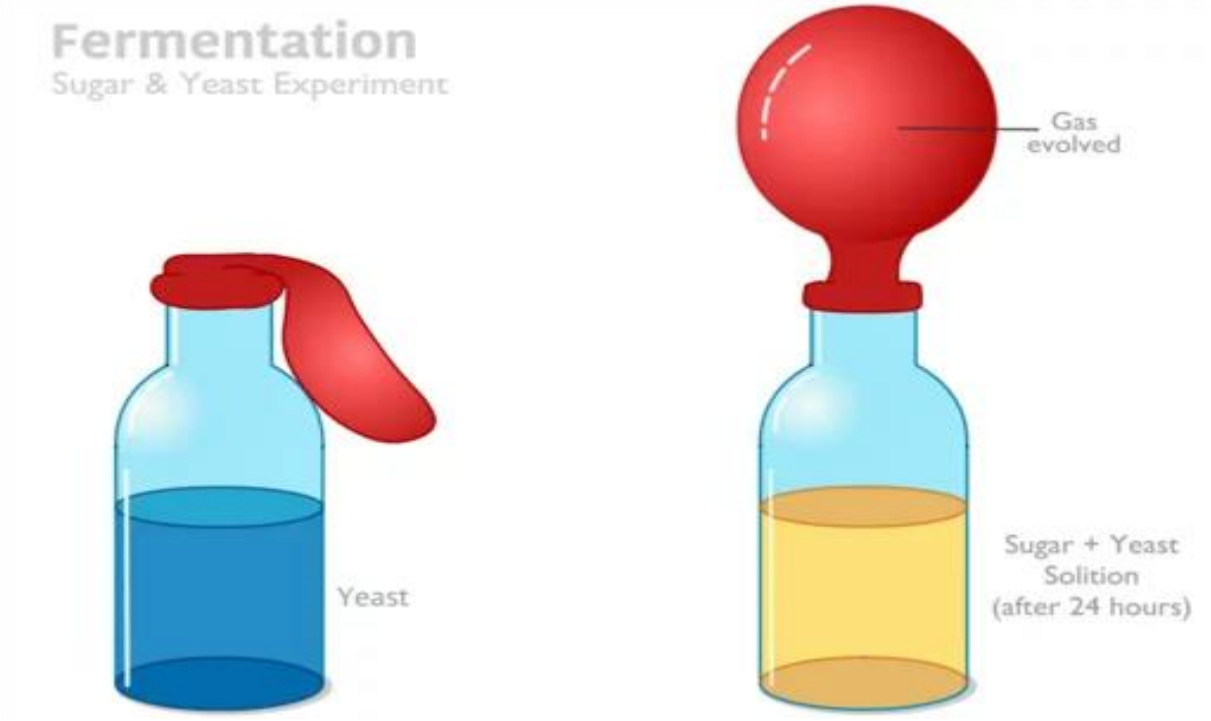
L9 Fermentation

At its core, fermentation is a metabolic process that allows microorganisms to convert sugars into different compounds. The two main types of microorganisms involved in fermentation are yeast and bacteria. Fermentation is a type of anaerobic respiration as it does not require oxygen.

Yeast is particularly famous for its role in alcoholic fermentation. When yeast encounters glucose it undergoes fermentation. This process produces two essential byproducts: carbon dioxide (CO_2) and ethanol (alcohol). Carbon dioxide is a gas that creates bubbles in beverages like beer and champagne and causes bread dough to rise. Ethanol, on the other hand, is the alcohol in alcoholic beverages.

$$\text{glucose} \longrightarrow \text{ethanol} + \text{carbon dioxide}$$

In addition to its culinary applications, fermentation has important scientific and industrial uses. In biotechnology and pharmaceuticals, microorganisms are harnessed for the production of antibiotics, vaccines, and other essential products. Furthermore, fermentation is a crucial step in the production of biofuels, contributing to sustainable energy sources.



In the diagram above the yeast has done fermentation releasing carbon dioxide which fills the balloon. The sugar and yeast solution will also contain the other product of fermentation, ethanol.

Independent practice

1. What is a microorganism?
2. State the reactant in fermentation.
3. State the products in fermentation.
4. **Extended writing (paragraph needed)** Compare anaerobic respiration in humans and in yeast.
5. Why will a brewery use yeast?
6. What happens if a baker forgets to use yeast?
7. Suggest what happens to the yeast when a baker puts the dough in the oven, and why.

James want to investigate how the mass of sugar will effect the amount carbon dioxide yeast can produce through anaerobic respiration.

8. State the independent variable in the experiment.
9. State the depended variable in the experiment.
10. State a control variable for the experiment.

Mass of sugar (g)	Volume of carbon dioxide collected (cm^3)			Average
	1	2	3	
0	0	0	0	0
10	5	6	5	5
20	10	11	10	10
30	15	15	9	15
40	20	21	20	20
50	26	24	25	25
60	30	30	30	30

11. Why was the experiment done 3 times for each mass?
12. Identify any anomalous results.
13. **Extended writing (paragraph needed).** Write a conclusion for the results from the experiment.
14. Suggest how they measured the volume of carbon dioxide produced.

L10 Response to exercise

Several changes occur to the body during exercise.

Our breathing rate increases during exercise. An increase in breathing allows more oxygen to enter the body so that more glucose can be broken down to release more energy in aerobic respiration. Our heart rate increases during exercise. An increased heart rate causes blood to travel to the working muscles faster. Blood carries glucose (in blood plasma) and oxygen (in red blood cells) so the muscles receive more of both allowing for more respiration to take place and more energy to be released.

Investigation - How does exercise duration affect breathing rate?

1. Sit as still as possible and count how many breathes you take in 1 minute
2. Quickly and safely jog on the spot for 1 minute.
3. Record the number of breathes taken in 1 minute whilst still.
4. Wait for breathing rate to return to normal.
5. Exercise for 2 minutes, then record number of breaths in one minute whilst still.
6. Repeat, adding one minute to exercise until you have 6 sets of results.

Example data

Number of minutes of exercise	Number of breaths in one minute after exercise
0	15
1	17
2	20
3	23
4	27
5	31

Independent practice

1. State 2 changes that occur to the body during exercise.
2. What type of respiration will the body switch to during vigorous exercise?
3. **Extended writing (paragraph needed)** Explain why the changes during exercise occur.
4. What does breathing rate mean?
5. Why will an increased breathing rate continue after exercise?
   Look at the method for investigating breathing rate after exercise on the other page and use it to help you answer questions 6-8
6. State the independent variable.
7. State the dependent variable.
8. State a control variable.
9. **Extended writing (paragraph needed).** Write a method for how to investigate the effect different exercises on breathing rate.
10. How could a person measure the heart rate?
11. How would a person modify the experiment on the other page to measure the effect of exercise on heart rate.
12. What are some factors that can influence an individual's resting heart rate and breathing rate, and how can these rates be improved or maintained for better health?
13. How does age play a role in determining what is considered a normal or healthy heart rate and breathing rate, and what changes can occur over time?
14. In what ways can monitoring heart rate and breathing rate be valuable for individuals in managing their health and well-being, and what tools or techniques are available for this purpose?