Pupil worksheets

Photosynthesis — A survival guide

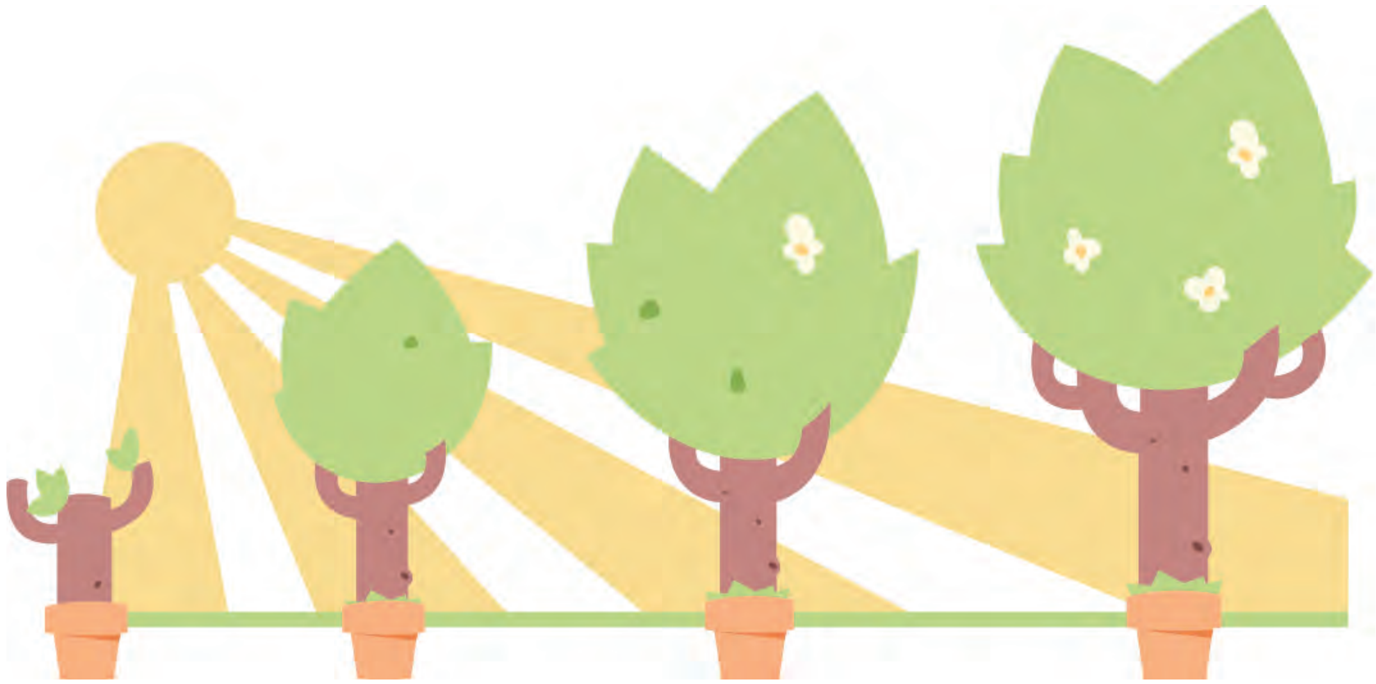
Debbie Eldridge

Activity sheet

1

Where does the wood come from?

An experiment carried out by Jean Baptiste van Helmont (1580 – 1644)



This is an extract from van Helmont's diary…

"I took an earthenware pot in which I put 200 pounds of earth that had dried in a furnace. I moistened it with rain water and implanted in it a trunk of a willow tree weighing 5 pounds. I planted it in the garden and covered the earth with an iron lid punched with many holes to allow rain water in. At length, after 5 years, the tree did weigh 169 pounds and 3 ounces. I again dried the earth in the vessel and found it weighed almost 200 pounds (less about 2 ounces). Therefore 164 pounds of wood, bark and roots arose out of water only."

Draw a table showing the mass of the tree and soil at the beginning and end of his experiment.

?

1. What was the change in mass of the tree?
2. What was the change in mass of the soil?
3. What did van Helmont conclude from his experiment?
4. Do you agree with his conclusion?
5. What other explanations could there be for the results he found?

Activity sheet 1

A class was asked whether they agreed with van Helmont's conclusion. Here are some of their responses:

Activity sheet 1

In groups, choose one of the cards below and consider the questions and information on the card. After you have discussed the questions and information try to come up with a summary of your groups' thoughts.

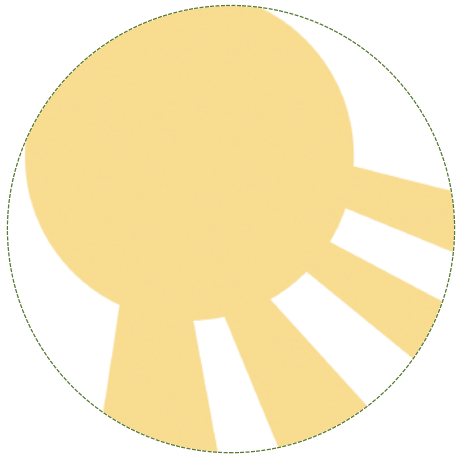
Card 1A

"Only the water could have made this much difference..."

Think about water.

- Is water a food source?
- Would you survive on water alone?
- Do we know how much water was added to the pot over the five years?
- What should van Helmont have done if he had wanted to prove that all this increase in mass was from water?
- What measurements could he have taken?

- Do you think van Helmont was correct to say that water alone accounted for the growth of the willow tree? Try to summarise your thoughts using some of the points above to support your argument.



Card 1B

But I think that plants make their food from sunlight…

What is sunlight?

- Does sunlight have mass?
- Living things are made of atoms. Are there any atoms in sunlight?
- Could sunlight contribute to the increase in mass of the plant?
- Is sunlight needed for plants to grow? What role do you think it might have?

- Do you think it is correct to say that plants make their food from sunlight? Try to summarise your thoughts using some of the points above to support your argument.

Activity sheet

1

Card 1C

Some of the tree may have grown from minerals in the soil

How much did the mass of the soil decrease over the five years?

- Could this have contributed to the growth of the plant? How much?

- Can plants grow without soil? Look at the results of the investigation below on mung beans: Mung bean seeds were germinated and grown in two solutions – one containing all the minerals found in soil, one with just water (no minerals). The plants were grown for the same time and in the same conditions.
- Can plants grow without minerals?
- Do minerals have an effect?

- Do you think it is correct to say that some of the tree came from minerals in the soil? How much could the minerals have contributed to growth?

Fig 1–All minerals

Fig 2–Water only

Card 1D

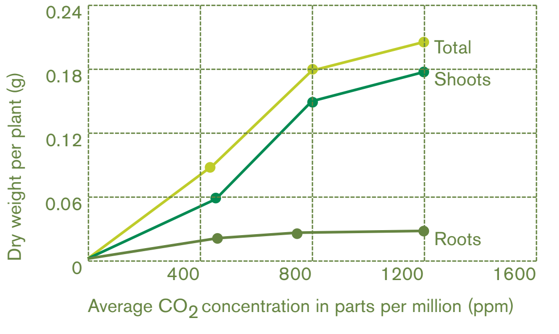
van Helmont may not have known about the gases in the air

What gases are in the air?

- Do the gases in the air have mass? (If you compare an empty balloon and one filled with air you will soon find out.)

- How could you show that these gases have an effect on increasing the mass of a plant?

- Look at the results of an experiment that examined the growth of plants at three different concentrations of carbon dioxide. What does it tell you? Can gases in the air affect growth? Which gas is shown to have an effect in these experiments?

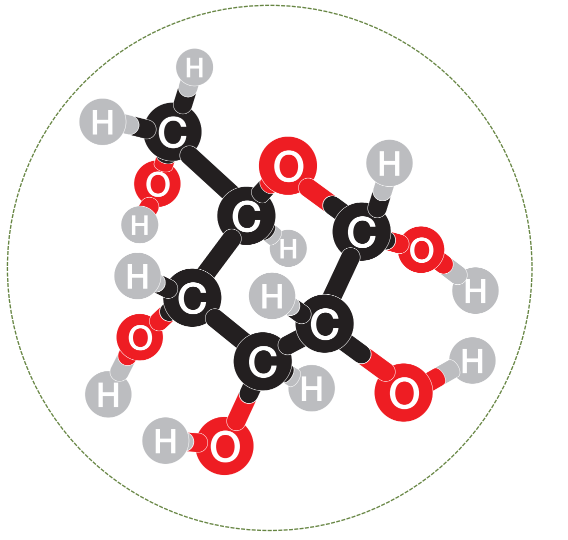


Activity sheet

2

The story of photosynthesis

Fig 3–Carbohydrate molecular structure



Take a look at how plants make their food.

We know that the food plants made from photosynthesis are called CARBOHYDRATES.

If we look at the word 'CARBOHYDRATE' we can tell quite a lot about it...

Carbohydrates contain the atoms CARBON, HYDROGEN and OXYGEN.

This carbohydrate *(Fig 3)* is called glucose – it is a sugary substance and you are probably very familiar with its taste if you have eaten or drunk any of the products opposite.

?

1. **So, which part of the word carbohydrate means that it contains carbon?**
2. **And which part of the word means that it contains hydrogen?**
3. **Now, can you suggest what the letters ATE mean when placed on the end of a chemical name?**
4. **Figure 3 above is a chemical picture of one carbohydrate. Count how many carbon, hydrogen and oxygen atoms this molecule has…**

Activity sheet 2

Now, if you were a plant and you had to make this carbohydrate, what atoms are you going to need and where could you get them from?

If we had some carbon dioxide *(Fig 4)*, could we make carbohydrates from it?

Fig 4–Carbon dioxide (CO_2)

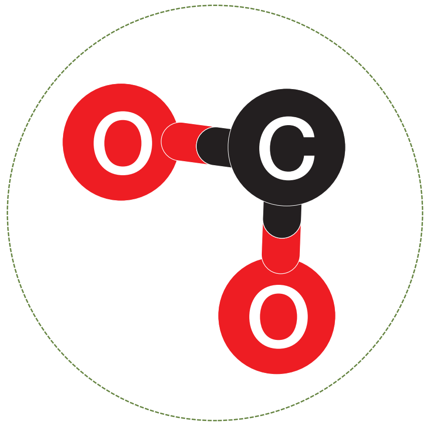
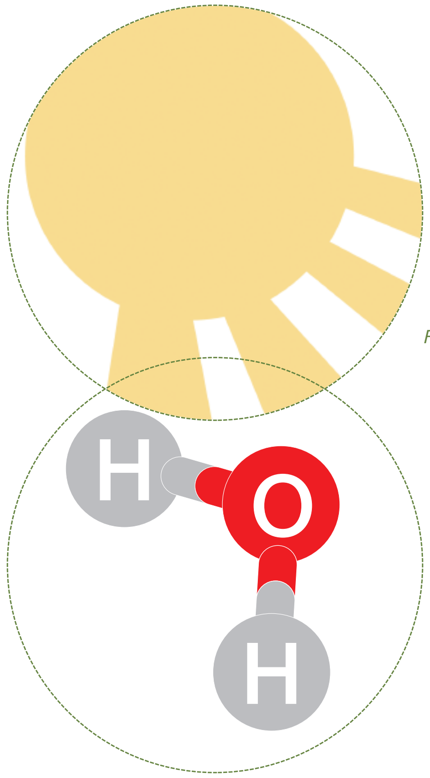


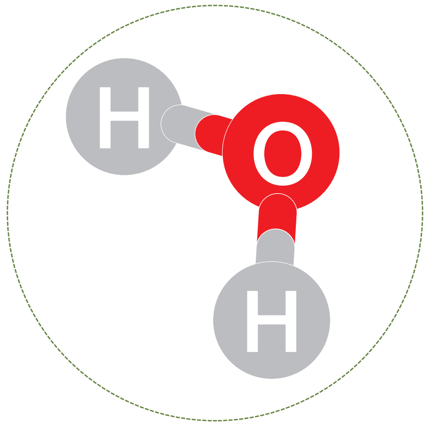
Fig 6–Water (H_2O) & Sunlight



What atoms would still be missing?

If we had some water as well as the carbon dioxide, what extra atom could this supply?

Fig 5–Water (H_2O)



OK – suppose we have the carbon dioxide and some water (H_2O) *(Fig 5)* – we would need to split the water up to release the hydrogen from it.

The process of splitting water into hydrogen and oxygen is very difficult. However – with the help of sunlight energy plants can split the water and use the hydrogen to combine with the carbon and oxygen from carbon dioxide.

When light energy is used to split water, there is a product left over that is not needed. What is this product?

You may have come across this idea before – it seems that photosynthesis not only results in the production of carbohydrates such as glucose, but also releases oxygen into the air – which is a good thing as we will see later

We know that plants use sunlight energy to split water (H_2O) into hydrogen and oxygen.
The hydrogen is added to the carbon dioxide to make CARBOHYDRATES.

The oxygen produced from this splitting of water is released into our atmosphere.

We summarise this using a chemical equation:

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

carbon dioxide, water, carbohydrate, oxygen

Activity sheet 3

Talk about...

?

1. **What do these products have in common?**
2. **Are there any similarities and differences between them?**

Activity sheet

4

What sort of carbohydrates do plants make?

Glucose and other sugars such as sucrose and fructose are soluble so need to be linked together in long chains to make substances like starch and cellulose. Starch is useful for storing sugar. Cellulose is used to build plant cell walls.

If we want to find evidence of glucose, starch and cellulose in plants, we can test for these different carbohydrates with iodine solution (for starch), Benedict's reagent (for sugars) and Schulze's reagent (for cellulose).

Materials:

Each group will need:

- One white tile
- A knife/scalpel
- A pestle and mortar
- One boiling tube
- One small bottle of iodine solution
- One small bottle of Benedict's reagent
- Three samples of each plant e.g. onion, apple, grape, celery, potato

Materials to be shared:

Access to a water bath set at 90^{o}C

HAZARDS: Take care with knives. Only the teacher should handle Schulze's reagent.

Activity sheet

4

Method:

1. Collect three samples of each plant you want to test. For each sample you collect think about what part of the plant this has come from. Onions for example are an underground storage organ; apples are the fruit and celery is a leaf stalk. Fill in the first column of your results table to describe which part of the plant you are testing.
2. Place two samples of each plant on a white tile or other non absorbent surface. You may want to break the structure up a little with a knife or scalpel.
3. Place the third in a pestle and mortar and grind it up with a little water. Then place it into a boiling tube and cover it with Benedict's solution. Place this tube in a water bath set at 90^{o}C and leave it for 5 minutes while you carry out the other tests.
4. Go back to your first two samples on the white tile. Place a few drops of iodine solution on one of the samples and ask your teacher to place a few drops of Schulze's reagent on the other. Leave for a few minutes so the indicator has time to soak into the plant material.
5. Record your observations in the results table.

To test for glucose you add Benedicts' reagent and place in a water bath at 90^{o}C for 5 minutes. If glucose is present the colour changes from blue to orange (sometimes it takes a while and the colour looks a green yellow as it is changing).

To test for starch you add iodine solution. If starch is present the reddish brown iodine solution changes to a blue black colour.

To test for cellulose you add Schulze's reagent. If cellulose is present it will turn a purple colour.

?

1. What did your results show?

2. Remind yourself – where do the atoms that make up these carbohydrates come from?

Extension

Take small pieces of cotton wool/paper towel or packaging from an egg box. Place on a white tile. Try adding iodine solution and Shulze's reagent to each. Where do the products come from? Can you explain your observations by thinking about how these products are made.

Results table

Plant	Part of plant being tested	Observations when Indicator added		
		Benedict's reagent	Iodine solution	Schulze's reagent

Activity sheet

5

How can we show that plants use carbon dioxide?

We know that carbon dioxide is in the air but as it is an invisible gas we need to use particular methods to detect it. Changes in carbon dioxide concentration can be detected using an indicator called hydrogencarbonate indicator.

Atmospheric air contains 0.04% carbon dioxide. When atmospheric air is bubbled through the indicator it is an orange red colour. However, if a plant is using carbon dioxide in photosynthesis it will remove carbon dioxide from the indicator and the indicator turns first a deeper red and then more purple.

← Increasing CO_2 in indicator | Atmospheric level of CO_2 | Decreasing CO_2 in indicator →

Materials:

Each group will need:

- Four transparent containers with lids
- Three equal length sprigs of *Cabomba* or other pondweed
- Hydrogencarbonate indicator sufficient to fill four containers
- One lamp
- One flat sided glass tank to act as a heat screen
- A small piece of neutral density shading or a square of muslin – enough to surround one of the containers.

Method

- Take four transparent containers that can be sealed easily.
- Rinse the containers with a small amount of indicator.
- Add a standard volume of indicator to each container and in three of the containers, place equal length sprigs of pondweed e.g. *Cabomba.*
- Seal all the containers.
- Take one containing pondweed and place it in a dark cupboard.
- Take a second one containing pondweed and cover it with shading.
  This can be done using layers of muslin or if you want to know exactly how much light you are cutting out you can use a neutral density filter.
- The remaining two containers (one with and one without pondweed), should be left uncovered.
- The containers (apart from the one in the dark) should then be placed the same distance from a bright white light source.
  The experiment should be left until there is a noticeable change in colour (this maybe as little as one hour or as long as overnight depending on the light intensity and how much pondweed there is). Make sure the lamp will not cause overheating of your water. If the light is very powerful you could place a transparent screen between the light and the plant, or a flat sided container of cold water to absorb the heat but not the light.
- When there is a noticeable change in colour in the indicator, remove the shading and compare the colours in the four containers to those in the picture above.

Results:

(Either refer to your own results or look at the specimen results on the PowerPoint.)

Activity sheet

5a

You may wish to complete this table..

Results table

Container	*Cabomba* present	% of full light	Colour of indicator	Has the carbon dioxide in the indicator increased or decreased?	What does this tell you?
1	Yes	100%			
2	Yes				
3	Yes	0%			
4	No	100%			

OR you might prefer to answer these questions:

?

1. Describe your observations.
2. Link these observations with what you know about photosynthesis.
3. Do they confirm what you set out to show in this experiment?
4. What happened to the indicator when the pondweed was placed in the dark?
5. What do you deduce from this?
6. Can you think of any improvements to the method which you would carry out if you had the time to repeat this experiment?
7. What colour would the indicator go if the plant is respiring and carrying out photosynthesis at the same rate? Why?
8. Select the two times of the day that this is most likely to happen?
   NIGHT, DAWN, MID MORNING, LUNCHTIME, AFTERNOON, DUSK

Here is a reminder of some information you might find useful...

Green plants and algae use up carbon dioxide – removing it from the indicator as they carry out photosynthesis. BUT...

They also produce carbon dioxide as they respire – and all living things respire ALL THE TIME.

Activity sheet

5b

Matching cards excersise

Select the correct colour that the indicator will go in each container

Results table

Contents of container	Colour of indicator	Explanation
Hydrogencarbonate indicator and pondweed, placed 20 cm away from a lamp.		Both respiration and photosynthesis are taking place. In this case, the pondweed is using up more carbon dioxide in photosynthesis than it is producing in respiration.
Hydrogencarbonate indicator and pondweed, surrounded by a thin layer of shading, placed 20 cm away from a lamp.		Both respiration and photosynthesis are taking place. In this case, the pondweed is using up the same amount of carbon dioxide in photosynthesis as it is producing in respiration.
Hydrogencarbonate indicator and pondweed surrounded by a thicker layer of shading, placed 20 cm away from a lamp.		Both respiration and photosynthesis are taking place. In this case, the pondweed is using up less carbon dioxide in photosynthesis than it is producing in respiration.
Hydrogencarbonate indicator and pondweed placed in a cupboard.		Respiration is taking place in the pondweed. It isn't using up any carbon dioxide in photosynthesis; it is only producing it in respiration.

Activity sheet

5b

Select the correct explanation for each of the colour changes

Results table

Contents of container	Colour of indicator	Explanation
Hydrogencarbonate indicator and pondweed, placed 20 cm away from a lamp.	Purple	
Hydrogencarbonate indicator and pondweed, surrounded by a thin layer of shading, placed 20 cm away from a lamp.	Red	
Hydrogencarbonate indicator and pondweed surrounded by a thicker layer of shading, placed 20 cm away from a lamp.	Orange	
Hydrogencarbonate indicator and pondweed placed in a cupboard.	Yellow	

Explanations

- Both respiration and photosynthesis are taking place. In this case, the pondweed is using up less carbon dioxide in photosynthesis than it is producing in respiration.
- Both respiration and photosynthesis are taking place. In this case, the pondweed is using up the same amount of carbon dioxide in photosynthesis as it is producing in respiration.
- Respiration is taking place in the pondweed. It isn't using up any carbon dioxide in photosynthesis; it is only producing it in respiration.
- Both respiration and photosynthesis are taking place. In this case, the pondweed is using up more carbon dioxide in photosynthesis than it is producing in respiration.

Activity sheet 5b

Use arrows to join up the correct colour that the indicator will go with the correct explanation to each of the contents

← Increasing CO_2 in indicator — Atmospheric level of CO_2 — Decreasing CO_2 in indicator →

Results table

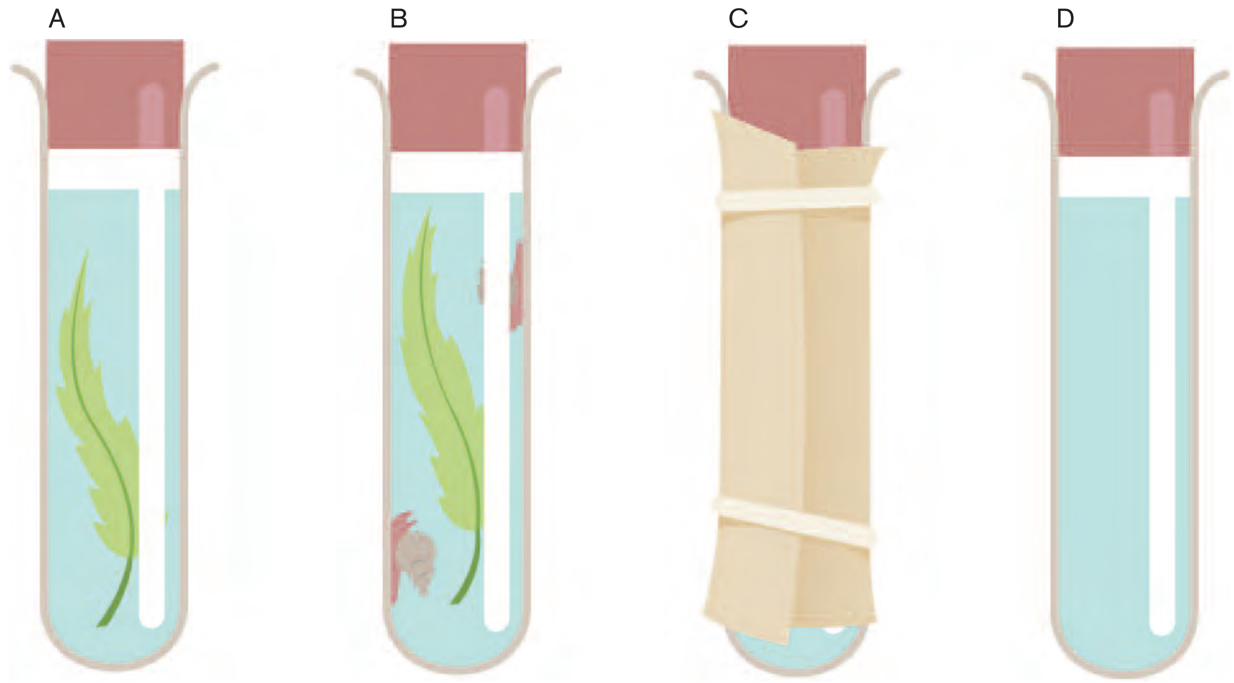
Contents of container	Colour of indicator	Explanation
Hydrogencarbonate indicator and pondweed, placed 20 cm away from a lamp.	Red	Respiration is taking place in the pondweed. It isn't using up any carbon dioxide in photosynthesis; it is only producing it in respiration.
Hydrogencarbonate indicator and pondweed, surrounded by a thin layer of shading, placed 20 cm away from a lamp.	Orange	Both respiration and photosynthesis are taking place. In this case, the pondweed is using up more carbon dioxide in photosynthesis than it is producing in respiration.
Hydrogencarbonate indicator and pondweed surrounded by a thicker layer of shading, placed 20 cm away from a lamp.	Yellow	Both respiration and photosynthesis are taking place. In this case, the pondweed is using up less carbon dioxide in photosynthesis than it is producing in respiration.
Hydrogencarbonate indicator and pondweed placed in a cupboard.	Purple	Both respiration and photosynthesis are taking place. In this case, the pondweed is using up the same amount of carbon dioxide in photosynthesis as it is producing in respiration.

Activity sheet 5c

Hydrogencarbonate indicator solution changes colour when the amount of carbon dioxide dissolved in it changes. The table opposite shows details of these colour changes.

Colour of indicator solution	Amount of carbon dioxide dissolved in indicator
Red	Same amount of carbon dioxide as in the air
Yellow	More carbon dioxide than in the air
Purple	Less carbon dioxide than in the air

The tubes were left in bright sunlight for two hours



Pondweed — Small snails & pondweed — Pondweed — Indicator only

?

1. What would be the colour of the indicator solution in tube A?
2. Name the process taking place in the cells of plant which causes this colour change.
3. The colour of the indicator in tube B did not change. Explain why.
4. Tube C is wrapped to keep the light out. The indicator changed to yellow. Explain why.
5. Why was it necessary to include tube D in the experiment?
6. Colour is a qualitative change and cannot easily be measured. Can you design an experiment using this indicator to work out how fast different plants photosynthesise?

Activity sheet

6

Gas exchange at different times of the day

?

1. Can you draw a set of pictures to show what type of gasses a plant takes in and gives out, and how much, during different times of the day? One of the pictures has been done for you.

Dawn

Late morning

Afternoon

Evening

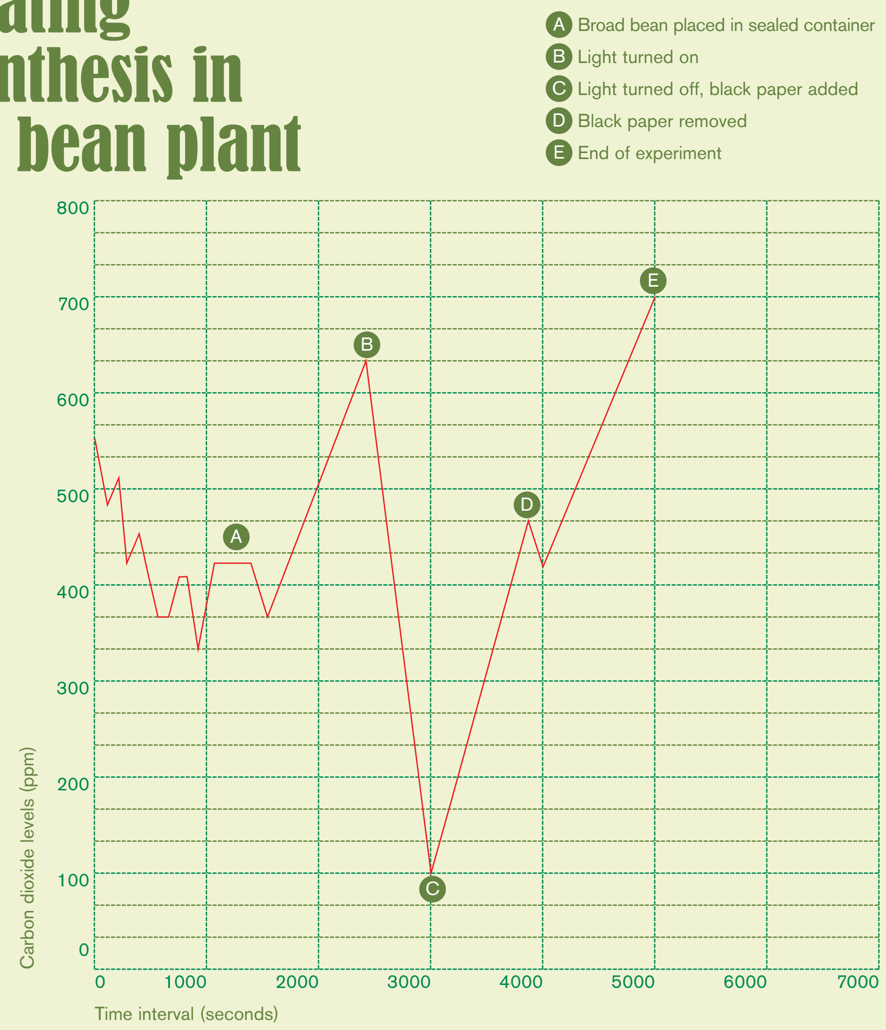
Midnight

Activity sheet

7

Investigating photosynthesis in a broad bean plant

Fig 7–Broad bean plant and logging probe



A broad bean plant was placed in a tall chamber with a data logging probe *(Fig 7)* **to detect the concentration of carbon dioxide (parts per million).**

The aim of the experiment was to record the changes in carbon dioxide over a prolonged period when the plant was exposed to a range of light treatments. We could then relate this to changes in the photosynthetic rate of the plant.

Examine the graph above showing the changes in carbon dioxide levels opposite. Study it carefully to try to understand what is happening. Use the questions after the graphs to help you analyse the graphs in detail.

For the first 1000 seconds of the experiment the carbon dioxide probe was left in atmospheric air.

1. Describe the general trend in concentration of carbon dioxide during this period.

The probe was then placed inside the transparent sealed container without any plant inside. (A)

2. How can you tell that the probe was now in a sealed container? Are the values more or less consistent than when it was left in the atmosphere?

The broad bean plant was then placed in the container but at this stage there were no external lights on and the area was quite shaded.

3. What happens to the level of carbon dioxide?
4. What does this tell you about the ability of the broad bean to photosynthesise at low light intensities?

At 2400 seconds a bright light was switched on. (B)

5. What begins to happen almost immediately?
6. What process is causing this change?

At 3000 seconds the plant in the container was completely surrounded with black paper and the light switched off. (C) At 4000 seconds the black paper was removed but no lights switched on in the lab. (D)

7. Is there any difference between the slope of the graph over two time periods?
8. How could you get the carbon dioxide levels to remain relatively stable within the container?
9. The soil in the pot containing the bean plant was surrounded by a plastic bag. If there were organisms in the soil; how might this have affected the results?
10. If you were repeating this experiment can you think of ways you could alter the design of the experiment to provide better data than is shown here?

If you have access to a data logger and probe for carbon dioxide you may wish to set up this experiment yourselves. If you do, remember the light intensity in a lab is only a small fraction of natural light and you will need a bright light source to see the results of photosynthesis.

Activity sheet

8

Measuring photosynthesis by oxygen evolution

Fig 8

Cup your hand around the *Cabomba* sprig and gently flatten the fronds against the central stem Carefully lower the flattened *Cabomba* into measuring cylinder, tip of sprig lowermost, and hold the end of the stem against the glass with your finger. *(Fig 8)*

In this experiment you are going to use the aquatic plant *Cabomba* to observe bubbles of oxygen which are released as the plant carries out photosynthesis. These bubbles can be counted and the rate of bubbling can give you an indication of the rate of photosynthesis. If we alter the light intensity, does the rate of bubbling vary?

Setting up the *Cabomba*

You will need:

- 250 cm³ measuring cylinder or a measuring cylinder that is just longer than your *Cabomba* sprig
- *Cabomba* sprig
- 400 cm³ 1% solution of sodium hydrogencarbonate.

Fill the measuring cylinder with a 1% sodium hydrogen carbonate solution. *(Fig 9)*

Fig 9

Activity sheet

8

Fig 10

Cut the stem of the *Cabomba* sprig at an angle under the surface of the liquid. This cut end must remain in the liquid or an air lock may form. You should be able to observe bubbles of gas rising from the cut. *(Fig 10)*

Place your *Cabomba* in front of a bright light source and let the plant equilibrate for five minutes. (You may want to place a flat sided container of water between the measuring cylinder and the lamp to prevent the water in the measuring cylinder heating up.) Count the bubbles produced in 30 seconds. Repeat the reading twice more and record your results in a table. Move the measuring cylinder so that it is different distances from the light source and let equilibrate again. Repeat the experiment until you have enough results to show a pattern. *(Fig 11 & 12)*

Fig 11

Fig 12

Activity sheet 8

Results table

Distance from light source (cm)	Number of bubbles released in 30 seconds			Mean number of bubbles
	Test 1	Test 2	Test 3	

Plot a graph to show how the number of bubbles is affected as distance from the light source is changed.

?

1. **What are the input, outcome and controlled variables in this experiment?**
2. **Describe the pattern shown by your graph(s).**
3. **What is the relationship between the variables?**
4. **Can you explain the pattern shown by the graph using your understanding of photosynthesis?**
5. **Is the pattern shown in your graph what you expected or were some of your results unexpected?**
6. **If you had any unexpected results, were they just a 'one-off' (a random error) or did all of the repeats give the same result? (This gives you an indication of how reliable your results were).**
7. **Were there any ways you could have improved this experiment? Were they all the same size bubbles? Could you think of a way of measuring the volume of gas given off?**
8. **Predict what would happen to the number of bubbles if you increased the power of the light bulb.**

Extension:
Light intensity decreases with distance from a light source, but the relationship is not linear.
The light intensity decreases quite rapidly as distance is increased.
The relationship is:

Light intensity is proportional to $\frac{1}{d^2}$

where d = distance

This means that at 5 cm from the light source the intensity is 1/25 of the intensity at 1 cm and the light intensity at 10 cm is 1/100 of the intensity at 1 cm. If you plot number of bubbles against the light intensity, you may get a more meaningful relationship.

Activity sheet 9

Early earth

Look at any stagnant pond and you'll be able to imagine early Earth. Green scum. Most scientists believe it's the way things were back before the planet had enough oxygen to allow more complex life forms to evolve. For the first billion and a half years (4.0 – 2.5 billion years ago. 1 billion = 1000 million), Earth's atmosphere contained no free oxygen, and therefore earth's oceans contained no dissolved oxygen. Your scummy ancestors had the planet to themselves up to about 2.2 billion years ago. These single-celled organisms were the only things that could survive without access to oxygen. But then things changed...

Fig 13–Grasses

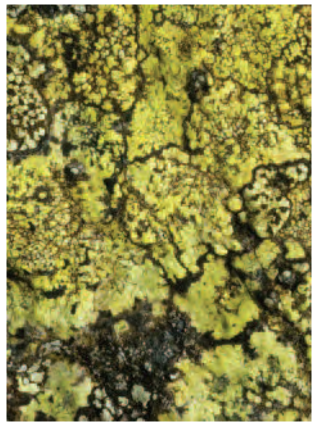


Fig 14–Moss (Rhizocarpon geographicum)

Fig 15–Liverworts

Fig 16–Red banded rock

Oxygen first appeared on the surface of the Earth when the first photosynthetic cyanobacteria (blue/green algae) developed the ability to split water molecules using the sun's energy. The oxygen did not build up in the atmosphere for a long time, since it was absorbed by rocks such as iron that could be easily oxidized (rusted). To this day, most of the oxygen produced over time is locked up in the ancient rock formations found in ancient sedimentary rock.

It was not until ~1 billion years ago that the reservoirs of rock became oxidized and the free oxygen stayed in the air.

When free oxygen began to build up in the atmosphere, it formed two gases new to Earth. One was molecular oxygen (O_2), and oxygen opened a door to the evolution of whole new life forms. The other was ozone (O_3), a gas that forms high in Earth's atmosphere and acts as a sort of global sunscreen. This protects the Earth's surface from the most harmful UV radiation. One of the amazing things about life on Earth is that, by producing oxygen, the earliest organisms created conditions that enabled subsequent, more complex forms of life to thrive.

But how did plants make the transition to land? To invade the land plants had to prevent drying out and develop ways to reproduce. In water they were able to just dump their gametes (reproductive cells), into the water. On land, that doesn't work.

Lichens are believed to have been amongst the first photosynthetic organisms to exist on land. A lichen is not a single organism but a combination of two organisms that live together intimately. A fungus can team up with photosynthetic organisms like cyanobacteria or green algae to form lichens. These organisms can live without rain for months, providing protection for photosynthetic organisms, which produce oxygen and release it into the atmosphere.

The first independent land plants were the mosses and liverworts that grow close to the ground, absorbing water and nutrients directly through their cells. For these plants to reproduce on land they needed to be in a wet environment where they could rely on a film of water through which their gametes could swim.

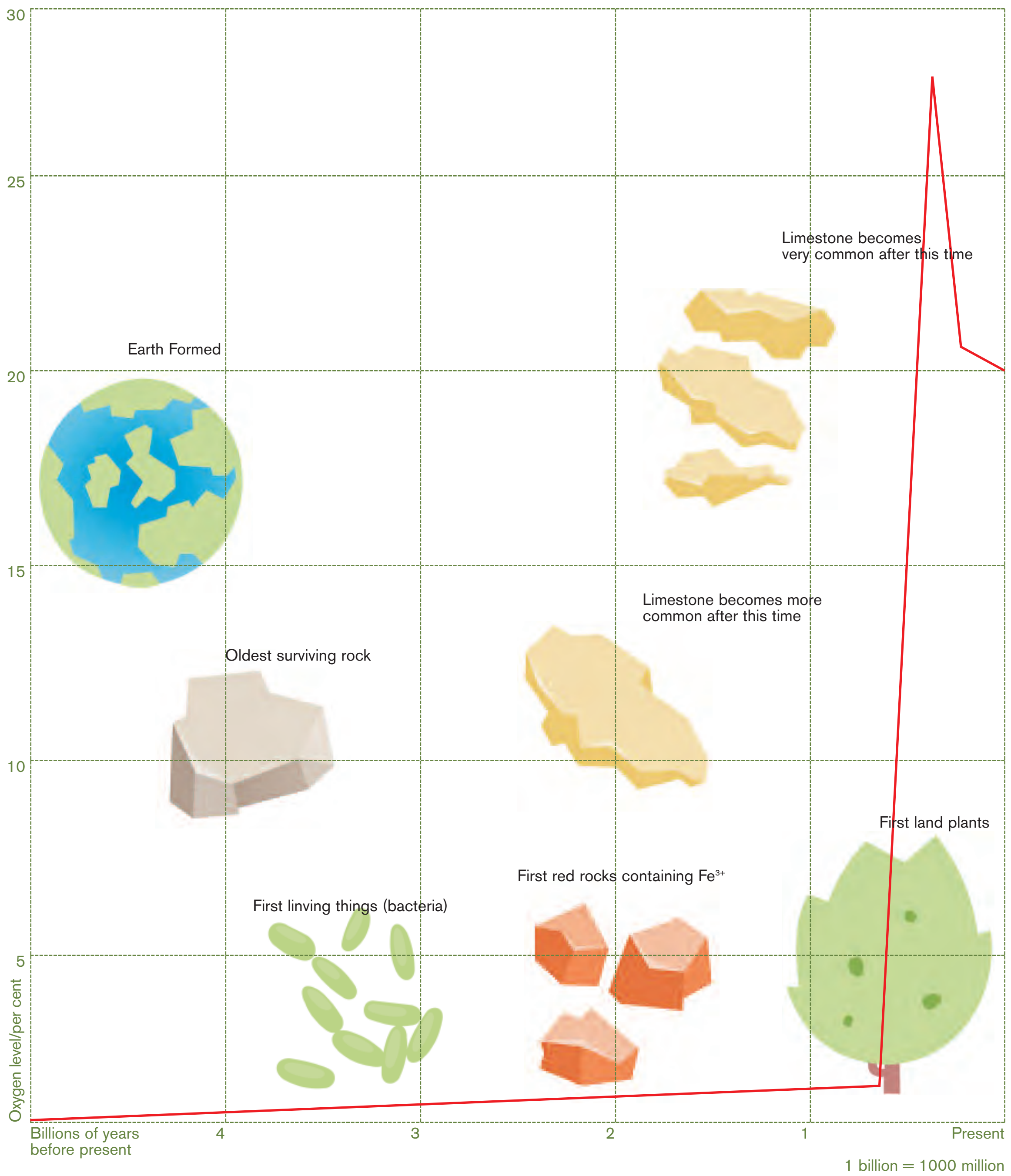
Millions of years later plants have evolved the ability to live and reproduce on land. These seed plants 'package' the male gamete in a pollen grain – an ingenious solution that frees themselves from the need for water to get the reproductive cells together.

* 1st paragraph adapted from "How the Scum of the Earth led to Advanced life" by Robert Roy Britt

(Fig 13 & 14 © John Bebbington FRPS)

Activity sheet 9

Look at the graph below which shows the changes in the earth's atmosphere since it formed over 4.5 billion years ago



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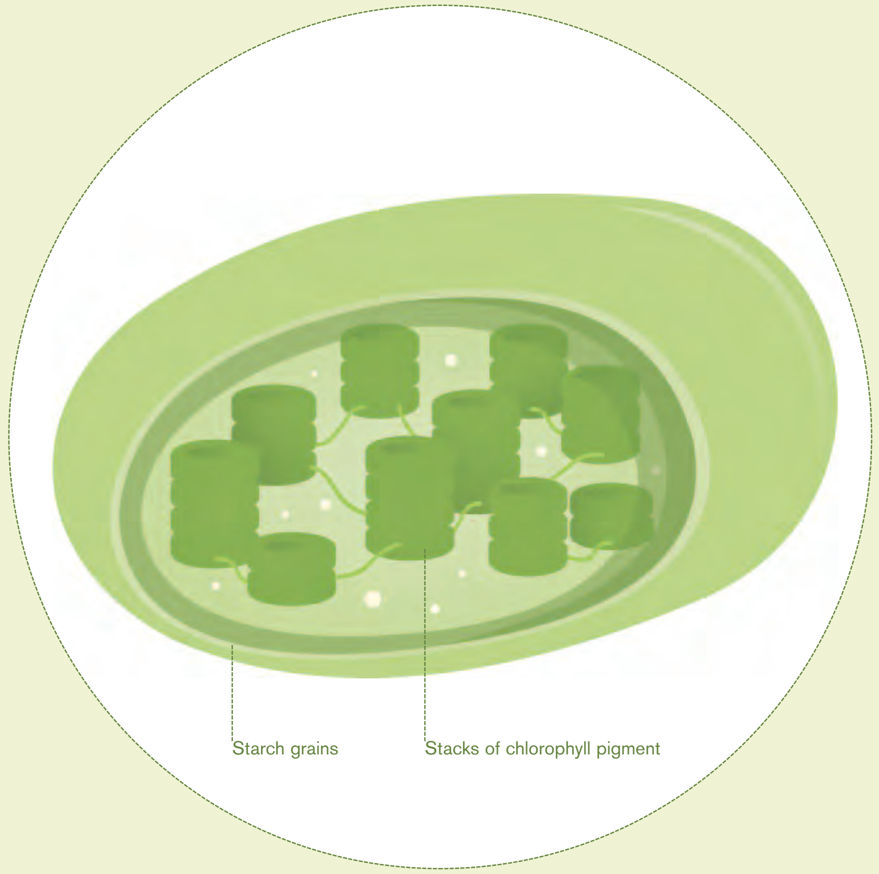
1. There was no ozone when life first appeared. Why was the formation of ozone not possible at this stage?
2. Life is thought to have evolved underwater. Why do you think the conditions were better there?
3. Primitive life started producing oxygen 3 billion years ago and yet the graph shows that oxygen levels started to increase significantly less than 1 billion years ago. What does the text suggest is the explanation for this?
4. What was the major adaptation that plants had to achieve in order to be able to live on land?
5. The graph shows that about 0.3 billion years ago the oxygen level may have risen as high as about 27% and then it dropped back to its present 20% What would you think the plant life would have been like at this time?
6. Apparently forest fires were common about 0.3 billion years ago and charcoal remains are evidence of this. What would this have done to the oxygen and carbon dioxide levels?

Activity sheet 10

What are chloroplasts?



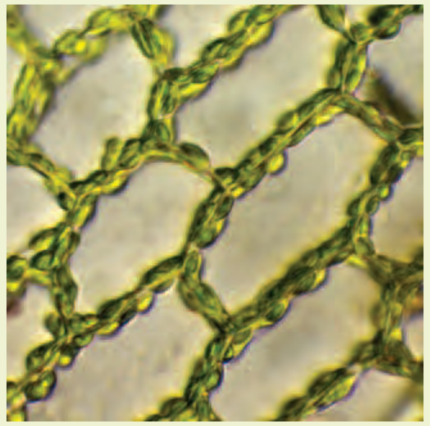


Fig 17–Chloroplasts clustered around the edges of the leaf cells

Fig 18–Chloroplasts in the guard cells from the lower leaf surface

Information:
Chloroplasts are small green 'bodies' in some plant cells which enable the plant to 'capture' sunlight energy.

The chloroplast is filled with a green pigment called chlorophyll. If you imagine an oblong shaped boiled sweet with a filling…the sweet is like the chloroplast and the filling is the chloro"phyll"

Looking at chloroplasts:

- Select a plant which has a very thin leaf such as *Elodea* or simple moss leaves.
- Place a single leaf on a microscope slide, add a drop of water and a cover slip.
- Look at the leaf down a microscope and see if you can identify the small green chloroplasts.
- If you have difficulty seeing the chloroplasts, look at the cells at the edge where the leaf is very thin.

If you look very carefully you may be able to see the chloroplasts moving around within the cell. Your teacher may show you a video clip of this effect.

Activity sheet 10

Fig 19–Potato slice

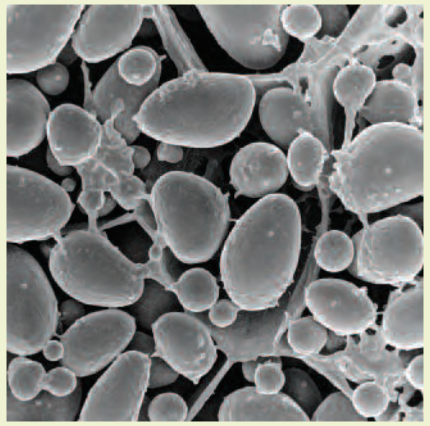


Fig 20–Starch grains X700 magnification

Chloroplasts absorb light energy and enable the plant to use this to build carbohydrates such as starch. In many high power images of chloroplasts we can see the starch grains (see diagram and previous page).

The plant is able to export these carbohydrates to other parts of the plant where starch grains build up. For example a potato tuber stores starch grains – so although it has no chloroplasts to make carbohydrates – they are packaged up and stored there.

Looking at the starch grains stored in a potato tuber:

- **Take a small section of potato tissue and cut a very thin slice onto a white tile.**
- **Take approximately 1cm² of thinnest tissue and place it on a microscope slide.**
- **Add one or two drops of iodine solution.**
- **Place a cover slip over the potato tissue.**
- **Examine it under the microscope.**

You may see that some of the starch grains are very large and some quite small. The starch grains in the chloroplasts in the figure on the previous page are very small but remember the potato tuber is the main storage organ so we might expect large grains to build up here.

Variegated plants such as these only have chloroplasts in some of the leaf cells.

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1. **Which cells of the leaf would you expect to show evidence of starch grains if you left this plant in the light for a few hours?**
2. **How would you expect the growth rate of a plant with variegated leaves to compare to a normal totally green plant? Can you explain why you think this?**

Activity sheet 11

Can we show that only the green parts of the leaf produce starch in photosynthesis?

We know that the plant converts the simple sugars made in photosynthesis into starch for storage. Why don't we look to see if there is any starch in the non-green areas of the leaf?

Try this practical activity:

Materials:

Each group will need:

- Beakers 1 x 250 cm³ and 1 x 100cm³
- Bunsen burner
- Tripod
- Gauze
- Boiling tube plus holder
- Forceps
- Ethanol (~25cm³)*
- White tile
- Iodine solution in dropping bottle
- A leaf from a variegated plant which has been illuminated for 24 hours

* To be given out by teacher

Hazard:

Ethanol is highly flammable and must not be placed near a flame. When the leaf has been in boiling water for a minute, it is essential that the Bunsen burner is switched off before you collect the ethanol.

Activity sheet 11

Method

1. Take a variegated plant which has been under bright light for 24 hours and remove one of the leaves.
2. Make a sketch of the leaf showing approximately where the green and non green areas are.
3. Half fill a 250 cm^3 beaker with water and bring it to the boil using a Bunsen burner, tripod and gauze.
4. Place the leaf in the boiling water for one minute to get rid of the waxy coating on the leaf.
5. Turn off the Bunsen burner (see hazard above).
6. Collect a boiling tube and place the leaf from the boiling water into the tube using forceps.
7. Your teacher will pour ethanol into the tube until about one third full.
8. Place the boiling tube with ethanol and the leaf inside the beaker of hot water and leave for 5 – 10 minutes. The ethanol will remove the colour from the leaf because the chlorophyll is soluble in the ethanol. When we remove the leaf it should have lost the green colour and you will see the ethanol has turned green.
9. Pour off the ethanol into a clean beaker and place the leaf back in the hot water to rinse off the ethanol and soften the leaf.
10. Lay the leaf out on a white tile and "flood" the leaf with iodine solution.
11. Pour off the excess iodine solution and examine the leaf carefully to see where the starch is. Record your observations by sketching the leaf again after staining.

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1. **Why is the leaf placed in boiling water?**
2. **Why is the leaf placed in ethanol?**
3. **Why is the leaf placed back in the water after it has been in ethanol?**
4. **Why is iodine solution added to the leaf?**

Conclusion:

Look at the two sketches you have made of the variegated leaf.
Where is there evidence of starch?
Where is there no starch?
What does this suggest?

Extension:

In the past some scientists have been able to create 'pictures' in a leaf, The pictures are formed in starch by illuminating a leaf through a negative placed in a slide projector (This picture is a print on which a question was superimposed)

Can you explain why we see this image?

Activity sheet 12a Bringing it all together

Light

$CO_2 + H_2O \longrightarrow O_2 + \text{Glucose}$

Chlorophyll

In each of the bubbles pupils put details of a practical or activity that they have completed which illustrates/ demonstrates this part of the reaction.

Activity sheet 12b

Words for concept mapping

Chlorophyll

Photosynthesis

Light energy

Starch

Chloroplast

Sugar

Oxygen

Iodine solution

Carbohydrate

Starch grains

Carbon dioxide

Respiration

Glucose

Water

Cellulose