Unit 9C Plants and photosynthesis

About the unit

In this unit pupils learn:
- about photosynthesis as the key process producing new plant biomass
- that the carbon dioxide for photosynthesis comes from the air and that the water is absorbed through the roots
- that chlorophyll enables a plant to utilise light in photosynthesis
- about the role of the leaf in photosynthesis
- about the importance of photosynthesis to humans and other animals

In scientific enquiry pupils:
- consider how knowledge about the gases in the air has led to development of ideas about photosynthesis
- interpret data and graphs using scientific knowledge and understanding
- investigate photosynthesis in pond weed, controlling relevant variables

This unit is expected to take approximately 7.5 hours.

Where the unit fits in

This unit builds on unit 7D 'Variation and classification' and unit 7C 'Environment and feeding relationships'.

It relates to unit 7I 'Energy resources', unit 8A 'Food and digestion', unit 8B 'Respiration', unit 8D 'Ecological relationships', unit 8F 'Compounds and mixtures', unit 9G 'Environmental chemistry' and unit 9H 'Using chemistry'.

It provides the foundation for unit 9D 'Plants for food' and for work in key stage 4 on limiting factors in photosynthesis, energy transfer through an ecosystem and the mineral requirements of plants.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: identify variables relevant to an investigation of photosynthesis and suggest how these might be controlled; make observations and measurements using an appropriate technique, and use measurements to produce a graph; explain patterns in graphs using scientific knowledge and understanding

some pupils will not have made so much progress and will: suggest how to control variables identified for them in an investigation of photosynthesis, making appropriate observations and measurements and producing a graph

some pupils will have progressed further and will: relate findings about the production of oxygen in photosynthesis to wider environmental issues, *eg seasonal changes*

in terms of life processes and living things

most pupils will: identify carbon dioxide from the air and water as the raw materials, and light as the energy source, for photosynthesis; explain photosynthesis as the source of biomass and represent photosynthesis by a word equation; describe how leaves are adapted for photosynthesis and how roots are adapted to take in water; distinguish between photosynthesis and respiration in plants

some pupils will not have made so much progress and will: identify carbon dioxide from the air and water as the raw materials for photosynthesis; recognise that plants take in water through their roots and that photosynthesis takes place in leaves

some pupils will have progressed further and will: describe how cells in the leaf and root are adapted for photosynthesis and for taking in water; represent photosynthesis as a symbol equation; describe the relationship between photosynthesis and respiration in plants

Prior learning

It is helpful if pupils:

- know how organisms are sorted into groups based on features in common
- can describe the basic structure of plants, *eg leaf, root, stem, flower*
- know the conditions that plants need to grow well
- know that green plants take in water through their roots and that the leaf plays a part in photosynthesis
- know that respiration releases carbon dioxide

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:

- carry out a test for starch in which a flammable liquid is heated
- plan and carry out an investigation into photosynthesis in pondweed

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for the activities, and consider what modifications are needed for individual classroom situations.

Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly:

- specialised words, *eg conifer, palisade cell, chlorophyll, biomass*
- words with similar but distinct meanings, *eg glucose and sugar*
- composite words, *eg photosynthesis, biomass*, and explore their meaning
- words and phrases relating to scientific enquiry, *eg anomalous results, annotation*

Through the activities pupils could:

- identify what information is needed and show this by using different texts as sources

Resources

Resources include:

- oxygen probe for datalogging
- secondary sources to explore economically important plant products
- organisms, including Elodea, de-starched flowering plants, plants with extensive root systems and a selection of leaves, including variegated leaves
- leaf templates
- photographs, video clips showing time-lapse photography
- prepared slides of roots with root hairs
- specimens or photographs of plants growing without soil, *eg hydroponic plants*
- slides and micrographs showing leaf structure
- a range of familiar plant products, *eg cotton fibre, rice, potatoes, wooden spills, corn oil*
- secondary sources to show variation of carbon dioxide concentration around leaves over a 24-hour period

Out-of-school learning

Pupils could:

- visit botanical gardens or local garden centres to explore the diversity of plant groups and habitats
- read about forest clearances and the consequent loss of biodiversity
- watch television programmes about plant life and gardening

1	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How do plants grow?				
	• that green plants do not absorb 'food' from the soil • that green plants use carbon dioxide and water to produce biomass • the meaning of the terms 'photosynthesis' and 'biomass' • to represent photosynthesis by a word equation	• Show pupils a range of photographs or video clips, including, if possible, time-lapse sequences, illustrating that new biomass is formed as plants grow and that they can grow to an enormous size. Ask pupils about the conditions needed for healthy plant growth and the role of the root and leaf in this. Ask them to suggest where the new material in plants comes from. Challenge ideas about the material coming from the soil, *eg show photographs or specimens of plants growing without soil*; *ask why the soil doesn't disappear from pots in which plants are growing*; *look at large fruits and vegetables such as marrow, pumpkin, cucumber*. • Establish that plants use carbon dioxide from the air and water taken in through the roots to make glucose, which is usually converted to starch for storage. Remind pupils of the formulae for carbon dioxide and water and show them how the equation for photosynthesis builds up. Introduce and explain the terms 'biomass' and 'photosynthesis'.	• identify the sources of raw materials in photosynthesis • explain the terms 'photosynthesis' and 'biomass' • provide some evidence that plants do not obtain biomass from the soil • construct the word equation for photosynthesis	• A common misconception is that plants obtain their food from the soil. It is worth establishing that this is not the case early on in the teaching sequence, and reinforcing this idea throughout the unit. • In key stage 2, pupils are likely to have explored the conditions needed for healthy plant growth, the role of the leaf and the functions of the root. Unit 7F 'Simple chemical reactions' introduces ideas about chemical reactions producing new materials. These are reinforced in unit 8E 'Atoms and elements', where pupils will have used symbols for elements and simple formulae.
	• that light is needed for photosynthesis • that the raw materials for photosynthesis are taken from the environment around the plant • to interpret and draw conclusions from data	• Remind pupils that plants need light as well as carbon dioxide and water in order to grow well. Establish with pupils that the chlorophyll in plants enables them to absorb light, which is necessary for photosynthesis. Provide them with secondary sources showing how the carbon dioxide and/or oxygen concentration around leaves varies over a 24-hour period. Ask them to find patterns in data and to relate these to night and day. Establish that the evidence supports photosynthesis taking place in the presence of daylight.	• identify that the carbon dioxide level is lower in daylight • explain this, *eg the leaves are using carbon dioxide during the day* • conclude that photosynthesis takes place when there is daylight	• At this stage, only a general understanding is required that more light results in more growth because there is more photosynthesis. • Extension: pupils could be asked to suggest further investigations to test their conclusions.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What is the role of the leaf in photosynthesis?			
• to test for the presence of starch in a leaf • to heat flammable liquid safely • that chlorophyll and light are necessary for photosynthesis	• Explain to pupils that the glucose formed is usually stored as starch and ask them about a test for starch. Demonstrate how this can be carried out on a leaf. • Provide pupils with a variety of leaves, *eg variegated leaves, leaves kept in the dark for a few days, leaves covered with cut-out templates, copper beech leaves,* so they can investigate starch distribution. • Discuss the results with pupils and ask them to explain their observations. Compile a summary of all the observations and establish that starch is stored in the green parts of leaves and those parts that have been exposed to light. Establish with pupils that the chlorophyll in plants enables them to absorb light, which is necessary for photosynthesis.	• detect the presence of starch in a photosynthesising leaf and relate it to the presence of chlorophyll • relate photosynthesis to exposure of the leaf to light, *eg etiolation*	• Pupils will have carried out a test for starch in unit 8B 'Respiration'. • Pupils may need to sketch the pattern of green and white/pink on a variegated leaf before testing it for starch, to be better able to correlate starch distribution with presence of chlorophyll. • Extension: some pupils could be asked to find out about the molecular structures of glucose, sucrose and starch and the relationship between them. They will have seen models and representations of large molecules in unit 8E 'Atoms and elements'. ⚠ **Safety** – emphasise the hazards of heating flammable liquids and show an appropriate way to heat ethanol, *eg using water from an electric kettle or a water bath*
• that oxygen is produced during photosynthesis • to decide how to measure the rate of photosynthesis • to control variables • to present results in tables and graphs, identifying anomalous results • about variation between leaves • that leaves are adapted to photosynthesise efficiently	• Extend this work by providing pupils with actively photosynthesising pondweed (Elodea) and with opportunities to discuss in groups how they could detect oxygen production. Help pupils to refine their suggestions and investigate how the release of oxygen from pondweed varies with light intensity, and to present their results as line graphs where appropriate. • Ask pupils to suggest what happens to the oxygen produced by water plants, if necessary reminding them about organisms that respire aerobically in a pond, including pondweed and aquatic plants. Help pupils to draw up a respiration and photosynthesis cycle for a pond.	• devise a way of measuring photosynthesis, *eg by timing the collection of a fixed volume of oxygen; by using an oxygen probe* • describe how the rate of production of oxygen varies with light intensity • produce appropriate graphs of their results and identify and explain any anomalous results • explain that oxygen released from photosynthesis is used by animals in respiration	• Pupils will have considered respiration in animals and plants in unit 8B 'Respiration'. • Changing oxygen concentration in water can be monitored using ICT. ⚠ **Safety** – if mains voltage lamps are used as light sources for pondweed, make sure they have been tested using a portable appliance tester. Remind pupils not to splash water onto the hot bulb. Pupils' plans must be checked for health and safety before practical work begins

3	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
	• how leaf cells close to the upper surface are adapted for photosynthesis	• Review pupils' knowledge of cell structure with quick questions. Provide them with microscope slides or secondary sources, *eg 35mm slides, photomicrographs,* so that they can see the internal structure of the leaf. Ask them to compare the leaf cells close to the upper surface with other cells and to suggest how they are adapted for photosynthesis, *eg comparing the darker upper surface of leaves with the lower surface.* • Discuss their ideas with them and establish the idea that the leaf is designed to absorb light efficiently in its habitat.	• describe differences between leaf cells, and explain that those close to the upper surface photosynthesise effectively, *eg are long and thin, have many chloroplasts*	• Pupils may need to be reminded how to use a microscope correctly and to avoid reflecting sunlight with a mirror, if this is the source of illumination. • There are 'cut-and-stick' leaf templates available showing cell types. • In unit 7D 'Variation and classification' pupils may have investigated the variation of leaf size in shady and sunny places. They could be reminded of this and asked to relate it to their understanding of photosynthesis.
	Checking progress			
	• to relate ideas about plant growth to evidence about gas exchange and to the cellular structure of the leaf • how ideas about plant growth have changed	• Help pupils to make a summary of the key points about photosynthesis. Provide them with information on earlier ideas about the growth of plants, *eg Van Helmont's conclusions about a willow tree's growth before carbon dioxide was known; the work of Joseph Priestley,* and, using the key points, discuss with them how knowledge about gases in the air and cells has helped to change ideas.	• identify key ideas and summarise them correctly • recognise that scientists draw conclusions from evidence in the light of what is currently known	• Information about Van Helmont's ideas can be found in texts and history of science resources.
	What happens to the glucose produced in leaves?			
	• that plants store starch • that new materials made from glucose produced during photosynthesis lead to an increase in biomass • that the glucose from photosynthesis provides energy for all living processes in the green plant • to identify what information is needed and use different texts as sources	• Remind pupils, *eg by showing them the word and/or symbol equations,* that the first product of photosynthesis is glucose and that some of this is used in plant respiration. Ask pupils about foods from plants that contain sugars and starches and, if appropriate, demonstrate, *eg using models, photographs,* how the structures of sugars and starches are related. • Present pupils with a range of familiar plant products, *eg cotton fibre, rice, potatoes, wooden spills, perfume, corn oil, textured vegetable protein (TVP), paper.* Ask what substances could be found in each, *eg cellulose, fats, proteins, starches, sugars.* Explain that these form a plant's biomass together with the glucose used in plant respiration. • Ask pupils to use secondary sources to investigate an economically important plant product or products, and present information on products from biomass as a poster, helping them to identify what is needed.	• identify photosynthesis as the source of biomass in plants • explain that glucose made in photosynthesis is used for respiration • describe all parts of the plant as deriving from the products of photosynthesis • select, compare and synthesise information from different texts	• Extension: there is an opportunity to investigate the social and environmental issues relating to the use of forest products and the consequences of logging in tropical and northern forests.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What is the role of the root in photosynthesis?			
• that roots are adapted to take in water and this is used in photosynthesis • that plants use water in many ways • that roots require oxygen for respiration • to make careful observations and record these in drawings • that plants need sources of nitrogen and other elements in the form of minerals • that mineral deficiency hinders plant growth	• Ask pupils to suggest reasons why plants need water taken in by roots. Provide pupils with plants with growing root systems, *eg garlic cloves suspended over water, water lettuce, cress seedlings*, or a video clip of growing roots. Discuss with pupils how the roots are adapted for taking in water. • Challenge pupils to explain why plants in flooded or waterlogged soil die despite easy access to water and minerals. • Ask pupils to examine roots with root hairs, *eg cress*, or secondary sources, *eg prepared slides, animations,* and to make their own annotated drawings showing how roots are adapted for their functions. • Show pupils four pieces of evidence of movement of materials in plants, *eg root hairs on germinating mung beans, celery sticks which have been soaked in a dye to show movement up xylem vessels, a transverse section through a stem showing vascular bundles, and a leaf*. Ask them to use the evidence to explain the movement of substances from the soil and through the plant, and to present their ideas diagrammatically. • Review earlier work on the production of biomass. Ask pupils why farmers put fertilisers on fields. Provide boxes of plant fertiliser for pupils to explore the ingredients listed, and ask them to use secondary sources to find out why plants need certain minerals, *eg nitrate and potassium,* for healthy growth.	• explain the functions of water in plants, *eg in photosynthesis, to transport minerals, to make the plant firm, for cell growth, to cool leaves, to form fruits* • describe how roots are adapted for taking in water, *eg by being spread out, being branched, having a large surface area, having root hairs* • describe how the root-hair cell is adapted for its function • explain that root cells need oxygen supplies in the soil for respiration • suggest how substances from the soil enter and move through the plant • recognise that plants need mineral salts for growth • relate a plant's need for nitrates to making protein and hence healthy growth	• At key stage 2 pupils are likely to have considered the role of the root in taking up water and in anchoring the plant in the soil. • Garlic cloves suspended from a pin over a test tube produce extensive roots in one to two weeks. • Mung beans provide a reliable source of easily observable root hairs. • Celery sticks work best if leaves are still attached. This also provides an opportunity to make clear the links between the vascular system in both stem and leaves. • Details of transport through plants are not required, but pupils could associate root hairs with absorption. • At this stage it is not necessary to discuss the specific plant requirements for a whole range of minerals. However, it is useful for pupils to know that nitrates are needed to make protein.
Why are green plants important in the environment?			
• that photosynthesis removes carbon dioxide from the air and produces oxygen • to consider issues of environmental protection from several perspectives • to compare the word equations for respiration and photosynthesis	• Ask pupils about the importance of maintaining the proportion of oxygen in the air, and provide them with secondary sources of information to show the extent of variation in this over long periods of time. Remind pupils of the reactions involved in respiration and photosynthesis. Ask why green plants are important to the environment and discuss the range of plants involved. Provide pupils with a case study about forest conservation and ask them to identify the advantages and disadvantages of cutting down forest from the perspectives of a range of people. Organise a debate or role play for discussion of the issues.	• describe how carbon dioxide and oxygen concentrations in the air have varied over time • explain how photosynthesis and respiration can help maintain the balance of gases in the air • identify the main sources of oxygen from photosynthesis • identify the advantages and disadvantages of forest conservation for a range of people and other living things	• The greenhouse effect and global warming are included in unit 9G 'Environmental chemistry'. It is important that pupils realise that carbon dioxide is not the only 'greenhouse gas' and that the evidence about global warming is complex.

5	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
	Reviewing work			
	• to relate ideas of photosynthesis to a particular organism	• Provide pupils with a large diagram/drawing of a tree and ask them to construct a flow chart around it showing: – that plants can use carbon dioxide and water to produce biomass – that light is needed for photosynthesis – the role of the leaf in photosynthesis and how it is adapted for its function – the role of the root in photosynthesis and how it is adapted for its function	• summarise the key ideas encountered in the unit	• It may be helpful for some pupils to have prepared phrases and sentences with which to annotate the diagram.