

O Level Biology (5090)

Unit 2: Plant Nutrition and Transport

Recommended Prior Knowledge

Unit 1 will supply students with valuable knowledge on the structure of plant cells as well as on diffusion, osmosis, and transport in the xylem. The basic structure of the starch and sugar molecules should be understood. Energy will have been mentioned with reference to active transport, but students should be aware that there are different forms of energy and that it can be transformed from one form to another.

Context

This Unit concentrates on the botanical relevance of topics covered in Unit 1 and forms a natural link with topics to be visited in several other Units, notably Units 3 and 7.

Outline

Photosynthesis, as the process responsible for the production of food for all living organisms, is explained. The basic biochemistry of the process as well as the conditions necessary for the process to occur, are considered. The structure and adaptation of a leaf and of leaf cells for photosynthesis are considered in some detail and reference is made to carbohydrate as the starting point for protein synthesis. A knowledge of leaf structure allows students then to investigate the process of transpiration. The Unit generates many opportunities for practical work, but for Centres operating in areas which experience marked seasonal change, some thought may have to be given to the best time for studying the Unit.

AO	Learning outcomes	Suggested activities and further guidance	Online resources	Other resources
4(a)	Understand that photosynthesis is the fundamental process by which plants manufacture carbohydrates from raw materials.	Explain that photosynthesis is a plant's method of nutrition. Only small molecules can be absorbed (by diffusion and osmosis) and these are used by the plant to build larg(er) molecules. Explain that energy is required to construct the larger molecules and is obtained as light energy. Some of this energy remains locked away (as chemical energy) in the molecules of carbohydrate produced.	Photosynthesis diagrams and explanations covering several learning outcomes in this unit: http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/plants/plants1.shtml http://www.s-cool.co.uk/gcse/biology/photosynthesis/photosynthesis.html	Textbooks M. & G. Jones – 5 How Green Plants Feed Mary Jones – Unit 4 Photosynthesis Ian J. Burton – Topic 6 Plant Nutrition

4(b)	Investigate the necessity for chlorophyll, light and carbon dioxide for photosynthesis, using appropriate controls.	<ul style="list-style-type: none"> - For chlorophyll, students should use a plant with variegated leaves e.g. variegated <i>Pelargonium</i>. Any locally available variegated leaf will suffice, however trial the experiment first to check that it stores starch, not sugar (common in monocot plants). - For light, use aluminium foil or black paper held either side of a leaf using paperclips. - For CO₂, place the plant under a bell jar, or similar, containing a beaker of concentrated sodium hydroxide solution to absorb CO₂. This may be more suited to a whole-class demonstration. <p>Include in all cases the importance of starting with a de-starched plant.</p> <p>Explain the importance of controls in scientific practice and invite students to list the variables which must be controlled during the above investigations. Stress the importance of keeping all variables constant other than the one being investigated.</p> <p>It is advisable to demonstrate the steps of the starch test on a leaf before allowing students to carry it out. If a naked flame is used for heating stress the danger of using flammable liquid and the need for safety precautions.</p>	<p>Practical to investigate the factors affecting photosynthesis: http://www.practicalbiology.org/areas/introductory/energy/photosynthesis/identifying-the-conditions-needed-for-photosynthesis,74,EXP.html</p> <p>Animation showing starch test procedure: http://www.footprints-science.co.uk/starch.htm</p>	
4(c)	State the equation (in words or symbols) for photosynthesis.	An equation in words is adequate, however if given an equation in symbols must balance. In both cases, 'light energy' rather than just 'energy' should be specified.		

4(d)	Investigate and state the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plants).	<p>Students may first be shown a water plant evolving bubbles of oxygen as it photosynthesises in bright light. Then invite students to suggest how they might investigate the effect of varying light intensity, temperature and carbon dioxide. If available the aquatic plant <i>Cabomba</i> is a reliable alternative to the commonly used <i>Elodea</i>. A leaf of the plant may also be viewed under the microscope to show the presence of chloroplasts.</p> <p>All experiments here are modifications of that in which a water plant is submerged in a container of water. The rate of photosynthesis is determined by measuring volumes or counting bubbles of O₂ released as the plant is exposed to one altered variable.</p>	<p>Practical to investigate the effect of light on photosynthesis in an aquatic plant: http://www.practicalbiology.org/a-reas/intermediate/energy/photosynthesis/investigating-factors-affecting-the-rate-of-photosynthesis.45.EXP.html</p> <p><i>Elodea</i> investigation apparatus and effect of factors: http://vle.northlearner.net/bedale_vle/file.php/22/Photosynthesis/limit.htm</p> <p>Interactive activity: http://www.kscience.co.uk/animations/photolab.htm</p>	
4(e)	Understand the concept of limiting factors in photosynthesis.	<p>The required factor which is in the shortest supply limits the rate at which a plant will photosynthesise. Show by a simple graph that the rate of photosynthesis levels off with increased availability of CO₂ or light. Invite students to suggest an explanation for this and to predict what might happen if the availability of the limiting factor is increased.</p> <p>Plot the results of the previous experiment from 4(d) to show how light acts as a limiting factor. Plot rate of reaction (bubbles O₂ released per minute) against light intensity (equal to 1/d² where d is the distance from the light source to the plant).</p>	See online resources listed against 4(a).	

4(f)	Describe the intake of carbon dioxide and water by plants.	<p>Carbon dioxide from the atmosphere and water from the soil are small molecules which are used to construct the larger glucose molecules formed during photosynthesis.</p> <p>Explain the entry of carbon dioxide through pores (stomata) in the leaf surface by diffusion and its subsequent diffusion through spaces between mesophyll cells. CO₂ then dissolves before entering the cells and diffusing into chloroplasts.</p>	See 4(i) below for resources to demonstrate action of guard cells and stomata. Resources to demonstrate diffusion are referenced in Unit 1.	
4(g)	Understand that chlorophyll traps light energy and converts it to chemical energy for the formation of carbohydrates and their subsequent storage.	<p>Chlorophyll absorbs the light energy and thus photosynthesis occurs where chlorophyll is located – in the chloroplasts. No details of light-dependent and independent reactions are required.</p> <p>Glucose manufactured by photosynthesis may be converted to starch and stored in the chloroplasts and/or converted to sucrose to be conducted to other organs (via phloem) for storage as sucrose or as starch. Invite students to suggest examples of such storage organs.</p> <p>Prepare a temporary slide using a thin scraping of potato tissue stained with iodine solution to show the presence of starch grains. Explain the storage of carbohydrate in the form of insoluble starch in terms of the osmotic balance of cells.</p>	<p>Uses of glucose made in photosynthesis: http://lgfl.skool.co.uk/content/keystage3/biology/pc/learningsteps/USGLC/launch.html</p> <p>Photomicrograph of starch grains: http://www.microscopy-uk.org.uk/mag/imgoct09/fig5.jpg</p>	
4(h)	Explain why most forms of life are completely dependent on photosynthesis.	Explain that the carbohydrates (and the proteins subsequently produced – see 4(j)) are important components of their own diets manufactured by plants. Fats and oils are also manufactured by plants. Students may be able to name common examples. Explain that humans require O ₂ to respire and that they breath out CO ₂ – the exact reverse of photosynthesis.		

<p>4(i)</p>	<p>Identify and label the cuticle, cellular and tissue structure of a dicotyledonous leaf, as seen in a cross-section under a microscope, and describe the significance of these features in terms of function, i.e.</p> <p>distribution of chloroplasts – photosynthesis;</p> <p>stomata and mesophyll cells - gas exchange;</p> <p>vascular bundles - transport.</p>	<p>Using a projected photomicrograph or TS diagram of a leaf and identify the main tissues - explaining the role of each part in photosynthesis.</p> <p>Supply students with a large, clear, unlabelled drawing of a leaf TS and, using the above resource, ask them to label their diagrams. Include labels for xylem and phloem (see Unit 3) as well as for vascular bundle and describe the functions of the two separate tissues.</p> <p>Explain the control of stoma size by water pressure within guard cells. Demonstrate the opening and closing of stomata by using two balloons to represent guard cells. Affixing a band of adhesive tape along one edge of each balloon prior to their inflation models the change in cell shape on becoming turgid.</p>	<p>Photomicrograph of leaf TS: http://images.botany.org/set-13/13-063v.jpg</p> <p>Leaf TS diagram (labelled): http://www.bbc.co.uk/schools/gcsebitesize/science/images/bi05004.gif</p> <p>Leaf TS diagram (unlabelled) http://www.ellenjmchenry.com/sitebuildercontent/sitebuilderpictures/leafXsectioncoloringpage.jpg</p> <p>Video clip of guard cells opening and closing stomata: http://www.youtube.com/watch?v=cFX4JrsPaUs</p>	<p>Bioscope CD TS leaves of <i>Erica</i> and privet</p>
<p>4(j)</p>	<p>Understand the effect of a lack of nitrate and magnesium ions on plant growth.</p>	<p>Carbohydrate manufactured by photosynthesis is the molecule which acts as the starting point for building other organic molecules. Plants must absorb ions from the soil in order to make these molecules. Magnesium is necessary for chlorophyll manufacture and nitrates for protein manufacture. Without magnesium a plant cannot photosynthesise and without proteins it cannot grow.</p> <p>Use live specimens and/or photographs to demonstrate plants grown under these deficiencies alongside a control which does not lack the ions.</p>	<p>Uses of glucose made in photosynthesis: http://lgfl.skool.co.uk/content/keystage3/biology/pc/learningsteps/USGLC/launch.html</p> <p>Magnesium deficiency: http://pgsgrow.com/blog/wp-content/uploads/2009/10/problems-with-acidic-soil0.jpg</p>	

6(a)	<p>Relate structure and functions of root hair cells to their surface area and to water and ion uptake.</p>	<p>The importance of surface area, in particular of root hair cells for the uptake of water and ions, has been covered in Unit 1. Learning outcomes 4(f) and 4(j) above have also referred to their uptake. This learning outcome provides an opportunity for these facts previously taught to be consolidated.</p>	<p>Root hair diagrams and photographs: http://www.biologie.uni-hamburg.de/b-online/e05/05b.htm</p> <p>Uptake by root hairs: http://lgfl.skool.co.uk/viewdetails_ks3.aspx?id=572</p>	<p>Textbooks Mary Jones – Unit 7 Transport in Flowering Plants</p> <p>M. & G. Jones – 7 Transport</p> <p>Ian J. Burton Topic 8 Transport in Flowering Plants</p>
6(b)	<p>State that transpiration is the loss of water vapour from the leaves through the stomata.</p>	<p>Ensure that students do not think that transpiration is the loss of water from the leaf surface, but that they realise that evaporation has occurred first from moist surfaces of mesophyll cells within the leaf and that water vapour then diffuses through the leaf spaces and out into the atmosphere down a concentration gradient. Ensure also that there is no confusion between guard cell and stoma(ta).</p>	<p>Basic transpiration animation: http://extension.oregonstate.edu/mg/botany/images/tree1.html</p> <p>Detailed transpiration animation: http://www.kscience.co.uk/animations/transpiration.swf</p>	
6(c)	<p>Describe:</p> <p>how water vapour loss is related to cell surfaces, air spaces and stomata;</p> <p>the effects of air currents (wind), and the variation of temperature, humidity and light intensity on transpiration rate;</p> <p>how wilting occurs.</p>	<p>Explain that those conditions which speed up or slow down the evaporation of water also speed up or slow down the rate of transpiration. Increased light intensity speeds up transpiration by virtue of the fact that it opens up the stomata to their fullest extent.</p> <p>A potometer provides good visual support to this section, however difficulty may be experienced in altering any of the variables required. Graphs may be drawn to show the effect of each factor on the rate of water loss/uptake.</p> <p>Explain that water lost from a plant must be replaced from the soil. If the rate of water loss exceeds its rate of uptake the plant will wilt (not 'wither'). Describe and invite students to explain the appearance of a wilted plant.</p>	<p>Use of a potometer: http://www.biologydaily.com/biology/Potometer</p> <p>Potometer interactive activity: http://www.sycd.co.uk/can_we_should_we/explore/plants/potometer-applet.html</p>	

6(d)	Investigate, using a suitable stain, the pathway of water in a cut stem.	Students will know that water travels in the xylem. This learning activity will demonstrate the distribution of xylem tissue in a chosen stem. Though not a stem, a 'stick' of celery is a suitable material for this demonstration, however any plant with a relatively colourless and fleshy stem is likely to be satisfactory. Students should cut the stem cleanly and place the cut end in a solution of a suitable stain (food dye is inexpensive and works well). Results can often be seen in 10 to 15 minutes when a further section is taken from the stem at a position just above the level of the solution. Students may then make a labelled drawing of their observations. The activity may be extended to compare and explain the rate of movement in a leafy and non-leafy stem.	Movement of dye through xylem of celery activity: http://www.york.ac.uk/res/sots/activities/celery.htm	
6(e)	Explain the movement of water through the stem in terms of transpiration pull.	Explain that the evaporation of water from mesophyll cells increases the concentration in the sap vacuole of those cells. Osmosis then draws more water up the xylem to replace the water lost. Dissolved in that water are ions which have been absorbed by the root hairs.	Refer to 6(b) above for resources illustrating the movement of water during the transpiration stream.	
6(f)	Identify the positions of xylem and phloem tissues as seen in transverse sections of unthickened, herbaceous, dicotyledonous roots, stems and leaves.	Use projected photomicrographs then diagrams to demonstrate the position and appearance of xylem and phloem in roots and stems (leaves have already been considered in 4(i) above). Use a transparency to project labelled diagrams of the position of the xylem and phloem in roots and stems. Supply students with blank copies of the diagrams to label.		Bioscope CD TS and LS of <i>Ranunculus</i> stem and root
6(g)	State the functions of xylem and phloem.	Annotate the diagrams from 6(f) above to indicate that phloem conducts SUCROSE (not glucose) and amino acids in solution and the xylem carries water and ions (dissolved salts).		