

**UNIT 3: Plant Nutrition and Transport**

**Recommended Prior Knowledge** Students should have a basic knowledge of carbohydrates and proteins and their uses within the body, the structure of a plant cell, and the process of osmosis, all of which were dealt with in Units 1 and 2. They should have an understanding of energy transfers from one form to another.

**Context** This Unit builds on ideas from Units 1 and 2. Concepts from this Unit will be revisited in Units 9 and 10.

**Outline** This Unit covers most of the plant physiology topics. There is a considerable range of practical work that can be carried out, much of which can be used to develop or to assess practical skills. Teachers working in countries where there are marked seasons will need to take this into consideration when planning the timing of this Unit.

The Unit begins by looking at the way in which plants manufacture organic substances using sunlight and inorganic molecules as their raw materials.

Candidates studying the supplement should look more deeply into how environmental factors affect the rate of photosynthesis, and how these factors can be controlled in glasshouse cultivation.

Knowledge of cell structure that was covered in Unit 1, is extended to look more fully at the structure and function of cells and tissues in a leaf. The idea of adaptation of structure to function should be reinforced when studying the leaf structure.

The movement of water from soil to air in xylem, and of organic products of photosynthesis in phloem, is considered.

Candidates studying the supplement should be introduced to examples of adaptations of plants to living in extreme conditions such as deserts, tropical rainforests and tundra.

Some wider issues relating to this Unit, such as the position of plants as producers in an ecosystem, and problems associated with the use of fertilisers and pesticides, will be considered in Unit 10.

	Learning Outcomes	Suggested Teaching Activities	Resources
II 6.2.1	Plant Nutrition. Photosynthesis <ul style="list-style-type: none"> <li>Define <i>photosynthesis</i> as the fundamental process by which plants manufacture carbohydrates from raw materials using energy from light.</li> <li>State the word equation for photosynthesis for the production of simple sugars and oxygen</li> </ul>	Plants can be considered as 'food factories', in which all the food in the world is initially made. Students should compare the needs of animals for organic nutrients, Unit 2, with those of plants, which only require inorganic compounds such as carbon dioxide and water for photosynthesis. Consumers compared with producers, this is a cross link with Unit 10. The initial products of photosynthesis are sugars (such as glucose) which can be converted to large, insoluble molecules such as starch for storage within the plant. Reference to fertilisers and agriculture in Unit 10.	<a href="http://www.associatedcontent.com/article/33148/rate_of_photosynthesis_in_elodea_underwater.html?cat=58">http://www.associatedcontent.com/article/33148/rate_of_photosynthesis_in_elodea_underwater.html?cat=58</a>  <a href="http://www-saps.plantsci.cam.ac.uk/articles/broad_light.htm">http://www-saps.plantsci.cam.ac.uk/articles/broad_light.htm</a>  <a href="http://www.aquaguide.net/page-63.html">http://www.aquaguide.net/page-63.html</a>

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II 6.2.1	<ul style="list-style-type: none"> <li>Investigate the necessity for chlorophyll, light and carbon dioxide for photosynthesis, using appropriate controls</li> <li>Describe the intake of carbon dioxide and water by plants.</li> <li>Explain that chlorophyll traps light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent storage</li> </ul>	<p>The process of photosynthesis should be considered at a fairly basic level, the light-dependent and light-independent stages should not be introduced.</p> <p>The important point to get across is the conversion of light energy to chemical energy. Chlorophyll absorbs light energy and enables it to be used to drive the reactions. (Ensure that students do not think that chlorophyll attracts light!)</p> <p>There is a wide variety of practical work that can be carried out. Students should know how to test a leaf for starch, and to carry out simple experiments into the need for light and chlorophyll for photosynthesis.</p> <p>The importance of controlled variables such as temperature can be introduced.</p> <p>The concentration of carbon dioxide can be changed using sodium hydrogencarbonate solution of different concentrations.</p> <p>The exchange of gases can be more easily understood when the structure of the leaf has been studied: II 6.2.2</p>	<p>Simple photosynthesis experiments</p> <p>Investigating the behaviour of leaf discs  <a href="http://www-saps.plantsci.cam.ac.uk/worksh eets/activ/prac5.htm">http://www-saps.plantsci.cam.ac.uk/worksh eets/activ/prac5.htm</a>          Instructions for a slightly different way of investigating the production of starch during photosynthesis, using leaf discs.</p> <p><a href="http://pascophysics.com/file_downloads/experiments/pdf-files/glx/biology/06-Photosynthesis-SV.pdf">http://pascophysics.com/file_downloads/experiments/pdf-files/glx/biology/06-Photosynthesis-SV.pdf</a></p> <p><a href="http://www.ucmp.berkeley.edu/greenalgae/greenalgae.html">http://www.ucmp.berkeley.edu/greenalgae/greenalgae.html</a></p>

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II 6.2.1	<p>Supplement.</p> <ul style="list-style-type: none"> <li>State the balanced equation for photosynthesis in symbols</li> </ul> $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ <ul style="list-style-type: none"> <li>Investigate and state the effect of varying           <ul style="list-style-type: none"> <li>light intensity</li> <li>carbon dioxide concentration</li> <li>temperature on the rate of photosynthesis (e.g. in submerged aquatic plants)</li> </ul> </li> <li>Define the term <i>limiting factor</i> as something present in the environment in such short supply that it restricts life processes</li> <li>Explain the concept of limiting factors in photosynthesis</li> <li>Explain the use of           <ul style="list-style-type: none"> <li>carbon dioxide enrichment</li> <li>optimum light</li> <li>optimum temperatures in glasshouse systems</li> </ul> </li> </ul>	<p>Investigations with Elodea (Canadian pondweed) can produce good quantitative data to illustrate the effect of light on the rate of photosynthesis. Light can be the limiting factor. Temperature could also be considered as a limiting factor but this is not so easy to carry out in the school lab. The concentration of carbon dioxide can be varied by adding sodium hydrogencarbonate to the water. Graphs of processed data can be used in class discussions on limiting factors.</p> <p>Strawberries, raspberries, rhubarb and cucumbers are all grown in glasshouses / under plastic covers where the carbon dioxide content can be increased and the temperature kept warm for maximum photosynthesis.</p>	<p><a href="http://botany.si.edu/projects/algae/classification/CHLOROPHYTA.htm">http://botany.si.edu/projects/algae/classification/CHLOROPHYTA.htm</a></p>

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<b>II</b> <b>6.2.2</b>	<p>Leaf Structure</p> <ul style="list-style-type: none"> <li>Identify and label the cuticle, cellular and tissue structure of a dicotyledonous leaf, as seen in cross-section under the light microscope, and describe the significance of these features in terms of functions to include:</li> <li>distribution of chloroplasts - photosynthesis</li> <li>stomata and mesophyll cells - gas exchange</li> <li>vascular bundles (xylem and phloem) - transport and support</li> </ul>	<p>Before considering the appearance of a section through a leaf, students should look at entire leaves and consider how they are adapted for photosynthesis. A section through a leaf can be shown on power point or from a model of a leaf. A simplified, labelled diagram should be made of a leaf section and the different parts are discussed.</p> <p>Students should be familiar with the structure of a palisade cell, and they can discuss how it is specialised for photosynthesis.</p> <p>The role of the upper epidermis that allows the maximum sunlight to reach the palisade layers should be mentioned.</p> <p>It can be helpful to think of a leaf as an organ that</p> <ul style="list-style-type: none"> <li>takes in the raw inorganic materials,</li> <li>uses light energy to convert the materials into chemical energy producing organic products and their removal for distribution throughout the plant.</li> </ul> <p>Drawings of leaves, and comparisons between two or more different kinds of leaves, make good practice or assessment material for the practical skills of observation and recording, and also for magnification calculations. (Unit 1. II 3)</p> <p>It is probably best not to go into any detail at this point about xylem and phloem function; they will be dealt with a little in 7.1.</p>	<p>Photomicrograph of Eleagnus leaf TS with vascular bundle</p> <p><a href="http://images.botany.org/set-13/13-063v.jpg">http://images.botany.org/set-13/13-063v.jpg</a></p>

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II 6.2.3	<p>Mineral requirements</p> <ul style="list-style-type: none"> <li>Describe the importance of: nitrate ions for protein synthesis magnesium ions for chlorophyll synthesis.</li> <li>Describe the uses and the dangers of the overuse of nitrogen fertilisers</li> </ul> <p>Supplement.</p> <ul style="list-style-type: none"> <li>Explain the effects of nitrate ion and magnesium ion deficiency on plant growth</li> </ul>	<p>Students should be reminded that carbohydrates contain carbon, hydrogen and oxygen only; plants can therefore make these from carbon dioxide and water. However, proteins also contain nitrogen, so a nitrogen source is necessary before some of the carbohydrate can be converted to protein. Nitrate ions from the soil are the main source of nitrogen for plants. For candidates studying the supplement a link can be made to the uptake of ions by root hairs II,4.2</p> <p>It may be best not to study the use of nitrogen fertilisers here, but rather to cover this fully in Unit 10 IV.5.1.</p> <p>This should be dealt with simply, considering the effects on a growing plant of a shortage of proteins or chlorophyll.</p> <p>A comparison can be made when plants are grown in culture solutions lacking magnesium, nitrates and a control. After a few weeks the growth of each plant can be compared.</p>	

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II 7.1	<p>Transportation Transport in plants</p> <ul style="list-style-type: none"> <li>State the functions of xylem and phloem</li> <li>Identify the positions of xylem and phloem tissues as seen in transverse sections of un-thickened, herbaceous, dicotyledonous roots, stems and leaves.</li> </ul>	<p>Root hair cells may already have been covered in Unit 1 II.2 as an example of a specialised cell, here root hair cells are dealt with in the context of the whole plant.</p> <p>Osmosis may need to be revised, before discussing the uptake of water through the soil, across the root, and up through xylem vessels and into the leaves.</p> <p>It should be emphasised that mineral ions enter the roots dissolved in water.</p> <p>Xylem vessels may have been discussed in Unit 1, II.2 and Unit 2, II.6.2.2. Here xylem vessels are considered in the context of water transport from root to leaves.</p> <p>The structure of xylem vessels should be simply covered stating that the vessels are made of a long column of dead, empty cells with lignified walls, stacked end to end. Xylem vessels provide support to the plant.</p>	
II 7.1.1	<p>Water uptake</p> <ul style="list-style-type: none"> <li>Identify root hair cells, as seen under the light microscope, and state their functions</li> <li>State the pathway taken by water through               <ul style="list-style-type: none"> <li>root</li> <li>stem</li> <li>leaf</li> </ul> </li> <li>(root hair, root cortex, xylem, mesophyll cells)</li> <li>Investigate, using a suitable stain, the pathway of water through the above-ground parts of a plant.</li> </ul>	<p>Students will find the path taken by the water easier to understand if they have some knowledge of the position of the vascular bundles in the plant. Simple diagrams can be made of a TS of a root and of a stem, showing the position of the xylem and phloem.</p> <p>Large and semi-transparent stems, such as the leaf petioles of celery, can be placed with their bases in a solution of a water-soluble dye (ink or food colouring). After a few days, the dye can be seen in the xylem vessels, spreading out into the veins in the leaves. If thin sections are cut, the positions of the xylem vessels show up clearly.</p>	

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II 7.1.1	Supplement <ul style="list-style-type: none"> <li>Relate the structure and functions of root hairs to their surface area and to water and ion uptake</li> </ul>	The structure of the root hairs can be compared with those of the villi and alveoli in their adaptation to their function of diffusion. Unit 2, 6.3.6 and Unit 4, 8.	
II 7.1.2	Transpiration <ul style="list-style-type: none"> <li>Define <i>transpiration</i> as evaporation of water at the surfaces of the mesophyll cells followed by loss of water vapour from plant leaves, through the stomata</li> <li>Describe how water vapour loss is related to.               <ul style="list-style-type: none"> <li>cell surfaces,</li> <li>air spaces and</li> <li>stomata</li> </ul> </li> <li>Describe the effects of variation of:               <ul style="list-style-type: none"> <li>temperature</li> <li>humidity</li> <li>light intensity on respiration rate</li> </ul> </li> </ul>	<p>It is important to understand that transpiration involves the loss of water vapour from the underside of the leaf, mostly through open stomata.</p> <p>Water in the cell walls of mesophyll cells evaporates, and diffuses through the air spaces and out of the leaf.</p> <p>The effect of transpiration in pulling water up xylem vessels can be compared to the effect of sucking a liquid up a straw.</p> <p>Experiments using potometers not only help students to understand the effects of environmental factors on the rate of transpiration, but also provide good opportunities to improve, or to be assessed on, all four experimental skills.</p> <p>It is important, however, that it is understood that a potometer measures water uptake, which is not absolutely the same as water loss.</p> <p>There is no need for elaborate potometers, a long piece of capillary tubing with a length of rubber tubing at one end into which the cut end of a shoot is pushed is effective. All the apparatus and cut twigs should be kept under water while assembling the apparatus, to avoid air locks.</p> <p>Laurel or ash leaves work well. The experiments can be extended by removing one leaf from the branch and recording the reduced water uptake. This is repeated until no leaves remain. A graph showing a reduction in water loss (uptake by the potometer) with fewer leaves illustrates the effect of the number of leaves on the transpiration process.</p> <p>Transpiration can also be investigated by using a hair dryer to vary the humidity.</p>	Good descriptions of plant adaptations for survival in hot, dry regions. <a href="http://www2.vernier.com/sample_labs/BWV-10-COMP-transpiration.pdf">http://www2.vernier.com/sample_labs/BWV-10-COMP-transpiration.pdf</a> <a href="http://www.biologyjunction.com/lab_9_transpiration.htm">http://www.biologyjunction.com/lab_9_transpiration.htm</a>

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II 7.1.2	<p>Describe how wilting occurs</p> <p>. Supplement</p> <ul style="list-style-type: none"> <li>Explain the mechanism of water uptake and movement in terms of transpiration producing a tension (pull) from above, creating a water potential gradient in the xylem, drawing cohesive water molecules up the plant</li> <li>Discuss the adaptations of the <ul style="list-style-type: none"> <li>leaf</li> <li>stem</li> <li>root</li> </ul> </li> </ul> <p>to three contrasting environments, to include</p> <ul style="list-style-type: none"> <li>pond</li> <li>garden</li> <li>desert</li> </ul> <ul style="list-style-type: none"> <li>with emphasis on local examples (where appropriate) and the factors described in the core.</li> </ul>	<p>Wilting is a good way for a plant to avoid further water loss, by reducing the leaf area from which evaporation can occur. The concept of turgor can be mentioned as the leaf cells wilt and become flaccid.</p> <p>Candidates will probably already have met the term 'water potential', in Unit 1 (section II.4). In normal conditions, the water potential in the air is lower than that in the soil solution. Thus water moves down a water potential gradient as it moves from soil to air, through the plant. If students are shown a wilting plant, they can think about why it is only the leaves that wilt. This can introduce the idea of xylem vessels, present in vascular bundles in leaves and stem, helping with support.</p> <p>Although students should look at examples of plant adaptations using plants that grow locally, it is also very useful to think about plants that grow in especially wet or dry environments, such as rain forest or desert.</p>	<p>Desert plant survival  <a href="http://www.desertusa.com/du_plantsurv.html">http://www.desertusa.com/du_plantsurv.html</a></p>



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II 7.1.3	<p>Translocation.</p> <ul style="list-style-type: none"> <li>Define <i>translocation</i> in terms of the movement of sucrose and amino acids in phloem</li> <li>from regions of production</li> <li>to regions of storage OR to regions of utilisation in respiration or growth</li> </ul>	<p>This idea will probably already have been met earlier in this Unit, when discussing the functions of leaves. Here it should be re-emphasised that carbohydrates are transported through a plant in the form of soluble carbohydrates such as sucrose, glucose and proteins as amino acids through the phloem tubes. No detail of phloem structure or function is required. It should be made clear that substances can be transported in any direction in phloem, for example from photosynthesising leaves down to roots for storage or upwards to growing buds, flowers, leaves and fruits for respiration and growth. Translocation also occurs from storage organs such as the root tubers to all parts of the plant.</p> <p>Consideration of the effects of 'ringing' a tree can help students to bring together their knowledge of stem structure and function. Ringing removes the phloem, which is near to the surface of a stem. If the ring is cut below the leaves, then all the cells beneath the ring are deprived of products of photosynthesis from the leaves, and eventually die.</p> <p>Grey squirrels and other small mammals gnaw the bark and destroy the phloem that is in the inner bark region.</p> <p>This section can be explained by drawing a coloured flow diagram to indicate the movement of the solutes to and from different parts of a plant.</p>	

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II 7.1.3	<p>Supplement</p> <ul style="list-style-type: none"> <li>Describe translocation throughout the plant of applied chemicals, including systemic pesticides</li> <li>Compare the role of transpiration and translocation in the transport of materials from sources to sinks, within plants at different seasons.</li> </ul>	<p>Students should understand that systemic pesticides are sprayed onto the leaves of the plant, and then absorbed by it through the cuticle or stomata and into the phloem tubes. They move through the plant in the phloem (translocation) and are taken in by any insect eating the plant or sucking up phloem sap. The disadvantages of systemic pesticides can be discussed in Unit 9 IV.2 as they may accumulate in the food chain.</p> <p>The students need to understand the term 'source' as where the substance is produced or enters the plant. sucrose is produced in the leaves nitrates are absorbed by the root hairs.</p> <p>The term 'sink' refers to the part of the plant where the substrate can be stored. starch in roots or stem amino acids in the root tips.</p> <p>Transpiration is important in relocating substances dissolved in water, cell sap such as amino acids.</p> <p>Students studying the supplement may discuss the role of water in the production of carbohydrates during photosynthesis and their subsequent translocation throughout the plant.</p>	