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**Knowledge Rich Curriculum Plan**

GCE Biology- Unit 3.5A Photosynthesis and Respiration



| **Lesson/Learning Sequence** | **Intended Knowledge:**  *Students will know that…* | **Prior Knowledge:**  *In order to know this, students need to already know that…* | **Tiered Vocabulary and Reading Activity** |
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| **Lesson 1:**  **Activating prior knowledge from Y12 topic B2** | Students will know that chloroplasts have complex structures that can be labelled with key language (stroma/lamellae/thylakoids/grana). They know that chlorophyll is one of many pigments that have the capacity to absorb light energy. They will know that different wavelengths of light are absorbed by different pigments.  Students will know how to interpret graphs representing absorption of different wavelengths of light. The data will enable them conclude that many plants are green based on the wavelengths of light that are absorbed by the photosynthetic pigments in a plant. | Students need to already know that photosynthesis is an endothermic reaction that requires energy from light. They will know how to label a diagram of a chloroplast with the terms grana/lamellae/thylakoid/ stroma). They will need to recall the ideas about the electromagnetic spectrum and where visible light is positioned. They will need to recall ideas about scale including nanometres to describe typical wavelengths for visible light.  Students need to already know how to interpret graphs by using the labels on axes. They will know how to describe relationships between variables based on irregular shaped curves. | *Stroma*  *Lamellae*  *Thylakoid*  *Grana*  *Intermembrane space*  *Pigment*  *Chlorophyll*  *Xanthophyll*  *Rhodopsin*  *wavelength* |
| **Lesson 2&3:**  **Required Practical: pigments in plants** | Students will know that risk assessments must be carried out when working with chemicals. They will know how to handle flammable chemicals according to recognised standards and consult CLEAPPS cards in the lab for guidance. They will know that chromatography principles apply when working with photosynthetic pigments. They will be able to calculate the Rf values for any pigments that are identified on their chromatograms.  Students will know how follow the instructions written on their student sheet and work independently to complete the RP procedure. They will be able to use their chromatogram to determine the Rf values for pigments that are separated. Data collected will be processed to enable students to infer the identity of pigments that have been separated. | Students need to already know that chromatography works by separating chemicals based on their size / charge/ affinity for the gel being used. The smaller molecules will travel the furthest on a chromatogram.  Students need to already know how to use pencil to mark the start position on a chromatogram and that pencil is insoluble in the solvents and therefore cannot interfere with the results being collected. They will need to be aware of the fact that the process must be stopped before the solvent front reaches the end of the gel because the results would be rendered void. | *Rf value*  *Chromatogram*  *TLC*  *Pigment*  *Mobile phase*  *Stationary phase* |

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| **Lesson 4:**  **Limiting Factors** | Students will know that Students will know that at 10oC enzymes are inactive; at above 45oC enzymes are denatured and stoma close. The optimum CO2 conc is 0.4%. Too much water causes soil to be waterlogged and this means too little Mg is absorbed and therefore chlorophyll cannot be produced i.e. plants die. The unit for light intensity is micromoles per m2 per sec. They will know that control experiments that have negative control demonstrate that the DV has no effect e.g., a plant in the dark cannot photosynthesise therefore dark is the control experiment.  Students will know how to annotate graphs representing rate of reaction to show saturation point and limiting factors. | Students need to already know CO2 in the atmosphere is 0.04%. Optimum is there 'best'. Agriculture is the correct word for farming. They will know that a limiting factor is a variable that can affect the rate of photosynthesis. Examples from GCSE are CO2, H2O, light intensity and temperature. They will know that the flat part of a graph is not describing stopped reactions but rather represents increase in rate.  Students need to already know how annotate a graph showing changes in rate of reaction to show where rate is increasing and where rate does not increase further. | *Saturation point*  *Rate*  *Intensity*  *Wavelength*  *Nanometre*  *Absorption*  *Spectrum*  *Concentration* |
| **Lesson 5:**  **Plants store energy in chemicals** | Students will know that energy is conserved in reactions. Plants transform light energy into chemical energy and this is used in active transport, DNA replication, cell division and protein synthesis. Plants are known as photoautotrophs because they make their own food. Photosynthesis is known as a metabolic pathway because it actually a series of smaller changes that are each controlled by enzymes. NADP is a coenzyme that transfers H group from one molecule to another. NADP can reduce a molecule by adding H or oxide a molecule by removing H. (If H moves, so does an electron) Reduced NADP is called NADPH. OIL RIG is the memory trick for oxidation and reduction.  Students will know how ATP and ADP are related; similarly, how NADP and NADPH are related. They will know how to explain the two different stages in photosynthesis as LDR and LIR. They will link their stages to the locations in a chlorophyllide LDR in thylakoids and LIP in stroma | Students need to already know the structure of ATP, that phosphorylation is a reaction where phosphate groups are added to molecules. ATP is an immediate source of energy in cells. It is small so it diffuses easily. ATP is NOT energy but it stores energy and is recycled between ADP and then ATP. They will recall that a coenzyme aids the function of enzymes by transferring a chemical group from one molecule to another. (topic 3.1)  Students need to already know how to connect life processes to photosynthesis. Locate places within chloroplasts where different processes occur. | *Photoautotroph*  *Metabolic pathway*  *Coenzyme*  *NAD*  *FAD* |
| **Lesson 6:**  **Light Dependant Reaction** | Students will know that the first stage in the process is known as the Light-dependent reaction given that there is a requirement for chlorophyll to absorb light energy to drive the chemical changes involved. Two types of reaction are involved: non-cyclic and cyclic-photophosphorylation. The key term 'photo-ionisation' describes how energy from the light causes electrons to be promoted in molecules known as 'photosystem I and photosystem II'. (Photosystems are proteins associated with chlorophyll molecules) The electrons release this acquired energy and it is then available to produce ATP and reduced NADP. H2O is split and releases O2 which diffuses out of the chloroplasts. Energy is used from 3 things: make ATP; NADPH, split water. Photosystems known as II and I are involved in photophosphorylation. Non-cyclic phosphorylation involves electrons moving along the ETC and energy being used to drive changes including production of O2 and movement of H ions across the thylakoid membrane. Key term; chemiosmotic theory' describes electron passing along the ETC to create a proton gradient that drives ATP synthesis. Cyclic phosphorylation produces less ATP; only involves PS1; only produces ATP; electrons are not passed to NADP.  Students will know how the chemical reactions involved in the light-reaction are related to the structure of a chloroplast. They will know where chlorophyll is located within the chloroplast. | Students need to already know that the structure of ATP and NADP from Y12 Biology topic 3.1. They will need to know that atoms have electrons arranged in electron shells. Energy can be absorbed by electrons and then released if the electron returns to a different shell. This is known as excitation. (Links to GCSE/GCE Chemistry and Physics)  Students need to already know how ATP releases energy from the phosphate - phosphate bond and how ideas about energy transfer and conservation are relevant to biology. Also links to membrane structure to explain how the transmembrane proteins and intrinsic proteins function as part of the electron transport chain. | *Photosystem*  *Photoionisation*  *Excitation*  *Thylakoid* |
| **Lesson 7:**  **Coenzymes and ATP** | Students will know that for enzymes to function properly, many require an additional factor to be present. They work by transferring a chemical group from one molecule to another. NADP is an example of a coenzyme used in photosynthesis. It can transfer H ions. It can either reduce or oxide another molecule ( reduce= to give H) and (oxide is to remove a H).  Conezymes used in respiration include NAD, coenzyme A and FAD. NAD and FAD transfer H ions (as NAPD); Coenzyme A transfers an acetate group between molecules.  Students will know that there are many different metabolic reactions that support life processes within cells. (The names for these different types of reaction are listed in the key terms) | They will recall enzymes as proteins and the levels of structure that explain the role as a catalyst. They will recall factors that affect the shape of a protein including the term ‘denature’.  They will recall the structure of ATP (3 components: base, pentose sugar and 3 phosphate groups.) | *Metabolism*  *Redox*  *Phosphorylation*  *Photolysis*  *Photo ionisation*  *Decarboxylation*  *Dehydrogenation* |

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| **Lesson 8/9: Light-independent reaction**  **(Calvin cycle)** | Students will know that LIR is linked to LDR (follows it) and makes use of the products of the LDR (ATP and NAPDH); it produces organism substances needed for life processes e.g., lipids, carbohydrates and proteins. LDR occurs in the stroma. Products include Triose Phosphate (3C) which can easily be converted to glucose (6C) and ribulose bisphosphate (5C). It needs ATP to be hydrolysed to provide the chemical energy and protons from NADPH. Key products to be named are: TP; Glycerate-3-phosphate; ribulose bisphosphate. 6C sugars known as hexose sugars. Some of the TP is used to make organic compounds and some continues in the Calvin Cycle.  Students will know how to locate the position of different sized C compounds on the Calvin Cycle diagram. (Calvin Cycle is another name for cyclical process where the LIR occurs.) | Students need to already know products from the LDR: ATP, NADPH. Naming sugars e.g., hexose, triose. Phosphorylation means adding phosphate group to a molecule that involves energy being stored. | *Triose sugars*  *Ribulose bisphosphate* |
| **Lesson 10:**  **RP Dehydrogenase activity during the Light Dependent Reaction** | Students will know that this RP is known as ‘The Hill Reaction’ and is a famous piece of experimental work that developed our understanding of the role of chlorophyll in photosynthesis. In photosystem 1, NADP is reduced when it acts as an electron acceptor. The enzyme that drives this reaction is a dehydrogenase enzyme. DCPIP is a dye that changes colour when it accepts an electron. When added to chloroplasts, DCPIP will preferentially accept the electrons that are being transported along the electron transport chain. If DCPIP changes colour, this is the evidence that photosynthesis is occurring. (DCPIP changes from blue to colourless). The rate of change of colour is indicative of the rate of enzyme activity.  Students will know how to carry out the required practical and collate valid data to use to draw a suitable conclusion*. \*If a colorimeter is used, the rate of change of absorbance can be used* | Students need to already know that LDR requires light. Different wavelengths are absorbed by different plant pigments. They will recall membrane structure and enzymes are affected by pH, temperature and substrate concentrations.  Students need to already know how identify variables in an investigation and to carry out a risk assessment. | *Photosystems*  *Dehydrogenase*  *Electron acceptor*  *DCPIP*  *Redox* |
| **Lesson 11:**  **Consolidation of separate ideas for Photosynthesis** | Chloroplasts have a structure that is closely related to the processes of photosynthesis. They will explain how the membranes involved in thylakoids are structured to allow the light-independent reaction to be coordinated. They will describe that the second stage of photosynthesis is linked to the first stage by the products NADPH, ATP and electrons. The second stage is known as the Calvin Cycle/Light independent reaction and produces the glucose molecules used to subsequently build all other biological molecules required by plants. | Fluid-mosaic model of a phospholipid bilayer. They will describe protein molecules embedded in the structure that carry out various functions including the electron-transport chain. They will state that enzymes that drive the process require coenzymes |  |
| **Lesson 12:**  **KS4 review Respiration and mitochondria:** | Students will know that respiration is one of the key life processes that all cells must carry out. Respiration is represented by a chemical equation: glucose + oxygen -🡪 carbon dioxide + water plus energy in the form of ATP. They will name the mitochondrion as the location for the process. They will recognise a diagram for mitochondrion.  Structure of mitochondria has a double-membrane enclosing it. The outer membrane is smooth and the inner membrane is folded to increase surface area. The folds are called cristae. The filling is known as the matrix. Number and shape of cristae vary between cell types. In humans, it still contains 16,569 base pairs, which code for two rRNAs, 22 tRNAs, and 13 proteins.  Only these 13 proteins (mostly subunits of respiratory chain complexes) are produced in the mitochondrion. Both mitochondrial membranes are very rich in proteins.  Porins in the outer membrane allow small molecules to be exchanged between the cytoplasm and the intermembrane space.  The inner mitochondrial membrane is completely impermeable even to small molecules (with the exception of O2, CO2, and H2O).  Numerous transporters in the inner membrane ensure the import and export of important metabolites.  The inner membrane also transports respiratory chain complexes, ATP synthase, and other enzymes.  The matrix is also rich in enzymes.  The main uses of mitochondria are:  the simpler molecules of nutrition are sent to the mitochondria to be processed and to produce charged molecules; these charged molecules combine with oxygen and produce ATP molecules; this process is known as oxidative phosphorylation.  Mitochondria help the cells to maintain proper concentration of calcium ions within the compartments of the cell. | Mitochondria is the plural for mitochondrion.  Typical size of the organelle as 0.5 – 3 micrometers (topic 3.2). ATP is adenosine triphosphate (topic 3.1)  ATP is a store of chemical energy that can be used to drive energy transfer needed for bond making during reactions in cells.  They will know from GCSE that there are two types of respiration: aerobic and anaerobic. They will recall that anaerobic respiration can produce lactic acid in human muscle cells and ethanol in yeast cells. | *Cristae*  *Matrix*  *Porins* |
| **Lesson 13:**  **Respiration pathway (Stage 1)** | Glycolysis is the first stage of both anaerobic and aerobic respiration. It occurs in the cytoplasm and is an anaerobic process. Glycolysis involves the following stages: a) phosphorylation of glucose to glucose phosphate, using ATP. B) production of triose phosphate c) oxidation of triose phosphate to pyruvate with a net gain of ATP and reduced NAD. If respiration is only anaerobic, pyruvate can be converted to ethanol or lactate using reduced NAD. The oxidised NAD produced in this way can be used in further glycolysis.  If respiration is aerobic, pyruvate from glycolysis enters the mitochondrial matrix by active transport. Aerobic respiration in such detail as to show that: (i) pyruvate is oxidised to acetate, producing reduced NAD in the process (vi) other respiratory substrates include the breakdown products of lipids and amino acids, which enter the Krebs cycle. The two chemical changes of glycolysis are phosphorylation and oxidation. One glucose molecule is split into two smaller 3C molecules called pyruvate. These changes happen in the cytoplasm and occur in both types of respiration regardless of what happens later. ATP is the source of the phosphate group. NADP accepts H ions to become reduced. The two molecules of pyruvate are transported into the mitochondrial matrix for the link reaction. | Students will know that respiration is a chemical reaction and can be represented by a summative equation. The reactants are glucose and oxygen; the products are carbon dioxide and water along with energy (triple students will know the term ATP). They will know that there are two types of respiration: aerobic and anaerobic. In humans, anaerobic respiration produces lactic acid and in yeast cells, ethanol is produced.  Students will know that mitochondria compartmentalise the cytoplasm to locate all the necessary chemicals solely related to respiration.  Phosphorylation is a chemical reaction which involves adding a phosphate group to a molecule *(seen in photosynthesis)* | *Glycolysis*  *Pyruvate*  *Triose phosphate*  *Lactate*  *Ethanol*  *NAD/FAD* |
| **Lesson 14:**  **Respiration pathway (Stage 2)** | (ii) The Link Reaction: acetate combines with coenzyme A in the link reaction to produce acetyl coenzyme A. The chemical reactions involved are: decarboxylation (removes CO2), oxidation (producing NADH); acetylation (acetate is combined with coenzymeA). Significantly, no ATP is produced in this stage. Given that stage 1 produces two molecules of pyruvate, the link reaction occurs twice for every glucose molecule. Products of the Link Reaction: two acetyl coenzymeA; two CO2 molecules and two reduced NAD | Stage 1 is called glycolysis and occurs in the cytoplasm. Glucose molecules (6C) are changed to the product is pyruvate (3C molecule). Crucially, Glycolysis occurs in both types of respiration. | *Coenzyme*  *ATP*  *Decarboxylation*  *Acetylation* |
| **Lesson 15:**  **Respiration (Stage 3)** | (iii) Kreb’s Cycle: two-carbon compound from the Link Reaction (acetyl coenzyme A) reacts with a four-carbon molecule being cycled in the Kreb’s Cycle, releasing coenzyme A and producing a six-carbon molecule that progresses round the Krebs cycle. This is a series of linked oxidation-reduction reactions. They occur in the matrix. The cycle happens once for each pyruvate molecule: it happens twice for every glucose molecule. (Regenerated coenzyme A goes back to the Link Reaction to be used again.) The 6C molecule goes to a 5C molecule. Decarboxylation removes a CO2 molecule. Dehydrogenation occurs with the H being used to produce reduced NAD. Dehydrogenation produces reduced FAD and two molecules of reduced NAD. ATP is also produced using substrate-level phosphorylation (movement of phosphate from one molecule to another). The product of this cycle is oxaloacetate. | Coenzymes are molecules that support enzyme activity. Oxidation is loss of electrons/removal of hydrogen and reduction is gain of electrons/addition of hydrogen. The structure of a mitochondrion with reference to the matrix. | *Regenerate* |
| **Lesson 16:**  **Respiration (Stage 4)** | (iv) Oxidative-phosphorylation. Energy is carried by electrons along the transport chain and is ultimately used to make ATP. (The electrons come from the reduced coenzymes) It involves an electron transport chain (integral protein molecules arranged in a specific sequence to support this process) and chemiosmosis (Movement of H+ ions across the inner membrane into the intermembrane space. It is the build up of protons that drives the formation of ATP by ATP synthase as the terminal protein in the sequence. The electron transport chain is a series of electron carriers | Phosphorylation is a chemical change where a phosphate group is added to a molecule. This involves a store of chemical energy. The new molecule is more reactive. | *Integral proteins*  *Chemiosomosis*  *ATP Synthase*  *Terminal protein*  *Electron carrier* |
| **Lesson 17:**  **Chemiosmotic theory** | This has been met in Photosynthesis already. It explains the synthesis of lots of ATP molecules by oxidative phosphorylation and is associated with the transfer of electrons down the electron transfer chain and passage of protons across inner mitochondrial membranes and is catalysed by ATP synthase embedded in these membranes (chemiosmotic theory) | Membrane structure involves embedded proteins. If arranged in a sequence there can be a progressive movement of electrons along this chain that sequentially transfers energy that can be used for other chemical changes. | *Oxidative phosphorylation* |
| **Lesson 18**  **RP Respiration**  **(The effect of temperature on the rate of cellular respiration: Yeast cells and methylene blue)** | Methylene Blue is an indicator but it is used in this practical because it is a preferential electron acceptor when compared the usual electron acceptors in the ETC. The rate of disappearing methylene blue is the simple way to determine rate at the different temperatures. (Alternatively, collect the carbon dioxide produced.) | Yeast cells respire anaerobically. A culture of yeast cells (unicellular organism that can survive with both anaerobic and aerobic respiration according to the availability of oxygen) can be used to illustrate the effect of temperature on the rate of respiration. | *Methylene Blue* |