Scheme of work

## Year 2 A-level Biology

## v1.0

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Scheme of work

## 3.5 Energy transfers in and between organisms

**Unit description**

Life depends on continuous transfers of energy.

In photosynthesis, light is absorbed by chlorophyll and this is linked to the production of ATP.

In respiration, various substances are used as respiratory substrates. The hydrolysis of these respiratory substrates is linked to the production of ATP.

In both respiration and photosynthesis, ATP production occurs when protons diffuse down an electrochemical gradient through molecules of the enzyme ATP synthase, embedded in the membranes of cellular organelles.

The process of photosynthesis is common in all photoautotrophic organisms and the process of respiration is common in all organisms, providing indirect evidence for evolution.

### 3.5.1 Photosynthesis

Prior knowledge:

**GCSE Additional Science**

* During photosynthesis, light is absorbed by chlorophyll and used to convert carbon dioxide and water to glucose and oxygen.
* The rate of photosynthesis may be limited by shortage of light, carbon dioxide or low/high temperature.
* Graphs can be interpreted showing how factors affect the rate of photosynthesis.
* There are benefits to artificially manipulating the environment in which plants are grown but these must be evaluated.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 7:**  Use of chromatography to investigate the pigments isolated from leaves of different plants, eg leaves from shade-tolerant and shade-intolerant plants or leaves of different colours. | 0.4 weeks | * Explain how to extract photosynthetic pigments from leaves and separate them using chromatography. * Identify photosynthetic pigments found in leaves of different plants. | **Learning activities:**   * questioning to recall the purpose of doing chromatography * students work through the chromatography practical * as extension work, students could then go on to calculate Rf values and compare them to published data to identify pigments * discussion and conclusions about the differences found in plant leaves of different colour and from different environments.   **Skills developed by learning activities:**   * AO1 – development of knowledge of a scientific technique * AO2 /AO3 – apply knowledge of scientific techniques and draw conclusions as to the pigments present * AT g and b * MS 1.9 – use an appropriate statistical test (eg to compare mean distances moved by different pigments) * PS 1.2 – apply scientific knowledge to practical contexts * Practical competency –8.4.2.1/8.4.2.2/8.4.2.3/8.4.2.4 | Students could undertake BIO6T P12 ISA. | [saps.org.uk/secondary/teaching-resources/181-student-sheet-10-thin-layer-chromatography-for-photosynthetic-pigments](http://www.saps.org.uk/secondary/teaching-resources/181-student-sheet-10-thin-layer-chromatography-for-photosynthetic-pigments)  [cleapss.org.uk](http://www.cleapss.org.uk/)  **Rich question:**  What is chromatography used for? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The light-dependent reaction of photosynthesis including:   * chlorophyll and photoionisation * some of the energy from electrons released during photoionisation is conserved in the production of ATP and reduced NADP * the production of ATP involves electron transfer and the passage of protons across chloroplast membranes (chemiosmotic theory) * photolysis of water produces protons, electrons and oxygen. | 0.2 weeks | * Describe the structure of chloroplasts. * Explain where, specifically, the light-dependent reaction occurs. * Explain the role of light in photolysis and photoionisation. * Explain how photoexcited electrons move along the electron transfer chain, and how ATP and reduced NADP are produced. * Explain chemiosmosis and the role of ATP synthase in producing ATP. | **Learning activities:**   * questioning to recall GCSE knowledge * teacher led explanation of the structure of a chloroplast * ask students to sketch a graph of how energised they felt throughout a typical day (most will show boosts every time they eat) * teacher explanation of process of light-dependent reaction of photosynthesis (using animations and videos). As an extension, students interpret energy level diagrams during electron transfer - linking energy level diagram to their graph to aid understanding * card sort – order the statements * exam questions.   **Skills developed by learning activities:**   * AO1/AO2 – development of understanding of the light dependent reactions of photosynthesis and application of knowledge to the context of exam questions * AO3 – interpret scientific ideas and information from energy level diagrams * extended exam answers. | **Past exam paper material:**  BIOL4 Jan 2013 – Q8a  BIOL4 Jan 2010 – Q8a | [uic.edu/classes/bios/bios100/lectures/light\_reaction.htm](http://www.uic.edu/classes/bios/bios100/lectures/light_reaction.htm)  **Rich questions:**   * What roles does light play in this process? * How is ATP produced? * How is reduced NADP produced? * Explain the role of water in the light-dependent reaction. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The light-independent reaction including:   * carbon dioxide reacts with RuBP to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme Rubisco * ATP and reduced NADP are used to reduce GP to triose phosphate (TP) * some of the TP is used to regenerate RuBP in the Calvin cycle * some of the triose phosphate is converted to useful organic substances. | 0.4 weeks | * Explain where the light-independent reaction occurs. * Describe the Calvin cycle. * Explain the roles of reduced NADP and ATP. * Interpret experimental data about the light independent reaction. | **Learning activities:**   * ask which parts of the photosynthesis equation remain unaccounted for * provide a synopsis of Calvin’s lollipop experiment, along with results from the chromatograms as to which substances were present at different times. Ask pupils to suggest a reaction sequence * teacher explanation of process of light-independent reaction (using animations and videos). Link to role of ATP and reduced NADP * analysis of data eg varying carbon dioxide levels of the concentrations of RuBP and GP * exam questions.   **Skills developed by learning activities:**   * AO1/AO2 – development of understanding of the light-independent reaction * AO2/AO3 – application of knowledge to exam questions and experimental data * extended exam answers. | **Past exam paper material:**  BIOL4 Jan 2013 – Q5  BIOL4 June 2012 –Q4  BIOL4 June 2013 – Q5  BIOL4 June 2010 – Q8a–8b  BIOL4 June 2011 – Q8c  BIOL4 June 2014 – Q8 | [uic.edu/classes/bios/bios100/lectures/calvin.htm](http://www.uic.edu/classes/bios/bios100/lectures/calvin.htm)  [wps.prenhall.com/wps/media/objects/1109/1135896/8\_3.html](http://wps.prenhall.com/wps/media/objects/1109/1135896/8_3.html)  **Rich questions:**   * What role does reduced NADP play in this process? * What role does ATP play in this process? * How many carbon atoms do RuBP, GP and TP have? * How is the chloroplast adapted to maximising the rate of photosynthesis in the stroma? |
| Extension |  |  | Students could produce a video podcast to summarise the whole process of photosynthesis. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 8:**  Investigation into the effect of a named factor on the rate of dehydrogenase activity in extracts of chloroplasts. | 1 week | * Design an experiment to investigate the effect of a named factor on the rate of the reaction catalysed by dehydrogenase. * Process data to calculate rates. * Represent raw and processed data clearly using tables and graphs. * Explain why scientists carry out statistical tests. * Calculate an appropriate statistical test and interpret values in terms of probability and chance. * Apply knowledge to draw and explain conclusions. * Evaluate the results conclusions. | **Learning activities:**  Students design an experiment to investigate the effect of a named variable, eg temperature, on dehydrogenase activity in extracts of chloroplasts. This could include:   * researching and designing a suitable method * risk assessment * carrying out (subject to teacher approval) * processing and presentation of data * selection and use of appropriate statistical tests * drawing conclusion and evaluating results.   **Skills developed by learning activities:**   * AO2 /AO3 – apply knowledge of scientific techniques and interpret data to draw conclusions * AT g and b * MS 1.9 – select (and use) an appropriate statistical test * MS 3.1 and MS 3.2 – transfer information between tables and graphs, and plot 2 variables on a graph * MS 3.5/MS 3.6 – calculate rate or work out rate from the slope of a tangent to a curve * PS 1.2 – apply scientific knowledge to practical contexts * PS 2.4 – consider key variables * PS 2.2/PS 3.1/MS 3.2/MS 1.3 – plot the experimental data in an appropriate format * PS 2.3/MS3.3 – evaluate data for errors and uncertainties, and consider margins of accuracy * 8.4.2.1/8.4.2.2/8.4.2.3/8.4.2.4/8.4.2.5 | BIO6T P11 ISA | [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk)  [nuffieldfoundation.org/practical-biology/investigating-light-dependent-reaction-photosynthesis](http://www.nuffieldfoundation.org/practical-biology/investigating-light-dependent-reaction-photosynthesis)  [scribd.com/doc/6468471/Teaching-A2-Biology-Practical-Skills](http://www.scribd.com/doc/6468471/Teaching-A2-Biology-Practical-Skills)  [aqa.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.aqa.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Light, temperature carbon dioxide (and mineral/ magnesium levels) can limit the rate of photosynthesis.  Farmers seek to overcome limiting factors in order to increase the productivity of land and maximise profits. | 0.6-0.8 weeks | * Explain what is meant by limiting factors. * Identify environmental factors that limit the rate of photosynthesis. * Interpret graphs showing the rate of photosynthesis and explain graphs in terms of which factors are rate limiting. * Explain how farmers seek to maximise crop growth through knowledge of rate limiting factors, and how this is a balance between cost vs profit. * Evaluate data relating to common agricultural practices used to overcome the effect of these limiting factors. | **Learning activities:**   * students could undertake an investigation of a named factor on the rate of photosynthesis using algal beads, algae or an aquatic plant * jigsaw tasks: in groups of three, each student goes off to access information about one of the named factors and the trends in rate graphs * group feedback and completion of an explanation table * teacher assessment and teaching of areas of weakness * exam questions/past ISA paper * teacher led explanation of agricultural practices to maximise rate * data evaluation task relating to agriculture.   **Skills developed by learning activities:**   * AO1 – knowledge of rate limiting factors * AO2 /AO3 – apply knowledge to trends in scientific data to make judgements * AT a – devise and carry out experiments to investigate the effect of named variables on the rate of photosynthesis * MS 1.9 – use an appropriate statistical test * MS 1.4 – understand simple probability * MS 3.4 – determine the compensation point in plants by reading off the intercept point * PS 1.2 – apply scientific knowledge to practical contexts * 8.4.2.1/8.4.2.2/8.4.2.3/8.4.2.4 | Students could undertake BIO6T P10, BIO6X 2013 or HBI6T P10 ISA  **Specimen assessment material**:  A-level Paper 2 (set 1) – Q8  **Past exam paper material:**  BIOL4 Jan 2011 – Q5  BIOL4 June 2014 – Q3c  BIO6X 2013 EMPA | [nuffieldfoundation.org/practical-biology/investigating-factors-affecting-rate-photosynthesis](http://www.nuffieldfoundation.org/practical-biology/investigating-factors-affecting-rate-photosynthesis)  [nuffieldfoundation.org/practical-biology/investigating-photosynthesis-using-immobilised-algae](http://www.nuffieldfoundation.org/practical-biology/investigating-photosynthesis-using-immobilised-algae)  [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk)  **Rich question:**  Show graphs and ask students to explain what the limiting factors are. |

### 3.5.2 Respiration

Prior knowledge:

**GCSE Additional Science**

* Respiration is an enzyme catalysed process.
* Aerobic respiration is mainly carried out within the mitochondria.
* During aerobic respiration, glucose and oxygen react to produce carbon dioxide and water. Energy is released in this process.
* The energy released during respiration is used to synthesise larger molecules, contract muscles (in animals), maintain a constant body temperature (birds and mammals) and produce amino acids (in plants).
* Anaerobic respiration releases less energy and is used when insufficient oxygen reaches the muscles.
* Glucose is not completely broken down and produces lactic acid. This causes muscle fatigue. An oxygen debt has to be repaid in order to oxidise the lactic acid into glucose and water.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Respiration produces ATP.  Aerobic respiration involves:   * glycolysis * active transport of pyruvate into the mitochondrial matrix * oxidation of pyruvate to acetate * production of acetyl CoA * the Krebs cycle * oxidative phosphorylation, associated with electron transfer and chemiosmosis, to synthesise ATP. | 0.6 weeks | * Know where the different stages of aerobic respiration occur. * Explain the significance of the oxidation reactions involved in glycolysis, the link reaction and the Krebs cycle. * Explain the roles of coenzymes and reduced NAD in respiration. * Describe the process of electron transfer associated with oxidative phosphorylation. * Explain chemiosmosis and the role of ATP synthase in producing ATP. * Apply knowledge to explain trends in data. | **Learning activities:**   * questioning to recall GCSE knowledge and AS knowledge of ATP * teacher led explanation of the stages involved in aerobic respiration (using animations and videos) * card sort – order the stages/molecules * exam questions. Include exam questions which focus on interpreting and explaining data.   **Skills developed by learning activities:**   * AO1/AO2 – development of understanding of aerobic respiration * AO2/AO3 – application of knowledge to exam questions * extended exam answers. | **Past exam paper material:**  BIOL4 Jan 2012 – Q8b  BIOL4 June 2013 – Q4  BIOL4 June 2010 – Q6  BIOL5 Jun 2014 – Q9 | [sumanasinc.com/webcontent/animations/content/cellularrespiration.html](http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html)  [highered.mheducation.com/sites/0072507470/student\_view0/chapter25/animation\_\_electron\_transport\_system\_and\_formation\_of\_atp\_\_quiz\_1\_.html](http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__electron_transport_system_and_formation_of_atp__quiz_1_.html)  [highered.mheducation.com/sites/0072507470/student\_view0/chapter25/animation\_\_how\_glycolysis\_works.html](http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_glycolysis_works.html)  [highered.mheducation.com/sites/0072507470/student\_view0/chapter25/animation\_\_how\_the\_krebs\_cycle\_works\_\_quiz\_1\_.html](http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_the_krebs_cycle_works__quiz_1_.html)  **Rich question:**  Provide statements and ask students whether they apply to glycolysis, the Krebs cycle or oxidative phosphorylation (or more than one). |
| Extension |  |  | Students could write an essay on the processes involved in aerobic respiration. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Glycolysis is the first stage of anaerobic and aerobic respiration.  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.  Other respiratory substrates include the breakdown products of lipids and amino acids, which enter the Krebs cycle. | 0.4 weeks | * Describe the process of anaerobic respiration in animals and some microorganisms. * Explain the advantage of producing ethanol or lactate using reduced NAD. * Compare and contrast aerobic and anaerobic respiration. * Interpret information/data about anaerobic respiration and apply knowledge. | **Learning activities:**   * Teacher led explanation of the stages involved in anaerobic respiration (using animations and videos) and the benefit of oxidising reduced NAD to produce ethanol or lactate * students draw a table comparing and contrasting aerobic and anaerobic respiration eg maximum number of ATP molecules generated * exam questions.   **Skills developed by learning activities:**   * AO1/AO2 – development of understanding of anaerobic respiration * AO2/AO3 – application of knowledge to exam questions. | **Past exam paper material:**  BIOL4 Jan 2013 – Q6  BIOL4 June 2011 – Q1  BIOL4 Jan 2010 – Q5. | [sumanasinc.com/webcontent/animations/content/cellularrespiration.html](http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html)  [highered.mheducation.com/sites/0072507470/student\_view0/chapter25/animation\_\_electron\_transport\_system\_and\_formation\_of\_atp\_\_quiz\_1\_.html](http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__electron_transport_system_and_formation_of_atp__quiz_1_.html)  **Rich questions:**   * Show students statements and ask them whether they apply to photosynthesis, anaerobic or aerobic respiration. * How do aerobic and anaerobic respiration differ? * Reduced NAD is used to produce lactate or ethanol from pyruvate. What is the advantage of this? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 9:**  Investigation into the effect of a named variable on the rate of respiration of cultures of single-celled organisms. | 1 week | * Design an experiment to investigate the effect of a named factor on a culture of single-celled organisms. * Process data to calculate rates. * Represent raw and processed data clearly using tables and graphs. * Calculate an appropriate statistical test and interpret values in terms of probability and chance. * Apply knowledge to draw and explain conclusions. * Evaluate the results and conclusions. | **Learning activities:**  Students design an experiment to investigate the effect of a named variable eg temperature on the rate of respiration of yeast/bacteria. This could include:   * working through key aspects of experimental design eg key variables * carrying out (subject to teacher approval) * processing and presentation of data * selection and use of appropriate statistical tests (eg comparison of mean rates at two different temperatures * BIO6T Q12 ISA or HBI6T P11 ISA.   **Skills developed by learning activities:**   * ATb – use a redox indicator to investigate dehydrogenase activity * PS 1.2 – apply scientific knowledge to practical contexts * PS 2.2/PS 3.1/MS 3.2/MS 1.3 – plot the experimental data in an appropriate format * PS 2.3/MS3.3 – evaluate data for errors and uncertainties and consider margins of accuracy * AO1/AO2 – application of knowledge to explain trends * AO3 – develop and refine practical design * MS 1.9 – use an appropriate statistical test * MS 1.4 – understand simple probability * 8.4.2.1/8.4.2.2/8.4.2.3/8.4.2.4/8.4.2.5. | BIO6T Q12 ISA  HBI6T P11 ISA  HIBI6X 2013 EMPA | [aqa.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.aqa.org.uk) |

### 3.5.3 Energy and Ecosystems

Prior knowledge:

**GCSE Science A**

* Green plants and algae absorb a small amount of the light that reaches them. The transfer from light energy to chemical energy occurs during photosynthesis. This energy is stored in the substances that make up the cells of the plants.
* The amount of material and energy contained with the biomass decreases at each successive stage in a food chain. This can be represented using a pyramid of biomass. This reduction is due to energy losses through waste and processes linked to respiration eg movement. Much of this energy is eventually transferred to the surroundings.

**GCSE Additional Science**

* The glucose from photosynthesis is used to produce fat, protein and cellulose, as well as being used in respiration and stored as starch.
* Some of the glucose is used for respiration.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Plants synthesise organic compounds from carbon dioxide. Most of the sugars are used as respiratory substrates.  The rest are used to make other biological molecules, which form the biomass of the plants.  Biomass can be measured in terms of mass of carbon or dry mass of tissue per given area per given time.  The chemical energy stored in dry biomass can be estimated using calorimetry. | 0.4 weeks | * Explain how plants utilise the sugars from photosynthesis. * Explain what is meant by biomass and how it can be measured. * Suggest units for biomass. * Explain the process of calorimetry. * Evaluate the accuracy of results from simple calorimetry. | **Learning activities:**   * set students a diagnostic question eg ‘where does an oak tree get the materials it needs to grow from?’. See if students relate glucose production from photosynthesis to biomass * comprehension exercise on the uses of sugars produced during photosynthesis. Get students to read this and produce a concept map * revisit diagnostic question * teacher led explanation of the measurement of biomass (including units) and how the energy within it can be estimated * exam questions.   **Skills developed by learning activities:**   * AO1 – knowledge of biomass * AO1/PS 4.1 – understand calorimetry * MS 0.1 – recognise and make use of appropriate units * MS3.3 – consider margins of error/ accuracy. | **Specimen assessment material**:  A-level Paper 3 (set 1) – Q5.4 and 5.6  **Past exam paper material**:  BIOL4 June 2014 – Q7ci | **Rich questions:**   * Explain the relationship between photosynthesis, respiration and biomass. * Explain how you could ensure that biomass was completely dry before weighing. |
| Extension |  |  | Students could conduct calorimetry experiments by burning dried plant/food samples and calculating energy released.  **Skills developed by learning activities:**   * AT a - investigations to find the dry mass of plant samples or the energy released by samples of plant biomass * 8.4.2.2/8.4.2.3 – use apparatus safely. | Questions from the BIO6T Q13 ISA |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The concept of gross primary production and net primary production and their mathematical relationship ie  *NPP* = *GPP* – *R*  NPP is available for growth and reproduction and for other trophic levels.  The net production of consumers, such as animals, can be calculated as:  *N = I –(F + R)* | 0.4 weeks | * Explain the concepts of gross primary production and net primary production. * Understand the mathematical relationship between the two and use it to calculate values when supplied with data. * Explain the reduction in energy/biomass along a food chain. * Explain the concept of net production in consumers, linked to how energy losses occur along food chains. * Apply knowledge to the context of exam questions. | **Learning activities:**   * provide food webs for students to interpret and ask questions for them to answer * introduce terminology eg trophic level * show energy/biomass losses along a food chain and how they occur. Teacher led explanation of the concepts of GPP and NPP and their mathematical relationship. Then discuss how net production is calculated * provide data for students about food chains and ask them to calculate NPP from appropriate data. They could also calculate % efficiency of the food chains * exam questions.   **Skills developed by learning activities:**   * MS0.2 – convert and carry out calculations of energy transfer using numbers in standard and ordinary form * MS0.3 – calculation of percentage efficiency and percentage yield * MS 2.3/MS 2.4 – substitute numerical values into, and solve, algebraic equations using appropriate units * extended exam answers. | **Past exam paper material:**  BIOL4 Jan 2012 – Q2  BIOL4 Jan 2013 – Q8b  BIOL4 June 2010 – Q4  BIOL4 June 2011 – Q2  BIOL4 Jan 2010 – Q8b | **Rich questions:**   * What do the arrows in food chains represent? * Why do humans tend to rear herbivores as their source of meat? * How is energy lost along a food chain? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The ways in which production is affected by farming practices designed to increase the efficiency of energy transfer. | 0.2 weeks | * Explain the ways in which production is affected by simplifying food webs. * Explain the ways in which farmers are reducing respiratory losses within a human food chain. * Interpret and calculate data on efficiency when provided with appropriate information. * Evaluate the ethics of some of these farming practices. | **Learning activities:**   * Teacher led explanation of how farmers can improve production by simplifying food webs and reducing respiratory losses. Question students about why this would provide more food for us * debate: give students different viewpoints and ask them to debate whether it is ethical to use these farming practices * continuum – students place themselves on a continuum line based on their opinion from the debate * exam questions.   **Skills developed by learning activities:**   * MS0.2 – convert and carry out calculations of energy transfer using numbers in standard and ordinary form * MS0.3 – calculation of percentage efficiency * essay writing skills. | **Past exam paper material:**  BIOL4 Jun 2012 – Q8a  BIOL4 Jun 2013 – Q8c  BIOL4 Jan 2010 – Q8  BIOL5 June 2014 – Q10b | [ciwf.org.uk/education](http://www.ciwf.org.uk/education/)  **Rich questions:**   * How could farmers improve efficiency? * Evaluate the advantages and disadvantages of using these methods. |

### 3.5.4 Nutrient cycles

Prior knowledge:

**GCSE Science A**

The carbon cycle involves the cycling of carbon through stages including: photosynthesis; consumption; respiration; death and decomposition; fossilisation and combustion.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Nutrients are recycled within natural ecosystems, exemplified by the phosphorous cycle, to include:   * the role of saprobionts in decomposition * the role of mycorrhizae in facilitating the uptake of water and inorganic ions by plants. | 0.2 weeks | * Describe the stages of the phosphorus cycle, and the ions at each stage. * Explain the role of saprobionts and mycorrhizae in the phosphorus cycle. * Interpret information/data about the phosphorus cycle and apply knowledge. | **Learning activities:**   * introduce the importance of nutrient recycling within ecosystems * brainstorm why phosphorus is a useful element in nature eg in ATP, DNA, phospholipds etc * teacher led explanation of the phosphorus cycle using videos and animations * card sort of the stages * exam questions.   **Skills developed by learning activities:**  AO1 **–** development of knowledge and understanding of the phosphorus cycle. |  | [sumanasinc.com/webcontent/animations/content/phosphorouscycle.html](http://www.sumanasinc.com/webcontent/animations/content/phosphorouscycle.html)  **Rich questions:**   * Explain the significance of phosphorus to living things. * What role do saprobionts and mycorrhizae play? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Nutrients are recycled within natural ecosystems, exemplified by the nitrogen cycle, to include:   * the role of bacteria in the nitrogen cycle in the processes of saprobiotic nutrition, ammonification, nitrification, nitrogen fixation and denitrification. | 0.4 weeks | * Describe the stages of the nitrogen cycle, and the ions/ molecules at each stage. * Explain the processes of saprobiotic nutrition, ammonification, nitrification, nitrogen fixation and denitrification within the nitrogen cycle. * Explain the role of saprobionts and mycorrhizae in the nitrogen cycle. * Interpret information/data about the nitrogen cycle and apply knowledge. | **Learning activities:**   * brainstorm how nitrogen is used eg in DNA, amino acids * students read comprehension on the nitrogen cycle * nitrogen cycle game – get students to model the movement of an atom of nitrogen * students generate questions they still have * teacher-led explanation of the nitrogen cycle, to address questions and reinforce * card sort of the stages * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge and understanding of the nitrogen cycle * AO2 – application of knowledge to the context set in exam questions * extended exam answers. | **Specimen assessment material**:  A-level Paper 3 (set 1) – Q5  **Past exam paper material:**  BIOL4 Jan 2013 – Q1  BIOL4 Jun 2012 – Q8b  BIOL4 June 2011 – Q8a  BIOL4 June 2014 – Q2 | [tes.co.uk/teaching-resource/nitrogen-cycle-game-6079926](http://www.tes.co.uk/teaching-resource/nitrogen-cycle-game-6079926/)  [mhhe.com/biosci/genbio/tlw3/eBridge/Chp29/animations/ch29/1\_nitrogen\_cycle.swf](http://www.mhhe.com/biosci/genbio/tlw3/eBridge/Chp29/animations/ch29/1_nitrogen_cycle.swf)  **Rich questions:**   * Explain the significance of nitrogen to living things. * Write an equation for the conversions which occur during: ammonification; nitrogen fixation; denitrification; nitrification. |
| Extension |  |  | * Culture nitrogen-fixing bacteria from root nodules of leguminous plants. * 8.4.2.1/8.4.2.3 – follow instructions/work safely * AT i/PS 4.1 – use aseptic techniques to culture bacteria on streak plates |  | [nuffieldfoundation.org/practical-biology/nitrogen-fixing-bacteria-root-nodules-leguminous-plants](http://www.nuffieldfoundation.org/practical-biology/nitrogen-fixing-bacteria-root-nodules-leguminous-plants) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of natural and artificial fertilisers to replace the nitrates and phosphates lost by harvesting plants and removing livestock.  The environmental issues arising from the use of fertilisers including leaching and eutrophication. | 0.4 weeks | * Explain why farmers utilise natural and artificial fertilisers. * Explain how eutrophication is caused, and what the impact is on the ecosystem in which it happens. * Interpret information/data about eutrophication and apply knowledge. | **Learning activities:**   * introduce the rationale behind using fertilisers on agricultural land * DARTS task: provide students with a comprehension on leaching and eutrophication which they must convert into diagrams and present to the class * class peer evaluation of presentations * work through some exemplar data about leaching and eutrophication * discussion/debate: should farmers use fertilisers? Students argue the case from different perspectives * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of eutrophication through the use of fertilisers * AO2 – application of knowledge to the context set in exam questions. | **Past exam paper material:**  BIOL4 Jan 2012 – Q6  BIOL4 June 2013 – Q8b  BIOL4 Jan 2011 – Q3  BIOL4 June 2011 – Q3b. | [nroc.mpls.k12.mn.us/Environmental%20Science/course%20files/multimedia/lesson78/animations/5a\_Lake\_Eutrophication.html](http://nroc.mpls.k12.mn.us/Environmental%20Science/course%20files/multimedia/lesson78/animations/5a_Lake_Eutrophication.html)  **Rich questions:**   * Explain how eutrophication occurs. * Suggest steps that could be taken to reduce eutrophication from farmland. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Extension:  design an investigation into the effect of named mineral ions on plants. | 0.2-0.4 weeks | * Recall the key features of good experimental design. * Apply knowledge to design a valid experiment to test the effect of named mineral ions on plant growth. | **Learning activities:**   * questioning about what constitutes good experimental design * provide students with an equipment list of available apparatus and chemicals * students write up a method for their proposed experiment.   **Skills developed by learning activities:**   * MS 1.9 – select an appropriate statistical test * PS 1.1/1.2 – solve problems set in, and apply scientific knowledge to, practical contexts. | Marking of experimental plans. | [nuffieldfoundation.org/practical-biology/investigating-effect-minerals-plant-growth](http://www.nuffieldfoundation.org/practical-biology/investigating-effect-minerals-plant-growth)  **Rich questions:**  What are the key features/principles of good experimental design? |

## 3.6 Organisms respond to changes in their internal and external environments

**Unit description**

A stimulus is a change in the internal or external environment. A receptor detects a stimulus. A coordinator formulates a suitable response to a stimulus. An effector produces a response.

Receptors are specific to one type of stimulus.

Nerve cells pass electrical impulses along their length. A nerve impulse is specific to a target cell only because it releases a chemical messenger directly onto it, producing a response that is usually rapid, short-lived and localised.

In contrast, mammalian hormones stimulate their target cells via the blood system. They are specific to the tertiary structure of receptors on their target cells and produce responses that are usually slow, long-lasting and widespread.

Plants control their response using hormone-like growth substances.

### 3.6.1 Stimuli, both internal and external are detected and lead to a response

#### 3.6.1.1 Survival and response

Prior knowledge:

**GCSE Science A**

* The nervous system enables humans to react to their surroundings and coordinate their behaviour.
* Reflex actions are automatic and rapid. They often involve sensory, relay and motor neurones.
* Plants are sensitive to light, moisture and gravity. Their shoots grow towards light and against the force of gravity. Their roots grow towards moisture and in thedirection of the force of gravity.
* Plants produce hormones to coordinate and control growth. Auxin controls phototropism and gravitropism (geotropism).
* The responses of plant roots and shoots to light, gravity and moisture are the result of unequal distribution of hormones, causing unequal growth rates.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Organisms increase their chance of survival by responding to changes in their environment.  In flowering plants, specific growth factors move from growing regions to other tissues, where they regulate growth in response to directional stimuli.  The effect of different concentrations of indoleacetic acid (IAA) on cell elongation in the roots and shoots of flowering plants as an explanation of gravitropism and phototropism in flowering plants. | 0.6-0.8 weeks | * Explain what is meant by phototropism and gravitropism, and by positive and negative tropisms. * Describe where IAA is produced. * Describe the effect of different IAA concentrations on root/shoot growth. * Explain how IAA causes positive phototropism in shoots. * Explain how IAA causes positive gravitropism in roots. * Apply knowledge of IAA to interpret results and draw conclusions. | **Learning activities:**   * teacher introduction to responses to change in environment linked to survival * questioning to assess GCSE knowledge of tropisms * introduce IAA in plants * interpret and process results and plot on graph * ask students to interpret data on the effect that different IAA concentrations have on root/shoot growth * provide information/pictures on the work done by Darwin, Boysen-Jensen, Paal, Went and Briggs and ask students to suggest explanations * teacher explanation and summary of tropisms linked to IAA production and distribution * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge relating to IAA and tropisms in plants * AO2/AO3 – interpret scientific data and apply knowledge of the effects of IAA to explain it * MS 0.2 – use/conversion of IAA concentrations in ordinary and standard form * MS 0.3 – calculation of percentage inhibition/stimulation * MS 2.3 – plot 2 variables from experimental data * AT h – carry out investigations into the effect of IAA on root growth in seedlings. | **Past exam paper material:**  BIOL5 June 2012 – Q7  BIOL5 June 2013 – Q3  BIOL5 June 2011 – Q3  **Exampro:**  Specimen paper Unit 5 Q10 | [nuffieldfoundation.org/practical-biology/interpreting-investigation-plant-hormones](http://www.nuffieldfoundation.org/practical-biology/interpreting-investigation-plant-hormones)  **Rich questions:**   * Describe the differences in how plant growth factors are produced and act, compared to hormones in animals. * Explain phototropism in stems. * Explain gravitropism in roots. |
| Extension |  |  | Students investigate the effect of IAA on root growth in seedlings. |  | [nationalstemcentre.org.uk/elibrary/resource/7259/the-effects-of-iaa-on-root-growth](http://www.nationalstemcentre.org.uk/elibrary/resource/7259/the-effects-of-iaa-on-root-growth) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Taxes and kineses as simple responses that can maintain a mobile organism in a favourable environment. | 0.2-0.4 weeks | * Explain what is meant by taxes and kineses and how they differ. * Explain how taxes and kineses aid survival. | **Learning activities:**   * teacher explanation of taxes and kineses * activity circus with different experiments for students to trial and draw conclusions from, eg earthworm taxis away from light by having a textbook over half a tray; woodlice kineses in dishes containing dry and moist paper towel; response of Calliphora larvae to light; positive phototaxis of algae. Ask them which taxis or kinesis is being displayed, how they know and whether it is a positive or negative response * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge and understanding of kineses and taxes * AO2 – application of knowledge to explain observations from activity circus * AT h – carry out investigations into taxes and kineses using living organisms. | **Past exam paper material:**  BIOL5 – June 2010 Q1  BIO6X June 2014 EMPA | [nuffieldfoundation.org/practical-biology/investigating-response-calliphora-larvae-light](http://www.nuffieldfoundation.org/practical-biology/investigating-response-calliphora-larvae-light)  [udel.edu/MERL/Outreach/Teacher's%20Guide/3.%20Phototaxis%20TE.pdf](http://www.udel.edu/MERL/Outreach/Teacher's%20Guide/3.%20Phototaxis%20TE.pdf)  **Rich questions:**   * Explain how a taxis and a kinesis differ. How might each manifest itself in the movement of the animal? * Provide examples of taxes and kineses for student to categorise as positive/negative taxes or kineses. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 10:**  Investigation into the effect of an environmental variable on the movement of an animal using either a choice chamber or a maze. | 0.8 weeks | * Represent raw and processed data clearly using tables. * Calculate an appropriate statistical test and interpret values in terms of probability and chance. * Apply knowledge of kineses to draw and explain conclusions. | **Learning activities:**  Students investigate the effect of a named variable, eg light intensity, on animal movement using a maze or choice chamber   * carrying out (subject to teacher approval) * processing and presentation of data * calculation and interpretation of a stats test * drawing conclusion and evaluating results * undertaking the BIO6X 2011 EMPA paper.   **Skills developed by learning activities:**   * AO2 – application of knowledge of kinesis and stats tests to explain and interpret observations * AT h – investigation of kineses in organisms * MS 1.9 – use an appropriate statistical test * PS 1.2 – apply scientific knowledge to practical contexts * 8.4.2.1/8.4.2.2/8.4.2.3/8.4.2.4. | BIO6X 2011 EMPA  **Exampro:**  BYB9 June 2005 – Q2  BYB9 Jan 2005 – Q2 | [nuffieldfoundation.org/practical-biology/using-choice-chamber-investigate-animal-responses-stimuli](http://www.nuffieldfoundation.org/practical-biology/using-choice-chamber-investigate-animal-responses-stimuli)  [nuffieldfoundation.org/practical-biology/investigating-turn-alternation-behaviour-woodlice](http://www.nuffieldfoundation.org/practical-biology/investigating-turn-alternation-behaviour-woodlice)  [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The protective effect of a simple reflex, exemplified by a three neurone simple reflex. | 0.2 weeks | * Explain the role of reflexes and why they are important. * Explain the role of sensory, intermediate and motor neurones in a reflex arc. * For a given context, explain the sequence of events which brings about a reflex action (from stimulus to response). | **Learning activities:**   * questioning to assess recall from GCSE and to recap key terms eg stimulus, effector * introduce the protective role of reflex actions * students could investigate reflex actions and suggest how they are protective, eg the ankle or knee jerk reaction, shining low power torch near eyes to observe pupillary light reflex, clicking fingers near eyes to observe blinking * teacher explanation using diagrams and animations * provide scenarios for students, eg withdrawal from touching a hot surface, and ask them to explain them. Generate a model answer * teach explanation of why reflex actions are so important * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge of the reflex arc and the protective effects of reflexes * AO2 – application of knowledge to explain scenarios involving reflex actions. | **Exampro:** BYB4 June 2004 – Q1 | [sumanasinc.com/webcontent/animations/content/reflexarcs.html](http://www.sumanasinc.com/webcontent/animations/content/reflexarcs.html)  **Rich question:**  Why are reflex actions much quicker than voluntary responses? |

#### 3.6.1.2 Receptors

Prior knowledge:

**GCSE Science A**

* Cells called receptors detect stimuli (changes in the environment).
* Receptors and the stimuli they detect include light receptors in the eyes; sound receptors in the ears; receptors for balance in our ears; chemical receptors on the tongue and in the nose which enable us to taste and smell; touch, pressure, pain and temperature receptors in the skill.
* Light receptor cells, like most animal cells, have a nucleus, cytoplasm and cell membrane.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Receptors only respond to specific stimuli. Stimulation of the receptor in the Pacinian corpuscle leads to the establishment of a generator potential.  The basic structure of a Pacinian corpuscle.  Deformation of stretch-mediated sodium ion channels in a Pacinian corpuscle leads to the establishment of a generator potential. | 0.4 weeks | * Explain the features of sensory reception which are common to all receptors. * Describe the structure of a Pacinian corpuscle. * Explain the stimulus which Pacinian corpuscles respond to. * Explain how a Pacinian corpsule produces a generator potential in response to a specific stimulus. | **Learning activities:**   * students could conduct a practical to determine the resolution of touch receptors in the skin, the temperature sensitivity of temperature receptors in the skin, or the habituation of touch receptors in skin * teacher explanation of the features of sensory reception which are common to all receptors. Exemplify this with discussion of the structure of a Pacinian corpuscle and how it produces a generator potential * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge and understanding of how Pacinian corpuscles work. * AT h – carry out investigations into receptors within the skin. | **Specimen assessment material:**  A-level Paper 2 (set 1) – Q4.2 | [nuffieldfoundation.org/practical-biology/assessing-skin-sensitivity-%E2%80%93-touch-discrimination](http://www.nuffieldfoundation.org/practical-biology/assessing-skin-sensitivity-%E2%80%93-touch-discrimination)  [nuffieldfoundation.org/practical-biology/assessing-skin-sensitivity-%E2%80%93-temperature-receptors](http://www.nuffieldfoundation.org/practical-biology/assessing-skin-sensitivity-%E2%80%93-temperature-receptors) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The human retina in sufficient detail to show how differences in sensitivity to light, sensitivity to colour and visual acuity are explained by differences in the optical pigments of rods and cones and the connections rods and cones make in the optic nerve. | 0.2 weeks | * Identify the pigments in rod and cone cells. * Explain how rod cells’ visual acuity, sensitivity to light and sensitivity to colour are accounted for by the presence of rhodopsin and connections to the optic nerve. * Explain how cone cells’ visual acuity, sensitivity to light and sensitivity to colour are accounted for by the presence of different forms of iodopsin and connections to the optic nerve. | **Learning activities:**   * provide information sheets/comprehensions on rod and cone cells around the room, and provide students with a question sheet to find the answers to * accept feedback and reinforce with teacher explanation. Include the concept of threshold level stimulation * students summarise differences between rods and cones in a table * provide data on trichromatic theory and ask students to interpret * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of rods and cones * AO2/AO3 – application of knowledge to observations and to explain experimental data (trichromatric theory). | **Past exam paper material:**  HBIO4 Jan 2013 – Q5  HBIO4 June 2012 – Q1b  HBIO4 June 2013 – Q1a–1bi  HBIO4 Jan 2011 – Q1a  HBIO4 June 2010 – Q2  HBIO4 June 2011 – Q7a–7b | [nuffieldfoundation.org/practical-biology/investigating-how-we-see-colour](http://www.nuffieldfoundation.org/practical-biology/investigating-how-we-see-colour)  [childrensuniversity.manchester.ac.uk/interactives/science/brainandsenses/eye](http://www.childrensuniversity.manchester.ac.uk/interactives/science/brainandsenses/eye/)  [psych.colorado.edu/~dbarth/PDFs/4052/4052%20Manual%20Chapters/Vision.pdf](http://psych.colorado.edu/~dbarth/PDFs/4052/4052%20Manual%20Chapters/Vision.pdf)  **Rich questions:**   * Why are rods able to respond to low light intensity? * Why do we see in greater detail when the image is focussed on the fovea? * What is the advantage to having cells which can respond to low and high light intensity? |
| Extension |  |  | Students can carry out the investigation as to how we see colour and apply knowledge to explain their findings. They can also map the distribution of rods and cones in the retina. |  |  |

**3.6.1.3 Control of heart rate**

Prior knowledge:

**GCSE Additional Science**

During exercise, the heart rate increases to increase blood flow to the muscles, ensuring increased supply of glucose and oxygen and increased rate of removal of carbon dioxide.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Myogenic stimulation of the heart and transmission of a subsequent wave of electrical activity.  The roles of the sinoatrial node (SAN), atrioventricular node (AVN) and Purkyne tissue in the bundle of His. | 0.2 weeks | * Describe, and locate on a diagram, the structures, which are responsible for events during the cardiac  cycle. * Explain the events which take place during the cardiac cycle to produce and transmit a wave of electrical activity to make the heart beat * Explain the roles of the SAN, AVN and bundle of His. | **Learning activities:**   * questioning to recap the structure and function of the heart * teacher explanation of how a heart beat is initiated and transmitted, and the roles of the SAN, AVN and bundle of His * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of the roles of the SAN, AVN and Purkinje fibres in generating and transmitting electrical activity to cause a heartbeat * extended exam answers. | **Past exam paper material:**  BIOL1 Jan 2010 – Q7a  BIOL1 June 2009 – Q2a  BIOL1 Jan 2011 – Q3c  BIOL1 June 2013 – Q8a  BIOL1 June 2012 – Q8a | [highered.mheducation.com/sites/0072495855/student\_view0/chapter22/animation\_\_conducting\_system\_of\_the\_heart.html](http://highered.mheducation.com/sites/0072495855/student_view0/chapter22/animation__conducting_system_of_the_heart.html)  **Rich questions:**   * What is meant by the term ‘myogenic’? * What is the role of the SAN, AVN and bundle of His? * What would happen if the ring of non-conducting tissue was not present? |
| Extension |  |  | * Students could design and carry out an investigation into the effect of a named variable on pulse rate. * Students could carry out calculations using CO=SV × HR (as 3.3.4.1). |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The roles and locations of chemoreceptors and pressure receptors and the roles of the autonomic nervous system and effectors in controlling heart rate. | 0.2 weeks | * Describe the location of, and the role played by, chemoreceptors and pressure receptors involved in detecting changes which lead to changes in heart rate. * Explain what is meant by the sympathetic and parasympathetic nervous system. * Explain the role of the autonomic nervous system (sympathetic and parasympathetic) in controlling heart rate. * Explain the role of the medulla oblongata. | **Learning activities:**   * questioning to students to ask how the heart would respond to exercise or fight, flight or fright situations. Ask students what the stimulus would be in response to exercise * elaborate on this by pointing out that the stimulus is a change in blood pH and blood pressure * teacher explanation of how heart rate is controlled, linking receptors to the medulla oblongata and the role of the autonomic nervous system * exam questions.   **Skills developed by learning activities:**  AO1 –development of knowledge and understanding of how heart rate is controlled**.** | **Past exam paper material:**  BIOL5 June 2012 – Q4  HBIO4 June 2013 – Q2  **Exampro:**  BYA6 Jan 2005 – Q7  BYA6 June 2005 – Q5 | [highered.mheducation.com/sites/0072943696/student\_view0/chapter13/animation\_\_chemoreceptor\_reflex\_control\_of\_blood\_pressure.html](http://highered.mheducation.com/sites/0072943696/student_view0/chapter13/animation__chemoreceptor_reflex_control_of_blood_pressure.html)  **Rich questions:**   * What is the difference between the sympathetic and parasympathetic nervous system? * What could act as a stimulus to change the heart rate? * Where are chemoreceptors and pressure receptors located? * How does the medulla oblongata increase/reduce heart rate? |

### 3.6.2 Nervous coordination.

#### 3.6.2.1 Nerve impulses

Prior knowledge **–** nothing explicitly relevant.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The structure of a myelinated motor neurone.  The establishment of a resting potential in terms of differential membrane permeability, electrochemical gradients and the movement of sodium ions and potassium ions.  Changes in membrane permeability lead to depolarisation and the generation of an action potential.  The all-or-nothing principle. | 0.6 weeks | * Describe and explain the structure of a myelinated motor neurone. * Explain what is meant by a resting and an action potential. * Explain the events in establishing a resting potential. * Explain the events in generating an action potential. * Explain what is meant by the all or nothing principle. | **Learning activities:**   * back to back: provide labelled diagram of a myelinated motor neurone – pairs of students sit back to back and one student describes the structure to another who recreates it on paper * questioning to recap membrane structure and the role of proteins from section 3.2.3 * teacher explanation of resting potentials and action potentials and the all or nothing principle. Use interactive animation to check understanding * give cards showing stages involved in resting and action potential and get students to sequence them * provide an A3 oscilloscope trace showing time against axon membrane potential (with resting potential and action potential shown. Get students to match each description on the earlier card sort to the part of the graph * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of motor neurone structure, resting potentials and action potentials * AO2/AO3 – interpret scientific data and apply knowledge of the resting and action potentials to explain the data. | **Specimen assessment material:**  A-level Paper 2 (set 1) – Q4.1 and 4.3  **Past exam paper material:**  BIOL5 June 2013 – Q10a  BIOL5 June 2010 – Q3  HBIO4 June 2011 – Q3  HBIO4 Jan 2010 – Q5 | [sites.sinauer.com/neuroscience5e/animations02.01.html](http://sites.sinauer.com/neuroscience5e/animations02.01.html)  [sites.sinauer.com/neuroscience5e/animations02.03.html](http://sites.sinauer.com/neuroscience5e/animations02.03.html)  [highered.mheducation.com/sites/0072495855/student\_view0/chapter14/animation\_\_the\_nerve\_impulse.html](http://highered.mheducation.com/sites/0072495855/student_view0/chapter14/animation__the_nerve_impulse.html)  [outreach.mcb.harvard.edu/animations/actionpotential\_short.swf](http://outreach.mcb.harvard.edu/animations/actionpotential_short.swf)  **Rich questions:**   * How is a resting potential established? * How is the membrane potential reversed during an action potential? * What is the all or nothing principle? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The passage of an action potential along non-myelinated and myelinated axons, resulting in nerve impulses.  Saltatory conduction affects the speed of conductance. | 0.6 weeks | * Explain how action potentials pass along unmyelinated neurones. * Describe what nodes of Ranvier are. * Describe how action potentials pass along myelinated neurones by saltatory conduction, and why this is faster than conductance along unmyelinated neurones. | **Learning activities:**   * teacher explanation of how action potentials pass along an unmyelinated neurone by stimulating the depolarisation of the next region along the neurone * explain how myelinated neurones have nodes of Ranvier in the myelin sheath, and how action potentials pass between along nodes by saltatory conduction * exam questions.   **Skills developed by learning activities:**  AO1– development of understanding of how action potentials pass along myelinated and unmyelinated neurones. | **Specimen assessment material:**  A-level Paper 2 (set 1) – Q4.1 and 4.4 | [blackwellpublishing.com/patestas/animations/actionp.html](http://www.blackwellpublishing.com/patestas/animations/actionp.html)  **Rich questions:**   * What are nodes of Ranvier? * Why is conduction along myelinated neurones quicker than along unmyelinated ones? |
| Extension |  |  | * Students could produce a video podcast or presentation of the whole process of a nerve impulse being generated and passing along an axon. * Presentation of work and peer evaluation and feedback. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The nature and importance of the refractory period in producing discrete impulses and in limiting the frequency of impulse transmission. | 0.2 weeks | * Explain what is meant by the refractory period and why action potentials are prevented. * Explain the importance of the refractory period. * Apply knowledge of action potentials and refractory period to the context of exam questions. | **Learning activities:**   * teacher explanation of refractory periods and why they are important * provide data of an oscilloscope trace with the refractory period marked on. Ask students to work out the maximum number of action potentials that could be generated per second * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of the refractory period and its importance * AO2/AO3 – interpret scientific data and apply knowledge about refractory period in limiting the frequency of action potentials. | **Past exam paper material:**  BIOL5 June 2013 – Q4b  HBIO4 June 2012 – Q7  HBIO4 June 2010 – Q10 | **Rich questions:**   * Give three reasons why the refractory period is important. * Why are nerve impulses unidirectional? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Factors affecting the speed of conductance: myelination and saltatory conduction; axon diameter; temperature. | 0.6 weeks | * Explain the factors which affect the speed of nerve impulse conductance. * Calculate an appropriate statistical test and interpret values in terms of probability and chance (eg mean speed of conductance at 2 different temperatures). * Apply knowledge to draw and explain conclusions/answer questions. | **Learning activities:**   * highlighting exercise – what factors affect the speed of conductance? Accept feedback and discuss * students could undertake the BIO6T P14 ISA practical and exam.   **Skills developed by learning activities:**   * AO1 – knowledge of the factors affecting speed of conductance * AO2/AO3 – application of knowledge to practical results * AO3 – evaluation of the methodology and results of other people’s investigations * MS 2.3/MS 2.4 – substitute numbers into an algebraic equation to convert distance fallen into reaction time * MS 1.2 – calculate the mean * MS 1.9 – select an appropriate statistical test (student’s t-test) * MS 1.4 – interpret stats test in terms of probability and chance, and whether to accept or reject H0. | BIO6T P14 ISA | [aqa.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.aqa.org.uk) |

#### 3.6.2.2 Synaptic transmission

Prior knowledge:

**GCSE Science A**

At a junction between neurones (synapse), a chemical is released that causes an impulse to be sent along the next neurone in the reflex arc.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The detailed structure of a synapse.  The sequence of events involved in transmission across a cholinergic synapse in sufficient detail to explain:   * unidirectionality * temporal and spatial summation * inhibition by inhibitory synapses. | 0.4 weeks | * Explain the functions of synapses. * Describe the detailed structure of a synapse. * Explain the sequence of events involved in transmission of an action potential from one neurone to another. * Explain why synaptic transmission is unidirectional. * Explain temporal, spatial summation, and inhibition by inhibitory synapses. | **Learning activities:**   * teacher explanation of the functions of synapses between neurones * back to back: provide labelled diagram of a synapse – pairs of students sit back to back and one student describes the structure to another who draws it ‘blind’ * teacher explanation of the stages involved in transmission across a cholinergic synapse * card sort – sequence the stages * provide definitions of unidirectionality, temporal and spatial summation and inhibition by inhibitory synapses. Ask pupils to suggest how the structure of a synapse and the sequence events achieves each one * teacher explanation of summation, inhibition and unidirectionality * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge of synapses and synaptic transmission * AO2 – application of knowledge to explain features of synapses. | **Past exam paper material:**  BIOL5 June 2013 – Q7a–7b  BIOL5 June 2011 – Q2b  HBIO4 Jan 2012 – Q1 | [highered.mheducation.com/sites/0072495855/student\_view0/chapter14/animation\_\_chemical\_synapse\_\_quiz\_1\_.html](http://highered.mheducation.com/sites/0072495855/student_view0/chapter14/animation__chemical_synapse__quiz_1_.html)  [mind.ilstu.edu/flash/synapse\_1.swf](http://www.mind.ilstu.edu/flash/synapse_1.swf)  **Rich questions:**   * Explain how the synapse structure and events involved in synaptic transmission allow for unidirectionality, spatial and temporal summation and inhibition by inihibitory synapses. * Why is it important that acetylcholinesterase hydrolyse acetylcholine? * Explain the role played by ATP after synaptic transmission. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The effects of specific drugs on a synapse.  NB recall of names and modes of action of individual drugs are not expected. | 0.2 weeks | Use information provided to predict and explain the effects of specific drugs on a synapse. | **Learning activities:**   * stimulus: provide some drug names on cards and ask students to categorise them in a way they feel is appropriate, eg by legal classification, effect of drug etc * introduce the idea that many drugs (both recreational and some medicinal) work by affecting synapses * provide information/data about some types of drugs (eg heroin, cocaine, atropine, curare), namely the characteristic effects of the drug, and the effect the drug has on synapses eg mimicking a neurotransmitter. Ask students to work in groups to explain the effect that the drug has.   NB recall of names and modes of action of individual drugs are not expected.   * accept feedback and discuss * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding that recreational and medicinal drugs often affect synapses * AO2/AO3 – interpret information and experimental data, and apply knowledge to explain the specific effects of drugs on a synapse. | **Past exam paper material:**  HBIO4 Jan 2011 – Q5  HBIO4 Jan 2010 – Q7a and 7c  BIOL5 June 2013 – Q7c | [outreach.mcb.harvard.edu/animations/synapse.swf](http://outreach.mcb.harvard.edu/animations/synapse.swf)  [biologymad.com/nervoussystem/synapses.htm](http://www.biologymad.com/nervoussystem/synapses.htm)  [thirteen.org/closetohome/science/html/animations.html](http://www.thirteen.org/closetohome/science/html/animations.html)  [users.rcn.com/jkimball.ma.ultranet/BiologyPages/D/Drugs.html](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/D/Drugs.html) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The detailed structure of a neuromuscular junction.  A comparison of transmission across a cholinergic synapse and across a neuromuscular junction. | 0.2 weeks | * Explain what a neuromuscular junction is. * Describe and explain the detailed structure of a neuromuscular junction. * Explain transmission across a neuromuscular junction by release of acetylcholine and compare this to synaptic transmission. * Explain how muscle fibres stimulated to contract by one motor neurone act as a motor unit. | **Learning activities:**   * teacher introduction to what a neuromuscular junction is * provide students with a diagram of the structure of a neuromuscular junction and ask them to compare to a synapse * teacher explanation of transmission across a neuromuscular junction. Ask them to compare this to the transmission across a synapse * exam questions from Exampro.   **Skills developed by learning activities:**  AO1 **–** development of knowledge of neuromuscular junctions and transmission across neuromuscular junctions. | **Exampro:**  BYA7 June 2004 – Q7 | **Rich questions:**   * How does an action potential arriving at a neuromuscular junction, trigger the release of acetylcholine? * What effect does acetylcholine have on the postsynaptic membrane? * In what ways is the transmission across a neuromuscular junction similar to transmission across a (excitatory) cholinergic synapse? |
| Extension |  |  | Students could be provided with mock answers to questions on nerves, synapses, and neuromuscular junctions and evaluate/improve the answers to complete this section. |  |  |

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### 3.6.3 Skeletal muscles are stimulated to contract by nerves and act as effectors

Prior knowledge **–** nothing explicitly relevant.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Muscles act in antagonistic pairs against an incompressible skeleton. | 0.2 weeks | * Explain the role of skeletal muscle, linked to the role of tendons and joints. * Explain how muscles which move bones that form part of a joint work as antagonistic pairs. To produce movement as they contract, muscles work against/are attached to an incompressible skeleton/bones. | **Learning activities:**   * teacher introduction to skeletal muscle in terms of it moving bones at a joint. Emphasise that this is related to muscle contraction which pulls the bones * students could produce working models of the arm, using balloons or elastic bands to represent the biceps and triceps. They could investigate what each one does as the arm raises or lowers * demonstration of antagonistic pairs by using forceps to pull on tendons in a dissected chicken leg (the pull of the forceps representing the muscle contraction) * teacher explanation that muscles can only generate force as they contract/shorten – they can only pull and not push * exam question.   **Skills developed by learning activities:**  AO1 **–** development of knowledge of antagonistic pairs of muscles. | **Past exam paper material:**  HBIO4 June 2012 – Q3a. | [wonderstruck.co.uk/files/KS3-Lesson-Plan-1-Muscles-and-Bones.pdf](http://wonderstruck.co.uk/files/KS3-Lesson-Plan-1-Muscles-and-Bones.pdf)  **Rich questions:**   * What are the three types of muscle in the body and what are their roles? * Muscles can pull as they contract, but they cannot push. What would happen to a bone if muscles did not work in antagonistic pairs? * Evaluate this statement: ‘in an antagonistic pair of muscles, one muscle contracts whilst the other relaxes’. |
| Extension |  |  | Highlighting exercise covering the different types of muscle and their role. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Gross and microscopic structure of skeletal muscle.  The ultrastructure of a myofibril. | 0.4 weeks | * Describe the gross structure of skeletal muscles. * Explain what is meant by a myofibril. * Describe the microscopic structure of skeletal muscle. * Explain what is meant by a sarcomere. * Explain how actin and myosin are arranged within a myofibril to produce contraction of a sarcomere. * Interpret diagrams to identify I bands, A bands, the H zone and the Z line on a diagram. | **Learning activities:**   * teacher explanation of the gross structure of skeletal muscle * students undertake microscopy of skeletal tissue. This using prepared slides of longitudinal and transverse sections of skeletal muscle. (It could also be done by them isolating and preparing slides of muscle fibres from the muscle on shin meat) * get them to draw observations * show low powered electron micrographs showing the detailed structure of a myofibril. Ask students to interpret and relate back to their observations * teacher explanation of the microscopic structure of skeletal muscle and the ultrastructure of a myofibril * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge and understanding of the structure of skeletal muscle, and the ultrastructure of myofibrils. * AO2 – application of knowledge to the context given in exam questions. * AT d/At e – examine prepared slides of skeletal muscle, and make drawings, using an optical microscope. | **Past exam paper material:**  HBIO4 Jan 2013 – Q9a–9b  HBIO4 Jun 2012 – Q3b  HBIO4 Jan 2011 – Q10a–10b  HBIO4 June 2010 – Q4a–4b | [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk)  **Rich questions:**   * What is a myofibril? * In which bands/zone would you find:  1. Myosin? 2. Actin?  * How would you work out the length of one sarcomere? * Explain the presence of large amounts of mitochondria and endoplasmic reticulum in the sarcoplasm. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The roles of actin, myosin, calcium ions and ATP in myofibril contraction.  The roles of calcium ions and tropomyosin in the cycle of actinomyosin bridge formation.  The roles of ATP and phosphocreatine in muscle contraction. | 0.4 weeks | * Recall how the release of acetylcholine across neuromuscular junctions, triggers the release of calcium ions. * Explain the importance of the release of calcium ions leading to a conformational change in tropomyosin. * Explain the sliding theory filament of myofibril contraction. * Explain the roles of key molecules myosin, actin, calcium and ATP in causing myofibril contraction. * Explain the role of phosphocreatine in muscle fibres. | **Learning activities:**   * provide students with two string lines – one containing drawing pins and the other containing bungs attached periodically. Challenge them to make the string of bungs move along the bench without directly pulling it, and only pulling the string of pins a maximum of 5 cm. Ask them to write down how they did it in as much detail as possible * teacher explanation of sliding filament theory. Link into their explanation of the string lines * card sort – sequence the stages of myofibril contraction * teacher explanation of the role of phosphocreatine in regenerating ATP in some muscle fibres * exam questions.   **Skills developed by learning activities:**  AO1 **–** development of knowledge and understanding of the mechanism of myofibril contraction. | **Past exam paper material:**  BIOL5 June 2012 – Q2  BIOL5 June 2013 – Q2a  BIOL5 June 2010 – Q6  BIOL5 June 2011 – Q10b  HBIO4 Jan 2012 – Q3  HBIO4 June 2013 – Q5  HBIO4 June 2010 – Q4c  HBIO4 June 2011 – Q2  HBIO4 Jan 2010 – Q2 | [nuffieldfoundation.org/practical-biology/modelling-sliding-filament-hypothesis](http://www.nuffieldfoundation.org/practical-biology/modelling-sliding-filament-hypothesis)  [bcs.whfreeman.com/thelifewire/content/chp47/4702001.html](http://bcs.whfreeman.com/thelifewire/content/chp47/4702001.html)  [blackwellpublishing.com/patestas/animations/myosin.html](http://www.blackwellpublishing.com/patestas/animations/myosin.html)  **Rich questions:**   * Evaluate this statement: ‘during contraction of a muscle, actin and myosin filaments contract and get shorter’. * Explain the roles of tropomyosin, ATP and Ca2+ ions in muscle contraction. |
| Extension |  |  | * Students produce a model of the sliding filament mechanism, representing the actin, myosin, tropomyosin, ATP and calcium ions using modelling materials. They could then take time lapse photos of their model and put them together as a narrated film. * Presentation of model/film to the rest of the group. * Peer evaluation. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The structure, location and general properties of slow and fast skeletal muscle fibres. | 0.2 weeks | * Describe the locations of slow and fast skeletal muscle fibres. * Describe differences in the structure of slow and fast skeletal muscle fibres. * Explain differences in the properties of slow and fast skeletal muscle fibres. | **Learning activities:**   * jigsaw task: working in pairs, one student researches slow muscles and the other fast muscles, using information and resources provided eg websites, comprehensions, textbooks etc * accept feedback and reinforce using teacher explanation * students produce a summary table comparing and contrasting * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge relating to the structure, location and properties of slow and fast skeletal muscle * AO2 – application of knowledge to exam questions. | **Past exam paper material:**  BIOL5 June 2013 – Q2b  BIOL5 June 2010 – Q7  HBIO4 Jan 2013 – Q9c  **Exampro:**  BYA7 Jan 2004 – Q7 | **Rich questions:**  Provide students with statement cards and ask them to categorise them as relating to fast or slow muscle fibres. |

### 3.6.4 Homeostasis is the maintenance of a stable internal environment.

#### 3.6.4.1 Principles of homeostasis and negative feedback

Prior knowledge:

**GCSE Science A**

* Internal conditions that are controlled include:
  + the water content of the body – water leaves the body via the lungs when we breathe out and via the skin when we sweat to cool us down and excess water is lost via the kidneys in the urine
  + the ion content of the body – ions are lost via the skin when we sweat and excess ions are lost via the kidneys in the urine
  + temperature – to maintain the temperature at which enzymes work best
  + blood sugar levels – to provide the cells with a constant supply of energy
* Many processes in the body are controlled by hormones, which are secreted by glands and are usually transported to their target organs by the bloodstream.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Homeostasis in mammals involves physiological control systems that maintain the internal environment within restricted limits.  The importance of maintaining a stable core temperature and stable blood pH in relation to enzyme activity.  The importance of maintaining a stable blood glucose concentration in terms of availability of respiratory substrate and of the water potential of blood. | 0.2 weeks | * Define what homeostasis is. * Explain why it is important that core temperature, blood pH, blood glucose concentration and blood water potential are maintained within restricted limits and the consequences of not doing so. | **Learning activities:**   * questioning to recall knowledge from GCSE. Lead this onto a definition of homeostasis * jigsaw task: in groups, students assign roles to gather information on the importance of one factor, eg temperature being maintained. They then each go to their respective information stations to research that factor (eg using websites, textbooks, videos etc.) * give students time to feedback and discuss * quiz: students work in teams to answer questions based on the knowledge they have accumulated (including data questions).   **Skills developed by learning activities:**   * AO1 – development of knowledge relating to homeostasis and some of the key factors which the body maintains within restricted limits * AO2/AO3 – application of knowledge to explain trends in data. | **Exampro:** Specimen paper Unit 5 – Q8  BYA6 June 2005 – Q2  BYB6 June 2005 – Q5  BYA6 Jan 2005 – Q3 | **Rich questions:**   * Explain how blood pH might fall and how the body would rectify this. * Explain the consequence to enzymes of  1. a fall in body temperature 2. a rise in body temperature.  * Suggest the effect on cells if blood sugar concentration were to rise, resulting in a fall in the water potential. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Negative feedback restores systems to their original level.  The possession of separate mechanisms involving negative feedback, controls departures in different directions from the original state, giving a greater degree of control. | 0.2 weeks | * Explain what is meant by negative and positive feedback. * Explain the general stages involved in negative feedback, and why these are used in homeostatic mechanisms. * Explain the benefit of having separate mechanisms for different departures from the original level. * Interpret information relating to examples of negative and positive feedback. | **Learning activities:**   * provide students with card statements of processes involved in a homeostatic mechanism covered at GCSE eg thermoregulation. Ask students to assemble them into a flow diagram in a way they feel is logical. * teacher-led explanation of how homeostasis relies on negative feedback with support of animation examples. Go through the stages, and get students to construct a template for a model answer (departure from normal🡪receptor🡪 co-ordinator 🡪 effector🡪 response🡪 return to normal) * go back to the card sort on thermoregulation and ask what the benefit is of having separate mechanisms for departures in difference directions * ask students to suggest what positive feedback would entail. Show rest of the animation showing positive feedback in labour * exam questions.     **Skills developed by learning activities:**   * AO1 – development of knowledge relating to positive and negative feedback and the use of negative feedback in homeostatic processes * AO2 – application of knowledge of positive and negative feedback to unfamiliar examples, when presented with appropriate information. | **Past exam paper material:**  BIOL5 June 2013 – Q4a and 4c  HBIO4 Jan 2013 – Q1a  HBIO4 Jan 2011 – Q6  **Exampro:**  BYA6 June 2004 – Q9 | [wps.aw.com/bc\_goodenough\_boh\_3/104/26720/6840414.cw/content/index.html](http://wps.aw.com/bc_goodenough_boh_3/104/26720/6840414.cw/content/index.html)  **Rich questions:**   * How do the principles of positive and negative feedback differ? * What is the benefit of having separate negative feedback mechanisms controlling departures in different direction from the original state? |

#### 3.6.4.2 Control of blood glucose concentration

Prior knowledge: nothing explicitly relevant from Science A or Additional Science.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The factors that influence blood glucose concentration. | 0.2 weeks | * Explain the factors which can influence blood glucose concentration. * Explain how hormones work to bring about a response. * Explain the role of the pancreas, specifically the α and β cells of the Islets of Langerhans, in regulating blood glucose concentration. * Explain what is meant by the terms glycogenesis, glycogenolysis and gluconeogenesis. * Apply knowledge to explain the stages involved in negative feedback in response to changes in blood glucose concentration. | **Learning activities:**   * questioning to assess recall from GCSE * teacher introduction to the action of hormones * provide information posters on the topics of: the actions of hormones; factors which influence blood glucose; the response to a reduction in blood glucose concentration; the response to an increase in blood glucose level. (NB These sheets should be an introduction to blood glucose regulation in the context of negative feedback and should be kept as overviews – the mechanisms of insulin/glucagon action will be explored in more detail in subsequent lessons) * accept feedback and reinforce * students could produce negative feedback diagrams for blood glucose rise and fall * students could produce a concept map, with space to add to in further lessons.   **Skills developed by learning activities:**  AO1 **–** development of knowledge relating to negative feedback in the context of blood glucose regulation. | **Past exam paper material:**  BIOL1 June 2013 – Q6  Specimen paper Unit 5 – Q3a and 3b | **Rich questions:**   * What roles do the α cells of the Islets of Langerhans play in regulating blood glucose concentration? * What roles do the β cells of the Islets of Langerhans play in regulating blood glucose concentration? * What factors influence blood glucose concentration and how do they influence it? * How do the hormones involved in bringing about adjustments to blood glucose concentration travel to their target organ? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The action of insulin by:   * attaching to receptors on the surfaces of target cells * controlling the uptake of glucose by regulating the inclusion of channel proteins in the surface membranes of target cells * activating enzymes involved in the conversion of glucose to glycogen.   The role of the liver in glycogenesis. | 0.2 weeks | * Explain what triggers the release of insulin. * Explain how insulin acts at the cellular level to lower blood glucose concentration. * Explain the role of the liver in glycogenesis. | **Learning activities:**   * questioning on the overview that students learnt previously * provide cards with statements on which students could categorise as would increase blood glucose concentration/ would decrease blood glucose concentration eg exercise, excitement, eating a bowl of pasta * teacher explanation of the action of insulin after it is released, and the role that this plays in promoting increased absorption, increased respiration, increased glycogenesis and increased conversion to fat * students add to their concept map which they began in previous lessons * students could interpret blood glucose concentration data relating to the impact of high GI and low GI foods * exam questions.   **Skills developed by learning activities:**  AO1 **–** development of knowledge relating to the mechanisms of action by insulin, and how it results in a decrease in blood glucose concentration. | **Past exam paper material:**  HBIO4 Jan 2012 – Q10a  HBIO4 June 2010 – Q11a  HBIO4 Jan 2010 – Q3a  **Exampro:**  BYB4 Jan 2004 – Q4a | [bcs.whfreeman.com/thelifewire/content/chp50/5002s.swf](http://bcs.whfreeman.com/thelifewire/content/chp50/5002s.swf)  [dnatube.com/video/8349/Animation-in-3D-of-the--Insulin-processes-mechanism](http://www.dnatube.com/video/8349/Animation-in-3D-of-the--Insulin-processes-mechanism)  **Rich questions:**   * Which cells produce insulin? * What are the three actions which insulin binding to insulin receptors brings about? * Which cells are especially affected in terms of increasing the rate of glucose absorption? * What role does the liver play? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The action of glucagon by:   * attaching to receptors on the surfaces of target cells * activating enzymes involved in the conversion of glycogen to glucose * activating enzymes involved in the conversion of glycerol and amino acids into glucose.   The role of the liver in glycogenolysis and gluconeogenesis. | 0.2 weeks | * Explain what triggers the release of glucagon. * Explain how glucagon acts at the cellular level to raise blood glucose concentration * Explain the role of the liver in glycogenolysis and gluconeogenesis. | **Learning activities:**   * questioning on the overview that students learnt previously * teacher explanation of the action of glucagon on liver cells after it is released, in terms of promoting conversion of glycogen, amino acids and glycerol into glucose * students add to their concept map which they began in previous lessons * exam questions.   **Skills developed by learning activities:**  AO1 **–** development of knowledge relating to the mechanisms of action by glucagon, and how it results in an increase in blood glucose concentration. | **Past exam paper material:**  BIOL5 June 2010 – Q8  HBIO4 June 2013 – Q9bii | [bcs.whfreeman.com/thelifewire/content/chp50/5002s.swf](http://bcs.whfreeman.com/thelifewire/content/chp50/5002s.swf)  **Rich questions:**   * When is glucagon released? * Which cells produce glucagon? * Which cells are the only cells that have glucagon receptors? |
| Extension |  |  | Students could produce an explanation of the process glucagon action (and insulin action) in the style of a fully annotated cartoon strip or piece of extended writing. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The role of adrenaline by:   * attaching to receptors on the surfaces of target cells * activating enzymes involved in the conversion of glycogen to glucose.   The second messenger model of adrenaline and glucagon action, involving adenylate cyclase, cAMP and protein kinase. | 0.2 weeks | * Explain what triggers the release of adrenaline. * Explain how adrenaline acts at the cellular level to control blood glucose concentration. * Explain the second messenger model related to adrenaline and glucagon action. * Describe the role of adenylate cyclase, cyclic AMP and protein kinase in the second message model. | **Learning activities:**   * provide students with the opportunity to generate questions on the processes discussed so far * think, pair, share: when would adrenaline be released? Based on your answer what effect would you predict it to have and why? * teacher explanation of the role of adrenaline in binding to receptors and activating enzymes in the liver to breakdown glycogen to glucose * think, pair, share: both glucagon and adrenaline involve activating cellular enzymes to breakdown glycogen to glucose, yet both bind to cell surface receptors outside the cell. Suggest how they activate enzymes inside the cell * teacher explanation of the second messenger model * students complete their concept map.   **Skills developed by learning activities:**   * AO1 – development of knowledge relating to the mechanism of action by adrenaline and the second messenger model * AO2 – application of knowledge to think-pair-share tasks. | **Past exam paper material:**  BIOL5 June 2012 – Q6a | [highered.mheducation.com/sites/0072507470/student\_view0/chapter17/animation\_\_second\_messenger\_\_camp.html](http://highered.mheducation.com/sites/0072507470/student_view0/chapter17/animation__second_messenger__camp.html)  **Rich questions:**   * When is adrenaline released? * Suggest how the binding of glucagon and adrenaline to liver cell surface receptors is able to activate enzymes inside the cells of the liver. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The causes of types I and II diabetes and their control by insulin and/or manipulation of the diet. | 0.4-0.6 weeks | * Explain the causes of type I and II diabetes. * Explain how type 1 and type 2 diabetes can be controlled. * Apply knowledge of blood sugar regulation and diabetes to interpret data. * Evaluate the positions of health advisers and the food industry in relation to the increased incidence of type II diabetes. | **Learning activities:**   * think, pair, share: provide students with data from a glucose tolerance test for a diabetic and non-diabetic and ask them to suggest an explanation * students can use the web to research types I and II diabetes (causes and methods of control) and produce an information pamphlet or presentation * teacher explanation to reinforce key messages * section B of the BIO6T Q13 ISA * exam questions * show data on the increasing incidence of type II diabetes * students could be provided with some stimulus material and then conduct a class debate on the increasing incidence of type II diabetes, taking on the roles of health advisers and representatives of food companies.   **Skills developed by learning activities:**   * AO1 – development of knowledge relating to types I and II diabetes, in terms of causes and control * AO2/AO3 – interpretation of experimentally derived data in exam questions and from the glucose tolerance test, and application of knowledge to explain/evaluate the data and evaluate societal arguments around particular types of food/drink * MS 1.10 – understand standard deviation in the context of diabetes studies contained within suggested exam questions. | **Past exam paper material:**  HBIO4 Jan 2012 – Q10b–10f  HBIO4 June 2013 – Q9a–9bi  HBIO4 June 2010 – Q11b–11g  HBIO4 June 2011 – Q6  HBIO4 Jan 2010 – Q3b  HBIO4 June 2013 – Q8  BIO6T – Q13 ISA Section B | **Rich questions:**   * Explain the causes of types I and II diabetes. * Why do diabetics have to manage their carbohydrate intake? * Why do diabetics have to be mindful about how much exercise they do? * What are the arguments for and against the banning of advertising for certain types of food and drink in order to lower the incidence of type II diabetes? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 11:** Production of a dilution series of a glucose solution and use of colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown ‘urine’ sample. | 0.4 weeks | * Apply knowledge of diabetes and biochemical tests, to design an experiment to identify the concentration of glucose in a ‘urine’ sample. * Explain how to use colorimetry of known concentrations, alongside calibration curves to identify unknown concentrations. * Explain the usefulness of calibration curves or standards. | **Learning activities:**   * show students some fake urine samples (water and yellow food dye) and tell them that at least one is from a diabetic (contains glucose) * provide opportunity for students to work in small groups to design a method for identifying the concentration of glucose in urine samples using the knowledge they have from unit 3.1 * accept feedback to jointly arrive at a method * students then conduct the practical * students plot a calibration curve and read off the value for the unknown urine sample.   **Skills developed by learning activities:**   * AO2 – application of knowledge of biochemical tests, colorimetry and calibration curves * AT b and c – production of a dilution series from a stock glucose concentration. Use colorimetric techniques to produce a * calibration curve * PS 1.1/1.2 – apply knowledge to solve problems in a practical context * MS 0.2 – convert concentrations between standard and ordinary form * PS 4.1 – use colorimetry/calibration curves * PS 3.1/MS 1.3/3.2 – plot a calibration curve and read off an unknown concentration. | Marking of accuracy of concentration determined by reading from calibration curve. | [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk)  **Rich question:**  Why can glucose concentration in urine be used as a means of diagnosing diabetes? |

#### 3.6.4.3 Control of blood water potential

Prior knowledge:

**GCSE Science A**

* Water and ions enter the body when we eat and drink.
* Water leaves the body via the lungs when we breathe out. Water and ions are lost via the skin when we sweat and excess water and ions are lost via the kidneys in the urine.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The structure of the nephron and its role in:   * the formation of glomerular filtrate * reabsorption of glucose and water by the proximal convoluted tubule * maintaining a gradient of sodium ions in the medulla by the loop of Henle * reabsorption of water by the distal convoluted tubule and collecting ducts. | 0.4 weeks | * Describe the structure of a nephron. * Explain the process of ultrafiltration and where it occurs. * Explain the process of selective reabsorption, where it occurs along a nephron and the transport processes involved. * Explain the adaptations of cells of the proximal convoluted tubule. * Explain the importance of maintaining a sodium ion gradient in the medulla, and how this is achieved. * Explain the reabsorption of water from the distal convoluted tubule and collecting ducts. | **Learning activities:**   * questioning to assess recall from GCSE * think, pair, share: provide data showing the concentrations of molecules/ions in the blood plasma and the glomerular filtrate. Ask pupils to suggest an explanation. * introduce the concept of a nephron, as well as the medulla and cortex of the kidney * provide a series of information stations for students to circulate round (videos, animations, suitable webpages, textbooks, comprehensions) * in groups, provide an unlabelled diagram of a nephron and ask students to work in pairs to use their knowledge to label and explain what is happening at different places * teacher explanation/reinforcement of the process of ultrafiltration and selective reabsorption * exam question   **Skills developed by learning activities:**   * AO1 – development of knowledge/understanding relating to the structure of a nephron, and the events which occur at different points along the nephron * AO2/AO3 – interpretation of data and application of knowledge to explain it. | **Specimen assessment material:**  A-level Paper 2 (set 1) – Q7.4  **Exampro:**  BYB4 Jan 2008 – Q2  BYB4 June 2004 – Q6  BYB4 June 2006 – Q5 | [bcs.whfreeman.com/thelifewire/content/chp51/5101s.swf](http://bcs.whfreeman.com/thelifewire/content/chp51/5101s.swf)  **Rich questions:**   * Explain what causes some molecules to be filtered into the filtrate and others not. * Which molecules are selective reabsorbed? By which processes does this occur? * Explain the countercurrent multiplier mechanism and why it is important for water reabsorption. |
| Extension |  |  | Interpret data relating the thickness of the medulla to the maximum urine concentration produced by a range of animals, including desert animals. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Osmoregulation as control of the water potential of the blood.  The roles of the hypothalamus, posterior pituitary and ADH in osmoregulation. | 0.2 weeks | * Explain the role of the hypothalamus and posterior pituitary gland in osmoregulation. * Explain the responses which are brought about by the release of ADH. * Apply knowledge to explain the stages involved in negative feedback in response to changes in blood water potential. | **Learning activities:**   * think, pair, share: provide data about water gains and losses. Provide scenarios and ask students what would happen within the body as a result eg ‘it is a hot day and you sweat more than normal’ * ask students to suggest how the body could adjust the water losses to balance out changes to water gains * teacher explanation of ADH and its role in osmoregulation. Explain the action of ADH on the kidneys * students could produce negative feedback diagrams for when blood has a lower water potential than normal and a higher water potential than normal * exam question.   **Skills developed by learning activities:**   * AO1 – development of knowledge relating to negative feedback in the context of osmoregulation and the role of ADH. * AO2/AO3 – interpretation of data and application of knowledge to think-pair-share tasks. * MS 1.3 – interpret pie charts. | **Specimen assessment material:**  A-level Paper 2 (set 1) – Q7.1 to 7.3  **Past exam paper material:**  BYB4 June 2008 – Q5 | **Rich questions:**   * Where are osmoreceptors located? * Where is ADH released from? * What effect does ADH have on the distal convoluted tubule and collecting duct (in the medulla)? What happens as a consequence of this? |

## 

## 3.7 Genetics, populations, evolution and ecosystems

**Unit description**

The theory of evolution underpins modern Biology. All new species arise from an existing species. This results in different species sharing a common ancestry, as represented in phylogenetic classification. Common ancestry can explain the similarities between all living organisms, such as common chemistry (eg all proteins made from the same 20 or so amino acids), physiological pathways (eg anaerobic respiration), cell structure, DNA as the genetic material and a ‘universal’ genetic code.

The individuals of a species share the same genes but (usually) different combinations of alleles of these genes. An individual inherits alleles from their parent or parents.

A species exists as one or more populations. There is variation in the phenotypes of organisms in a population, due to genetic and environmental factors. Two forces affect genetic variation in populations: genetic drift and natural selection. Genetic drift can cause changes in allele frequency in small populations. Natural selection occurs when alleles that enhance the fitness of the individuals that carry them rise in frequency. A change in the allele frequency of a population is evolution.

If a population becomes isolated from other populations of the same species, there will be no gene flow between the isolated population and the others. This may lead to the accumulation of genetic differences in the isolated population, compared with the other populations. These differences may ultimately lead to organisms in the isolated population becoming unable to breed and produce fertile offspring with organisms from the other populations. This reproductive isolation means that a new species has evolved.

Populations of different species live in communities. Competition occurs within and between these populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem.

### 3.7.1 Inheritance

Prior knowledge:

**GCSE Additional Science**

* When gametes join, one of each allele in a pair comes from each parent.
* Some characteristics are controlled by one gene, which might have different alleles.
* The allele which controls the development of a characteristic even if they are only present on one chromosome is called the dominant allele.
* The allele which controls the development of a characteristic only when the dominant allele is not present is called the recessive allele.
* Some disorders are inherited. These include polydactyly, which is caused by a dominant allele, and cystic fibrosis which is a recessive disorder.
* Genetic diagrams are biological models which can be used to predict the outcomes of genetic crosses.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The genotype is the genetic constitution of an organism.  The phenotype is the expression of this genetic constitution and its interaction with the environment.  There may be many alleles of a single gene.  In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous. | 0.2-0.4 weeks | Explain the meaning of the key terms:   * gene * allele * genotype * phenotype * homozygous * heterozygous. | **Learning activities:**   * diagnostic question to assess GCSE understanding – is it possible for two brown eyed parents to have a blue eyed child? Explain your answer * teacher-led explanation of the concepts of genes and alleles and the key terms required in the specification * card match – terms to definitions * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge and understanding of key terms and concepts relating to inheritance * ATh – ethical and safe use of organisms. |  | **Rich question:**  What is wrong with this statement: “he had two blue eyed genes which meant he had blue eyes”? |
| Extension |  |  | Students could set up an experiment to study Drosophila crosses and investigate ratios from genetic crosses eg dihybrid ratios. NB This will take about 3 weeks before adult offspring can be observed, but the results could be used in later experiments. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Alleles may be dominant or recessive.  The use of fully labelled genetic diagrams to interpret, or predict, the results of monohybrid crosses involving dominant and recessive alleles. | 0.2 weeks | * Define what is meant by dominant and recessive alleles and describe how to represent these. * Draw genetic diagrams of dominant/recessive monohybrid crosses to predict offspring genotypes and phenotypes. * Apply knowledge to calculate the predicted ratios of genotypes and phenotype of offspring when supplied with appropriate information. | **Learning activities:**   * stimulus: survey those in the class who can roll their tongue. Introduce the idea of this being controlled by two alleles of one gene – a dominant and a recessive one * teacher explanation of the principle of dominant and recessive alleles (related back to protein synthesis) and how these are symbolically represented * work through some examples, using Punnet squares to represent the inheritance of characteristics. Relate back to meiosis * students work through further examples independently * teacher-led explanation of how to interpret pedigree analysis diagrams to prove whether a characteristic is dominant or recessive.   **Skills developed by learning activities:**   * AO1 – development of understanding of dominant and recessive alleles, and their inheritance * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use information to represent phenotypic ratios in monohybrid crosses * MS 1.4 – understand simple probability associated with inheritance. | **Past exam paper material**:  BIOL4 June 2013 – Q3a–b  HBIO4 June 2013 – Q4  HBIO4 June 2010 – Q6 | [kscience.co.uk/animations/drosophila2.htm](http://www.kscience.co.uk/animations/drosophila2.htm)  [kscience.co.uk/animations/inheritance.htm](http://www.kscience.co.uk/animations/inheritance.htm)  **Rich questions:**   * Define what is meant by dominant and recessive alleles. * Why is it not correct to think of a cell ignoring the recessive allele if a dominant one is present? * Two heterozygous parents who can roll their tongue have 3 children. All 3 offspring can roll their tongue. They then fall pregnant with a 4th child. Does this mean that this one will be unable to roll their tongue? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Use of the chi-squared (χ2) test to compare the goodness of fit of observed phenotypic ratios with expected ratios. | 0.2 weeks | * Explain what the chi-squared test is used for. * Set a null hypothesis. * Use the chi-squared test to compared observed values against those predicted from genetic crosses. * Interpret chi-squared tests in terms of probability and chance. | **Learning activities:**   * ask pupils to do a genetic cross of heterozygous peas eg for colour and to work out the 3:1 ratio. Provide numbers of pea plants which don’t exactly match this ratio and ask students what possibilities exist to explain this difference in observed values * discuss the nature of probability and fertilisation events being unlinked and random * lead through students through a couple of worked examples of the chi-squared tests and how to interpret values – NB in written papers, students will not be expected to calculate a test statistic or find the value of P corresponding to the test statistic. They will be expected to interpret a value of P * provide further examples using simple dominant/recessive monohybrid crosses.   **Skills developed by learning activities:**   * AO1 – development of knowledge and understanding of the chi-squared test and how it is used * AO2 – application of knowledge to interpret chi-squared outcomes * MS 1.9 – use the χ2 test to investigate the significance of differences between expected and observed phenotypic ratios. | **Past exam paper material**:  BYA5 Jan 2003 – Q8a–8b | **Rich questions:**   * Why should you use chi-squared for inheritance investigations? * What is the null hypothesis for this? * How many degrees of freedom? * Interpret your results in terms of chance and probability. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Alleles may also be codominant.  The use of fully labelled genetic diagrams to interpret, or predict, the results of monohybrid crosses involving codominant alleles. | 0.2 weeks | * Define what is meant by codominant alleles, and describe how to represent these. * Draw genetic diagrams of codominant monohybrid crosses to predict offspring genotypes and phenotypes. * Apply knowledge to calculate the predicted ratios of genotypes and phenotype of offspring, using fully labelled diagrams, when supplied with appropriate information. * Use the chi-squared test to compare observed values against those predicted from genetic crosses. * Interpret P values from chi-squared tests in terms of probability and chance. | **Learning activities:**   * teacher explanation of the principle of co-dominant alleles and how these are symbolically represented * work through some examples, using Punnet squares to represent the inheritance of characteristics. Relate back to meiosis * students work through further examples independently, including chi-squared questions as well.   **Skills developed by learning activities:**   * AO1 – development of understanding of co-dominant alleles, and their inheritance. * AO2 – application of knowledge to unfamiliar contexts. * MS 0.3 – use information to represent phenotypic ratios in monohybrid crosses. * MS 1.4 – understand simple probability associated with inheritance. * MS 1.9 – use the χ2 test to investigate the significance of differences between expected and observed phenotypic ratios. | **Past exam paper material**:  BIOL4 June 2014 – Q4c | **Rich question:**  Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving codominance eg pink snapdragons, Tabby cats, Palamino horses, Human haemoglobin, orange moths. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of fully labelled genetic diagrams to interpret, or predict, the results of multiple allele crosses. | 0.2 weeks | * Describe how to represent alleles in crosses involving multiple alleles. * Draw genetic diagrams to predict offspring genotypes and phenotypes. * Apply knowledge to calculate the predicted ratios of genotypes and phenotype of offspring, using fully labelled diagrams, when supplied with appropriate information. * Use the chi-squared test to compared observed values against those predicted from genetic crosses. * Interpret P values from chi-squared tests in terms of probability and chance. | **Learning activities:**   * introduce the concept of blood groupings. Ask students to do a simple monohybrid cross for Rhesus blood groupings (antigen D gene) as a recap of dominant/recessive crosses) * introduce the ABO blood grouping system and the fact it is controlled by one gene. Ask students to suggest how this is possible * teacher explanation of the principle multiple allele inheritance and how these alleles are symbolically represented * work through some examples, using Punnet squares to represent the inheritance of characteristics * students work through further examples independently, including chi-squared questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of multiple alleles and their inheritance * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use information to represent phenotypic ratios in monohybrid crosses * MS 1.4 – understand simple probability associated with inheritance * MS 1.9 – use the χ2 test to investigate the significance of differences between expected and observed phenotypic ratios. | **Past exam paper material**:  BIOL4 June 2012 – Q2a–c  BIOL4 Jan 2011 – Q2a–b  BIOL4 June 2011 – Q5  **Exampro:**  BYA5 Jan 2007 – Q3  BYA5 June 2006 – Q7 | **Rich question:**  Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving multiple alleles eg ABO blood groups, coat colour in rabbits. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of fully labelled genetic diagrams to interpret, or predict, the results of crosses involving sex linkage. | 0.2 weeks | * Explain what is meant by sex-linked genes, and describe how to represent these. * Draw genetic diagrams of sex-linked crosses to predict offspring genotypes and phenotypes. * Apply knowledge to calculate the predicted ratios of genotypes and phenotype of offspring, using fully labelled diagrams, when supplied with appropriate information. * Use the chi-squared test to compared observed values against those predicted from genetic crosses. * Interpret P values from chi-squared tests in terms of probability and chance. | **Learning activities:**   * ask students to suggest why some characteristics eg red-green colour blindness, DMD are more common in men * teacher explanation of the principle sex linkage and how these alleles are symbolically represented * work through some examples, using Punnet squares to represent the inheritance of characteristics * students work through further examples independently, including chi-squared questions as well.   **Skills developed by learning activities:**   * AO1 – development of understanding of co-dominant alleles, and their inheritance * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use information to represent phenotypic ratios in monohybrid crosses * MS 1.4 – understand simple probability associated with inheritance * MS 1.9 – use the χ2 test to investigate the significance of differences between expected and observed phenotypic ratios. | **Past exam paper material**: BIOL4 Jan 2012 – Q5  BIOL4 Jan 2013 – Q3  BIOL4 June 2013 – Q3bii  BIOL4 June 2014 – Q4a-4b  BYA5 June 2008 – Q6  BYA5 June 2009 – Q4  **Exampro:**  BYB4 Jan 2004 – Q5  BYB4 June 2004 – Q5  BYB4 June 2006 – Q6  BYB4 June 2005 – Q4 | [kscience.co.uk/animations/drosophila2.htm](http://www.kscience.co.uk/animations/drosophila2.htm)  **Rich question:**  Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving sex linkage eg Duchenne muscular dystrophy, Haemophilia, Red/green colour blindness. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of fully labelled genetic diagrams to interpret, or predict, the results of dihybrid crosses involving dominant, recessive and codominant alleles. | 0.4 weeks | * Draw genetic diagrams of dihybrid crosses to predict offspring genotypes and phenotypes. * Apply knowledge to calculate the predicted ratios of genotypes and phenotype of offspring, using fully labelled diagrams, when supplied with appropriate information. * Use the chi-squared test to compare observed values against those predicted from genetic crosses. * Interpret P values from chi-squared tests in terms of probability and chance. | **Learning activities:**   * teacher explanation of dihybrid crosses as looking at the inheritance of two characteristics controlled by two unlinked genes, which are inherited independently of each other * work through some examples, using Punnet squares to represent the inheritance of characteristics * students work through further examples independently, including chi-squared questions as well.   **Skills developed by learning activities:**   * AT h – ethical and safe use of organisms * AO1 – development of understanding of dihybrid crosses * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use information to represent phenotypic ratios in dihybrid crosses * MS 1.4 – understand simple probability associated with inheritance * MS 1.9 – use the χ2 test to investigate the significance of differences between expected and observed phenotypic ratios. | **Exampro:**  BYA5 Jan 2005 – Q7  BYA5 Jan 2009 – Q6  BYB4 June 2006 – Q6  BYB4 June 2007 – Q5  BYB4 June 2009 – Q3 | [kscience.co.uk/animations/drosophila2.htm](http://www.kscience.co.uk/animations/drosophila2.htm)  **Rich question:**  Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving dihyrbid inheritance eg coat colour and hair length in guinea pigs, wing size and body colour in Drosophila. |
| Extension |  |  | Students look at the crosses undertaken several weeks previously investigating inheritance in Drosophila. Ask them to propose an explanation for the ratio. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of fully labelled genetic diagrams to interpret, or predict, the results of crosses involving autosomal linkage. | 0.2  weeks | * Apply knowledge to calculate the predicted frequencies of genotypes and phenotype of offspring, using fully labelled diagrams, when supplied with appropriate information. * Use the chi-squared test to compared observed values against those predicted from genetic crosses. * Interpret P values from chi-squared tests in terms of probability and chance. | **Learning activities:**   * provide data on the work of Bateson, Saunders and Punnet in 1905, showing the F1 and F2 generation results. Ask them to apply chi-squared to this, assuming it was a simple dihybrid cross (ie 9:3:3:1) to prove there was a significant difference between observed and expected * teacher explanation of autosomal linkage. Make it clear that this is investigating two genes on the same chromosome pair, unlike other examples studied so far * work through some examples, using Punnet squares to represent the inheritance of characteristics when supplied with the frequency of gametes with each combination of alleles * students work through further examples independently.   **Skills developed by learning activities:**   * AO1 – development of understanding of epistasis * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use information to represent phenotypic ratios in crosses involving epistasis * MS 1.4 – understand simple probability associated with inheritance * MS 1.9 – use the χ2 test. | **Specimen assessment material**:  A-level Paper 2 (set 1) – Q3 | [kscience.co.uk/animations/drosophila2.htm](http://www.kscience.co.uk/animations/drosophila2.htm)  **Rich question:**  Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving autosomal linkage eg linkage in flower colour and type of pollen in sweet peas, linkage of wing and eye colour. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of fully labelled genetic diagrams to interpret, or predict, the results of crosses involving epistasis. | 0.2 weeks | * Apply knowledge to calculate the predicted ratios of genotypes and phenotype of offspring, using fully labelled diagrams, when supplied with appropriate information. * Use the chi-squared test to compare observed values against those predicted from genetic crosses. * Interpret P values from chi-squared tests in terms of probability and chance. | **Learning activities:**   * teacher explanation of epistasis (the interference of one gene’s expression of another) * work through some examples using Punnet squares to represent the inheritance of characteristics * students work through further examples independently.   **Skills developed by learning activities:**   * AO1 – development of understanding of epistasis * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use information to represent phenotypic ratios in crosses involving epistasis * MS 1.4 – understand simple probability associated with inheritance. | **Exampro:**  BYB4 June 2005 – Q7  BYB4 Jan 2005 – Q5  BYB4 Jan 2006 – Q6  BYA4 Jan 2006 – Q6a | **Rich questions:**  Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving epistasis eg coat colour in rodent, fruit colour in summer squashes, flower colour in sweet peas, comb shape in chickens. |

### 3.7.2 Populations

Prior knowledge: nothing explicitly relevant.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Species exist as one or more populations.  A population as a group of organisms of the same species occupying a particular space at a particular time that can potentially interbreed.  The concepts of gene pool and allele frequency. | 0.2 weeks | * Define what is meant by the term ‘population’. * Explain what is meant when we refer to allele frequencies and a gene pool. * Explain why some genotypes cannot be determined by looking at phenotypes. | **Learning activities:**   * ask students the rich questions to expose common misconceptions * define the concept of a population. Introduce the concept of gene pools and the limitations of Mendel’s crosses * provide students with photocopied pictures of animals with the genotypes for one feature written on them (have a mixture of homozygous dominant, heterozygous and homozygous recessive individuals). Ask students to work out the frequency of genotypes and allele frequencies within the gene pool * summarise their findings as p+q=1.   **Skills developed by learning activities:**   * AO1 – development of understanding of population and gene pools * AO2/AO3 – analyse information and apply knowledge to work out allele frequencies * MS 0.3 – use percentages and decimals. | **Past exam paper material**:  BYA5 Jan 2005 – Q8a  BYA5 June 2003 – Q4a | **Rich questions:**   * Is the dominant allele more common in a population than the recessive allele? Explain your answer. * Is it possible to work out the genotypes of everyone in a population for a particular feature? Explain your answer. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The Hardy-Weinberg principle provides a mathematical model, which predicts that allele frequencies will not change from generation to generation. The conditions under which the principle applies.  The frequency of alleles, genotypes and phenotypes in a population can be calculated using the Hardy-Weinberg  equation:  p2 + 2pq + q2 = 1 | 0.4 weeks | * Explain what the Hardy-Weinberg principle predicts. * Explain the conditions under which Hardy-Weinberg principle is valid. * Describe and explain the mathematical equations used to express allele and genotype frequencies. * Apply knowledge of the Hardy-Weinberg equation to the data given in a question to calculate the frequency of an allele or genotype. | **Learning activities:**   * recap findings from last lesson that p + q =1 * teacher explanation of Hardy-Weinberg principle and the conditions under which it applies * worked examples of calculations using the Hardy-Weinberg equation as a class * students investigate the frequency of observable phenotypes within a population:   + make observations of observable phenotypes   + select and calculate an appropriate statistical test   + interpret the results of the stats tests to draw conclusions   + apply knowledge of inheritance and Hardy-Weinberg to explain your results and other data. * students follow the practical method from BIO6T P13 ISA, carry out the stats test and then do the ISA paper * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of Hardy–Weinberg principle * AO2 – application of knowledge to unfamiliar contexts * MS 0.3 – use percentages and decimals * MS 2.4 – students should be able to calculate allele, genotype and phenotype frequencies from appropriate data using the Hardy–Weinberg equation * MS 3.1 – translate information between numerical and algebraic forms * AT k – collect data about the frequency of observable phenotypes within a single population * PS 3.2/MS 1.9 – select and use an appropriate statistical test * 8.4.2.4. | **Specimen assessment material**:  A-level Paper 2 (set 1) – Q6.1  **Past exam paper material:**  BIOL4 June 2012 – Q2d  BIOL4 June 2013 – Q3c  BIOL4 Jan 2011 – Q2c  BIOL4 June 2010 – Q3  BIOL4 June 2011 – Q6a–bi | **Rich questions:**   * What assumptions does the Hardy-Weinberg principle make? * Do these principles apply in practice? * Why must both equations be equal to 1? |

**3.7.3 Evolution may lead to speciation**

Prior knowledge:

**GCSE Science A**

* Differences between individuals may be due to the genes they have inherited, the environment or a combination of the two.
* Plants often compete for light, water, space and minerals. Animals often compete for food, mates and territory.
* Organisms have adaptations which enable them to survive in the conditions in which they normally live.
* Darwin’s theory of evolution by natural selection states that all life evolved from simple organisms that developed three billion years ago.

**GCSE Additional Science**

New species arise as a result of isolation, genetic variation, natural selection and speciation.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Individuals within a population may show a wide range of variation in phenotype. This is due to genetic and environmental factors.  The primary source of genetic variation is mutation. Meiosis and the random fertilisation of gametes during sexual reproduction produce further genetic variation. | 0.2 weeks | * Explain why individuals within a population of a species may show a wide range of variation in phenotype. * Describe variation based on trends in graphs and link this to the causes of variation. | **Learning activities:**   * students could measure variation within the group * plot results using spreadsheets * teacher-led discussion of trends in data and the types/causes of variation. Link genetic variation back to work done in Year 1 on meiosis and mutation   **Skills developed by learning activities:**   * AT l – use software to process (eg calculate standard deviation) and plot data * MS 1.10 – understand and calculate standard deviation and range * AO1 – development of knowledge of variation and its causes * AO2/AO3 – application of knowledge to identify types of variation and causes from experimentally derived data * MS1.6 – calculate mean, median and mode for measured values. | **Past exam paper material:**  HBIO4 Jan 2013 – Q3  HBIO4 June 2011 – Q4 and Q10e | [learn.genetics.utah.edu/content/variation/sources](http://learn.genetics.utah.edu/content/variation/sources/)  **Rich questions:**   * What do we mean by continuous and discontinuous variation? * What causes discontinuous and continuous variation? * Explain why siblings are so varied, even though they have the same parents. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Predation, disease and competition for the means of survival result in differential survival and reproduction, ie natural selection.  Those organisms with phenotypes providing selective advantages are likely to produce more offspring and pass on their favourable alleles to the next generation. | 0.2 weeks | * Explain what is meant by selection. * Explain how natural selection is linked to inheritance of alleles by the next generation and adaptation. * Explain the concept of differential reproductive success. * Apply your knowledge to explain data. | **Learning activities:**   * set up cards around the room with factors which animals might compete for eg food. Make sure that some factors are in short supply and that they are well hidden and inaccessible to some students * give students five minutes to collect a full set of cards * discuss the principle of competition and the fact that those without a full set would not have survived and reproduced. You can also link the model into variation and adaptation eg tallest reach the highest cards * teacher led explanation of predation, disease and competition linked to survival. Link to Darwin’s observations. Contextualise with information on the factors eg facial tumour disease in Tazmanian devils * students use peppered moths simulation to model effects of natural selection or work through peppered moths student sheet (see resources) * exam questions.   **Skills developed by learning activities:**   * AO1/AO2/AO3 – development of knowledge of natural selection and selection pressures, and application to data * AT l – use computer programs to model the effects of natural selection. | **Specimen assessment material**:  A-level Paper 2 (set 1) – Q6.2  **Past exam paper material:**  BIOL4 Jan 2011 – Q4 | [nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-peppered-moths](http://www.nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-peppered-moths)  [nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-banded-snails](http://www.nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-banded-snails)  [peppermoths.weebly.com](http://peppermoths.weebly.com/)  [learn.genetics.utah.edu/content/selection](http://learn.genetics.utah.edu/content/selection/)  [arkive.org/education/teaching-resources-16-18](http://www.arkive.org/education/teaching-resources-16-18) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The effect of differential reproductive success on the allele frequencies within a gene pool.  The effects of stabilising, directional and disruptive selection.  Evolution as a change in the allele frequencies in a population. | 0.2 weeks | * Recall what is meant by allele frequency. * Explain what is meant by stabilising, directional and disruptive selection in the context of the effect that each has on phenotypes and allele frequencies. | **Learning activities:**   * questioning to recall directional and stabilising selection from 3.4.4 * teacher-led explanation of disruptive selection (alongside recap of other forms of selection if required). Use animation of the selection of finches on the Galapagos islands * card sort with examples of disruptive, directional and stabilising selection described. Students have to categorise * ask students to work in groups to explain the evolution of characteristics in a species eg a single hoof in horses, long necks in giraffes including the type of selection and reference to allele frequencies * presentation of explanation and peer assessment * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to forms of natural selection and their effect on allele frequencies * AO2/AO3 – application of knowledge to experimentally derived data (in exam questions). | **Past exam paper material:**  BIOL4 June 2011 – Q6bii;  BIOL4 Jan 2010 – Q1d;  BIOL4 June 2014 – Q5. | [wps.pearsoncustom.com/wps/media/objects/3014/3087289/Web\_Tutorials/17\_A02.swf](http://wps.pearsoncustom.com/wps/media/objects/3014/3087289/Web_Tutorials/17_A02.swf)  [bcs.whfreeman.com/thelifewire/content/chp23/2302001.html](http://bcs.whfreeman.com/thelifewire/content/chp23/2302001.html)  [nortonbooks.com/college/biology/animations/ch16a02.htm](http://nortonbooks.com/college/biology/animations/ch16a02.htm)  [learn.genetics.utah.edu/content/selection](http://learn.genetics.utah.edu/content/selection/)  **Rich question:**  What kind of selection is shown in the example of *Biston betularia*? Justify your answer. |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Reproductive separation of two populations can result in the accumulation of difference in their gene pools.  New species arise when these genetic differences lead to an inability of members of the populations to interbreed and produce fertile offspring, resulting in speciation.  Allopatric speciation and sympatric speciation. | 0.4 weeks | * Explain what is meant by allopatric and sympatric speciation. * Explain how natural selection and isolation may result in change in the allele and phenotype frequency and lead to the formation of a new species by allopatric speciation and sympatric speciation. * Explain possible mechanisms for sympatric speciation. * Apply knowledge to unfamiliar contexts. * Explain how evolutionary change over a long period of time has resulted in a great diversity of species. | **Learning activities:**   * teacher led explanation of the concept of reproductive separation preventing gene flow as a precursor to speciation * provide information stations eg videos, animations, textbook, comprehensions and websites for students to find out about allopatric and sympatric speciation * accept feedback. Question students about the mechanisms of reproductive isolation for sympatric speciation * think, pair, share: what could constitute a geographical barrier to some species, for allopatric speciation to occur? * use knowledge and teacher input to derive a model class answer * apply that answer to an example as a class * exam questions * link speciation to species diversity and what is shown by fossils. An example could be the evolution of lizards or whales.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to forms of natural selection and their effect on allele frequencies and species diversity * AO2 – application of knowledge to unfamiliar contexts in exam questions * extended exam answers. | **Past exam paper material**:  BIOL4 Jan 2013 – Q8c Q4  BIOL4 June 2013 – Q6  BIOL4 Jan 2011 – Q8c | [wps.pearsoncustom.com/wps/media/objects/3014/3087289/Web\_Tutorials/18\_A01.swf](http://wps.pearsoncustom.com/wps/media/objects/3014/3087289/Web_Tutorials/18_A01.swf)  [media.hhmi.org/biointeractive/films/OriginSpecies-Lizards.html](http://media.hhmi.org/biointeractive/films/OriginSpecies-Lizards.html)  [youtube.com/watch?v=H6IrUUDboZo](http://www.youtube.com/watch?v=H6IrUUDboZo)  **Rich questions:**   * Explain what happens to cause speciation. * How do the mechanisms of reproductive separation differ in allopatric and sympatric speciation? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The importance of genetic drift in causing changes in allele frequency in small populations. | 0.2 weeks | * Explain the process of genetic drift and its impact on allele frequencies. * Explain how genetic drift differs from natural selection. * Explain why genetic drift is important only in small populations. | **Learning activities:**   * provide students with photocopied pictures of animals with the genotypes for one feature written on them (used previously in the section 3.7.2) but limit the number to 10 animals in total. Get students to work out allele frequencies in the gene pool. Then ask students to close their eyes and randomly eliminate 4 cards from the 10. Repeat calculation of allele frequencies. Discuss findings, as chance should mean that some groups have significantly reduced the frequency of one allele * teacher explanation of genetic drift using animation * ask students to explain how this differs to natural selection * provide an example eg achromatopsia on the island of Pinegelap. Ask students to write a suggested explanation.   **Skills developed by learning activities:**   * AO1 – development of understanding of genetic drift * AO2/AO3 – application of knowledge to explain unfamiliar examples * MS 1.5 – apply knowledge of sampling to the concept of genetic drift * AT l – use computer programs to model the effects of genetic drift. | Assessment of students’ written explanations. | [nortonbooks.com/college/biology/animations/ch16a01.htm](http://nortonbooks.com/college/biology/animations/ch16a01.htm)  **Rich questions:**   * How is genetic drift fundamentally different to natural selection? * Why does genetic drift only have noticeable effects in small populations? |

### 3.7.4 Populations in ecosystems

Prior knowledge:

**GCSE Additional Science**

* Physical factors which affect organisms include: light; temperature; water availability; nutrient availability; carbon dioxide and oxygen availability.
* Quantitative data on the distribution of organisms can be obtained by random sampling with quadrats or sampling along a transect.
* Evaluation of methods used to collect environmental data, including understanding of the terms mean, median and mode and understanding that the sample size affects validity and reproducibility.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Populations of different species form a community.  Within a habitat, a species occupies a niche governed by adaptation to both abiotic and biotic conditions.  An ecosystem supports a certain size of population of a species, called the carrying capacity.  This population size can vary as a result of:   * the effect of abiotic factors * interactions between organisms: interspecific and intraspecific competition and predation. | 0.2 weeks | * Define the terms community, biotic, abiotic, ecosystem and niche. * Explain what is meant by the carrying capacity of a population, and the biotic and abiotic factors which determine population size. * Explain how some common abiotic factors could be measured. * Explain why no two species have exactly the same niche. | **Learning activities:**   * teacher-led explanation of ecosystems, populations and communities * ask pupils to brainstorm factors which could influence population sizes. Accept feedback and categorise into biotic and abiotic factors * do a card sort matching abiotic factors to the instruments/techniques used to measure them (and the units if appropriate) * teacher-led explanation of niches * use a past exam question to work through data to determine an organism’s niche * students attempt further exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to forms of natural selection and their effect on allele frequencies * AO2/AO3 – application of knowledge to experimentally derived data (in exam questions) * MS 0.1 – recognise and use appropriate units for abiotic measurements. | **Past exam paper material**: BIOL4 Jan 2012 – Q1a and Q1c  BIOL4 Jan 2012 – Q4  BIOL4 – June 2012 – Q3 | **Rich questions:**   * Why do no two species have exactly the same niche? * What happens when niches overlap? * Why is it incorrect to say that no two organisms have the same niche? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The size of a population can be estimated using randomly placed quadrats, or quadrats along a belt transect, for slow-moving or non-motile organisms. | 0.6 weeks | * Describe and explain the techniques of sampling at random using quadrats, and systematic sampling using transects. * Explain when it would be appropriate to use each technique. * Describe the different measures of abundance that can be measured. * Explain how sampling at random can be done to avoid bias. * Explain how to ensure that estimates and conclusions are reliable. | **Learning activities:**   * questioning about what students recall from GCSE * teacher explanation of the basis of sampling, how to conduct random and systematic sampling and how to ensure validity, reliability and eliminate bias * students conduct practical sampling. They should do sampling at random using quadrats and systematic sampling using transects. This could be done on a school field or as part of a field trip.   **Skills developed by learning activities:**   * AO1/PS 4.1 – development of understanding relating to sampling using quadrats and transects * AO2/AO3 – application of knowledge to experimentally derived data (in exam questions) * AT k – investigate the distribution of organisms in a named habitat using randomly placed frame quadrats, or a belt transect * AT k/MS 0.3 – use both percentage cover and frequency as measures of abundance of a sessile species * MS 0.4 – make estimates of percentage cover * MS 1.6 – calculate mean, median and mode for measured values from sampling * MS 1.5 – understand the principles of sampling * MS 1.7 – use a scatter diagram to identify a correlation between two measured values from a belt transect eg light intensity and percentage cover of Dog’s mercury * MS 1.9 – select and use an appropriate statistical test * PS 1.2/2.1 – understand how to design experiments to avoid bias and ensure a large enough sample size. | **Past exam paper material**:  BIOL4 Jan 2012 – Q3a  BIOL4 June 2013 – Q7  BIOL4 June 2010 – Q7  BIOL4 Jan 2010 – Q4  BIOL4 Jan 2010 – Q7  BIOL4 June 2014 – Q8c | [nuffieldfoundation.org/practical-biology/observing-patterns-distribution-simple-plant](http://www.nuffieldfoundation.org/practical-biology/observing-patterns-distribution-simple-plant)  [nuffieldfoundation.org/practical-biology/biodiversity-your-backyard](http://www.nuffieldfoundation.org/practical-biology/biodiversity-your-backyard) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The size of a population can be estimated using the mark-release-recapture method for motile organisms.  The assumptions made when using the mark-release-recapture method. | 0.2-0.4 weeks | * Explain the technique of mark-release-recapture and when it would be appropriate to use this technique. * Use given data to calculate the size of a population estimated using the mark-release-recapture method. * Explain why careful consideration must be given to the method used to mark animals. * Explain the assumptions which must be made during mark-release-recapture. | **Learning activities:**   * teacher led explanation of mark-release recapture technique, the ethical issues surrounding marking, and the assumptions/limitations of the technique * students conduct practical sampling using humane animal traps. Care should be taken not to harm the animals. This could be done on a school field or as part of a field trip * alternatively, the technique could be modelled using matchsticks, or sweets. Sample 10 matchsticks and mark them, then reintroduce back into the box and shake well. Resample 20 matchsticks and perform calculation as population estimate. Repeat using a different colour mark. Then count matchsticks to gauge accuracy of estimate * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to mark-release-recapture, the ethical issues surrounding it, and its assumptions/limitations * AO2 – application of knowledge, using given data to calculate population estimates * AT k/AT h – use the mark-release-recapture method to investigate the abundance of a motile species * MS 2.3/2.4 – substitute numerical values into the mark-release-recapture equation to solve the equation. | **Specimen assessment material**:  A-level Paper 3 (set 1) – Q1  **Past exam paper material**:  BIOL4 June 2012 – Q1b  BIOL4 June 2013 – Q4a and 4c  BIOL4 June 2010 – Q2  Questions from BIO6T Q14 | **Rich questions:**   * Why might it be inappropriate to put a brightly coloured mark on an animal? * Predict the effect on the accuracy of your estimate if:  1. some marks were to rub off prior to recapture 2. the second sample is conducted within an hour of release.  * Assuming that the technique is done correctly, why might all individuals still not be equally catchable? * Could mark-release-recapture be used to sample humans? Explain your answer.   [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 12:** Investigation into the effect of a named environmental factor on the distribution of a given species. | 1 week | * Propose a null hypothesis to test. * Design an experiment to investigate the effect of a named factor on the distribution of a given species, taking into account the need for data to be reliable. * Suggest what you will do for variables which cannot be controlled. * Represent raw and processed data clearly using tables and graphs. * Select and use an appropriate statistical test and interpret the P value that results in terms of probability and chance. * Apply knowledge to draw and explain conclusions. | **Learning activities:**  students design an experiment to investigate the effect of a named variable on the distribution of a given plant/animal species eg light intensity of the percentage cover of Dog’s mercury as you move away from a tree. This could include:   * researching a method * designing an experiment and risk assessing * carrying out (subject to teacher approval) – this could be done in school or as part of a field trip * processing and presentation of data * calculation and interpretation of statistical tests * conclusion and evaluation.   **Skills developed by learning activities:**   * AT a and k – use appropriate apparatus and sampling techniques in fieldwork * PS 1.1/1.2/2.4 – apply scientific knowledge to design a sampling investigation, identifying key variables * PS 2.2/PS 3.1/ MS 1.7 – plot the experimental data on a scatter graph * MS 1.6 – calculate mean, median or mode for measured values from sampling * MS 1.9 – use an appropriate statistical test * MS 1.4 – understand simple probability * AO1/AO2 – application of knowledge to explain trends * 8.4.2.1/8.4.2.2/8.4.2.3/8.4.2.4/8.4.2.5. | Marking of experimental write-up | [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Primary succession from pioneer species to climax community.  At each stage, certain species may be recognised which change the environment so that it becomes more suitable for other species.  The new species may change the environment in such a way that it becomes less suitable for the previous species.  Changes that organisms produce in their abiotic environment can result in a less hostile environment and change biodiversity. | 0.4 weeks | * Explain what succession is. * Explain how succession causes changes to ecosystems over time. * Explain the impact of environmental changes on biodiversity. * Apply knowledge to unfamiliar contexts. | **Learning activities:**   * look at a family tree of royal family and the succession to the throne. Ask students to define the word * provide students with some plant species cards (eg mosses, lichens and algae, shallow rooted grasses, deep rooted shrubs, rowan trees and oak trees), and some facts cards with information about each species. Ask them to try and put the cards in order of succession from pioneer species to climax community, with reasons * teacher led explanation with examples * group discussion about data showing biomass, species diversity and primary production during succession * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to succession * AO2/AO3 – application of knowledge to unfamiliar contexts and experimentally derived data * AT i – students could use turbidity measurements to investigate the growth rate of a broth culture of microorganisms * MS 2.5 – students could use logarithmic scale in representing the growth of a population of microorganisms * extended exam answers. | **Past exam paper material**:  BIOL4 Jan 2012 – Q3b  BIOL4 Jan 2013 – Q4a and 4b  BIOL4 June 2012 – Q1  BIOL4 June 2013 – Q2  BIOL4 Jan 2011 – Q8a  BIOL4 Jan 2010 – Q6  BIOL4 June 2014 – Q3a-3b | [geowords.org/ensci/imagesbook/04\_03\_succession.swf](http://www.geowords.org/ensci/imagesbook/04_03_succession.swf)  **Rich question:**  Why does succession begin with a pioneer species? |
| Extension |  |  | Students could study succession within hay infusions.  NB This will take longer than allowed for in this scheme of work. |  | [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Conservation of habitats frequently involves management of succession. | 0.2 weeks | * Use their knowledge and understanding to present scientific arguments and ideas relating to the conservation of species and habitats. * Evaluate evidence and data concerning issues relating to the conservation of species and habitats and consider conflicting evidence. * Know that management of succession can involve preventing succession occurring to maintain a desired community. | **Learning activities:**   * provide students with materials/web pages regarding conservation of habitat projects. Ask them what they have in common (all managing succession) * teacher led explanation of why conservation frequently involves managing succession * students should be given evidence (some of which should be conflicting) about conservation of habitats, and discuss the relative arguments * provide students with the role of presenting to the environment agency for funding to manage succession. They should present a reasoned, evidence-based case * exam question.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to conservation and succession management * AO2/AO3 – application of knowledge to, and interpretation of, scientific data and evidence to form reasoned arguments. | **Past exam paper material**:  BIOL4 June 2010 – Q5  **Exampro:**  BYA5 Jan 2003 – Q9d  BYA5 Jan 2004 – Q2  BYB4 June 2005 – Q4  BYB6 June 2005 – Q2a  BYB6 Jan 2005 – Q2  BYB6 Jan – 2004 Q7c. | [beep.ac.uk/content/415.0.html](http://www.beep.ac.uk/content/415.0.html)  [rspb.org.uk/ourwork/conservation/advice/wetscrub/managing.aspx](http://www.rspb.org.uk/ourwork/conservation/advice/wetscrub/managing.aspx)  **Rich questions:**   * What is conservation? * Why does conservation often involve managing succession? |

## 3.8 The control of gene expression

**Unit description**

Cells are able to control their metabolic activities by regulating the transcription and translation of their genome. Although the cells within an organism carry the same code genetic information, they translate only part of it. In multicellular organisms, this control of translation enables cells to have specialised functions, forming tissues and organs.

There are many factors that control the expression of genes and, thus, the phenotype of organisms. Some are external, environmental factors, others are internal factors. The expression of genes is not as simple as once thought, with epigenetic regulation of transcription being increasingly recognised as important.

Humans are learning how to control the expression of genes by altering the epigenome, and how to alter genomes and proteomes of organisms. This has many medical and technological applications.

Consideration of cellular control mechanisms underpins the content of this section. Students who have studied it should develop an understanding of the ways in which organisms and cells control their activities. This should lead to an appreciation of common ailments resulting from a breakdown of these control mechanisms and the use of DNA technology in the diagnosis and treatment of human diseases.

### 3.8.1 Alteration of the sequence of bases in DNA can alter the structure of proteins.

Prior knowledge:

**GCSE Science A**

New forms of a gene are generated by mutation.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Gene mutations might arise spontaneously during DNA replication. They include addition, deletion, substitution, inversion, duplication and translocation of bases.  The mutation rate is increased by mutagenic agents.  Mutations affecting one triplet and those which cause frame shift. | 0.2 weeks | * Describe what happens in substitution, addition, deletion, inversion, duplication and translocation mutations. * Explain how mutations can arise spontaneously, and the effect that mutagenic agents have on the rate of mutation. * Relate the nature of a gene mutation to its effect on the encoded polypeptide. | **Learning activities:**   * question students on what they recall from 3.4.3 on mutagenic agents and deletion and substitution mutations * provide students with a DNA sequence, a codon table and an instruction sheet on how to make one type of mutation to the sequence (give different types of mutations to different groups). The groups then work out the amino acid sequence produced from the wild type and mutated allele. Accept feedback from each group as to how different the mutated version was * teacher led explanation of mutations linked to protein structure and earlier knowledge of degeneracy * exam questions.   **Skills developed by learning activities:**   * AO1 – development of knowledge understanding of types of mutation and its consequences * AO2 – application of knowledge to information/context of exam questions. | **Specimen assessment material:**  A-level Paper 3 (set 1) – Q10.3  **Past exam paper material**:  BIOL5 June 2012 – Q1a-1c  BIOL5 June 2014 – Q1  HBIO4 Jan 2013 – Q10b  HBIO4 June 2011 – Q10c | **Rich questions:**   * What is meant by a frame shift mutation? * Explain why some types of mutation might not result in a change to the structure of the polypeptide that is produced. |

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### 3.8.2 Gene expression is controlled by a number of features.

#### 3.8.2.1 Most of a cell’s DNA is not translated.

Prior knowledge:

**GCSE Additional Science**

* Most types of animal cells differentiate at an early stage whereas many plant cells retain the ability to differentiate throughout life.
* Cells from human embryos and adult bone marrow, called stem cells, can be made to differentiate into many different types of cells, eg nerve cells.
* Human stem cells have the ability to develop into any kind of human cell.
* Treatment with stem cells may be able to help conditions such as paralysis.
* There are social and ethical issues concerning the use of stem cells from embryos in medical research and treatments.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The characteristics and source of totipotent, pluripotent, multipotent and unipotent stem cells.  The production of specialised cells from totipotent cells requires only part of the cell’s DNA to be translated.  Unipotent cells exemplified by formation of cardiomyocytes.  Pluripotent cells and their use in treating human disorders.  The production of Induced pluripotent cells (IPS cells). | 0.4-0.6 weeks | * Define what a stem cell is. * Explain the characteristics of totipotent, pluripotent, multipotent and unipotent stem cells, and the sources of each type. * Explain how induced pluripotent cells can be produced and why they are of interest. * Evaluate the use of stem cells in treating human disorders. | **Learning activities:**   * introduce the idea of some plant cells being totipotent throughout their life (so a cutting can give rise to a new plant). Outline that this is not true with differentiated mammalian cells. Introduce stem cells * provide information sheets on totipotent (linking back to differentiation and translating only some of the cell’s DNA), pluripotent, multipotent and unipotent cells (exemplified by formation of cardiomyocytes). Students circulate to find the answers to a series of questions * teacher explanation to reinforce * evaluation of use of stem cells in treating human disorders. This could be done as a debate * show students the video on IPS cells and get them to research IPS cells using selected websites. Ask them how IPS cells are made and whether this overcomes ethical objections around pluripotent embryonic stem cells * concept map * exam questions   **Skills developed by learning activities:**   * AO1 – development of understanding relating to the properties and uses of different types of stem cells * AO2/AO3 – application of knowledge and interpretation of, scientific data and evidence to evaluate the use of stem cells * 8.4.2.5 – Research IPS cells. | **Past exam paper material**:  BIOL5 June 2010 – Q6  BIOL5 June 2011 – Q6a  HBIO4 June 2014 – Q4 | [ncbe.reading.ac.uk/NCBE/SAFETY/tissuesafety.html](http://www.ncbe.reading.ac.uk/NCBE/SAFETY/tissuesafety.html)  [earn.genetics.utah.edu/content/stemcells](http://learn.genetics.utah.edu/content/stemcells/)  [eurostemcell.org/factsheet/reprogramming-how-turn-any-cell-body-pluripotent-stem-cell](http://www.eurostemcell.org/factsheet/reprogramming-how-turn-any-cell-body-pluripotent-stem-cell)  **Rich questions:**   * How do plants and mammals differ in relation to differentiation? * Why is only a small proportion of a cell’s DNA translated when it specialises? |
| Extension |  |  | * Practical activity to produce tissue culture from explants of cauliflower. * AT i – produce tissue cultures of explants of cauliflower (Brassica oleracea). |  | [saps.org.uk/secondary/teaching-resources/706-cauliflower-cloning-tissue-culture-and-micropropagation](http://www.saps.org.uk/secondary/teaching-resources/706-cauliflower-cloning-tissue-culture-and-micropropagation)  [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

**3.8.2.2 Regulation of transcription and translation**

Prior knowledge: nothing explicitly relevant.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| In eukaryotes, transcription of target genes can be stimulated or inhibited when specific transcriptional factors move from the cytoplasm into the nucleus.  The role of the steroid hormone, oestrogen, in initiating transcription. | 0.2 weeks | * Explain what a transcription factor is. * Describe the role of transcription factors in gene expression. * Describe the mechanism by which oestrogen is able to initiate transcription. * Interpret data provided from investigations into gene expression. | **Learning activities:**   * teacher introduction of the concepts of promoters and transcription factors * show animation of the mechanism by which oestrogen initiates transcription * card sort – sequence the stages * provide data from investigations into gene expression and oestrogen * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of how transcription factors can stimulate or inhibit transcription * AO2/AO3 – application of knowledge to, and interpretation of, scientific data from investigations into gene expression | **Past exam paper material**:  BIOL5 June 2010 – Q5  BIOL5 June 2011 – Q8a | **Rich questions:**   * Why is oestrogen able to directly enter the cell? * What is a transcriptional factor? * How does oestrogen stimulate/activate transcription factors? * Suggest why oestrogen only has an effect in certain tissues? |
| Extension |  |  | Students could undertake the beta-galactosidase experiment (see resources) as an introduction to gene regulation (in prokaryotes) if time permits. |  | [ncbe.reading.ac.uk/NCBE/PROTOCOLS/DNA/bgalactosidase.html](http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/DNA/bgalactosidase.html)  [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Epigenetic control of gene expression in eukaryotes.  Epigenetics involves heritable changes in gene function, caused by changes in the environment that inhibit transcription by:   * increased methylation of the DNA * decreased acetylation of associated histones.   The relevance of epigenetics on the development and treatment of disease, especially cancer. | 0.4 weeks | * Explain what epigenetics is, and what happens to the DNA or histone to modify gene expression. * Interpret data provided from investigations into gene expression. * Evaluate appropriate data for the relative influences of genetic and environmental factors on phenotype. * Explain how epigenetic control can cause disease, and how it could be used to treat diseases such as cancer. | **Learning activities:**   * conduct a class vote on whether identical twins should have similar predispositions to diseases linked to gene expression * show video from the learn.genetics.utah.edu link (see resources). Follow this up with teacher elaboration on how methylation and acetylation affect gene expression as well as answering of any questions * analyse data on the relative influences of genetic and environmental factors on phenotype from twin studies, and draw conclusions * exam question * teacher led explanation of epigenetic causes of disease and epigenetic therapy (with reference to cancer).   **Skills developed by learning activities:**   * AO1 – development of understanding relating to epigenetics and its relevance to developing and treating disease * AO2/AO3 – application of knowledge to explain trends in scientific data from studies of identical and fraternal twins. | **Past exam paper material**:  HBIO4 Jan 2012 – Q6  HBIO4 June 2013 – Q7 | [scientificamerican.com/article/epigenetics-explained](http://www.scientificamerican.com/article/epigenetics-explained/)  [learn.genetics.utah.edu/content/epigenetics](http://learn.genetics.utah.edu/content/epigenetics/)  **Rich questions:**   * Why is studying twins so useful when investigating the environmental effects on epigenetics? * What effect does DNA methylation have on gene expression? Why? * What effect does histone acetylation have on gene expression. Why? |
| Extension |  |  | Students could be given time to research the information and activities from the learn.genetics.utah.edu website eg lick your rats. |  |  |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| In eukaryotes and some prokaryotes, translation of the mRNA produced from target genes can be inhibited by RNA interference (RNAi). | 0.2 weeks | * Explain how gene expression can be inhibited by RNA interference of translation. * Explain how siRNA interferes with translation. * Interpret data provided from investigations into gene expression. | **Learning activities:**   * provide students with the materials (video and comprehension) from nature.com * get them to prepare a short presentation on what they have researched * peer evaluation of presentation and teacher explanation to address weaknesses and reinforce key points * provide data from investigations into RNAi and ask students to apply their knowledge * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of how RNA interference can inhibit gene expression * AO2/AO3 – application of knowledge to, and interpretation of, scientific data from investigations into gene expression. | **Past exam paper material**:  BIOL5 June 2013 – Q6  BIOL5 June 2011 – Q8b | [nature.com/nrg/multimedia/rnai/animation/index.html](http://www.nature.com/nrg/multimedia/rnai/animation/index.html)  [nature.com/horizon/rna/background/interference.html](http://www.nature.com/horizon/rna/background/interference.html)  **Rich questions:**   * Why is RNA interference specific to mRNA from a particular gene? * How is RNAi different from inhibition of gene expression by transcription factors? |

#### 3.8.2.3 Gene expression and cancer

Prior knowledge: nothing explicitly relevant.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The main characteristics of benign and malignant tumours.  The role of the following in the development of tumours:   * tumour suppressor genes and oncogenes * abnormal methylation of tumour suppressor genes and * oncogenes * increased oestrogen concentrations in the development of some breast cancers. | 0.4-0.6 weeks | * Describe the characteristics of benign and malignant tumours. * Explain the role of oncogenes/tumour suppressor genes, abnormal methylation and increased oestrogen concentrations in the development of cancer. * Evaluate evidence showing correlations between genetic and environmental factors and various forms of cancer. * Interpret information relating to the way in which an understanding of the roles of oncogenes and tumour suppressor genes could be used in the prevention, treatment and cure of cancer. | **Learning activities:**   * teacher explanation of the main characteristics of benign and malignant tumours, and the role of tumour suppressor genes and oncogenes in cancer. The Nowgen video could support this but be aware that cancer may be a sensitive issue for some students * students could undertake the BRAF activity, identifying mutations in the BRAF proto-oncogene and compare against the COSMIC online database * discuss how this information could be used in the future to prevent, treat or cure cancer * teacher explanation of the role of abnormal DNA methylation, and increased oestrogen concentrations in the role of cancer development * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding of tumours, and the possible reasons for developing tumours * AO2 – application of knowledge to exam questions * AO3/AT I – evaluation of scientific data showing correlations and comparison of data against bioinformatics database * essay-writing skills. | **Specimen assessment material:**  A-level Paper 3 (set 1) – Q4  A-level Paper 3 (set 1) – Q9  **Past exam paper material**:  BIOL5 June 2010 – Q10b  HBIO4 June 2014 – Q8  HBIO4 Jan 2013 – Q5  HBIO4 Jan 2012 – Q9  HBIO4 June 2011 – Q9  HBIO4 June 2010 – Q8  HBIO4 Jan 2010 – Q9d | [sanger.ac.uk/research/projects/cancergenome](http://www.sanger.ac.uk/research/projects/cancergenome/)  [yourgenome.org/teachers/roleofcancergenes.shtml](http://www.yourgenome.org/teachers/roleofcancergenes.shtml)  [yourgenome.org/teachers/braf.shtml](http://www.yourgenome.org/teachers/braf.shtml) |

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### 3.8.3 Using genome projects

Prior knowledge: nothing explicitly relevant.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Sequencing projects have read the genomes of a wide range of organisms.  Determining the genome of simpler organisms allows the proteome to be determined. This may have many applications, including the identification of potential antigens for use in vaccine production.  In more complex organisms, the presence of non-coding DNA and of regulatory genes means that knowledge of the genome cannot easily be translated into the proteome.  Sequencing methods are continuously updated and have become automated. | 0.4 weeks | * Explain the principles of gel electrophoresis in separating DNA fragments. * Explain how sequencing techniques have become automated and faster. * Explain why it is harder to translate genomic sequences into the proteome for complex organisms than for simpler organisms. | **Learning activities:**   * teacher explanation of the technique of electrophoresis * students could research the Human Genome project (and other genome projects) * show students the speed animation and ask them to highlight points which have allowed sequencing methods to become faster and more automated * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating DNA sequencing techniques and genome projects * AO2/AO3 – application of knowledge to, interpret sequences from gel patterns. | **Past exam paper material**:  BIOL5 June 2013 – Q8c  **Exampro:**  BYB2 June 2005 – Q6 | [wellcome.ac.uk/Education-resources/Education-and-learning/Resources/Animation/WTDV026689.htm](http://www.wellcome.ac.uk/Education-resources/Education-and-learning/Resources/Animation/WTDV026689.htm)  [yourgenome.org/teachers/sequencing.shtml](http://www.yourgenome.org/teachers/sequencing.shtml)  [yourgenome.org/teachers/speed.shtml](http://www.yourgenome.org/teachers/speed.shtml)  [yourgenome.org/teachers/hgp.shtml](http://www.yourgenome.org/teachers/hgp.shtml)  [wellcome.ac.uk/Education-resources/Education-and-learning/Resources/Animation/WTX056051.htm](http://www.wellcome.ac.uk/Education-resources/Education-and-learning/Resources/Animation/WTX056051.htm) |

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### 3.8.4 Gene technologies allow the study and alteration of gene function allowing a better understanding of organism function and the design of new industrial and medical processes.

#### 3.8.4.1 Recombinant DNA technology

Prior knowledge:

**GCSE Science A**

* In genetic engineering, genes from the chromosomes of humans and other organisms can be ‘cut out’ using enzymes and transferred to cells of other organisms.
* Genes can also be transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics.
* Genes transferred to crop plants are called genetically modified (GM) crops. Examples of these include crops that are resistant to insect attack or herbicides. These crops generally show increased yield.
* Concerns about GM crops include the effect on populations of wild flowers and insects, and uncertainty about the effects of eating GM crops on human health.
* There are economic, social and ethical arguments for and against genetic engineering, including GM crops.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Recombinant DNA technology involves the transfer of fragments of DNA from one organism, or species, to another, resulting in translation within the recipient (transgenic organism) due to the universal nature of the genetic code.  Fragments of DNA can be produced by several methods, including:   * conversion of mRNA to cDNA, using reverse transcriptase * using restriction enzymes to cut a fragment containing the desired gene from DNA * creating the gene in a ‘gene machine’. | 0.2 weeks | * Explain what is meant by recombinant DNA technology. * Explain how the methods given in the specification can be used to produce fragments of DNA containing a desired gene. * Explain what is meant by a restriction endonuclease and how they work to leave sticky ends. | **Learning activities:**   * teacher introduction to recombinant DNA technology * questioning to assess recall from GCSE * think, pair, share: how do we isolate a gene from the rest of the DNA to produce a DNA fragment? * teacher led explanation on the three methods required in the specification. Include an overview of how Type 2 restriction endonucleases cut to leave a sticky end * provide students with palindromic sequences and recognition site information for different Type 2 restriction endonucleases and ask them to draw the two pieces which would form when cut. This could be extended to look at how many pieces would be produced for an extended sequence with several restriction sites * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to recombinant DNA technology and production of DNA fragments * AO2 – application of knowledge of restriction endonuclease recognition sites to work out sticky ends produced. | **Past exam paper material**:  HBIO4 June 2014 – Q9bi  HBIO4 Jan 2011 – Q9a  **Exampro:**  BYA2 Jan 2005 – Q2 | [highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0073383074/811328/restriction\_endonucleases.swf::Restriction%20Endonucleases](http://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0073383074/811328/restriction_endonucleases.swf::Restriction%20Endonucleases)  **Rich questions:**   * What is cDNA? * Why would it be inappropriate to produce cDNA of the human insulin gene by trying to find mRNA in a small intestine epithelial cell? * What is meant by the term palindromic recognition sequence? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The principles of the polymerase chain reaction (PCR) as an *in vitro* method to amplify DNA fragments. | 0.2 weeks | * Describe the process of PCR in amplifying DNA fragments. * Explain the role of primers and Taq polymerase in PCR. * Explain the processes of strand separation, primer annealing, and strand synthesis. * Evaluate the pros and cons of using PCR to clone DNA fragments over in vivo methods. | **Learning activities:**   * get students to use the Virtual PCR lab (see resources) to work through the laboratory technique of PCR * teacher-led explanation of PCR and the stages involved. Use videos and animations to support your explanation * ask students to compare and contrast PCR to DNA replication * ask students to work out the number of copies you would have from one original DNA fragment after a specified number of cycles * card sort – order the stages and match up explanation cards to each * exam questions.   **Skills developed by learning activities:**   * AO1/PS4.1 – development of understanding of the process of PCR and its applications * AO2/AO3 – application of knowledge to, and interpretation of, scientific data and evidence to form reasoned arguments * AT l – computer modelling of PCR * MS 0.5 and MS 2.5 – students could use calculators with exponential functions and a logarithmic scale to represent the increase in the number of copies of DNA fragments present after multiple cycles of PCR. | **Specimen assessment material:**  A-level Paper 3 (set 1) – Q10.5  **Past exam paper material**:  HBIO4 Jan 2013 – Q10c  HBIO4 Jan 2011 – Q9b | [sumanasinc.com/webcontent/animations/content/pcr.html](http://www.sumanasinc.com/webcontent/animations/content/pcr.html)  [dnalc.org/view/15475-The-cycles-of-the-polymerase-chain-reaction-PCR-3D-animation.html](http://www.dnalc.org/view/15475-The-cycles-of-the-polymerase-chain-reaction-PCR-3D-animation.html)  [dnalc.org/resources/animations/pcr.html](http://www.dnalc.org/resources/animations/pcr.html)  [earn.genetics.utah.edu/content/labs/pcr](http://learn.genetics.utah.edu/content/labs/pcr/)  **Rich questions:**   * What is the purpose of adding DNA primers? * Why is Taq polymerase used in the PCR? * How many fragments would you have after 20 cycles of PCR? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The culture of transformed host cells as an *in vivo* method to amplify DNA fragments, involving:   * the addition of promoter and terminator regions to the fragments of DNA * the use of restriction endonucleases and ligases to insert fragments of DNA into vectors * transformation of host cells using these vectors * the use of marker genes to detect genetically modified (GM) cells or organisms. | 0.8 weeks | * Explain what gene cloning is and why it is important in a range of applications. * Describe the stages involved in in vivo gene cloning. * Explain the importance of the addition of promoter and terminator regions. * Explain the importance of the use of restriction enzymes and sticky ends. * Explain the methods used for transformation. * Explain the use of marker genes and replica plating. * Interpret information provided in exam questions, to interpret which colonies have been successfully transformed with recombinant DNA. | **Learning activities:**   * teacher explanation of how to clone in vivo (using videos and animations) * card sort of the stages * exam questions.   **Skills developed by learning activities:**   * AO1/PS 4.1 – development of understanding relating to the process of in vivo gene cloning * AO2/AO3 – interpretation of information in exam questions and application of knowledge about in vivo gene cloning * MS 0.3 – use percentages when discussing/working out the proportion of cells which are successfully transformed. | **Specimen assessment material:**  A-level Paper 3 (set 1) – Q5  **Past exam paper material**:  BIOL5 June 2012 – Q5  **Past exam paper material**:  BIOL5 June 2012 – Q1  HBIO4 June 2014 – Q9bi  HBIO4 Jan 2013 – Q6  HBIO4 June 2010 – Q9 | [dnalc.org/resources/animations/restriction.html](http://www.dnalc.org/resources/animations/restriction.html)  [dnalc.org/resources/animations/transformation1.html](http://www.dnalc.org/resources/animations/transformation1.html)  [highered.mheducation.com/sites/0072556781/student\_view0/chapter14/animation\_quiz\_1.html](http://highered.mheducation.com/sites/0072556781/student_view0/chapter14/animation_quiz_1.html)  **Rich questions:**  Why is the percentage of cells successfully transformed with recombinant DNA so low? |
| Extension |  |  | * Students could use the Lambda NCBE protocol to use electrophoresis and restriction endonuclease enzyme to investigate restriction enzyme specificity. * Students could undertake a practical to transform bacteria with a recombinant plasmid (see NCBE protocol). Kits are commercially available eg from NCBE, Biorad.   **Skills developed by learning activities:**  AT g – investigatethe specificity of restrictionenzymes using extractedDNA and electrophoresis. |  | [ncbe.reading.ac.uk/NCBE/PROTOCOLS/PDF/LambdaSG.pdf](http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/PDF/LambdaSG.pdf)  [ncbe.reading.ac.uk/NCBE/PROTOCOLS/DNA/PDF/DNA08.pdf](http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/DNA/PDF/DNA08.pdf)  [ncbe.reading.ac.uk/NCBE/SAFETY/dnasafety1.html](http://www.ncbe.reading.ac.uk/NCBE/SAFETY/dnasafety1.html)  [cleapss.org.uk](file:///\\internal\dfs\QMTeams\Content%20and%20Resources\Subjects\Science\1.%20A-level\Biology\SoW\www.cleapss.org.uk) |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The applications and implications of recombinant DNA technology. | 0.4 weeks | * Interpret information relating to the use of recombinant DNA technology. * Evaluate the ethical, financial and social issues associated with the use and ownership of recombinant DNA technology in agriculture, in industry and in medicine. * Balance the humanitarian aspects of recombinant DNA technology with the opposition from environmentalists and anti-globalisation activists. | **Learning activities:**   * continuum – who is in favour of transgenic/GM organisms? * jigsaw task: students work in groups of 4, with one going to become an expert in one of four areas. Provide materials on the use of recombinant DNA technology in agriculture, medicine, industry and the environment. For each area, provide case studies/data of how recombinant DNA technology has been used eg Bt Maize, pharming, GM mustard plants removing excessive selenium * feedback and completion of summary table * repetition of continuum – have opinions changed * debate: should the UK allow the commercial growing of GM crops. Assign students viewpoints to reflect those who would benefit from humanitarian aspects against those who oppose GM. In addition to researcher applications, provide further information relating to risks.   **Skills developed by learning activities:**   * AO1 – development of understanding of how recombinant DNA technology is used * AO2/AO3 – application of knowledge to, and interpretation/evaluation of, scientific data and case studies to form reasoned arguments * 8.4.2.5. | **Past exam paper material**:  HBIO4 June 2014 – Q9biii  HBIO4 June 2010 – Q5 | [bionetonline.org/English/Content/ff\_intro.htm](http://www.bionetonline.org/English/Content/ff_intro.htm)  **Rich questions:**   * What are the potential benefits to mankind of transgenic/GM organisms? * What are the valid objections that some people have to using recombinant DNA technology? * Would your viewpoint depend on your circumstances? * Should companies be allowed to patent genes? * Why has the UK not approved widespread commercial growing of GM crops? |

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Relate recombinant DNA technology to gene therapy. | 0.2 weeks | * Explain the principles of gene therapy. * Explain the use of liposomes and viruses in delivering genes into cells. * Explain the difference between somatic and germ line therapy, and why germ line therapy is prohibited.   (NB the first three bullet points are not required AO1 specification knowledge but used to develop ideas).   * Evaluate the effectiveness and risks of gene therapy. | **Learning activities:**   * teacher-led explanation of gene therapy and the use of viruses and liposomes to deliver the gene to cells * students explore online gene therapy kit to determine pros and cons of using liposomes and viruses. Accept feedback and discuss * comprehension on possible applications of gene therapy in treating certain diseases * teacher-led explanation of the risks and issues surrounding effectiveness of liposomes and viruses.   - exam questions.  **Skills developed by learning activities:**   * AO1 – development of understanding relating to gene therapy, its effectiveness and its risks * AO2 – application of knowledge to evaluate gene therapy * MS 0.3 – use percentages when discussing/working out the proportion of cells which take up and express the therapeutic gene. | **Past exam paper material**:  BIOL5 June 2012 – Q6 | [learn.genetics.utah.edu/content/genetherapy](http://learn.genetics.utah.edu/content/genetherapy/)  **Rich questions:**   * Why are viruses used in some forms of gene therapy? * Why does gene therapy become less effective with successive treatments? * Describe a risk of using viruses? * What further challenges would be faced in using gene therapy to cure genetic diseases caused by mutations in multiple genes? |

#### 3.8.4.2 Differences in DNA between individuals of the same species can be exploited for identification and diagnosis of heritable conditions.

Prior knowledge:

**GCSE Additional Science**

* Some disorders are inherited. These include polydactyly and cystic fibrosis.
* Embryos can be screened for the alleles which cause these disorders.
* There are ethical, economic and social arguments for and against embryo screening.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The use of labelled DNA probes and DNA hybridisation to locate specific alleles of genes.  The use of labelled DNA probes that can be used to screen patients for heritable conditions, drug responses or health risks.  The use of this information in genetic counselling and personalised medicine. | 0.4 weeks | * Explain how DNA probes and hybridisation are used to locate specific alleles. * Explain the benefits of screening for genetic diseases. * Explain some of the issues raised by screening, and the role of genetic counsellors. * Evaluate information relating to screening individuals for genetically determined conditions and drug responses. | **Learning activities:**   * ask students who would want to be screened for a genetic disease. Inform them that they were all screened at birth for PKU and why this was done * teacher explanation of DNA probes and hybridisation to screen for heritable conditions, drug responses or health risks * students could model this by being given a “DNA probe” with a short sequence and some DNA sequences from people – they have to find if the probe would hybridise and where * continuum line – Is genetic testing a good thing which we should all have done? * genome generation card scenarios – Students discuss all or some of the scenarios. Summarise the concerns eg should insurance companies have the right to know? * explanation of role of genetic counsellors * repeat the continuum – have opinions changed? * exam questions.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to genetic screening and counselling * AO2 – application of knowledge to form reasoned arguments. | **Specimen assessment material:**  A-level Paper 2 (set 1) – Q10.5  **Past exam paper material**:  BIOL5 June 2012 – Q8  BIOL5 June 2013 – Q8a and 8b  BIOL5 June 2014 – Q8  HBIO4 Jan 2013 – Q10e  HBIO4 Jan 2011 – Q10  HBIO4 Jan 2010 – Q9a-c | [yourgenome.org/teachers/genomegeneration.shtml](http://www.yourgenome.org/teachers/genomegeneration.shtml)  [earn.genetics.utah.edu/content/disorders/counselors](http://learn.genetics.utah.edu/content/disorders/counselors/)  [bionetonline.org/English/content/gh\_intro.htm](http://www.bionetonline.org/English/content/gh_intro.htm)  **Rich questions:**   * Explain how a radioactive DNA probe would be used in screening? * What is the value of genetic screening? * Why are some people concerned about having screening for a wide range of genetic diseases and predispositions? * What can genetic counsellors provide advice on, and what can they not advise on? |

#### 3.8.4.3 Genetic fingerprinting

Prior knowledge:

**GCSE Additional Science**

Each person (apart from identical twins) has unique DNA. This can be used to identify individuals in a process known as DNA fingerprinting.

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| An organism’s genome contains many variable number tandem repeats (VNTRs). The probability of two individuals having the same VNTRs is very low.  The technique of genetic fingerprinting in analysing DNA fragments that have been cloned by PCR, and its use in determining genetic relationships and in determining the genetic variability within a population.  The use of genetic fingerprinting in the fields of forensic science, medical diagnosis, animal and plant breeding. | 0.2 weeks | * Describe the methodology involved in producing a genetic fingerprint. * Explain what variable number tandem repeats are, and how these allow the production of a virtually unique genetic fingerprint. * Explain the applications of genetic fingerprinting. * Interpret genetic fingerprint patterns and draw conclusions. | **Learning activities:**   * questioning to establish recall from GCSE * teacher explanation of VNTRs and how they vary between people * students could use a computer model to model DNA fingerprinting (see resources) * teacher explanation to elaborate on learning so far (using animation) * information treasure hunt – find information to set questions about the applications of genetic fingerprinting by visiting information stations * accept feedback * model how to interpret genetic fingerprints eg in paternity cases and provide further examples for students to work through.   **Skills developed by learning activities:**   * AO1 – development of understanding relating to genetic fingerprinting and its applications * AO2/AO3 – interpretation of genetic fingerprints to draw valid conclusions * MS 1.4 – consider the probability of two people (not identical twins) having the same VNTRs * essay-writing skills. | **Past exam paper material**:  BIOL5 June 2011 – Q10a  **Exampro:**  BYA2 June 2005 – Q8 | [highered.mheducation.com/sites/dl/free/0072835125/126997/animation40.html](http://highered.mheducation.com/sites/dl/free/0072835125/126997/animation40.html)  [pbslearningmedia.org/asset/tdc02\_int\_creatednafp2](http://www.pbslearningmedia.org/asset/tdc02_int_creatednafp2/)  **Rich questions:**   * Why might PCR be used with DNA fingerprinting? * Why are forensics officers so careful to avoid contaminating a crime scene? * What proportion of bands would you expect to match between a child and its father? |
| Extension |  |  | Identify examples of DNA fingerprinting in the news. This may include the identification of most suitable zoo animals for breeding programmes, medical diagnosis, forensic science. |  |  |