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## 

## (9610)

## Outline Schemes of Work

For teaching from September 2016 onwards  
For A-level exams in June 2018 onwards

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**Introduction**

This Scheme of work has been prepared by teachers for teachers. We hope you will find it a useful starting point for producing your own schemes.

The Scheme of Work is designed to be a flexible medium term plan for the teaching of content and development of the skills that will be assessed. It covers the needs of the specification for the International A2 units of Biology 9610.The teaching of investigative and practical skills is embedded within the specification. We are producing a Practical Handbook that provides further guidance on this. There are also opportunities in this scheme of work, such as the inclusion of rich questions.

We have provided links to some resources. These are illustrative and in no way an exhaustive list. We would encourage teachers to make use of any existing resources, as well as resources provided by Oxford International AQA Examinations and new textbooks written to support the specification. Please note there may be access restrictions to certain websites from certain countries.

Prior knowledge noted below comprises knowledge from the current double science (ie Core and Additional Science) International GCSE specifications. Students who studied the separate Science International GCSE courses will have this knowledge but may also have been introduced to other topics which are relevant to the International A-level content. Topics only found in separate sciences are not included in the prior knowledge section.

We know that teaching times vary from school to school. In this scheme of work we have made the assumption that it will be taught over about 30 weeks with 4½ to 5 hours of contact time per week. Teachers will need to fine tune the timings to suite their own students and the time available. It could also be taught by one teacher or by more than teacher with topics being taught concurrently.

The **assessment opportunities** column details AQA past paper questions that have been mapped to this new Oxford International AQA qualification and are available through the international Exampro from early 2016. Of course there are also Sample Assessment Materials for download at oxfordaqaexams.org.uk/9610

**Unit 3: Populations and genes**

**Unit description**

Living organisms form structured communities within dynamic but essentially stable ecosystems through which energy is transferred and chemical elements are cycled. Humans are part of the ecological balance and their activities affect it both directly and indirectly. Consideration of these effects is one of the main themes of this unit and should lead to an understanding that sustainability of resources depends on effective management of the conflict between human needs and conservation.

The individuals that comprise a particular species share the same genes but usually have different combinations of alleles of these genes. Individuals inherit alleles from their parents.

A species exists as one or more populations. Genetic variation in populations results from genetic drift and natural selection. Genetic drift may cause changes in allele frequency in small populations. Natural selection occurs when alleles that affect the fitness of individuals that carry them change in frequency. A change in the allele frequency in a population is evolution.

### 3.3.1 The effect of biotic and abiotic factors on populations

#### 3.3.1.1 Populations, communities and ecosystems

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 an ecological context:   * a population is all the organisms of one species in a habitat. * populations of different species form a community. * a community and the non-living components of its environment form an ecosystem.   Within a habitat, a species occupies a niche governed by  adaptation to both biotic and abiotic conditions. | 0.2  weeks | * define the terms community, population, biotic, abiotic, ecosystem and niche. * explain why no two species have exactly the same niche. * interpret and analyse experimentally derived data to identify a species niche. | **Learning activities:**   * + Teacher led explanation of ecosystems, populations and communities.   + 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:**  **Mathematical requirement 2 –** Recognise and use appropriate units for abiotic measurements.  **AO1 –** Development of understanding relating to ecological concepts.  **AO2/AO3 –** Application of knowledge to experimentally derived data (in exam questions). | **Past exam paper material**: BIOL4 – Jan 12 Q1a and Q1c;  BIOL4 – Jan 12 Q4;  BIOL4 – June 12 Q3;  HBIO5 – June 15 Q3a.  Exampro  BYA4 Jan 2005 Q8;  BYA4 June 2005 Q5 | **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? |

#### 3.3.1.2 Variation in population size

Prior knowledge:

- Plants often compete for light, water, space and minerals. Animals often compete for food, mates and territory.

**-** Physical factors which affect organisms include: light; temperature; water availability; nutrient availability; carbon dioxide and oxygen availability.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Population size may vary as a result of:   * + - the effect of abiotic factors.     - interactions between organisms, including interspecific and intraspecific competition and predation. | 0.2 – 0.4  weeks | * + - explain the factors which influence population size.     - analyse and interpret data relating to the numbers and distribution of organisms recognising correlations and causal relationships. | **Learning activities:**   * + Ask pupils to brainstorm factors which could influence population sizes. Accept feedback and get them to categorise into biotic and abiotic factors.   + Teacher led explanation of how population sizes and distributions might be affected by biotic and abiotic factors.   + Students could be provided with data about interactions between species influencing distributions and population size, e.g. red squirrels in the UK due to competition from grey squirrels.   + The HBI6T Q15 Pleurococcus practical could be undertaken, followed by Section A of the ISA exam.   + Past exam questions   **Skills developed by learning activities:**  **AO1 –** Development of understanding relating to the factors which influence population size.  **AO2/AO3 –** Application of knowledge to experimentally derived data (in exam questions). | **Past exam paper material**:  HBI6T ISA Q15;  BIOL4 – June 12 Q3;  BIOL4 – Jan 11 Q4;  HBIO5 – June 13 Q4;  HBIO5 – June 15 Q4  HBIO5 – June 10 Q3.  Exampro  BYA4 Jan 2006 Q2;  Specimen Paper Unit 4 – Q5;  BYB4 – June 2005 Q1 | **Rich questions:**  - Identify some abiotic and biotic factors which could influence population sizes. |
| Extension |  |  | Pupils could utilise quadrats or mark-release-recapture techniques to measure the size of populations. |  |  |

#### 3.3.1.3 Ecological succession

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** |
| Primary succession from colonisation by pioneer species to climax community.  At each stage in succession, certain species may be recognised that change the environment so that it becomes more suitable for other species with different adaptations.  The new species may change the environment in such a way that it becomes less suitable for the previous species.  Changes that organisms produce 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 (e.g. 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.  - Past 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.  - Extended exam answers. | **Past exam paper material**:  BIOL4 – Jan 12 Q3b;  BIOL4 – Jan 13 Q4a and 4b;  BIOL4 – June 12 Q1;  BIOL4 – June 13 Q2  BIOL4 – Jan 11 Q8a;  BIOL4 – Jan 10 Q6;  BIOL4 – June 14 Q3a-3b;  BIOL4 – June 10 Q5; | [**http://www.geowords.org/ensci/imagesbook/04\_03\_succession.swf**](http://www.geowords.org/ensci/imagesbook/04_03_succession.swf)  [**http://www.nationalstemcentre.org.uk/elibrary/resource/10249/bog-core-analysis-and-climate-change**](http://www.nationalstemcentre.org.uk/elibrary/resource/10249/bog-core-analysis-and-climate-change)  **Rich questions:**  - Why must succession begin with a pioneer species?  - Why are pioneer species eventually succeeded? |
| Extension |  |  | - Students could study succession within hay infusions. N.B. This will take longer than allowed for in this scheme of work and will need to be risk assessed by centres. |  |  |

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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. | **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.  - Past 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 10 Q5;  Exampro –  BYB4 – June 2005 Q4;  BYB6 – June 2005 Q2a;  BYB6 – Jan 2005 Q2;  BYB6 – Jan 2004 Q7c;  BYA4 – Jan 2004 Q2  BYA5 – Jan 2003 Q9d; | [**http://www.beep.ac.uk/content/415.0.html**](http://www.beep.ac.uk/content/415.0.html)  [**http://www.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? |

### 3.3.2 Photosynthesis

Life depends on the continuous transfer of energy. Photosynthesis is the main route by which energy enters an ecosystem.

#### 3.3.2.1 The light-dependent reaction

Prior knowledge:

**-** During photosynthesis, light is absorbed by chlorophyll and used to convert carbon dioxide and water to glucose and oxygen.

- Oxidation is loss of electrons, reduction is gain of electrons.

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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 in such detail as to show that:  • chlorophyll absorbs light. Light energy excites electrons.  • energy from these excited electrons generates ATP and reduced NADP  • the production of ATP involves electron transfer down the electron transfer chain and the passage of protons across chloroplast membranes. ATP production is catalysed by ATP synthase embedded in the chloroplast membranes.  • photolysis of water produces protons, electrons and oxygen. | 0.2 weeks | • describe the structure of chloroplasts.  • explain where, specifically, the light dependent reactions occur.  • 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.  • interpret energy levels diagrams.during electron trasfer. | **Learning activities:**  - Questioning to recall prior knowledge. Include questioning about reduction and oxidation.  - 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 reactions of photosynthesis (using animations and videos). Link energy level diagram to their graph to aid understanding.  - Card sort – order the statements.  - Past 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 13 Q8a;  BIOL4 – Jan10 Q8a. | [**http://www.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 reactions. |

#### 3.3.2.2 The light-independent reaction

Prior knowledge:

**-** During photosynthesis, light is absorbed by chlorophyll and used to convert carbon dioxide and water to glucose and oxygen.

- Oxidation is loss of electrons, reduction is gain of electrons.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The light-independent reaction in such detail as to show that:  • carbon dioxide reacts with RuBP to form two molecules of glycerate 3-phosphate (GP), a reaction 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 reactions occur.  • explain the Calvin cycle and the molecules involved.  • 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 reactions (using animations and videos). Link to role of ATP and reduced NADP.  - Analysis of data, e.g. varying carbon dioxide levels of the concentrations of RuBP and GP.  - Past exam questions.  **Skills developed by learning activities:**  **AO1/AO2 –** Development of understanding of the light independent reactions.  **AO2/AO3 –** Application of knowledge to exam questions and experimental data.  - Extended exam answers. | **Past exam paper material:**  BIOL4 – Jan 13 Q5;  BIOL4 – June 12 Q4;  BIOL4 – June 13 Q5;  BIOL4 – June 10 Q8a and 8b.  BIOL4 – June 11 Q8c.  BIOL4 – June 14 Q8. | [**http://www.uic.edu/classes/bios/bios100/lectures/calvin.htm**](http://www.uic.edu/classes/bios/bios100/lectures/calvin.htm)  [**http://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 investigate the work of/suggest explanations for the data of Melvin Calvin *et al*. |  |  |

#### 3.3.2.3 Limiting factors

Prior knowledge:

- 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** |
| The use of statistical tests by scientists.  The setting of null hypotheses.  The interpretation of stats tests in terms of probability and chance, and acceptance or rejection of the null hypothesis. | 0.6 weeks | • explain what stats tests are used by scientists.  • select and utilise an appropriate stats test.  • calculate the stats test correctly when provided with data.  • correctly interpret the results of the stats test in terms of probability and chance. | **Learning activities:**  - Teacher led explanation of null hypotheses and how/why stats tests are used.  - Provide titles of possible investigations throughout the specification and ask students to sort them into each appropriate stats test. They could also set a null hypothesis for each.  - Teacher led explanation of how to calculate each of the required stats tests, modelling with examples, and how to interpret it in terms of probability and chance and acceptance/rejection of the null hypothesis.  - Provide students with experimental data and ask them to select the correct test, calculate the stats test and interpret the result.  **Skills developed by learning activities:**  **Mathematical requirement 6, 8 and 9 –** Use an appropriate stats test. Understand simple probability.  **AO1 –** Development of knowledge and understanding of the stats tests (set up in the specification) and why scientists use them. |  | **Rich questions:**  - Why do scientists carry out statistical tests on their data? |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The principle of limiting factors as applied to the effects of carbon dioxide concentration, light and temperature on the rate of photosynthesis.  **Required practical 7 -** Investigation of the effect of a specific limiting factor such as light intensity on the rate of photosynthesis | 1 week | • explain what is meant by rate limiting factors.  • identify environmental factors that limit the rate of photosynthesis. | **Learning activities:**  - Students could undertake an investigation of a named factor on the rate of photosynthesis using algal beads, algae or an aquatic plant, e.g. Cabomba or duckweed.  This should involve: carrying out, devising an appropriate table and graph, performing an appropriate stats test and drawing a conclusion.  - Students could undertake the questions from the relevant ISA (see assessment opportunities that their practical pertains to.  **Skills developed by learning activities:**  **AO2 /AO3 –** Apply knowledge to trends in scientific data to make judgements.  **Mathematical requirement 6 and 8 –** Use an appropriate stats test. Understand simple probability.  Calculation of rate. | Candidates could undertake  BIO6T P10 ISA; BIO6X 2013 EMPA; HBI6T Q14 ISA or HBI6T P10 ISA. | [**http://www.nuffieldfoundation.org/practical-biology/investigating-factors-affecting-rate-photosynthesis**](http://www.nuffieldfoundation.org/practical-biology/investigating-factors-affecting-rate-photosynthesis)  [**http://www.nuffieldfoundation.org/practical-biology/investigating-photosynthesis-using-immobilised-algae**](http://www.nuffieldfoundation.org/practical-biology/investigating-photosynthesis-using-immobilised-algae)  **Rich questions:**  - Why do scientists carry out statistical tests on their data? |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The principle of limiting factors as applied to the effects of carbon dioxide concentration, light and temperature on the rate of photosynthesis. | 0.2 weeks | • explain what is meant by rate limiting factors.  • interpret graphs showing the rate of photosynthesis and explain graphs in terms of which factors are rate limiting. | **Learning activities:**  - Jigsaw tasks: In groups of 3, each student goes off to access information about one of the named factors and the trends in rate graphs.  - Group feedback to each other to gain a complete understanding of all 3 factors, and completion of an explanation table.  - Teacher assessment and teaching of areas of weakness.  -Past exam questions/past ISA paper.  **Skills developed by learning activities:**  **AO1 –** Knowledge of rate limiting factors.  **AO2 /AO3 –** Apply knowledge to trends in scientific data to make judgements. | **Past exam paper material:**  BIOL4 – Jan 11 Q5;  BIOL4 – June 14 Q3c. | **Rich questions:**  - Show graphs and ask students to explain what the limiting factors are. |
| Extension |  |  | - Students could produce a video podcast to summarise the whole process of photosynthesis. |  |  | |

### 3.3.3 Respiration

#### 3.3.3.1 Glycolysis

Prior knowledge:

– Respiration is an enzyme catalysed 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).

- Oxidation is loss of electrons, reduction is gain of electrons.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Glycolysis takes place in the cytoplasm and is common to both aerobic and anaerobic respiratory pathways.  Glycolysis in such detail as to show that:  • glucose is phosphorylated to glucose phosphate using ATP  • triose phosphate is produced and is oxidised to pyruvate with a net gain of ATP and reduced NAD. | 0.2 weeks | • explain what cellular respiration is.  • describe where in the cell glycolysis occurs.  • explain the main reactions which occur during glycolysis. | **Learning activities:**  - Questioning to recall prior knowledge about respiration and reduction/oxidation. Ask pupils to define what respiration is.  - Stimulus material could be placed in an activity circus to introduce aerobic and anaerobic respiration and get students to explain their observations and apply some prior learning from GCSE, e.g.  • tubes of hydrogen carbonate indicator containing maggots, germinating peas, pondweed surrounded by metal foil.  • germinating peas v boiled peas inside vacuum flasks with a thermometer in.  • yeast respiring in a side arm flask bubbling into limewater.  - Teacher led explanation that respiration is actually a series of complex reactions (give an overview of the names of the different reactions. Explain the steps involved in glycolysis (using animations and videos).  **Skills developed by learning activities:**  **AO1 –** Development of understanding of glycolysis.  AO2 – Application of prior knowledge to activity circus. | **Past exam paper material:**  HBIO5 – June 15 Q2a-b. | [**http://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)  [**http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html**](http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html)  **Rich questions:**  Evaluate the statement “Respiration occurs in the mitochondria of cells”.  Why must some ATP be hydrolysed at the beginning of the process? |

#### 3.3.3.2 Anaerobic respiration

Prior knowledge:

– 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.

- Oxidation is loss of electrons, reduction is gain of electrons.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| In anaerobic respiration, pyruvate is concerted to ethanol and carbon dioxide or to lactate using reduced NAD. NAD is regenerated in this way and may be used in further glycolysis. | 0.2 weeks | • explain the process of anaerobic respiration in animals and some microorganisms.  • explain the advantage of producing ethanol or lactate using reduced NAD.  • 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 NADH to produce ethanol or lactate.  - Past 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 13 Q6;  BIOL4 – Jan10 Q5c/d;  BIOL4 – June 15 Q6c.  HBI6T P14 ISA  Exampro -  Several questions including:  BYA4 – June 2005 Q7;  BYA4 Jan 2005 Q1;  BYB3 – Jan 2006 Q5 | [**http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html**](http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html)  **Rich questions:**  - Why is reduced NAD used to produce lactate or ethanol from pyruvate? |

#### 3.3.3.3 Aerobic respiration

Prior knowledge:

**GCSE Additional Science**

– 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.

- Oxidation is loss of electrons, reduction is gain of electrons.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| In aerobic respiration, pyruvate from glycolysis enters the mitochondrial matrix by active transport.  Aerobic respiration in such detail as to cover:  - oxidation of pyruvate to acetate  - production of acetyl CoA  - production of a 6 carbon molecule and release of CoA.  - the Krebs cycle.  - oxidative phosphorylation, associated with electron transfer and chemiosmosis, to synthesise ATP. | 0.6 weeks | • explain where the different stages of aerobic respiration occur.  • explain the main reactions which occur during the link reaction and the Krebs cycle.  • explain the roles of FAD and NAD in respiration.  • explain 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.  • compare and contrast aerobic and anaerobic respiration. | **Learning activities:**  - Teacher led explanation of the stages involved in aerobic respiration (using animations and videos).  - Card sort – order the stages/molecules.  - Students draw a table comparing and contrasting aerobic and anaerobic respiration, e.g. number of ATP molecules generated.  - Past 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 12 Q8b;  BIOL4 – June 13 Q4.  BIOL4 – June 10 Q6.  BIOL5 – Jun 14 Q9;  BIOL4 – June 11 Q1;  HBIO2 – Jan 10 Q5;  Exampro -  Several questions including:  BYA5 – June 2006 Q3;  BYA4 – Jan 2004 Q8;  BYB4 – June 2006 Q7 | [**http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html**](http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html)  [**http://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)  [**http://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, Krebs cycle or Oxidative phosphorylation (or more than one)  - How do aerobic and anaerobic respiration differ? |
| 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** | |
| **Required practical 8:**  **Investigation of a specific variable such as substrate or temperature on the rate of respiration of a suitable organism such as yeast or a locust.** | 1 week | • design and experiment to investigate the effect of a named factor on a culture of single cells 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 quality of results and reliability of conclusions. | **Learning activities:**  Students design an experiment to investigate the effect of a named variable, e.g. temperature on the rate of respiration of an organism, (e.g. yeast). Suggestions for doing this can be found through the past ISA material listed.  The activities could include:  - working through key aspects of experimental design e.g. key variables.  - carrying out (subject to teacher approval).  - processing and presentation of data.  - discussion of the theory behind, and the calculation of, stats tests.  - BIO6T Q12 ISA or HBI6T P11 ISA  **Skills developed by learning activities:**  **Mathematical requirement 6, 8, 14 –** Use an appropriate stats test. Understand simple probability. Calculation of rate.  **AO1/AO2** – Application of knowledge to explain trends in a practical context.  **AO4 –** Develop and refine practical design. Evaluate data for errors and uncertainties, and consider margins of accuracy. | BIO6T Q12 ISA or  HBI6T P11 ISA;  HIBI6X 2013 EMPA  **Past exam paper material:**  BIOL4 – June 12 Q6;  BIOL4 – Jan 11 Q6 | | [**http://www.nuffieldfoundation.org/practical-biology/measuring-rate-metabolism**](http://www.nuffieldfoundation.org/practical-biology/measuring-rate-metabolism) |

#### 3.3.3.4 Respiratory substrates.

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 breakdown products of lipids and amino acids enter the Krebs cycle and can also be used as respiratory substrates.  The Respiratory Quotient (RQ) may be used to indicate respiratory substrate and is the ratio of carbon dioxide produced to oxygen consumed. The carbon dioxide and oxygen must be given in the same units, and in quantities proportional to the number of molecules involved. | 0.4 weeks | • explain how other respiratory substrates can feed into the Krebs cycle.  • explain what is meant by the RQ.  • calculate RQ from appropriate data.  • suggest appropriate explanations of RQs in terms of carbohydrate, lipid or protein as a respiratory substrate.  • explain why any conclusions that are drawn are tentative in nature. | **Learning activities:**  - Introduce the idea of Respiratory Quotient by getting students to undertake a practical using a respirometer and invertebrates/plant material.  - From their data get them to calculate the respiratory quotient. Teacher explanation that moles of volumes of gas are acceptable units.  - Teacher led explanation that the breakdown products of lipids and amino acids can also be used as respiratory substrates. Explain that different respiratory substrates have different RQ values.  - Provide appropriate data and get students to calculate RQs for a range of substrates.  - Question students about why the RQ values from published data don’t match those from their experiment. Discuss the idea that an organism may be respiring a mixture of compounds/may be respiring anaerobically as well.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirement 2 –** Use appropriate units for RQ.  **AO1/AO2 –** Development of understanding of respiratory substrates/Respiratory Quotient, and application of knowledge to explain calculations.  **AO4 –** Description of how respirometers can be used. | Assessment of student calculations. | [**http://www.nuffieldfoundation.org/practical-biology/measuring-respiratory-quotient**](http://www.nuffieldfoundation.org/practical-biology/measuring-respiratory-quotient)  **Rich questions:**  - What is RQ?  - Why might any conclusions drawn from RQ calculations be tentative in nature? |

### 3.3.4 Energy transfer through ecosystems

#### 3.3.4.1 Energy transfer

Prior knowledge:

- 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, e.g. movement. Much of this energy is eventually transferred to the surroundings.

- 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** |
| Energy is transferred through the trophic levels in food chains and food webs.  The transfer of energy from producers to consumers and between consumers is inefficient. Quantitative consideration of energy transfer between trophic levels.  Pyramids of number, biomass and energy and their relationship to corresponding food chains and webs. | 0.4  weeks | • explain what is transferred between trophic levels.  • explain how energy is lost along food chains.  • calculate the % efficiency of energy transfer between trophic levels.  • represent feeding relationships using pyramids of number, biomass and energy.  • interpret pyramids of biomass, number and energy. | **Learning activities:**  - Provide food webs for students to interpret and ask questions for them to answer as an assessment of prior learning.  - Ask them what the arrows in food chains represent.  - Introduce terminology e.g. trophic level.  - Teacher led explanation of energy/biomass losses along a food chain and how they occur. Introduce decomposers and saprophytic microorganisms within the context of food webs and where some of the energy goes.  - Provide data to students for them to calculate the % efficiency of the food chains.  - Teacher led explanation of pyramids of number, biomass and energy related to food chains. Discuss appropriate units with students.  - Students should be provided with relevant data and should draw pyramids of biomass, number and/or energy.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirements 2, 3 and 14 –** Calculation of % efficiency and % yield. Construct and interpret pyramids of number, biomass and energy, and use appropriate units based on the data. | **Past exam paper material:**  BIOL4 – Jan 10 Q8b;  BIOL4 – Jan 12 Q2  Exampro  BYB4 – June 2006 Q4;  BYB4 – Jan 2006 Q1;  BYB4 – June 2004 Q3;  BYB4 – Jan 2004 Q2; BYA5 – Jan 2005 Q5 | **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?  - Why might pyramids of number not always be pyramid shaped, but pyramids of biomass and energy are? |

#### 3.3.4.2 Energy and human food production.

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 concept of Gross primary production and Net primary production and their mathematical relationship, i.e.  Net primary production may be calculated from the equation  *NPP* = *GPP* – *R*  NPP is available for growth and reproduction and for other trophic levels.  The net production of consumers, such as mammals, may be calculated as:  *N = I –(F + R)* | 0.2  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 energy losses along food chains.  • apply knowledge to the context of exam questions. | **Learning activities:**  - 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.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirements 1, 2 11 and 12** – Substitute numerical values into, and solve, algebraic equations using appropriate units. Convert and carry out calculations of energy transfer using numbers in standard and ordinary form.  - Extended exam answers. | **Past exam paper material:**  BIOL4 – Jan 12 Q2**:**  BIOL4 – Jan 13 Q8b;  BIOL4 – June 10 Q4.  BIOL4 – June 11 Q2.  BIOL4 – Jan10 Q8b;  BIOL4 – June 15 Q3. | **Rich questions:**  - Which measure of production represents the energy available to the next trophic level? |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Farming practices increase the efficiency of energy transfer by:  • using chemical pesticides, biological agents and integrated systems to reduce energy losses and simplify non-human food webs  • reducing respiratory losses within food chains involving humans. | 0.2  weeks | • apply their understanding of ecological principles to provide scientific arguments that explain how specific farming practices affect productivity.  • interpret and calculate data on efficiency when provided with appropriate information.  • evaluate data considering economic, environmental and ethical issues involved with farming practices that increase productivity. | **Learning activities:**  - Teacher led explanation of how farmers can improve productivity by simplifying food webs, using chemical/biological control and integrated systems, 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 valid to use these farming practices. They should consider ethical, economic and environmental arguments (dependent on their assigned role).  - Continuum – Students place themselves on a continuum line based on their opinion from the debate.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirements 1 and 2 –** Convert and carry out calculations of energy transfer using numbers in standard and ordinary form.  Calculation of % efficiency.  - Extended exam answers. | **Past exam paper material:**  BIOL4 – Jun 12 – Q5;  BIOL4 – Jun 12 – Q8a;  BIOL 4 – Jun 13 Q8a and c;  BIOL 4 – Jan10 Q8c;  BIOL5 – June 14 Q10b  BIOL4 – June 10 Q4;  HBIO2 June 09 – Q9; | [**http://www.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. |

### 3.3.5 Nutrient cycles

#### 3.3.5.1 Principles of nutrient cycling.

Prior knowledge:

- 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** |
| Different chemical elements are found within organic substances in living organisms.  Decomposers and saprophytic microorganisms play an important role in releasing these elements into the environment in the form of ions or simple inorganic molecules. These are ultimately taken up by producers and incorporated into organic molecules.  Digestion and assimilation result in substances containing these elements being passed along food chains. | 0.2  weeks | • explain the role of producers in nutrient cycling.  • explain how elements contained within organic molecules become part of the biomass of other organisms.  • explain the role of saprophytic microorganisms in nutrient cycling. | **Learning activities:**  - Stimulus question: Why are some of William Shakespeare’s atoms in you and how did they get there? Which atoms might they include?  - Introduction to nutrient cycling within ecosystems.  - Challenge students to name a biological molecule which contains the element you display. Do this for the elements carbon, nitrogen and phosphorus.  - Teacher led explanation of the roles of producers in nutrient cycling. Extend this to explain how digestion and assimilation ensure that elements as well as energy are passed along food chains. Finally, describe the role of saprophytic microorganisms.  - Students take the principles discussed and suggest what a general nutrient cycle diagram might look like.  **Skills developed by learning activities:**  **AO1** – Development of knowledge and understanding of the principles of nutrient cycling. |  | **Rich questions:**  Why are some of William Shakespeare’s atoms in you and how did they get there? Which atoms might they include?  - What role do decomposers and saprophytic microorganisms play?  - How are key elements incorporated into organic molecules? |

#### 3.3.5.2 The carbon cycle.

Prior knowledge:

- 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** |
| The importance of respiration, photosynthesis and human activity in giving rise to short-term fluctuations and long-term changes in global carbon dioxide concentration.  The roles of carbon dioxide and methane in enhancing the greenhouse effect and bringing about climatic change. | 0.4  weeks | • describe the stages of the carbon cycle.  • analyse, interpret and evaluate data relating to short-term fluctuations in carbon dioxide concentration.  • analyse, interpret and evaluate data relating to the effects of climate change on the yield of crop plants and the life cycles and numbers of insect pests. | **Learning activities:**  - Questioning of students about their learning last lesson and their suggested diagram of what a general nutrient cycle must contain.  - DARTS task: Provide comprehension material on the carbon cycle. Student must translate this into a detailed diagram. Accept feedback.  - Teacher led explanation of the carbon cycle using videos and animations to reinforce misconceptions.  - Card sort of the stages.  - Students could write a paragraph “In autumn, trees lose their leaves. Describe how carbon compounds in leaves can be recycled so that they can be used again by trees”  - Discuss the impact of increasing CO2 and CH4 emissions in causing climate change. Discuss the possible implications for this.  - Provide data for students to interpret/evaluate on the effects of climate change. Discuss their findings.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirement 15 and 16 –** Interpret line and scatter graphs.  **AO1** – Development of knowledge and understanding of the carbon cycle.  **AO2/AO3 –** Application of knowledge to interpret and evaluate data about the effects of climate change.  - Extended written answers. | BIOL5 – June 2014 Q8b;  BIOL4 – June 2015 Q7a-b;  BIOL4 – June 2010 Q8c.  BIOL4 – June 2011 Q8b-8c.  BIOL4 – Jan 2010 Q2. | **Rich questions:** |
| Extension |  |  | - Students could calculate their carbon footprint or undertake the “Microbes ate my homework” investigation . |  | [**http://www.carbonfootprint.com/calculator.aspx**](http://www.carbonfootprint.com/calculator.aspx)  [**http://www.nuffieldfoundation.org/practical-biology/carbon-cycle#node-2707**](http://www.nuffieldfoundation.org/practical-biology/carbon-cycle#node-2707) |

#### 3.3.5.3 The nitrogen cycle.

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 role of bacteria in the nitrogen cycle in sufficient detail as to illustrate the processes of ammonification,  nitrification, denitrification and nitrogen fixation. | 0.4  weeks | • describe the stages of the nitrogen cycle, and the ions/molecules at each stage.  • explain the processes of ammonification, nitrification, nitrogen fixation and denitrification within the nitrogen cycle.  • explain the role of saprophytic bacteria and mycorrhizae in the nitrogen cycle.  • interpret information/data about the nitrogen cycle and apply knowledge. | **Learning activities:**  - Brainstorm why nitrogen is needed, e.g. 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.  - Past 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. | **Past exam paper material:**  BIOL4 – Jan 13 Q1;  BIOL4 – Jun 12 – Q8b.  BIOL4 – June 11 Q8a.  BIOL4 – June 14 Q2.  BIOL4 – June 15 Q2.  BIOL4 – June 10 Q3b. | [**http://www.tes.co.uk/teaching-resource/nitrogen-cycle-game-6079926/**](http://www.tes.co.uk/teaching-resource/nitrogen-cycle-game-6079926/)  [**http://www.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. |  | [**http://www.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 in replacing nutrients lost by harvesting plants and removing livestock.  Leaching and eutrophication arising from the use of fertilisers. | 0.4  weeks | • explain why farmers utilise natural and artificial fertilisers.  • explain how leaching and eutrophication are 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.  - Past 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 12 Q6;  BIOL4 – Jun 13 Q8b;  BIOL4 – Jan 11 Q3;  BIOL4 – June 11 Q3b. | [**http://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. |

### 3.3.6 Inheritance

#### 3.3.6.1 Principles

Prior knowledge:

-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 of an organism is its genetic constitution.  The phenotype is the expression of this genetic constitution and its interaction with the environment.  There may be many alleles of a single gene.  Alleles may be dominant, recessive or codominant.  In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous. | 0.2  weeks | • explain the meaning of the key terms: gene; allele; genotype; phenotype; homozygous; and heterozygous.  • explain the basis for dominance and co-dominance of alleles. | **Learning activities:**  - Question students about prior learning in relation to inheritance.  - 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.  - Model the idea of dominance by providing two demonstrators with instructions for making a simple circuit involving a LED – one has correct instructions with the diode in the correct direction, and the other has faulty instructions with the diode facing in the wrong direction. Nevertheless, the class got to see a working circuit. Relate to the idea of dominant/recessive alleles.  - Show a co-dominant characteristic and ask students for suggestions as to what is happening.  - Card match – terms to definitions.  **Skills developed by learning activities:**  **AO1 –** Development of knowledge and understanding of key terms and concepts relating to inheritance. |  | **Rich questions:**  - 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 e.g. dihybrid ratios. N.B. This will take about 3 weeks before adult offspring can be observed, but the results could be used in later experiments/lessons. |  |  |

#### 3.3.6.2 Patterns of inheritance

Prior knowledge:

**-** 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.

- 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 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.  • explain the principle underlying dominant and recessive alleles.  • draw 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.  • interpret pedigree analysis diagrams, citing evidence from them in support of explanations. | **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:**  **Mathematical requirement 3, 6 and 14 –** Understand simple probability associated with inheritance. Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of dominant and recessive alleles, and their inheritance.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material**:  BIOL4 – June 13 Q3a-b;  HBIO4 – June 13 Q4;  HBIO4 – June 10 Q6 | [**http://www.kscience.co.uk/animations/drosophila2.htm**](http://www.kscience.co.uk/animations/drosophila2.htm)  [**http://www.kscience.co.uk/animations/inheritance.htm**](http://www.kscience.co.uk/animations/inheritance.htm)  **Rich questions:**  - Define 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? |
| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Use of the chi-squared (χ2) test to determine whether there is a significant difference between the expected genetic ratios and the observed 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:**  - Question students about the principles of using stats tests covered previously.  - Ask pupils to do a genetic cross of heterozygous peas, e.g. 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 students through a couple of worked examples of the chi-squared tests and how to interpret values.  - Provide further examples using simple dominant/recessive monohybrid crosses.  **Skills developed by learning activities:**  **Mathematical requirement 3, 6, 8 and 14 –** Usethe χ2 test to investigate thesignificance of differences between expected and observed phenotypic ratios. Interpret χ2 in terms of probability and chance. Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **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. | **Past exam paper material**:  Exampro  BYA5 – Jan 03 Q8a and 8b | **Rich questions:**  - Why do scientists use statistical tests?  - 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 co-dominant.  The use of fully labelled genetic diagrams to interpret, or predict, the results of monohybrid crosses involving co‑dominant alleles. | 0.2  weeks | • define what is meant by co-dominant alleles, and describe how to represent these.  • draw co-dominant monohybrid crosses to predict offspring genotypes and phenotypes.  • apply knowledge to calculate the predicted ratios of genotypes and phenotypes 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 chi-squared tests in terms of probability and chance. | **Learning activities:**  **-** Stimulus: Show pictures of snapdragon plants, and ask them to suggest what is different about this compared to the dominant/recessive inheritance seen so far.  - 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:**  **Mathematical requirement 3, 6, 8 and 14 –** Usethe χ2 test to investigate thesignificance of differences between expected and observed phenotypic ratios. Interpret χ2 in terms of probability and chance. Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of co-dominant alleles, and their inheritance.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material**:  BIOL4 – June 14 Q4c; | **Rich questions:**  - Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving codominance, e.g. pink snapdragons, tabby cats, Palomino 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 multiple allele crosses.  • draw multiple allele crosses to predict offspring genotypes and phenotypes.  • apply knowledge to calculate the predicted ratios of genotypes and phenotypes 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 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 as well.  **Skills developed by learning activities:**  **Mathematical requirement 3, 6, 8 and 14 –** Usethe χ2 test to investigate thesignificance of differences between expected and observed phenotypic ratios. Interpret χ2 in terms of probability and chance. Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of multiple alleles and their inheritance.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material**:  BIOL4 – June 12 Q2a-c;  BIOL4 – Jan 11 Q2a-b.  BIOL4 – June 11 Q5;  BYA5 – Jan 07 Q3;  BYA5 – June 06 Q7 | **Rich questions:**  - Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving multiple alleles, e.g. 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 alleles, and describe how to represent these.  • draw sex-linked crosses to predict offspring genotypes and phenotypes.  • apply knowledge to calculate the predicted ratios of genotypes and phenotypes 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 chi-squared tests in terms of probability and chance. | **Learning activities:**  **-** Ask students to suggest why some characteristics e.g. 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:**  **Mathematical requirement 3, 6, 8 and 14 –** Usethe χ2 test to investigate thesignificance of differences between expected and observed phenotypic ratios. Interpret χ2 in terms of probability and chance. Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of sex-linked alleles, and their inheritance.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material**: BIOL 4 – Jan2012 Q5;  BIOL4 – Jan 13 Q3;  BIOL4 – June 13 Q3bii.  BIOL4 – June 14 Q4a-4b;  BYA5 – June 08 Q6;  BYA5 – June 09 Q4.  Exampro –  BYB4 – Jan 2004 Q5;  BYB4 – June 2004 Q5;  BYB4 – June 2006 Q6;  BYB4 - June 2005 Q4 | [**http://www.kscience.co.uk/animations/drosophila2.htm**](http://www.kscience.co.uk/animations/drosophila2.htm)  **Rich questions:**  - Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving sex linkage, e.g. 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. | 0.2-0.4 weeks | • draw dihybrid crosses to predict offspring genotypes and phenotypes.  • apply knowledge to calculate the predicted ratios of genotypes and phenotypes 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 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 separate 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:**  **Mathematical requirement 3, 6, 8 and 14 –** Usethe χ2 test to investigate thesignificance of differences between expected and observed phenotypic ratios. Interpret χ2 in terms of probability and chance. Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of dihybrid crosses.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material**:  BYA5 – Jan 05 Q7;  BYA5 – Jan 09 Q6;  BYB4 – June 06 Q6;  BYB4 – June 07 Q5;  BYB4 – June 09 Q3 | [**http://www.kscience.co.uk/animations/drosophila2.htm**](http://www.kscience.co.uk/animations/drosophila2.htm)  **Rich questions:**  - Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving dihyrbid inheritance e.g. 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  epistasis. | 0.2  weeks | • apply knowledge to calculate the predicted ratios of genotypes and phenotypes 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 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:**  **Mathematical requirement 3, 6 and 14 –**Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of epistasis.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material**:  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, e.g. coat colour in rodent, fruit colour in summer squashes, flower colour in sweet peas, comb shape in chickens. |

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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 phenotypes 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 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 (i.e. 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 % of gametes with each combination of alleles.  - Students work through further examples independently.  **Skills developed by learning activities:**  **Mathematical requirement 3, 6 and 14 –**Construct monohybrid cross diagrams. Show offspring as ratios/fractions/%.  **AO1 –** Development of understanding of autosomal linkage.  **AO2 –** Application of knowledge to unfamiliar contexts. |  | [**http://www.kscience.co.uk/animations/drosophila2.htm**](http://www.kscience.co.uk/animations/drosophila2.htm)  **Rich questions:**  - Ask students to interpret or predict the offspring when provided with parental genotypes for examples involving autosomal linkage, e.g. linkage in flower colour and type of pollen in sweet peas, linkage of wing and eye colour. |

### 3.3.7 Allele frequencies in populations

#### 3.3.7.1 Principles and applications

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 the study of population genetics, a population may be considered as a group of potentially interbreeding organisms of the same species occupying a particular space at a particular time.  The concept of a gene pool as the complete set of alleles for a gene in a single population.  The concept of allele frequency as the fraction of the genes in the gene pool that is a particular allele. | 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 measured 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 as relating to only one breeding pair.  - 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:**  **Mathematical requirement 1, 2, 11 and 12 –** Use of percentages and decimals. Translate information between algebraic and numerical forms.  **AO1 –** Development of understanding of population and gene pools.  **AO2/AO3 –** Analyse information and apply knowledge to work out allele frequencies. | **Past exam paper material**:  BYA5 – Jan 05 Q8a;  BYA5 – June 03 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 influence of selection for high yielding breeds of domesticated animals and cultivated plants. | 0.2  weeks | • explain the principles of selective breeding (artificial selection).  • explain the advantages of selective breeding of domesticated animals and cultivated plants.  • explain the effect of selective breeding on genetic diversity.  • evaluate the disadvantages of selective breeding. | **Learning activities:**  - Teacher explanation of selective breeding linked to genetic diversity. Provide examples, e.g. the breeding of different varieties of wheat and sheep and model how these were selectively bred. Use video to support this.  - Discuss what effect selective breeding has on allele frequency and genetic diversity.  - Ask students to explain how this differs to natural selection.  - Provide students with another example of selective breeding. Get them to provide a suggested explanation independently.  - Exam questions  **Skills developed by learning activities:**  **Mathematical requirement 9 –** Interpretation of standard deviations in exam questions.  **AO1 –** Development of understanding of artificial selection.  **AO2/AO3 –** Application of knowledge to explain unfamiliar examples. | **Past exam paper material**:  HBIO2 – June 13 Q6b;  HBIO2 – Jan 13 Q4;  HBIO2 – Jan 10 Q10b;  HBIO2 – June 09 Q2c;  BIOL 2 – June 12 Q2;  BIOL 2 – June 14 Q2; | [**http://www.saps.org.uk/secondary/teaching-resources/818-norman-borlaug**](http://www.saps.org.uk/secondary/teaching-resources/818-norman-borlaug)  **Rich questions:**  - Explain the effect of selective breeding on genetic diversity.  - Explain the advantages and disadvantages of selective breeding.  - How is selective breeding fundamentally  different to natural selection? |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Genetic bottlenecks involve severe reductions in population size due to environmental events or human activities which reduces variation in the gene pool.  Genetic drift results in a change in the frequency of alleles in a population of organisms due to chance. When there are few copies of an allele, the effect of genetic drift is larger. | 0.2  weeks | • explain the processes of genetic bottlenecking and genetic drift and its impact on allele frequencies/genetic diversity.  • explain how genetic drift differs from natural selection.  • explain why genetic drift has a larger effect on small populations.  • interpret information and apply knowledge to unfamiliar contexts. | **Learning activities:**  - Provide students with photocopied pictures of animals (used previously) with the genotypes for one feature written on them 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 6 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 bottlenecks and genetic drift linked to genetic diversity. Provide examples, e.g. achromatopsia on the island of Pingelap due to bottlenecking. Ask students to write a suggested explanation.  - Ask students to explain how this differs to natural selection.  - Past exam questions.  **Skills developed by learning activities:**  **AO1 –** Development of understanding of genetic bottlenecking and genetic drift.  **AO2/AO3 –** Application of knowledge to explain unfamiliar examples. | **Past exam paper material**:  BIOL2 – Jan 13 Q3ci;  BIOL2 – June 15 Q7b;  BIOL2 – June 09 Q6;  Assessment of students’ written explanations. | [**http://nortonbooks.com/college/biology/animations/ch16a01.htm**](http://nortonbooks.com/college/biology/animations/ch16a01.htm)  **Rich questions:**  - After several generations from the bottlenecking event, what will have happened to the:  - population size?  - genetic diversity within the population?  - How is genetic drift fundamentally different to natural selection?  - Why does genetic drift have a more noticeable effect in small populations? |

#### 3.3.7.2 The Hardy-Weinberg principle and the Hardy-Weinberg equation

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 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 | 0.6  weeks | • explain what the Hardy-Weinberg principle predicts.  • describe and explain the mathematical equations used to express allele and genotype frequencies.  • explain the conditions under which Hardy- Weinberg principle applies.  • use the Hardy-Weinberg equation to calculate allele, genotype and phenotype frequencies from appropriate data. | **Learning activities:**  - Recap findings from 3 lessons ago that  p + q =1.  - Teacher explanation of Hardy-Weinberg principle and the conditions under which it applies.  - Worked examples of Hardy-Weinberg calculations as a class. Then get students to work through examples independently. Practice as many as possible.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirement 1, 2, 11 and 12 –** Use of percentages and decimals. Translate information between algebraic and numerical forms.  **AO1 –** Development of understanding of Hardy-Weinberg principle.  **AO2 –** Application of knowledge to unfamiliar contexts. | **Past exam paper material:**  BIOL4 – June 12 Q2d;  BIOL4 – June 13 Q3c;  BIOL4 – Jan 11 Q2c;  BIOL4 – June 10 Q3;  BIOL4 – June 11 Q6a-bi; | **Rich questions:**  - What assumptions does Hardy-Weinberg principle make?  - Do these principles apply in practice?  - Why must both equations be equal to 1? |

### 3.3.8 Evolution may lead to speciation

#### 3.3.8.1 The theory of evolution

Prior knowledge:

**-** 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.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| **Required practical 9 -** A laboratory based investigation of the effect of competition on seedling growth.  Design a valid experiment, using the work of others as a starting point, to investigate and solve a problem in a scientific context.  Identify variables including those that must be controlled.  Evaluate findings to draw meaningful conclusions. | 0.8 weeks | • evaluate and select appropriate information from published methods, and refine to produce a workable method.  • represent raw and processed data clearly using tables.  • apply knowledge to draw and explain conclusions.  • evaluate the quality of results and reliability of conclusions. | **Learning activities:**  Students design an experiment to investigate the effect of competition in the growth of seedlings, e.g. mustard seeds. This should include:  - Method – Provide students with experimental techniques for this, and ask them to evaluate these and produce their own method using elements of those supplied.  - Risk assessment.  - Carrying out (subject to teacher approval).  (Leave seeds to grow, so interpretation of the results will be done in a subsequent lessons, possibly after further teaching of the next section).  - Processing and presentation of data (including an appropriate stats test).  - Evaluation and explanation findings.  **Skills developed by learning activities:**  **Mathematical requirement 7, 8,14, -** Construct appropriate tables to collect data. Carry out and interpret an appropriate stats test.  **AO2/AO3** – Application of knowledge to explain trends in the data.  **AO4 –** Evaluate, select and refine scientific procedures. |  | [**http://www.saps.org.uk/secondary/teaching-resources/186-student-sheet-5-investigating-seed-germination-experiment**](http://www.saps.org.uk/secondary/teaching-resources/186-student-sheet-5-investigating-seed-germination-experiment)  [**http://www.scienceteacherprogram.org/biology/diez1.html**](http://www.scienceteacherprogram.org/biology/diez1.html) |
| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Evolution is a theory that may be considered as a change in the allele frequencies in a population.  Individuals within a population may show a wide range of phenotypic variation.  Predation, disease and competition for the means of survival result  in differential survival and reproduction.  Those organisms with phenotypes providing selective advantages  are likely to produce more offspring and pass on their favourable alleles to the next generation. This may affect the frequency of specific alleles within the gene pool. | 0.4  weeks | • explain what is meant by a selection pressure, and which factors can act as selection pressures.  • explain how natural selection is linked to variation, adaptation and inheritance of alleles by the next generation.  • explain the concept of reproductive success.  • apply your knowledge to explain data.  • explain how natural selection may account for changes in allele and phenotype frequency when provided with appropriate data. | **Learning activities:**  - Set up cards around the room with factors which animals might compete for, e.g. food. Make sure that some factors are in short supply and that they are well hidden and inaccessible to some students. Give students four 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, e.g. 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, e.g. Devil facial tumour disease in Tazmanian devils.  - Students use Peppered moths simulation to model effects of natural selection or work through student sheet (see resources).  - Provide data on changes in allele/phenotype frequency and ask pupils to suggest how natural selection could have caused this.  - Past exam questions.  **Skills developed by learning activities:**  **AO1/AO2/AO3 –** Development of knowledge of natural selection and selection pressures, and application to data. | **Past exam paper material:**  BIOL4 – Jan 11 Q4  HBIO2 June 10 – Q10b. | [**http://www.nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-peppered-moths**](http://www.nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-peppered-moths)  [**http://www.nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-banded-snails**](http://www.nuffieldfoundation.org/practical-biology/selection-action-%E2%80%93-banded-snails)  [**http://peppermoths.weebly.com/**](http://peppermoths.weebly.com/)  [**http://learn.genetics.utah.edu/content/selection/**](http://learn.genetics.utah.edu/content/selection/)  [**http://www.arkive.org/education/teaching-resources-16-18**](http://www.arkive.org/education/teaching-resources-16-18) |

#### 3.3.8.2 Selection and speciation

Prior knowledge:

- New species arise a result of as 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** |
| The effect of differential  reproductive success on the allele frequencies within a gene pool.  The effects of stabilising, directional and disruptive selection. | 0.4  weeks | • explain what is meant by stabilising, directional and disruptive selection in the context of the effect that each has on allele frequencies.  • identify types of selection from distribution curves.  • interpret data relating to the effect of selection in producing change within populations.  • apply knowledge of types of selection to unfamiliar contexts. | **Learning activities:**  - Ask rich question as a stimulus and gauge student responses.  - Introduce the concept of directional, disruptive and stabilising selection with examples. Link this to the distribution curves for populations subjected each. Use animation of the selection of finches on the Galapagos islands.  - Card sort with examples of disruptive, directional and stabilising selection described (e.g. Australian snakes with big heads being able to eat the poisonous Cane toad, resulting in death of those with large heads; fossilised ferns showing little difference to modern day ferns). Students have to categorise.  - Revisit rich question to reassess responses.  - Ask students to work in groups to develop an explanation to explain the evolution of characteristics in a species e.g. 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.  - Past exam questions.  **Skills developed by learning activities:**  **AO1 –** Development of understanding relating to forms of natural selection and their effect on allele frequencies.  **AO2 –** Application of knowledge to explain changes /lack of changes in the distribution curves/features of a population.  **AO3 -** Interpret data from graphs showing selection. | **Past exam paper material:**  BIOL4 – June 11 Q6bii;  BIOL4 – Jan 10 Q1d;  BIOL4 – June 14 Q5.  BIOL2 June 12 Q2;  BIOL2 Jan 11 Q6;  BIOL2 June 09 Q3 (except 3b);  BIOL2 Jan 12 Q5 (except 5c). | [**http://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)  [**http://bcs.whfreeman.com/thelifewire/content/chp23/2302001.html**](http://bcs.whfreeman.com/thelifewire/content/chp23/2302001.html)  [**http://nortonbooks.com/college/biology/animations/ch16a02.htm**](http://nortonbooks.com/college/biology/animations/ch16a02.htm)  [**http://learn.genetics.utah.edu/content/selection/**](http://learn.genetics.utah.edu/content/selection/)  **Rich questions:**  Fossils indicate that crocodiles and sharks have remained relatively unchanged for millions of years. Does this indicate that they are no longer subject to natural selection?  - 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 populations may result in differences in their gene pools.  New species arise  when genetic differences lead to an inability of members of  the separated populations to interbreed and produce fertile offspring.  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 a 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 reproductive isolation resulting in 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 isolation preventing gene flow as a precursor to speciation.  - Provide information stations, e.g. 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.  - Past 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 13 Q8c  BIOL4 – June 13 Q6;  BIOL4 – Jan 11 Q8c;  HBIO2 – Jan 12 Q10b;  HBIO5 – June 13 Q8bi;  HBIO5 – June 15 Q8. | [**http://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)  [**http://media.hhmi.org/biointeractive/films/OriginSpecies-Lizards.html**](http://media.hhmi.org/biointeractive/films/OriginSpecies-Lizards.html)  [**http://www.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 isolation differ in allopatric and sympatric speciation? |

## **Unit 4: Control**

**Unit description**

Consideration of control mechanisms underpins the content of this unit. Students who have studied it should develop an understanding of the ways in which organisms and cells control their activities.

Multicellular organisms are able to control the activities of different tissues and organs within their bodies. They do this by detecting stimuli and responding by way of particular effectors; plants rely on specific growth factors; animals use hormones and nerve impulses. By responding to stimuli, animals increase their probability of survival by moving to favourable environments and by maintaining optimal conditions for their metabolism.

Cells are also able to control their metabolic activities by regulating the transcription and translation of their genome. Although the cells within an organism carry the same genetic code, they translate only part of it.

### 3.4.1 Control systems involve stimulus and response.

#### 3.4.1.1 Taxes and kineses

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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.  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, e.g. 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.  - Past 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. | **Past exam paper material:**  BIOL5 – June 10 Q1;  BIO6X June 2014 EMPA.  Exampro  BYB9 – June 2005 Q2 | [**http://www.nuffieldfoundation.org/practical-biology/investigating-response-calliphora-larvae-light**](http://www.nuffieldfoundation.org/practical-biology/investigating-response-calliphora-larvae-light)  [**http://www.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. |

#### 3.4.1.2 The reflex arc

Prior knowledge:

- 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.

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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 bring about a reflex action (from stimulus to response). | **Learning activities:**  **-** Questioning to assess recall from GCSE and to recap key terms, e.g. stimulus, effector.  - Introduce the protective role of reflex actions.  - Students could investigate reflex actions and suggest how they are protective, e.g. 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, e.g. 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.  - Past 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. | **Past exam paper material:**  Exampro – BYB4 – June 2004 Q1 | [**http://www.sumanasinc.com/webcontent/animations/content/reflexarcs.html**](http://www.sumanasinc.com/webcontent/animations/content/reflexarcs.html)  **Rich questions:**  - Why are reflex actions much quicker than voluntary responses? |

### 3.4.2 Receptors.

#### 3.4.2.1 The Pacinian corpuscle

Prior knowledge:

- 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** |
| The Pacinian corpuscle as an example of a receptor to illustrate the following:  • receptors respond to specific stimuli  • stimulation of a receptor 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. | 0.2 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 corpuscle produces a generator potential in response to a specific stimulus. | **Learning activities:**  - 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.  - Past exam questions.  **Skills developed by learning activities:**  **AO1 –** Development of knowledge and understanding of how Pacinian corpuscles work. | **Past exam paper material:**  BIOL5– June 15 Q5a;  UK A-level Specimen Paper 2 – Q4.2 | **Rich questions:**  - What stimulus does a Pacinian corpuscle respond to?  - What is a generator potential?  - Explain how a generator potential is established. |

#### 3.4.2.2 The human retina

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 human retina only in sufficient detail as to show how differences in sensitivity to light and colour and visual acuity are explained by differences in the optical pigments of rods and cones and the connections that the rods and cones make in the optical nerve. | 0.4 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 iodopsin and connections to the optic nerve. | **Learning activities:**  - Introduce the parts of the eye and how the eye focusses light that is scattered by objects/from objects, to form an image on the retina.  - Provide information sheets/comprehensions on rod and cone cells around the room, and provide a question sheet to 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.  - Past 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 13 Q5;  HBIO4 – June 12 Q1b;  HBIO4 – June 13 Q1a –Q1bi;  HBIO4 – Jan 11 Q1a;  HBIO4 – June 10 Q2;  HBIO4 – June 11 Q7a-7b; | [**http://www.nuffieldfoundation.org/practical-biology/investigating-how-we-see-colour**](http://www.nuffieldfoundation.org/practical-biology/investigating-how-we-see-colour)  [**http://www.childrensuniversity.manchester.ac.uk/interactives/science/brainandsenses/eye/**](http://www.childrensuniversity.manchester.ac.uk/interactives/science/brainandsenses/eye/)  [**http://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 (and find their blind spot). |  |  |

### 3.4.3 Nerve impulses and synaptic transmission.

#### 3.4.3.1 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 subsequent repolarisation. The generation of an action potential and the all-or-nothing principle.  The role of ATP and sodium-potassium pumps in re-establishing the resting potential. | 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 the role of the sodium-potassium pump.  • apply knowledge to explain oscilloscope traces representing resting and action potentials.  • 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.  - Past 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. | **Past exam paper material:**  BIOL5 – June 13 Q10a;  BIOL5 – June 10 Q3;  HBIO4 – June 11 Q3;  HBIO4 – Jan 10 Q5; | [**http://sites.sinauer.com/neuroscience5e/animations02.01.html**](http://sites.sinauer.com/neuroscience5e/animations02.01.html)  [**http://sites.sinauer.com/neuroscience5e/animations02.03.html**](http://sites.sinauer.com/neuroscience5e/animations02.03.html)  [**http://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)  [**http://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.  Factors affecting the speed of conductance: myelination and  saltatory conduction. | 0.2 weeks | • explain how action potentials pass along unmyelinated neurones.  • describe what Nodes of Ranvier are.  • explain 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 along nodes by saltatory conduction.  - Past 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 – Q4.1 and 4.4 | [**http://www.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.  - Past 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 13 Q4b;  HBIO4 – June 12 Q7  HBIO4 – June 10 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.  - 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:**  **Mathematical requirements 5, 6, 7, 12 -** Substitute numbers into an algebraic equation to convert distance fallen into reaction time. Calculate the mean. Select an appropriate stats test (Standard error and 95% confidence limits). Interpret stats test in terms of probability and chance, and whether to accept or reject H0.  **AO1** – Knowledge of the factors affecting speed of conductance.  **AO2/AO3** – Application of knowledge to practical results.  **AO4 –** Evaluation of the methodology and results of other people’s investigations. | BIO6T P14 ISA |  |

#### 3.4.3.2 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 cholinergic synapse in sufficient detail to explain:  • unidirectionality  • temporal and spatial summation. | 0.4  weeks | • explain the functions of synapses.  • describe and explain the detailed structure of a synapse.  • explain the sequence of events involved in transmission of an action potential from one neurone to another.  • explain how synaptic transmission allows for unidirectionality, temporal and spatial summation. | **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 of events achieves each one.  - Teacher explanation of summation, inhibition and unidirectionality.  - Past 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 13 Q7a and 7b;  BIOL5 – June 11 Q2b;  HBIO4 – Jan 12 Q1; | [**http://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)  [**http://www.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 detailed structure of a neuromuscular junction in sufficient detail to explain:  • unidirectionality  • temporal and spatial summation  . | 0.2 weeks | • explain what a neuromuscular junction is.  • describe and explain the detailed structure of a neuromuscular junction.  • explain how action potentials are transmitted across a neuromuscular junction by release of acetylcholine, and compare this to synaptic transmission.  • explain how neuromuscular junction transmission allows for unidirectionality, temporal and spatial summation.  • 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.  - Past 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;  BIOL5R– June 15 Q6c; | **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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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The effects of specific drugs and toxins on a synapse. | 0.2 weeks | • use information provided to predict and explain the effects of specific drugs and toxins on synaptic transmission. | **Learning activities:**  - Stimulus: Provide some drug names on cards and ask students to categorise them in a way they feel is appropriate, e.g. 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 (e.g. heroin, cocaine, atropine, curare), namely the characteristic effects of the drug, and the effect the drug has on synapses, e.g. mimicking a neurotransmitter. Ask students to work in groups to explain the effect that the drug has.  **N.B. recall of names and modes of action of individual drugs are not expected.**  - Accept feedback and discuss.  - Past 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 11 Q5;  HBIO4 – Jan 10 Q7a and 7c;  BIOL5 – June 13 Q7c;  BIOL5R– June 15 Q6a-b; | [**http://outreach.mcb.harvard.edu/animations/synapse.swf**](http://outreach.mcb.harvard.edu/animations/synapse.swf)  [**http://www.biologymad.com/nervoussystem/synapses.htm**](http://www.biologymad.com/nervoussystem/synapses.htm)  [**http://www.thirteen.org/closetohome/science/html/animations.html**](http://www.thirteen.org/closetohome/science/html/animations.html)  [**http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/D/Drugs.html**](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/D/Drugs.html) |

### 3.4.4 Skeletal muscles as effectors.

#### 3.4.4.1 The sliding filament theory of muscle contraction

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** |
| 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, linked to isotropic bands and anisotropic bands and the thickness of each type of protein filament.  • identify I bands, A bands, the H zone and the Z line on a diagram.  • interpret the appearance of diagrams or photographs of myofibrils at different stages of muscle contraction. | **Learning activities:**  - Teacher explanation of the gross structure of skeletal muscle.  - Students undertake microscopy of skeletal tissue. Do 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.  - Past 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 ofknowledge to the context given in exam questions. | **Past exam paper material:**  HBIO4 – Jan 13 Q9a-9b;  HBIO4 – Jun 12 Q3b;  HBIO4 – Jan 11 Q10a-10b;  HBIO4 – June 10 Q4a and 4b;  BIOL5 – June 12 Q2a-b; | **Rich questions:**  - What is a myofibril?  - In which bands/zone would you find:  a) Myosin?  b) 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, ATP and tropomyosin in the cycle of actinomyosin bridge formation and myofibril contraction. | 0.4 weeks | • recall how the release of acetylcholine across neuromuscular junctions, triggers the release of Ca2+ ions.  • explain the importance of the release of calcium ions in causing a conformational change in tropomyosin.  • explain the sliding theory filament of myofibril contraction.  • explain the roles of key molecules myosin, actin, calcium ions and ATP in causing myofibril contraction. | **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 5cm. 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.  - Past 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 13 Q2a;  BIOL5 – June 10 Q7;  BIOL5 – June 11 Q10b;  HBIO4 – Jan 12 Q3;  HBIO4 – June 13 Q5;  HBIO4 – June 10 Q4c;  HBIO4 – June 11 Q2;  HBIO4 – Jan 10 Q2 | [**http://www.nuffieldfoundation.org/practical-biology/modelling-sliding-filament-hypothesis**](http://www.nuffieldfoundation.org/practical-biology/modelling-sliding-filament-hypothesis)  [**http://bcs.whfreeman.com/thelifewire/content/chp47/4702001.html**](http://bcs.whfreeman.com/thelifewire/content/chp47/4702001.html)  [**http://www.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. |  |  |

#### 3.4.4.2 Muscles 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** |
| The roles of ATP and phosphocreatine in providing the energy supply during muscle contraction. | 0.2 weeks | • explain the role of ATP and phosphocreatine in some muscle fibres. | **Learning activities:**  - Questioning to recap the process of myofibril contraction. Emphasise the role of ATP.  - Teacher explanation of the role of phosphocreatine in regenerating ATP in some muscle fibres.  - Past exam questions.  **Skills developed by learning activities:**  **AO1 –**Development of knowledge and understanding of the role of ATP and phosphocreatine during muscle contraction. | **Past exam paper material:**  BIOL5 – June 12 Q2c;  BIOL5 – June 14 Q6a-b.  HBIO2 – Jan 12 Q8b;  HBIO2 June 09 Q6b; | **Rich questions:**  - Explain the roles of phosphocreatine and ATP in muscle contraction.  - How does phosphocreatine supply energy to the muscle?  - Under what circumstances would phosphocreatine be used by the body?  - How is phosphocreatine replenished? |

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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 | • describe the three types of muscle in the body.  • explain the role of skeletal muscle, linked to the role of tendons and joints.  • explain why muscles which move bones that form part of a joint, work as antagonistic pairs.  • describe some common antagonistic pairs in the body. | **Learning activities:**  - Teacher introduction to skeletal muscle in terms of it moving bones as part of 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 of why muscles work as antagonistic pairs  - Past exam question.  **Skills developed by learning activities:**  **AO1 –** Development of knowledge of antagonistic pairs of muscles. | **Past exam paper material:**  HBIO4 – June 12 Q3a; | [**http://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 expands”. |
| 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** |
| 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.  • explain 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, e.g. websites, comprehensions, textbooks etc.  - Accept feedback and reinforce using teacher explanation.  - Students produce a summary table comparing and contrasting.  - Past 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 13 Q2b;  BIOL5 – June 10 Q7;  HBIO4 – Jan 13 Q9c.  BIO6T ISA P 2015  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. |
| Extension |  |  | Students could undertake the BIO6T ISA P from 2015 as a practical and assessment to develop investigative skills. |  |  |

### 3.4.5 Control systems in plants.

#### 3.4.5.1 Principles

Prior knowledge:

-Plants produce hormones to coordinate and control growth.

- Plant growth hormones are used in agriculture and horticulture as weed killers and as rooting hormones.

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Plant growth substances are signal molecules that are produced in plants and occur in very low concentrations. They regulate targeted cells near to their site of production or move to other tissues where they regulate a variety of processes including growth in response to directional stimuli, fruit development and closure of stomata as a response to drought. | 0.2 weeks | • identify and explain what plant growth substances are.  • explain how plant growth substances regulate targeted cells.  • describe some of the potential roles played by different plant growth substances. | **Learning activities:**  - Teacher introduction to the concept of control systems in plants relying on plant hormones. Explain that these are made in low concentrations, and regulate targets close to their production site or travel around the plant to regulate targets further away.  - Provide students with simplified information sheets around the room based on the roles that different growth substances play, e.g. auxins, cytokinins, abscisic acid, ethene, gibberellins. Provide students with a question race, which they have to find to the answers to.  - Accept feedback based on findings and summarise some of the roles played by plant hormones.  - Students could complete a concept map.  **Skills developed by learning activities:**  **AO1 -** Development of knowledge relating to the potential roles and method of control of plant hormones (as an introduction to the topic). |  | **Rich questions:**  - When a plant experiences drought, abscisic acid production in the roots increases. It then travels to leaf. Suggest what role it plays to bring about a response. |

#### 3.4.5.2 Auxins and tropisms

Prior knowledge:

-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** |
| Tropisms as growth responses to directional stimuli that can maintain the roots and shoots of flowering plants in a favourable environment.  The effect of different concentrations of indoleacetic acid (IAA) on  cell elongation in the roots and shoots of flowering plants as an explanation of responses to light and gravity in flowering plants. | 0.4 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 and positive gravitropism in roots.  • apply knowledge of IAA to interpret results and draw conclusions. | **Learning activities:**  - Questioning to assess prior knowledge.  - Stimulus: Show students cress grown in a clinostat vs those grown on a lab bench, and cress grown in a dark box with small holes for light. Students observe and suggest explanations.  - Introduce IAA in plants as a class of auxin.  - Interpret and process results from the interpretation activity and plot on graph.  - Students 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 different tropisms using the animation (including whether they are positive or negative) linked to IAA production/distribution.  - Past 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.  **AO4 –** Description of scientists’ work on tropisms. | **Past exam paper material:**  BIOL5 – June 12 Q7;  BIOL5 – June 13 Q3;  BIOL5 – June 11 Q3;  BIOL5R– June 15 Q7b-c; | [**http://www.nuffieldfoundation.org/practical-biology/interpreting-investigation-plant-hormones**](http://www.nuffieldfoundation.org/practical-biology/interpreting-investigation-plant-hormones)  [**http://www.saps.org.uk/secondary/teaching-resources/1238-tropisms-how-do-plants-grow-in-space**](http://www.saps.org.uk/secondary/teaching-resources/1238-tropisms-how-do-plants-grow-in-space)  [**http://www.sumanasinc.com/webcontent/animations/content/plantgrowth.html**](http://www.sumanasinc.com/webcontent/animations/content/plantgrowth.html)  **Rich questions:**  - Describe the differences in how plant growth factors are produced and act, compared to hormones in animals.  - What effect does a high concentration have on root and shoot growth?  - Explain phototropism in stems.  - Explain gravitropism in roots. |
| Extension |  |  | Students investigate the effect of IAA on root growth in seedlings. |  | [**http://www.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** |
| **Required practical 10 -** Investigation of the effect of a suitable variable on the direction of growth of a root or a shoot. | 0.4 weeks | • interpret and explain results from an investigation into tropisms, using knowledge of IAA and its effect on root and/or shoot growth. | **Learning activities:**  - Students conduct an investigation into the effect of a variable on shoot/root growth. An example investigation is provided in resources.  - Students should interpret the results based on their knowledge of tropisms and write a detailed conclusion based on their knowledge of IAA and its effect on shoots.  **Skills developed by learning activities:**  **AO2/AO3** – Application of knowledge to explain observations from the investigation. |  | [**http://www.saps.org.uk/secondary/teaching-resources/185-student-sheet-8-the-response-of-seedlings-to-light-phototropism-experiment**](http://www.saps.org.uk/secondary/teaching-resources/185-student-sheet-8-the-response-of-seedlings-to-light-phototropism-experiment) |

#### 3.4.5.3 Ethene and abscisic acid (ABA)

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 role of ethene in fruit ripening.  Control of ethene allows climacteric fruits such as bananas to be picked green and artificially ripened after shipping. | 0.2 weeks | • explain the role of ethene.  • explain what is meant by positive feedback, as exemplified by ethene.  • explain how fruit producers and supermarkets can apply knowledge of the role of ethene to ensure that certain fruits are at peak ripeness when they go on sale. | **Learning activities:**  - Question students about their learning from 3.4.5.1 to recap the role of ethene in fruit ripening.  - Provide students with a pre-set up version of the experiment suggested in the resources. Students can test the fruits for richness using iodine solution.  - Question them why bags 5-8 had ripened when bags 1-4 had not.  - Introduce the concept of positive feedback in the context of ethene. Question students about how we could make use of this knowledge.  - Teacher led explanation of how fruit can be picked in an unripe state, and made to ripen after shipping to ensure it is perfectly ripened for sale in shops.  - Students could interpret data relating to the effect of ethene concentration in the atmosphere on metabolism and ripening in climacteric fruits.  **Skills developed by learning activities:**  **AO1 –** Development of knowledge relating to the effect of ethene on fruit ripening, and how this knowledge is used.  **AO2/AO3 –** Interpret scientific data and apply knowledge of the effects of ethene to explain it. |  | [**http://chemistry.about.com/od/chemistryexperiments/ss/ethyleneexp.htm#step3**](http://chemistry.about.com/od/chemistryexperiments/ss/ethyleneexp.htm#step3)  **Rich questions:**  - Suggest how knowledge of ethene can be used to ensure that bananas reach peak ripeness as they are put on sale in supermarkets.  - Why would ethene not be used on fruits such as cherries to cause ripening?  - Fruit produces ethylene in response to stress too, e.g. bruising or chilling. What would have happened to the speed of ripening of the pears if chilled bananas had been put in the bag? Explain your answer. |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The role of abscisic acid in closing the stomata whenplants are water-stressed and the roots are deficient in water.  The translocation of abscisic acid from the roots, through the vascular system to the leaves where it modulates potassium ion and sodium ion uptake within the guard cells. | 0.2 weeks | • describe the role of abscisic acid (ABA) and the conditions under which it is produced.  • describe where ABA is made and where its target cells are.  • explain how ABA travels to the site of its target cells.  • explain, in detail, the mechanism by which ABA causes guard cell closure. | **Learning activities:**  - Question students about their learning from 3.4.5.1 to recap the role of ABA in fruit ripening.  - Ask students to work in pairs to apply their knowledge from 3.2.8 to suggest the route by which the ABA travels by translocation.  - Teacher explanation of its role in greater detail relating to the mechanism by which it modulates K+ and Na+ ion uptake within guard cells, causing K+ efflux and leading to an increase in water potential of guard cells, which results in guard cell closing. Link to earlier work on active transport and osmosis from 3.1.4.2 and 3.1.4.3.  - Students could write up a summary of the process as a flow chart or extended writing piece (which could be assessed).  **Skills developed by learning activities:**  **AO1 –** Development of knowledge relating to the role of ABA in closing the stomata in response to drought.  **AO2/AO3 –** Apply knowledge of osmosis, active transport and translocation to explain the transport and mechanism of action of ABA. | Assessment of students’ summaries. | **Rich questions:**  - Suggest how ABA is able to travel from the roots (where it is produced) to the leaves where it has its effect. |

### 3.4.6 Homeostasis and negative feedback.

#### 3.4.6.1 The principles of homeostasis

Prior knowledge:

- 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

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| In mammals, homeostasis 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. | 0.2  weeks | • define what homeostasis is.  • describe some factors which are maintained by the body within restricted limits.  • for each factor, explain why it is important that it is maintained within restricted limits and the consequences of not doing so. | **Learning activities:**  - Questioning to recall prior learning. Lead this onto a definition of homeostasis.  - Show students a video clip of an athlete running. Ask what factors might change if allowed to.  - Jigsaw task: In groups, students assign roles to gather information on the importance of one factor e.g. temperature being maintained, blood pH being maintained (N.B. Do not cover homeostasis of blood glucose). They then each go to their respective information stations containing information about the importance of factor being maintained (e.g. comprehension/ video/internet). (Choose resources carefully so as not to go into the mechanisms of homeostasis at this point).  - 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. | HBIO2 – June 09 – Q6c;  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 seek to rectify this.  - Explain the consequence to enzymes of a). A fall in body temperature b). A rise in body temperature. |

#### 3.6.4.2 Feedback

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** |
| Negative feedback restores systems to their original level.  The possession of separate mechanisms involving negative  feedback controlling departures in different directions from the original state, gives a greater degree of control.  Positive feedback also occurs and results in greater departures from the original levels.  Positive feedback is often associated with the breakdown of control systems, e.g. control of temperature. | 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 card statements of processes involved in 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 and relate it to a breakdown of control systems as well.  - Students contrast negative and positive feedback.  - Past exam questions requiring interpretation of information.    **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 13 Q4a and 4c;  HBIO4 – Jan 13 Q1a;  HBIO4 – Jan 11 Q6;  Exampro -  BYA6 – June 2004 Q9; | [**http://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? |

### 3.4.7 Hormones and the control of blood glucose concentration.

#### 3.4.7.1 Glucose concentration and its control

Prior knowledge:

- Internal conditions that are controlled include 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** |
| The importance of maintaining a stable blood glucose concentration in terms of energy transfer and water potential of the blood.    The factors that influence blood glucose concentration. | 0.2 weeks | • explain the factors which can influence blood glucose levels.  • 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:**  - Teacher introduction to the action of hormones.  - Provide information posters on the importance of maintaining a stable blood glucose concentration; factors which influence blood glucose; the response to a reduction in blood glucose level; the response to an increase in blood glucose level. (N.B, 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 sections).  - 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 further in coming 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 13 Q6;  Specimen paper Unit 5 Q3a and 3b. | **Rich questions:**  - Why is it important that blood glucose levels are controlled?  - 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 levels and how do they influence them?  - 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 role of the liver in glycogenesis, glycogenolysis and gluconeogenesis | 0.2 weeks | • explain the role of the liver in glycogenesis.  • explain the role of the liver in glycogenolysis and gluconeogenesis. | **Learning activities:**  - Provide cards with statements on which students could categorise as: would increase blood glucose level/would decrease blood glucose level, e.g. exercise, excitement, eating a bowl of pasta.  - Provide stimulus material, e.g. comprehensions, videos from the internet, internet websites, textbooks about the role of the liver in glycogenesis, glycogenolysis and gluconeogenesis. In teams, students send one person to each station of material.  - Students feedback and used their combined knowledge to complete a concept map about the role of the liver in these three blood sugar regulating processes.  - Accept class feedback. Teacher explanation to clarify misconceptions and reinforce key messages.  **Skills developed by learning activities:**  **AO1 –** Development of knowledge relating to negative feedback in the context of blood glucose regulation. |  | **Rich questions:**  - Define what we mean by glycogenesis, glycogenolysis and gluconeogenesis.  - Under what circumstances would the glycogenesis occur in the liver?  - Under what circumstances would the glycogenolysis occur in the liver?  - Under what circumstances would the gluconeogenesis occur in the liver? |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The causes and risk factors associated with Type 1 and Type 2 diabetes. Control by manipulation of the diet and with insulin. | 0.4  weeks | • explain the causes of type 1 and type 2 diabetes and associated risk factors.  • explain how type 1 and type 2 diabetes can be controlled.  • use their knowledge of biology to explain specific symptoms of diabetes.  • analyse, interpret and evaluate data associated with specific risk factors and the incidence of 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 diabetes type 1 and 2 (causes, symptoms and methods of control) and produce an information pamphlet or presentation.  - Presentation of findings or some form of assessment task.  - Teacher explanation to reinforce key messages.  - Section B of the BIO6T Q13 ISA.  - Show data on the increasing incidence of type 2 diabetes and the risk factors associated with diabetes. Question students on how to interpret risk factor data.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematic requirement 9 and 10 –** Understand standard deviation and the symbols > and < in the context of diabetes studies contained within some of the suggested exam questions.  **AO1 -** Development of knowledge relating to Type 1 and Type 2 diabetes, in terms of causes, symptoms and control.  **AO2/AO3 –** Interpretation of experimentally derived data in exam questions and application of knowledge to explain/evaluate the data.  **AO4** – Describe the glucose tolerance test. | **Past exam paper material:**  HBIO4 – Jan 12 Q10b-10f;  HBIO4 – June 13 Q9a-9bi;  HBIO4 – June 10 Q11b-11g;  HBIO4 – June 11 Q6;  HBIO4 – Jan 10 Q3b;  HBIO4 – June 13 Q8;  BIO6T Q13 ISA Section B | **Rich questions:**  - Explain the causes of Type 1 and Type 2 diabetes.  - Why do diabetics have to manage their carbohydrate intake?  - Why do diabetics have to be mindful about how much exercise they do? |

#### 3.4.7.2 The role of insulin

Prior knowledge:

- 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** |
| Insulin as a protein hormone that acts 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. | 0.2 weeks | • explain what triggers the release of insulin.  • explain the stages involved in the action of insulin. | **Learning activities:**  **-** Questioning on the overview that student’s learnt previously.  - 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 a previous lesson.  - Students could interpret blood glucose concentration data relating to the impact of high GI and low GI foods.  - Past 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 12 Q10a;  HBIO4 – June 10 Q11a;  HBIO4 – Jan 10 Q3a;  Exampro – BYB4 – Jan 04 Q4a | [**http://bcs.whfreeman.com/thelifewire/content/chp50/5002s.swf**](http://bcs.whfreeman.com/thelifewire/content/chp50/5002s.swf)  [**http://www.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? |

#### 3.4.7.3 The role of glucagon

Prior knowledge:

- 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** |
| Glucagon acts 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. | 0.2 weeks | • explain what triggers the release of glucagon.  • explain the stages involved in the action of glucagon. | **Learning activities:**  **-** Questioning on the overview that student’s 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.  - Past 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 10 Q8;  HBIO4 – June 13 Q9bii; | [**http://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 of glucagon action (and insulin action) in the style of a fully annotated cartoon strip or piece of extended writing. |  |  |

**3.4.7.4 The role of adrenaline**

Prior knowledge:

- 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** |
| Adrenaline acts 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 adenyl cyclate, cyclic AMP and protein kinase. | 0.2 weeks | • explain what triggers the release of adrenaline.  • explain the stages involved in the action of adrenaline (linked to blood glucose concentration).  • explain the second messenger model related to adrenaline and glucagon action.  • describe the role of adenyl cyclate, cyclic AMP and protein kinase in the second message model. | **Learning activities:**  - Provide students the opportunity to generate questions on the processes discussed so far.  - Think – Pair – Share: When would adrenaline be made? 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 12 Q6a. | [**http://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. |

### 3.4.8 Control of heart rate.

Prior knowledge:

- 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 stimulate and transmit a wave of electrical activity to make the heartbeat.  - explain the roles of the SAN, AVN and bundle of His. | **Learning activities:**  - Questioning to recap the structure and function of the heart from section 3.2.6 including the pressure and volume changes which occur during atrial/ventricular systole.  - Teacher explanation of how a heartbeat is initiated and transmitted, and the roles of the SAN, AVN and bundle of His. Use animation to support this.  - Students could be given a series of sentence starters from section 3.2.6 to complete with their new knowledge, e.g. “ventricular systole occurs 0.2 seconds after atrial systole because…”  - Past 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:**  BIOL 1 – Jan10 Q7a;  BIOL1 – June 09 Q2a;  BIOL1 – Jan 11 Q3c;  BIOL1 – June 13 Q8a;  BIOL1 – June 12 Q8a;  HBIO1 – Jan 2009 Q1 | [**http://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 carry out calculations using  CO=SV x HR (as 3.2.6.2) |  |  |

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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, the autonomic nervous system and effectors in  controlling heart rate. | 0.2 weeks | • explain 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:**  - Question 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 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.  - Past 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 12 Q4;  HBIO4 – June 13 Q2;  Exampro –  BYA6 - Jan 2005 Q7;  BYA6 – June 2005 Q5 | [**http://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? |

### 3.4.9 Regulation of transcription and translation

#### 3.4.9.1 Epigenetic control of gene expression

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** |
| Epigenetic changes results from changes in gene function, without alterations in the DNA base sequence. These changes are preserved when cells divide.  They may be associated with:  • increased methylation of the DNA  • decreased acetylation of associated histones. | 0.4  weeks | • explain what epigenetics is, and what happens to the DNA 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.  - Past exam questions.  **Skills developed by learning activities:**  **AO1 –** Development of understanding relating to epigenetics and its causes.  **AO2/AO3–** Application of knowledge to explain trends in scientific data from studies of identical and fraternal twins. | **Past exam paper material**:  HBIO4 – Jan 12 Q6;  HBIO4 – June 13 Q7; | [**http://www.scientificamerican.com/article/epigenetics-explained/**](http://www.scientificamerican.com/article/epigenetics-explained/)  [**http://learn.genetics.utah.edu/content/epigenetics/**](http://learn.genetics.utah.edu/content/epigenetics/)  **Rich questions:**  - Why are twin studies so useful when investigating the environmental effects on epigenetics?  - What effect does methylation have on gene expression? Why?  - What effect does 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, e.g. lick your rats. |  |  |

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| **Learning objective** | **Time taken** | **Learning Outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Abnormal methylation of tumour suppressor genes and oncogenes play a role in the development of cancer. | 0.4  weeks | • explain the role of oncogenes/tumour suppressor genes and abnormal methylation in the development 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 of and treatment for cancer. | **Learning activities:**  - Questioning to recall the role of tumour suppressor and proto-oncogenes in the cell cycle and how mutation of these can lead to cancer (from section 3.2.11.2).  - Discuss how this information could be used in the future to prevent, treat or cure cancer.  - Teacher explanation of the role of abnormal methylation in cancer development.  - Past 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 –** Evaluation of scientific data showing correlations.  - Essay writing skills. | **Past exam paper material**:  HBIO4 – June 11 Q9;  UK A-level Specimen assessment material Paper 2 – Q9. |  |

#### 3.4.9.2 RNA interference.

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** |
| MicroRNA (miRNA) and small interfering RNA (siRNA) bind to mRNA produced from target genes and increase or decrease their activity. | 0.2  weeks | • explain how gene expression can be inhibited by RNA interference of translation.  • explain the mechanism by which miRNA and 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 RNA interference and ask students to apply their knowledge.  - Past 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 13 Q6;  BIOL5 – June 11 Q8b. | [**http://www.nature.com/nrg/multimedia/rnai/animation/index.html**](http://www.nature.com/nrg/multimedia/rnai/animation/index.html)  [**http://www.nature.com/horizon/rna/background/interference.html**](http://www.nature.com/horizon/rna/background/interference.html)  **Rich questions:**  - Why is RNA interference by miRNA or siRNA specific to mRNA from a particular gene?  - How do miRNA and siRNA prevent/reduce translation? |

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

Prior knowledge:

**-** 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, e.g. 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** |
| During development, totipotent cells translate only part of their DNA, resulting in cell specialisation.  Totipotent cells occur only for a limited time in mammalian embryos. Pluripotent, multipotent and unipotent cells are found in mature mammals. They can divide to form a limited number of different cell types. | 0.4  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 totipotent cells undergo cell specialisation to produce a range of cells.  • evaluate the use of stem cells in treating human disorders. | **Learning activities:**  - Introduce the idea of 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 cardiomycetes). 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.  - Continuum line to gauge student’s personal views.  - Concept map.  - Past 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 10 Q6;  BIOL5 – June 11 Q6a;  HBIO4 – June 14 Q4. | [**http://www.ncbe.reading.ac.uk/NCBE/SAFETY/tissuesafety.html**](http://www.ncbe.reading.ac.uk/NCBE/SAFETY/tissuesafety.html)  [**http://learn.genetics.utah.edu/content/stemcells/**](http://learn.genetics.utah.edu/content/stemcells/)  **Rich questions:**  - How do plant and animal cells differ in relation to differentiation?  - Why is only a small proportion of the cell’s DNA translated when it specialises? |
| Extension |  |  | - Show students the video on IPS cells and get them to research IPS cells using selected websites. Ask them how they are made and whether this overcomes ethical objections around pluripotent embryonic stem cells. |  | [**http://www.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) |

### 3.4.10 Recombinant DNA technology

#### 3.4.10.1 Principles

Prior knowledge:

- 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.

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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. | 0.2  weeks | • explain what is meant by recombinant DNA technology and transgenic organisms.  • explain the principle of what happens to produce transgenic organisms, and why the cell is able to translate DNA from two different species. | **Learning activities:**  - Questioning to assess prior learning about the topic.  - Teacher explanation about the principles of recombinant DNA technology.  - Students could undertake a practical to transform bacteria with a recombinant plasmid (see NCBE protocol). Kits are commercially available e.g. from NCBE, Biorad.  **Skills developed by learning activities:**  **AO1 –** Development of understanding relating to the principles of recombinant DNA technology.  **AO4 –** Describe the procedure of producing transgenic organisms. |  | **Rich questions:**  - What is recombinant DNA technology?  - Should we be pursuing recombinant DNA technology for some applications?  [**http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/DNA/PDF/DNA08.pdf**](http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/DNA/PDF/DNA08.pdf)  [**http://www.ncbe.reading.ac.uk/NCBE/SAFETY/dnasafety1.html**](http://www.ncbe.reading.ac.uk/NCBE/SAFETY/dnasafety1.html)  [**http://www.bio-rad.com/en-us/category/pglo-plasmid-gfp-kits**](http://www.bio-rad.com/en-us/category/pglo-plasmid-gfp-kits) |

#### 3.4.10.2 Production of fragments of DNA

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** |
| 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 the DNA.  • artificial gene synthesis. | 0.2  weeks | • explain the methods which could be used to isolate a gene and produce a DNA fragment.  • explain what is meant by a restriction endonuclease and how they work to leave sticky ends. | **Learning activities:**  - 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.  - Past 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.  **AO4 –** Describe the procedure of producing cDNA fragments. | **Past exam paper material**:  HBIO4 – June 14 Q9bi.  HBIO4 – Jan 11 Q9a;  HBIO4 – Jan 12 Q2a-b  Exampro –  BYA2 – Jan 2005 Q2;  BYA2 – June 2005 Q7 | [**http://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? |

#### 3.4.10.3 *In vitro* amplification of DNA fragments

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 principles of the polymerase chain reaction (PCR) as a method of amplifying DNA fragments.  The polymerase chain reaction may also be used to identify specific 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, and explain how PCR can be used to amplify and identify DNA fragments.  - 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.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical Requirement 13 –** 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.  **AO1/AO4 –** 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. | **Past exam paper material**:  HBIO4 – Jan 13 Q10c;  HBIO4 – Jan 11 Q9b | [**http://www.sumanasinc.com/webcontent/animations/content/pcr.html**](http://www.sumanasinc.com/webcontent/animations/content/pcr.html)  [**http://www.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)  [**http://www.dnalc.org/resources/animations/pcr.html**](http://www.dnalc.org/resources/animations/pcr.html)  [**http://learn.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 Taqpolymerase used over DNA polymerase?  - How many fragments would you have after 20 cycles of PCR? |

#### 3.4.10.4 *In vivo* amplification of DNA fragments

Prior knowledge:

- 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** |
| 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. | 0.4  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 addition of promoter and terminator regions.  • explain the importance 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.  - Past exam questions.  **Skills developed by learning activities:**  **Mathematical requirement 3 –** Use percentages when discussing/working out the proportion of cells which are successfully transformed.  **AO1 –** 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.  **AO4 –** Describe the procedure of producing transgenic organisms. | **Specimen assessment material:**  A-level Paper 3 – Q5  **Past exam paper material**:  BIOL5 – June 12 Q5;  **Past exam paper material**:  BIOL5 – June 12 Q1;  HBIO4 – June 14 Q9bi;  HBIO4 – Jan 13 Q6;  HBIO4 – June 10 Q9 | [**http://www.dnalc.org/resources/animations/restriction.html**](http://www.dnalc.org/resources/animations/restriction.html)  [**http://www.dnalc.org/resources/animations/transformation1.html**](http://www.dnalc.org/resources/animations/transformation1.html)  [**http://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 % of cells successfully transformed with recombinant DNA so low? |

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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 | • explain some of the applications of recombinant DNA technology in the fields of medicine, agriculture, the environment and industry.  • interpret information relating to the use of recombinant DNA  Technology.  • evaluate the ethical, financial and social issues associated with  the use of recombinant DNA technology. | **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 e.g. Bt Maize, pharming, GM mustard plants removing excessive selenium, Golden rice.  - Feedback and completion of summary table.  - Repetition of continuum – have opinions changed.  - Debate: Should our Government 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. | **Past exam paper material**:  HBIO4 – June 14 Q9biii.  HBIO4 – June 10 Q5; | [**http://www.bionetonline.org/English/Content/ff\_intro.htm**](http://www.bionetonline.org/English/Content/ff_intro.htm)  [**http://www.saps.org.uk/secondary/teaching-resources/828-genetic-engineering-and-photosynthesis**](http://www.saps.org.uk/secondary/teaching-resources/828-genetic-engineering-and-photosynthesis)  [**http://www.saps.org.uk/secondary/teaching-resources/823-gm-crop-plants**](http://www.saps.org.uk/secondary/teaching-resources/823-gm-crop-plants)  **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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