Higher Biology

Resource Guide

March 2014

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This resource guide has been produced in response to requests from practitioners who attended the NQ Sciences events at Hampden Stadium in December 2013. Those attending felt it would be useful to have a document which helped them navigate to the most relevant resources quickly.

The following pages show the Mandatory Course Key Areas table from the SQA Higher Biology *Course and Unit Support Notes*. An additional fourth column has been included which contains hyperlinks to useful resources. **Please note: Practitioners are not required to use the resources listed – they are only included as helpful suggestions. Practitioners should also refer to the SQA website for the most up to date Course and Unit Support Notes.**

To further assist practitioners - content new to the course from the Higher Still Higher has been highlighted in green and links to useful SQA documentation have been included at the beginning of each unit. The SQA documentation relating to the course is shown here.

SQA Documents	**Web link**
Course Specification	http://bit.ly/1m6eliD
Course Assessment Specification	http://bit.ly/1j3MdCc
Course and Unit Support Notes (the original document which has been modified in the succeeding pages)	http://bit.ly/1dNxPcq
Assessment Overview published June 2013	http://bit.ly/NUOBPH
Specimen Examination paper and marking scheme	http://bit.ly/1dNydYd
Points of change and areas of stability across National 5 and CfE Higher	http://bit.ly/NUPNT5

Education Scotland learning materials	
Education Scotland Higher Sciences website – Higher Biology	http://bit.ly/1iBdtaC
National Qualifications Glow Portal – Higher Biology	http://bit.ly/1nsZRz6

DNA and the Genome		**Unit Specification http://bit.ly/QfTncl**	
Mandatory Course key areas	**Suggested learning activities**	**Exemplification of key areas**	**Useful resources**
1 The structure and replication of DNA (a) Structure of DNA —nucleotides (deoxyribose sugar, phosphate and base), sugar–phosphate backbone, base pairing (adenine, thymine and guanine, cytosine), by hydrogen bonds and double stranded antiparallel structure, with deoxyribose and phosphate at 3' and 5' ends of each strand. (i) Organisation of DNA — circular chromosomal DNA and plasmids in prokaryotes. Circular plasmids in yeast. Circular chromosome in mitochondria and chloroplasts of eukaryotes. Linear chromosomes in the nucleus of eukaryotes.	Case study examining the experimental evidence of the bacterial transformation experiments of Griffiths and identification of DNA as the transforming principle by Avery *et al.*, phage experiments of Hershey and Chase, Chargaff's base ratios and the X-ray crystallography of Wilkins and Franklin. Watson and Crick's double-helix model as an evidence-based conclusion. Case study on Meselson and Stahl experiments on DNA replication. DNA gel electrophoresis. Comparison of DNA extraction from peas and kiwi fruit (false positive result in latter as DNA is obscured by pectin).	All cells store their genetic information in the base sequence of DNA. The genotype is determined by the sequence of bases. The DNA found in the linear chromosomes of the nucleus of eukaryotes is tightly coiled and packaged with associated proteins. Prior to cell division, DNA is replicated by a DNA polymerase. DNA polymerase needs a primer to start replication.	GLOW365 resources Education Scotland – teacher resources. http://bit.ly/1gY0NGh Fast talking 'Crashcourse' video clip (13 minutes) – best used after learners have had an initial introduction to DNA. http://www.youtube.com/watch?v=8kK2zwjRV0MF DNA Learning Centre – animation with descriptive text. Gel electrophoresis animation sequence *Student activity suggestions* Create DNA – cut circles, pentagons and rectangles from coloured card. Use wooden spills for sugar-phosphate bonds. Construct large DNA molecules for wall displays. Education Scotland research/poster activity on DNA research scientists

			Education Scotland activities – • Prokaryote or eukaryote? • Packing of DNA in eukaryotic chromosomes and simple and clear PowerPoint • Key vocabulary sheet National Centre for Biotechnology Education (NCBE) – practical extraction of DNA. Extraction of DNA from peas

(b) Replication of DNA by DNA polymerase and primer. Directionality of replication on both template strands — DNA polymerase adds complementary nucleotides to the deoxyribose (3') end of a DNA strand. Fragments of DNA are joined together by ligase.	Virtual or physical modelling of DNA replication.	DNA is unwound and unzipped to form two template strands. This process occurs at several locations on a DNA molecule. DNA polymerase can only add DNA nucleotides in one direction resulting in one strand being replicated continuously and the other strand replicated in fragments.	Anatomy and Physiology – DNA Replication and Quiz Education Scotland case study – How does DNA replicate? Teacher notes Learner notes McGraw Hill – animation and quiz about PCR
(i) Polymerase chain reaction (PCR) amplification of DNA using complementary primers for specific target sequences. DNA heated to separate strands then cooled for primer binding. Heat-tolerant DNA polymerase then replicates the region of DNA. Repeated cycles of heating and cooling amplify this region of DNA.	Case study on the use of PCR, including practical using thermal cycler or water baths. Emphasise the 'needle in a haystack' accuracy of primers and the amplification of 'a haystack from the needle' by PCR. Investigating plant evolution using chloroplast DNA and PCR.	The polymerase chain reaction (PCR) is a technique for the amplification of DNA *in vitro*. In PCR, primers are complementary to specific target sequences at the two ends of the region to be amplified. DNA is heated to separate the strands. Cooling allows primers to bind to target sequences. Heat-tolerant DNA polymerase then replicates the region of DNA. Repeated cycles of heating and cooling amplify this region of DNA.	Education Scotland – Polymerase Chain Reaction student activity and PowerPoint. Investigating plant evolution using chloroplast DNA and PCR practical – links to purchase of kit from Reading University. http://bit.ly/1jQSfVm Education Scotland case study – PCR and electrophoresis Education Scotland PowerPoint on extracting DNA from plant material Education Scotland practical on DNA extraction, purification, PCR and electro gelphoresis. Aims and method PowerPoint

2 Gene expression The phenotype is determined by the proteins produced as the result of gene expression, influenced by intra- and extra-cellular environmental factors. Only a fraction of the genes in a cell are expressed.	Separation and identification of fish proteins by agarose gel electrophoresis.	The genetic code used in transcription and translation is found in all forms of life.	Teacher's guide Topic guide
(a) Gene expression is controlled by the regulation of transcription and translation. (i) Structure and functions of RNA Single strand, replacement of thymine with uracil and deoxyribose with ribose compared to DNA. mRNA (messenger) carries a copy of the DNA code from the nucleus to the ribosome. rRNA (transfer) and proteins form the ribosome. Each tRNA carries a specific amino acid.		mRNA is transcribed from DNA in the nucleus and translated into proteins by ribosomes in the cytoplasm.	SSERC – Gene expression: • Protein electrophoresis • NCBE materials for electrophoresis • Tissue culture of plant material – SSPS material *SSERC login required* http://www.sserc.org.uk/index.php/biology-2/biology-resources/higher-biology-revised/dna-and-the-genome/3420-gene-expression Education Scotland learner activities PowerPoints and quizzes on protein synthesis. Education Scotland – animation showing translation
(ii) Transcription of DNA into primary and mature RNA transcripts to include the role of RNA polymerase and complementary base pairing. The introns of the primary transcript of mRNA are non-coding and are	Modelling transcription and translation using virtual and physical resources.	RNA polymerase moves along DNA unwinding and unzipping the double helix and synthesising a primary transcript of RNA from RNA nucleotides by complementary base pairing. Introns (non-coding regions of	Bead Factory – protein synthesis activity. See Higher Biology folder on Glow 365 Sciences site http://bit.ly/glowsciences

removed in RNA splicing. The exons are coding regions and are joined together to form mature transcript. This process is called RNA splicing. (iii) Translation of mRNA into a polypeptide by tRNA at the ribosome. tRNA folds due to base pairing to form a triplet anticodon site and an attachment site for a specific amino acid. Triplet codons on mRNA and anticodons translate the genetic code into a sequence of amino acids. Start and stop codons exist. Codon recognition of incoming tRNA, peptide bond formation and exit of tRNA from the ribosome as polypeptide is formed. (iv) One gene, many proteins as a result of RNA splicing and post-translational modification. Different mRNA molecules are produced from the same primary transcript depending on which RNA segments are treated as exons and introns. Post-translation protein structure modification by cutting and combining polypeptide chains or by		genes) and exons (coding regions of genes).	Education Scotland animation – transcription DNA Learning Centre animations – Transcription and translating: RNA splicing An interactive DVD is also available with various levels of commentary. Education Scotland learner activities – one gene many proteins

adding phosphate or carbohydrate groups to the protein. (v) Proteins are held in a three-dimensional shape — peptide bonds, folded polypeptide chains, hydrogen bonds, interactions between individual amino acids.	Investigation of the shape and structure of fibrous and globular proteins using RasMol or protein explorer software. Separation and identification of amino acids using paper chromatography.	Proteins have a large variety of structures and shapes resulting in a wide range of functions. Amino acids are linked by peptide bonds to form polypeptides. Polypeptide chains fold to form the three-dimensional shape of a protein, held together by hydrogen bonds and other interactions between individual amino acids.	Education Scotland animation – Regulation of gene expression Protein Data Bank video clip explaining amino acid structure and protein formation.
(b) Cellular differentiation is the process by which a cell develops more specialised functions by expressing the genes characteristic for that type of cell. Differentiation into specialised cells from meristems in plants; embryonic and tissue (adult) stem cells in animals. (i) Research and therapeutic uses of stem cells by reference to the repair of damaged or diseased organs or tissues. Stem cell research provides	Tissue culture of plant material. Case study on use of stem cells in repair of diseased or damaged organs (eg skin grafts, bone marrow transplantation and cornea repair).	Meristems are regions of unspecialised cells in plants that are capable of cell division. Stem cells are relatively unspecialised cells in animals that can continue to divide and can differentiate into specialised cells of one or more types. In the very early embryo, embryonic stem cells differentiate into all the cell types that make up the organism. Tissue (adult) stem cells replenish differentiated cells that need to be replaced and give rise to a more	Education Scotland animation – stem cell development EuroStemCell video (15 minutes) with ethics discussions possible – stem cell story MCB animation – therapeutic uses of stem cells Education Scotland role play – stem cell therapy for spinal cord injuries.

information on how cell processes such as cell growth, differentiation and gene regulation work. Stem cells can be used as model cells to study how diseases develop or for drug testing. The ethical issues of stem cell use and the regulation of their use.	Case study on ethics of stem cell research and sources of stem cells. For example, embryo cells must not be allowed to develop beyond 14 days, around the time a blastocyst would be implanted in a uterus. Sources of stem cells include embryonic stem cells, tissue (adult) stem cells and attempts to reprogram specialised cells to an embryonic state. Ethical issues could include: regulations on the use of embryo stem cells, the use of induced pluripotent stem cells and the use of nuclear transfer techniques.	limited range of cell types, eg red bone marrow produces various blood cell types. Once a cell becomes differentiated it only expresses the genes that produce the proteins characteristic for that type of cell. The therapeutic uses of stem cells should be exemplified by reference to the repair of damaged or diseased organs, eg corneal transplants, and skin grafts for burns.	EuroStemCell/MRC/ University of Edinburgh - stem cells in the news Education Scotland – video on stem cell research Education Scotland – case study on stem cells Education Scotland PowerPoint – Introduction to stem cells

3 Genome (a) The structure of the genome — coding and non-coding sequences include those that regulate transcription and those that are transcribed to RNA but are never translated. Some non-coding sequences have no known function.	Non translated forms of RNA include tRNA, rRNA and RNA fragments.	The genome of an organism is its hereditary information encoded in DNA. DNA sequences that code for protein are defined as genes. A genome is made up of genes and other DNA sequences that do not code for proteins. Most of the eukaryotic genome consists of these non-coding sequences. Non-translated forms of RNA include tRNA, rRNA and RNA fragments.	Education Scotland handout – The structure of the genome
(b) Mutations are changes in the genome that can result in no protein or an altered protein being expressed. (i) Single gene mutations involve the alteration of a DNA nucleotide sequence as a result of the substitution, insertion or deletion of nucleotides. Single-nucleotide substitutions include: missense, nonsense and splice-site mutations. Nucleotide insertions or deletions result in frame-shift mutations or an expansion of a nucleotide sequence repeat.	Investigate mutant yeast or germination rates of irradiated seeds. Investigate how point mutations can be silent, neutral, missense, nonsense or frame-shift. Research reasons for geographical variation in incidence of post-weaning lactose tolerance or sickle-cell trait in humans as examples of point mutation.	 Regulatory sequence mutations can alter gene expression. Splice site mutations can alter post-transcriptional processing.	 Education Scotland – point mutations teacher guide Pearson Education – animation about mutations Education Scotland – animation about mutations

(ii) Chromosome structure mutations — duplication, deletion and translocation. (iii) The importance of mutations and gene duplication in evolution (iv) Polyploidy — errors during the separation of chromosomes during cell division can result in cells with whole genome duplications. Importance of polyploidy in evolution and human food crops	Analyse evidence for formation of human chromosome 2 by fusion of two ancestral chromosomes. Gene duplication and alpha and beta globins in haemoglobin. Research polyploidy in plants and importance in origin of crop plants. Research rarity of polyploidy in animals.	Alterations to the structure of one or more chromosomes. Importance of gene duplication in evolution. Polyploidy examples include banana (triploid) and potato (tetraploid), as well as swede, oil seed rape, wheat and strawberry.	McGraw Hill animation and quiz – Changes in Chromosome Structure Education Scotland animation – Chromosomal mutations Education Scotland – teacher and learner notes Polyploidy
(c) Evolution — the changes in organisms over generations as a result of genomic variations. (i) Gene transfer. Vertical (inheritance) - from parent to offspring as a result of sexual or asexual reproduction. Horizontal - prokaryotes and viruses can exchange genetic material in this way. (ii) Selection. Natural selection is the non-random increase in frequency of DNA sequences that increase survival.	Gather data on sexual selection in brine shrimp.	Prokaryotes can exchange genetic material horizontally, resulting in rapid evolutionary change. Prokaryotes and viruses can transfer sequences horizontally into the genomes of eukaryotes. The non-random reduction in frequency of deleterious DNA sequences. The differences in outcome as a	Think Darwin, Think Evolution, Think Now – Edinburgh University self-study learner materials (61 page PDF) Education Scotland – teacher and learner activity on inheritance Shelf 3D video clip on sexual selection & evolution – discusses apparent anomalies to natural selection.

Sexual selection is an increase in successful reproduction. (iii) Genetic drift. The random increase and decrease in frequency of sequences, particularly in small populations, as a result of neutral mutations and founder effects. (iv) Speciation is the generation of new biological species by evolution. The importance of geographical barriers in allopatric speciation. The importance of behavioural or ecological barriers in sympatric speciation. Hybrid zones.	Research different definitions of the term species (e.g. biological species concept, phylogenetic species concept) and the difficulty of applying species definition to asexually reproducing organisms. Research the London Underground mosquito. Collaborative data gathering of hooded crow and carrion crow hybrid zone in Scotland.	result of stabilising, directional and disruptive selection. A species is a group of organisms capable of interbreeding and producing fertile offspring, and which does not normally breed with other groups. The formation of hybrid zones in regions where the ranges of closely related species meet.	Education Scotland document with six activities and teacher notes, including video clips and games – selection and drift Education Scotland document with five activities, teacher and student and notes – speciation

(d) Genomic sequencing — the sequence of nucleotide bases can be determined for individual genes and entire genomes. To compare sequence data, computer and statistical analyses (bioinformatics) are required. (i) Evidence from phylogenetics and molecular clocks to determine the main sequence of events in evolution. (ii) Comparison of genomes from different species. Comparison of genomes reveals that many genes are highly conserved across different	Research how sequencing technologies use techniques such as fluorescent tagging of nucleotides to identify the base sequence. Case study on the evolution of bears and primates using Geneious software. Highly conserved DNA sequences are used for comparisons of distantly related genomes. Compare number and proportion of shared genes between organisms such as *C. elegans*, *Drosophila* and humans. Research the importance of the *Fugu* genome as an example of a very small vertebrate genome with a high rate of chromosome	The use of sequence data to study the evolutionary relatedness among groups of organisms. Sequence divergence is used to estimate time since lineages diverged. For example, comparison of sequences provides evidence for three main domains (bacteria, archaea and eukaryotes). The use of sequence data and fossil evidence to determine the main sequence of events in evolution of life: cells, last universal ancestor, photosynthetic organisms, eukaryotes, multicellularity, animals, land plants, vertebrates. Many genomes have been sequenced, particularly of disease-causing organisms, pest species and species that are important	Original paper from Nature for analysis – Human genome analysis Website listing genomes of many species – Blast website Allows comparison of sequences and creation of own gene sequences to find (used by Roslin Institute). CassioPeia Project video explaining the main principles – molecules of life Education Scotland unit with student and teacher notes and activities – molecular clocks DNA Learning Centre interactive video – Mitochondrial DNA and the molecular clock interview Video from Richard Dawkins Foundation Why are there still chimpanzees? Comparing human and chimpanzee genomes

organisms	deletion. Comparison of human and chimp genomes reveals rapid change in genes for immune system and regulation of neural development over last 6 million years.	model organisms for research.	
(iii) Personal genomics and health. Analysis of an individual's genome may lead to personalised medicine through knowledge of the genetic component of risk of disease and likelihood of success of a particular treatment.	Comparison of individual's genomes focuses on point mutations, repetitive sequence errors and blocks of duplication and deletion.	Pharmacogenetics. The difficulties in distinguishing between neutral and harmful mutations in both genes and regulatory sequences, and in understanding the complex nature of many diseases.	Education Scotland teacher and student notes plus video clips and games – personal genomics

Metabolism and Survival		**Unit Specification** http://bit.ly/1gYupnb	
Mandatory Course key areas	**Suggested learning activities**	**Exemplification of key areas**	**Useful resources**
1 Metabolism is essential for life (a) Introduction to metabolic pathways — integrated and controlled pathways of enzyme-catalysed reactions within a cell. (i) Anabolic (energy requiring) and catabolic (energy releasing) pathways — can have reversible and irreversible steps and alternative routes. (ii) Membranes form surfaces and compartments for metabolic pathways — protein pores, pumps and enzymes embedded in phospholipid membranes.	Case study on the toxic effects of venoms, toxins and poisons on metabolic pathways. Examine photomicrographs to compare ultrastructure of prokaryotes and eukaryotes and compartments and membranes in mitochondria and chloroplasts.	Metabolic pathways involve biosynthetic processes (anabolism) and the breakdown of molecules (catabolism) to provide energy and building blocks. Membranes can form compartments to localise the metabolic activity of the cell. The high surface to volume ratio of small compartments allows high concentrations and high reaction rates.	Education Scotland – teacher's guide on metabolism SSERC activities – • Competitive and non-competitive inhibition and b-galactosidase • ATP- dependent reactions *SSERC login required* Education Scotland animation – enzyme action including competitive and non-comp inhibition Education Scotland vocabulary bingo activity based on metabolic processes
(b) Control of metabolic pathways (presence or absence of particular enzymes and the regulation of the rate of reaction of key enzymes within the pathway (i) Induced fit and the role of the active site of enzymes including shape and substrate affinity. Activation energy. The effects of substrate and end product	Enzyme induction experiments such as ONPG and lactose metabolism in *E. coli* and PGlo experiments. Activation energy experiments, comparing heat, manganese dioxide and catalase action on hydrogen peroxide.	Regulation can be controlled by intra- and extra cellular signal molecules. The role of the active site in orientating reactants, lowering the activation energy of the transition state and the release of products with low affinity for	DNA Learning Centre – Jacob-Monod stepped animation explanation Pearson Education animation – enzyme substrate interaction Boardworks animation – Induced fit

concentration on the direction and rate of enzyme reactions. Enzymes often act in groups or as multienzyme complexes. (ii) Control of metabolic pathways through competitive, non-competitive and feedback inhibition.	Experiments on reaction rate with increasing substrate concentration. Investigate the inhibition of beta galactosidase by galactose and its reversal by increasing ONPG concentration. Experiments on product inhibition with phosphatase.	the active site. Most metabolic reactions are reversible and the presence of a substrate or the removal of a product will drive a sequence of reactions in a particular direction. Genes for some enzymes are continuously expressed. These enzymes are always present in the cell and they are controlled through the regulation of their rates of reaction. Competitive inhibition (binds to active site), non-competitive inhibition (changes shape of active site) and feedback inhibition (end product binds to an enzyme, catalysing a reaction earlier in the pathway). Competitive inhibition can be reversed by increasing substrate concentration.	Education Scotland – phosphatase practical • end product inhibition experiment from AH • p.27-39 technician's guide • student guide and teacher info.

(c) Cellular respiration — glucose broken down, hydrogen electrons removed by dehydrogenase enzymes, releasing ATP. (i) The role of ATP in the transfer of energy and the phosphorylation of molecules by ATP. Metabolic pathways of cellular respiration. The breakdown of glucose to pyruvate in the cytoplasm in glycolysis, and the progression pathways in the presence or absence of oxygen (fermentation). The formation of citrate. Pyruvate is broken down to an acetyl group that combines with coenzyme A to be transferred to the citric acid cycle as acetyl coenzyme A. Acetyl coenzyme A combines with oxaloacetate to form citrate followed by the enzyme mediated steps of the cycle. This cycle results in the generation of ATP, release of CO_2, and the regeneration of oxaloacetate in the matrix of the mitochondria. Dehydrogenase enzymes remove H ions and electrons, which are passed to	Experiments on ATP dependent reactions, eg luciferase, luminescent reactions. Investigate a phosphorylated substrate (eg glucose-1-phosphate) using suitable positive and negative controls in the design of an experiment. Research how Hans Krebs discovered the citric acid cycle. Experiments on inhibition of citric acid cycle with malonic acid and DCPIP as an indicator of dehydrogenase activity.	Cellular respiration pathways are present in cells from all three domains of life. The metabolic pathways of cellular respiration are of central importance to cells. They yield energy and are connected to many other pathways. ATP is used to transfer energy to synthetic pathways and other cellular processes where energy is required. The return flow of H ions rotates part of the membrane protein ATP synthase, catalysing the synthesis of ATP. The phosphorylation of intermediates in glycolysis in an energy investment phase and the direct generation of ATP in an energy payoff stage. Pyruvate progresses to the citric acid cycle if oxygen is available. In the absence of oxygen, the pyruvate undergoes a fermentation to either lactate or ethanol and CO_2.	Animation on cellular respiration – broken down in to overall, glycolysis, Krebs and Electron transfer. Uses NAD and FAD.

coenzymes NAD or FAD (forming NADH or FADH2) in glycolysis and citric acid pathways. The high energy electrons are passed to the electron transport chain on the inner mitochondrial membrane and results in the synthesis of ATP. (iii) ATP synthesis - high energy electrons are used to pump H ions across a membrane and the flow of these ions synthesises ATP by the membrane protein ATP synthase. Oxygen is the final electron acceptor, which combines with H ions and electrons, forming water. (iv) Substrates for respiration (starch and glycogen, other sugar molecules, amino acids and fats).	Experiments with yeast dehydrogenase, eg using resazurin. Investigation of different sugars as respiratory substrates in yeast. Research different use of substrates during exercise and starvation.	The electron transport chain as a collection of proteins attached to a membrane. Energy is released and ATP synthase generates ATP. Other sugar molecules can be converted to glucose or glycolysis intermediates for use as respiratory substrates. Proteins can be broken down to amino acids and converted to intermediates of glycolysis or the citric acid cycle for use as respiratory substrates. Fats can also be broken down to intermediates of glycolysis and the citric acid cycle.	Education Scotland animation – electron transport chain

2 Maintaining Metabolism (a) Metabolic rate (i) Measurement of oxygen consumption, carbon dioxide and heat production. (ii) High metabolic rates require efficient delivery of oxygen to cells. Comparative physiology of heart chambers, circulation and lung arrangement in amphibians, reptiles, mammals and birds, and heart and circulation in fish. (iii) Physiological adaptations of animals for low oxygen niches. (iv) The use of maximum oxygen uptake as a measure of fitness in humans.	Investigate metabolic rate using oxygen, carbon dioxide and temperature probes. Case study on adaptations to survive low oxygen niches.	Comparison of metabolic rates of different organisms at rest. Low oxygen niches, eg high altitude, deep diving. The variation in atmospheric oxygen concentration over a long geological timescale and how this relates to maximum terrestrial body size.	Education Scotland case study activity and work sheet for low oxygen environments – animal adaptations to low oxygen niches Education Scotland report writing resources (data) on oxygen dissociation curves and diving mammals – Resource sheet Review sheet for above activity Self-assessment checklist for above

(b) Metabolism in conformers and regulators. (i) The ability of an organism to maintain its metabolic rate is affected by external abiotic factors. (ii) Conformers internal environment is dependent upon external environment. Conformers may have low metabolic costs and a narrow ecological niche. Behavioural responses to maintain optimum metabolic rate. (iii) Regulators control their internal environment, which increases the range of possible ecological niches. Regulation requires energy to achieve homeostasis. (iv) Negative feedback control and thermoregulation in mammals including the role of the hypothalamus, nerves, effectors and skin.	Case study on the response of a conformer to a change in an environmental factor. Comparisons of marine and estuarine invertebrates and their response to variation in salinity. Experiments using thermistors or infra-red thermometers on skin temperature and its regulation in humans.	Abiotic factors such as temperature, salinity and pH. Conformers may have a narrow ecological niche unless they can tolerate or resist variation in their external environment. The importance of regulating temperature for optimal enzyme-controlled reaction rates and diffusion rates for maintenance of metabolism.	GLOW 365 PowerPoint – Conformers and regulators. http://bit.ly/glowsciences See Higher Biology/Metabolism and Survival folder Heyer resource – Homeostasis & Thermoregulation slides Includes images and diagrams Education Scotland case study – effect of temperature on brine shrimp (*Artemia*). Needs shrimp cysts and takes min 48hrs. Teacher's guide Technician's guide Student information sheet Can be repeated with hatched shrimps using 0% – 30% saline solutions, measuring heart rate.

(c) Maintaining metabolism during environmental change. (i) Surviving adverse conditions Dormancy is part of some organisms' lifecycle and may be predictive or consequential. Examples of dormancy include hibernation and aestivation. Hibernation is often defined in terms of mammals. Aestivation allows survival in periods of high temperature or drought. Daily torpor as a period of reduced activity in organisms with high metabolic rates.	Research and scientific presentation on aspects of surviving adverse conditions. Seed dormancy experiments. Research seed banks and the practicalities of maintaining viable stocks.	Organisms must have adaptations to survive and/or avoid adverse conditions. Many environments vary beyond the tolerable limits for normal metabolic activity for any particular organism. To allow survival during a period when the costs of continued normal metabolic activity would be too high, the metabolic rate can be reduced.	Twelve short BBC video clips (1 – 5 mins) on different animals' dormancy versions – animal dormancy clips Three short BBC clips on aestivation Three BBC clips (2-4 mins) on torpor
(ii) Avoiding adverse conditions by migration. Migration avoids metabolic adversity by expending energy to relocate to a more suitable environment. Long-distance migration studies. Innate and learned influences on migratory behaviour.	Evaluate procedures and results of studies investigating triggers for migration, navigation adaptations. Research the genetic control of migratory behaviour in studies of populations of the blackcap.	The use of specialised techniques in studies of long-distance migration, such as individual marking and types of tracking to overcome the difficulties involved in the study of migratory vertebrates and invertebrates. The design of experiments to investigate the innate and learned influences on migratory behaviour.	BBC Scotland bird migration article – unique bird migration discovered Animal migration research from Nature Education giving reasons for and examples of migrations, including altitudes, distances and maps.

(d) Extremophiles Some species have enzymes that are extremely tolerant and allow them to thrive in environments that would be lethal to almost all other species. Examples of extremophiles include thermophilic bacteria living in hot springs or seabed vents.	Research different types of extremophiles. Research use of H_2 in methanogenic bacteria and H_2S in sulphur bacteria.	Use of heat-tolerant DNA polymerase from thermophilic bacterium in PCR. Some species living in hot springs or seabed vents generate their ATP by removing high-energy electrons from inorganic molecules.	March 2013 BBC Nature article 'Life of extremophiles' including heat, cold and altitude – extremophiles BBC video (3 mins) on extremophiles and space BBC and NASA

3 Metabolism in microorganisms Microorganisms to include archaea, bacteria and some species of eukaryota. (a) Environmental control of metabolism. (i) Variations in growth media and control of environmental factors. Microorganisms require an energy source (chemical or light) and simple chemical compounds for biosynthesis. Many microorganisms can produce all the complex molecules required. Other microorganisms require more complex compounds to be added to the growth media. Culture conditions include sterility to eliminate any effects of contaminating microorganisms, control of temperature, control of oxygen levels by aeration and control of pH by buffers or the addition of acid or alkali. (ii) Phases of growth and doubling or generation time of exponential growth and changes in culture conditions. Phases to include lag, log/exponential,	Investigate the growth of microbes under different cultural and environmental conditions using standard laboratory equipment and simple fermenters. Isolate yeast from grapes using selective media and appropriate growing conditions.	Microorganisms include species that use a wide range of substrates for metabolism and produce a wide range of products from their metabolic pathways. As a result of their adaptability microorganisms are found in a wide range of ecological niches and can be used for a variety of research and industrial uses because of their ease of cultivation and speed of growth. Energy is derived either from chemical substrates or from light in photosynthetic microorganisms. Complex compounds such as vitamins or fatty acids. Growth media can be composed of specific substances or can contain complex ingredients such as beef extract. Interpretation of exponential growth on normal and semi-logarithmic scales. Lag phase of growth where microorganisms adjust to the conditions	Education Scotland research activities plus practical on effect of temp. on microbe growth – prokaryotes and eukaryotes student activities Education Scotland PowerPoint – culturing microbes Education Scotland teacher's guide on controlling metabolism – Introduces primary and secondary metabolites and inducers/inhibitors. Education Scotland teacher's guide on culture conditions

stationary and death. (iii) Control of metabolism through the addition of metabolic precursors, inducers or inhibitors to give a required product. Secondary metabolism can confer an ecological advantage.	Experiments on the induction of enzymes in microorganisms. Research industrial processes that use microorganisms. Suitable processes that involve underpinning biology include: citric acid production, glutamic acid production, penicillin production and therapeutic proteins such as insulin, human growth hormone and erythropoietin.	of the culture by inducing enzymes that metabolise the available substrates. Log or exponential phase of growth. Stationary phase where the culture medium becomes depleted and metabolites accumulate and secondary metabolites are produced. Death phase where lack of substrate and the toxic accumulation of metabolites causes death of cells. Exposure to UV light and other forms of radiation or mutagenic chemicals results in mutations some of which may produce an improved strain. Mutant strains are often genetically unstable and revert to the wild type in continuous cultureCo.	Pearson Education animated video on bacterial growth – lag, log stationary and death. Education Scotland teacher's guide on bacterial growth Education Scotland research activities on medical uses of microbes. Education Scotland teacher's notes and student questions on metabolism in microorganisms.
(b) Genetic control of metabolism. (i) Wild strains of microorganisms can be improved by mutagenesis, selective	Investigate transfer of DNA using bacteria. Experiments investigating the effects of UV radiation on UV sensitive yeast.	Some bacteria can transfer plasmids or pieces of chromosomal DNA to each other (horizontal transfer) or take up DNA from their environment to produce	Animation from Glencoe Online – bacterial conjugation transfer of a plasmid

breeding and culture or recombinant DNA.		new strains. In fungi and yeast, new genotypes can be brought about by sexual reproduction between existing strains.	
(ii) Recombinant DNA technology, plasmids and artificial chromosomes. Restriction endonucleases. Use of ligase in recombinant DNA. Gene introduction to increase yield or to prevent the survival of the microorganism in an external environment. Control of gene expression in recombinant plasmids and artificial chromosomes. Use of recombinant yeast cells.	Case study on bacterial transformation.	Restriction endonucleases cut target sequences of DNA and can leave sticky ends. Vectors with complementary sticky ends are then combined with target sequences using ligase. Genes that remove inhibitory controls or amplify specific metabolic steps in a pathway can be introduced to increase yield. As a safety mechanism, genes are often introduced that prevent the survival of the microorganism in an external environment. Recombinant plasmids and artificial chromosomes contain marker genes and restriction sites in addition to genes for self-replication and regulatory sequences to allow the control of gene expression. Plant or animal recombinant DNA in bacteria may result in polypeptides that are folded incorrectly or lack post-translational modifications. These proteins may be produced more successfully in a recombinant yeast cell.	Education Scotland animation – DNA Technology and gene transfer

(c) Ethical considerations in the use of microorganisms, hazards and control of risks.	Research the development of a microbiological product from discovery to market.		Education Scotland case study on bacterial transformation Includes support notes for Bio-Rad P-Glo kit, PowerPoints, teacher and student notes and health and safety advice.

Sustainability and Interdependence		Unit specification http://bit.ly/1gZU9Q7	
Mandatory Course key areas	**Suggested learning activities**	**Exemplification of key areas**	**Useful resources**
1 The science of food production (a) Food supply. (i) Food security and sustainable food production. Increase in human population and concern for food security leads to a demand for increased food production. Food production must be sustainable and not degrade the natural resources on which agriculture depends. (ii) Agricultural production depends on factors that control plant growth. The area to grow crops is limited. Increased food production will depend on factors that control plant growth: breeding of higher yielding cultivars, protecting crops from pests, diseases, competition.	Case study on challenge of providing food for the global human population. Contribution of biological science to interdisciplinary approaches to food security.	Food security is the ability of human populations to access food of sufficient quality and quantity. Most human food comes from a small number **of** plant crops. All food production is dependent ultimately upon photosynthesis. Plant crops examples include cereals, potato, roots and legumes. Breeders seek to develop crops with higher nutritional values, resistance to pests and diseases, physical characteristics suited to rearing and harvesting as well as those that can thrive in particular environmental conditions.	Education Scotland resources – science of food production Global Food Security Programme video (3 mins) and other resources. Rothampsted Research website – http://www.rothamsted.ac.uk/tools Crop specific interactive forecasting Live data from a real farm – farm host Free organised farm visits in your area – RHET farm visits

Livestock produce less food per unit area than plant crops due to loss of energy between trophic levels. (b) Plant growth and productivity. (i) Photosynthesis. Energy capture by photosynthetic pigments to generate ATP and for photolysis. Transmission and reflection of light that is not absorbed by pigments. Absorption spectra of Chlorophyll a and b and carotenoids compared to the action spectra for photosynthesis. Carotenoids extend the range of wavelengths absorbed by photosynthesis and pass the energy to chlorophyll. Absorbed energy excites electrons in the pigment molecule. Transfer of these high energy electrons through electron transport chains releases energy to generate ATP by ATP synthase. Energy is also used for photolysis, in which water is split into oxygen, which is evolved, and hydrogen, which is transferred to the coenzyme NADP.	Examination of spectrum of visible light and artificial light sources with a simple spectroscope. Examine light transmission through extracted chlorophyll with a simple spectroscope. Investigate the action spectra of photosynthesis in plants using coloured filters. Chromatography of photosynthetic pigments. Research photosynthetic pigments in other photoautotrophs. Carry out the Hill reaction.	Livestock production may be possible in managed and wild habitats unsuitable for cultivation of crops.	Compare bacterial and plant electron excitation systems; photophosphorylation McGraw Hill animation – electron transfer chains in chloroplasts

The enzyme RuBisCO fixes carbon dioxide by attaching it to ribulose bisphosphate (RuBP) in the Calvin cycle. The intermediate produced is phosphorylated by ATP and combined with hydrogen from NADPH to form glyceraldehyde-3-phosphate (G3P). G3P is used to regenerate RuBP and for the synthesis of sugars. These sugars may be synthesised into starch or cellulose or pass to other biosynthetic pathways to form a variety of metabolites.	Research the inhibition of Rubisco by oxygen. Experiments on the synthesis of starch from glucose-1-phosphate by potato phosphorylase.		Animations from Biology 203 Cell Biology Laboratory – The Calvin cycle in stages or The Calvin cycle
(ii) Plant productivity Net assimilation is the increase in mass due to photosynthesis minus the loss due to respiration and can be measured by the increase in dry mass per unit leaf area. Productivity is the rate of generation of new biomass per unit area per unit of time. Biological yield of a crop is the total plant biomass. Economic yield is the mass of desired product. The harvest index is calculated by dividing the dry mass of economic yield by the dry mass of biological yield.	Measure net assimilation rate in leaf samples under a variety of conditions. Carry out experimental investigations on limiting factors in photosynthesis. Analyse data on crop planting density, biological yield and economic yield using leaf area index, crop growth rates and harvest index.	Plant and animal breeding involves the manipulation of heredity to develop new and improved organisms to provide sustainable food sources. Breeders seek to develop crops and stock with higher yields, higher nutritional	Pass my exams website – learner resources for factors affecting the rate of photosynthesis

(c) Plant and animal breeding by manipulation of heredity: for improved plant crops, improved animal stock, to support sustainable food production.	Investigate resistance of potato varieties to *Phytophthera infestans*.	values, resistance to pests and diseases, physical characteristics suited to rearing and harvesting as well as those that can thrive in particular environmental conditions.	National Geographic video showing extremes of selective breeding (5mins). Shows semen collection from bull for artificial insemination – supercow breeding

(i) Plant field trials are carried out in a range of environments to compare the performance of different cultivars or treatments and to evaluate GM crops. In designing field trials account has to be taken of: the selection of treatments, the number of replicates and the randomisation of treatments. (ii) Selecting and breeding Animals and cross pollinating plants are naturally outbreeding. In inbreeding, selected plants or animals are bred for several generations until the population breeds true to the desired type due to the elimination of heterozygotes. Test crosses can be used to identify unwanted individuals with heterozygous recessive alleles. Inbreeding depression is the accumulation of recessive, deleterious homozygous alleles. Self-pollinating plants are naturally inbreeding and less susceptible to inbreeding depression due to the elimination of deleterious alleles by natural selection. In outbreeding species inbreeding depression is avoided by selecting for the desired characteristic while maintaining an otherwise genetically diverse population.	Evaluate crop trials to draw conclusions on crop suitability, commenting on validity and reliability of trial design and the treatment of variability in results. Analyse patterns of inheritance in inbreeding and outbreeding species (monohybrid cross, F1 and F2 from two true breeding parental lines, back cross, test cross). Case studies on the development of particular crop cultivars and livestock breeds.	The selection of treatments (to ensure fair comparisons); the number of replicates (to take account of the variability within the sample) and the randomisation of treatments (to eliminate bias when measuring treatment effects).	Rothampsted Research website – GM wheat trial resources University of Nebraska step by step animation about corn crossing Norway historic breeds programme – ancient cow breeds Research paper on effect of inbreeding on the dairy industry

(iii) Cross breeding and F_1 hybrids In animals, individuals from different breeds may produce a new crossbreed population with improved characteristics. As an F2 population will have a wide variety of genotypes a process of selection and backcrossing is required to maintain the new breed. Alternatively the two parent breeds can be maintained to produce crossbred animals for production. (iv) Test cross. Test crosses can be used to identify unwanted individuals with heterozygous recessive alleles. In plants F1 hybrids, produced by the crossing of two different inbred lines, creates a relatively uniform heterozygous crop. F1 hybrids often have increased vigour and yield. The F2 generation is genetically variable and of little use for further production although it can provide a source of new varieties. Genetic transformation techniques allow one or more genes to be inserted into a genome and this genome can then be used in breeding programmes.	Case histories of plant mutations in breeding programmes. Mutation breeding has brought about improvement to a number of crops in disease resistance, dwarf habit (eg in cereals) and chemical/nutritional composition (eg low euricic acid in rape seed). Research/study of self-pollinating plants- naturally inbreeding and less susceptible to inbreeding depression due to the elimination of deleterious alleles by natural selection. Genetic transformations in plant breeding include *Bt* toxin gene for pest resistance, glyphosate resistance gene for herbicide tolerance and golden rice, a cultivar that contains a pre cursor of vitamin A.	New alleles can be introduced to plant and animal lines by crossing a cultivar or breed with an individual with a different, desired genotype.	Goldies Room website animation – test cross interactive Transgenic Crops website – teacher resources on transgenic plants The Golden Rice project homepage

(v) Genetic technology As a result of genome sequencing, organisms with desirable genes can be identified and then used in breeding programmes.		.	GMO Compass website – information on pest resistant crops
(d) Crop protection (i) Weeds, pests and disease populations compete with crops reducing productivity. Properties of annual weeds include rapid growth, short life cycle, high seed output, long-term seed viability. Properties of perennial weeds with competitive adaptations — storage organs and vegetative reproduction. Most of the pests of crop plants are invertebrate animals such as insects, nematode worms and molluscs. Plant diseases can be caused by fungi, bacteria or viruses, which are often carried by invertebrates.			Syngenta website – crop pest library showing effects and control measures for many crop pests. Iowa State University booklet presentation on weed life cycles and growth – introduction to weed science

(ii) Control of weeds, pests and diseases by cultural means. The advantages of plant protection chemicals which are selective or systemic. Protective applications of fungicide based on disease forecasts are often more effective than treating a diseased crop. (iii) Problems with plant protection chemicals may include toxicity to animal species, persistence in the environment, can accumulate or be magnified in food chains, produce resistant populations.	Investigate the incidence and viability of potato cyst nematode cysts in samples of soil continuously cropped with potatoes and in samples of soil cropped with potatoes as part of a rotation. Case study on the control of weeds, pests and or diseases of agricultural crops by cultural and chemical means.	The use of pesticides may also result in a population selection pressure producing a resistant population.	Article on persistent chemicals in salmon from the National STEM Centre. Article from National STEM Centre on obligations of industry to minimise pollution
(iv) Biological control and integrated pest management.	Case studies on, for example, control of glasshouse whitefly with the parasitic wasp *Encarsia*, control of glasshouse red spider mite with the predatory mite *Phytoseiulus* and/or control of butterfly caterpillars with the bacterium *Bacillus thuringiensis*. Investigate the chemical and biological control of red spider mite.	In biological control the control agent is a natural predator or parasite of the pest. Integrated pest management combines chemical and biological control.	Green Methods website – advice on green methods of pest control.

(e) Animal welfare and behavioural indicators of poor welfare. The costs, benefits and ethics of providing different levels of animal welfare in livestock production. Behavioural indicators include stereotypes, misdirected behaviour, failure in sexual or parental behaviour, altered levels of activity.	Research the five freedoms for animal welfare.		Compassion in World Farming website offers one view point and a useful free DVD. 'Stimulus response' video can be obtained free from the National STEM Centre website. .
(i) Observing behaviour (ethology) The observed behaviours of domesticated animals in natural or semi-natural settings. Information from these studies can be used to improve the environment for domesticated animals. The use of preference tests and measurements of motivation in animal welfare studies.	Interpret and evaluate ethograms to form hypotheses and draw conclusions on animals' behaviour needs and to develop an awareness of scientific evidence rather than anthropomorphism when creating an environment for domestic animals.		Choice of twenty two animal behaviour videos on the National STEM Centre website.

2 Interrelationships and dependence (a) Symbiosis — relationships between members of two different species. (i) Parasitic relationships and transmission — a parasite benefits in terms of energy or nutrients, whereas its host is harmed by the loss of these resources. Transmission of parasites to new hosts using direct contact, resistant stages and vectors. Some parasitic lifecycles involve secondary hosts. (ii) Mutualism including evolution of mitochondria and chloroplasts. Both mutualistic partner species benefit in an interdependent relationship. (b) Social behaviour Many animals live in social groups and have behaviours that are adapted to group living such as social hierarchy or cooperative hunting and defence.	Observe microscope slides of parasites. Research the links between these symbioses and anthropogenic climate change.	Symbiotic relationships are coevolved and intimate. Parasites often have more limited metabolism so often cannot survive out of contact with a host. Examples include the cellulose-digesting protozoa/bacteria in the guts of many herbivores and the photosynthetic algae in the polyps of coral. Cooperative hunting may benefit subordinate animals as well as dominant, as the subordinate animal may gain more food than by foraging alone; also food sharing will occur as long as the reward for sharing exceeds that for foraging individually.	Education Scotland resources on symbiosis and social behaviour including teacher's notes, learner material and accompanying symbiosis PowerPoint BBC website – thirty video clips showing dominance hierarchy in a number of species. BBC website – thirty five video clips showing Pack hunting in various species.

(i) Altruism and kin selection and its influence on survival. An altruistic behaviour harms the donor individual but benefits the recipient. Behaviour that appears to be altruistic can be common between a donor and a recipient if they are related (kin). The donor will benefit in terms of the increased chances of survival of shared genes in the recipient's offspring or future offspring. (ii) Social insects, the structure of their society and their ecological importance — evolution of the societies of insects such as bees, wasps, ants and termites, in which only some individuals contribute reproductively. Most members of the colony are workers who cooperate with close relatives to raise relatives. Ecological importance — social insects are often keystone species within their ecosystems. Some species are of economic importance to humans providing ecosystem services such as pollination and pest control.	Investigate reciprocal altruism using the prisoner's dilemma. Analyse data on helper behaviour and relatedness.	Reciprocal altruism, where the roles of donor and recipient later reverse, often occurs in social animals. The prisoner's dilemma as a simple model of altruism.	BBC website – video about termites BBC website – five videos providing information on bees Many resources are available from the Buzzaboutbees website. BBSRC website – list of projects looking at pollinators

(iii) Primate behaviour Complex behaviours that support social structure to reduce unnecessary conflict, group behaviour, the influence of external factors such as the complexity of social structure include ecological niche, resource distribution and taxonomic group.	Case study on primate behaviour.	Long period of parental care in primates gives an opportunity to learn complex social behaviours. To reduce unnecessary conflict, social primates use ritualistic display and appeasement behaviours. Grooming, facial expression, body posture and sexual presentation important in different species. In some monkeys and apes, alliances form between individuals which are often used to increase social status within the group.	Education Scotland – teacher and learner resources on chimpanzee behaviour

3 Biodiversity (a) Mass extinction, and the regaining of biodiversity. Fossil evidence indicates that there have been several mass extinction events in the past. Following each mass extinction event, biodiversity has been regained slowly as some surviving taxonomic groups radiate. The difficulties in estimating past and current species extinction rates. The extinction of mega fauna correlated with the spread of humans. The escalating rate of ecosystem degradation caused by humans is causing the rate of species extinction to be much higher than the natural background rate.	Research the Permian, Cretaceous and Holocene mass extinction events.		Education Scotland – teacher's notes on biodiversity Education Scotland student card sort activity 1 on mass extinction BBC website – tree of life free poster download
(b) Measuring biodiversity. Measurable components of biodiversity include genetic diversity, species diversity and ecosystem diversity. (i) The number and frequency of alleles in a population as a measure of genetic diversity. Genetic diversity comprises the genetic variation represented by the number and frequency of all the alleles in a population.	Research the importance of producing a central database of all known species and the difficulties involved in ensuring its accuracy. It is estimated that there are about 2 million known species. Of these, about half are animals, most of which are insects. Of the vertebrate animals, most are fish. There are about 0.25 million species of flowering plants.	If one population dies out then the species may have lost some of its genetic diversity, and this may limit its ability to adapt to changing conditions.	Education Scotland – teacher support notes 1 on biodiversity. Education Scotland – biodiversity student activity 2.

(ii) Species diversity comprises the number of different species in an ecosystem (the species richness) and the proportion of each species in the ecosystem (the relative abundance). The effects of isolation and area on the species diversity of habitat islands. (iii) Ecosystem diversity refers to the number of distinct ecosystems within a defined area. (c) Threats to biodiversity (i) Exploitation and recovery of populations and the impact on their genetic diversity. Small populations may lose the genetic variation necessary to enable evolutionary responses to environmental change (the bottleneck effect).	Case study using fieldwork to compare biodiversity indices of different areas (eg polluted versus unpolluted river, monoculture versus set-aside, an ecosystem with invasive species versus an ecosystem with native species, a disturbed habitat versus an undisturbed habitat). Analyse data on island biogeography. Compare ecosystem diversity in different land areas. Analyse data on exploitation of whale or fish populations. Use of gel electrophoresis in monitoring harvest species. Research impact of naturally low genetic diversity within cheetah populations.	A community with a dominant species has a lower species diversity than one with the same species richness but no particularly dominant species. Reduction of a population to a level that can still recover. This loss of genetic diversity can be critical for many species, as inbreeding results in poor reproductive rates. Some species have a naturally low genetic diversity in their population and yet remain viable.	Education Scotland – teacher support notes 2 on biodiversity. Education Scotland – biodiversity student activity 4 (treasure hunt loop game). BBC video clips on blue whales New York Times – documentary video (5 mins) on Alaskan whaling as a tradition WWF species directory of endangered species

(ii) Habitat loss, habitat fragments and their impact on species richness. Habitat fragments suffer from degradation at their edges and this may further reduce their size; species adapted to the habitat edges may invade the habitat at the expense of interior species. To remedy widespread habitat fragmentation, isolated fragments can be linked with habitat corridors allowing species to feed, mate and recolonise habitats after local extinctions.	Research impact of habitat fragmentation and benefits of habitat corridors for tiger populations.		BBC website – video about Tiger corridor creation
(iii) Introduced, naturalised and invasive species and their impact on indigenous populations. Introduced (non-native) species are those that humans have moved either intentionally or accidentally to new geographic locations. Those that			Education Scotland – biodiversity student activity 5 (map poster activity). BBC website – videos about different invasive species

become established within wild communities are termed naturalised species. Invasive species are naturalised species that spread rapidly and eliminate native species. Invasive species may well be free of the predators, parasites, pathogens and competitors that limit their population in their native habitat. They may prey on native species, out-compete them for resources or hybridise with them.	Case study on invasive species.		BBC website – a video diary of Japanese Knotweed as a homewrecker
(iv) Analysing climate change and its impact on biodiversity.	Use climate change modelling software.	Biological and other sources of data for analysing the effects of climate change on biodiversity. The challenges associated with modelling the impact of climate change on species and ecosystem diversity.	BBC climate change prediction from real data Climate change modelling power points, activities, computer spread sheets and modelling resources on the National STEM Centre website.